Massachusetts Division of Marine Fisheries 2010 to 2016 HubLine Eelgrass Restoration

Final Report

Submitted to:

The Massachusetts Department of

Environmental Protection

Prepared by:

Tay Evans, Jillian Carr, Katelyn Frew, Mark

Rousseau, Kathryn Ford Ph.D., Alex Boeri

David E. Pierce, Ph.D.
Director

March 2018

Table of Contents

1.0 Executive Summary

The Massachusetts Division of Marine Fisheries (DMF) Hub3 eelgrass restoration project (2010-2016) was funded as mitigation for eelgrass impacts off Woodbury Point in Beverly from the trenching of the Algonquin HubLine Natural Gas Pipeline that extended from Boston to Beverly in 2003. This restoration followed an effort conducted by DMF between 2004 and 2007 where over four acres of eelgrass were restored to Boston Harbor off Long Island and Peddocks Island as mitigation for general environmental impacts associated with HubLine construction (since 2007, the original four acres grew to over ten acres of restored eelgrass). This second eelgrass restoration effort targeted Salem Sound and Boston Harbor and included the impact site and sites that rated well in site selection models. A total of 14 sites were assessed for eelgrass transplant potential using small-scale test-plots (13 planted by DMF and one by Battelle). Seven successful test-plot sites were selected for full-scale transplanting of approximately 0.06 to 0.8 acres at each site from 2010 to 2015. The eelgrass planting method varied based on site conditions and included horizontal rhizome, Pickerell's burlap disk, and rock methods. Monitoring efforts from 2012 to 2016 included SCUBA-based monitoring and acoustic mapping surveys, at specific time points after planting. Three sites were successful (met one or all of the success criteria) after the full-transplant, resulting in restoration of 0.97 ha (2.4 acres) of eelgrass as of 2016. Our successful restoration sites are Middle Ground and Woodbury Point in Salem Sound and Governors Island Flats in Boston Harbor. Failure of some test-plots and fully planted sites was due to multiple factors including winter storms, smothering by algae mats, crab bioturbation, conflicts with boating and fishing activity, planting method and poor sediment and water quality. This report describes the second HubLine eelgrass mitigation project that was funded in 2010 with planting and monitoring from 2011 to 2016.

2.0 Background

The Massachusetts Division of Marine Fisheries (DMF) Hub3 eelgrass restoration project was funded as part of the mitigation for impacts to eelgrass (*Zostera marina*) resulting from the Algonquin Gas Transmission, LLC (Algonquin) HubLine Pipeline Project (HubLine). HubLine involved seafloor trenching and installation of a 30-inch diameter liquid natural gas pipe, impacting approximately 1.8 acres of eelgrass off of Woodbury Point in Salem Sound in 2003 (Figure 1). The Department of Environmental Protection (DEP) 401 Water Quality Certificate (WQC) required post-construction monitoring to assess recovery of eelgrass within the impact area. In 2008, an interagency working group concluded that the eelgrass had not recovered and therefore required mitigation. In February 2009, Algonquin's representatives, TRC Environmental and Battelle, presented an eelgrass restoration site selection analysis to the interagency working group (Battelle and TRC 2009a). This analysis identified sites potentially suitable for eelgrass restoration, which Battelle test-transplanted in the summer of 2009. In fall 2009, Battelle reported on the results of their test-plots (Battelle and TRC 2009b). In November 2009, DEP amended the 401 WQC (#W015087) and Waterways License (#5491) requiring Algonquin to mitigate 1.8 acres of eelgrass habitat (Appendix A). In 2010, Algonquin funded DMF to implement the full-scale mitigation project (Appendix A). DMF accepted funds subject to the terms of the amended WQC and was responsible for providing annual reports on the progress of the project and expenditure of the funds. DMF addressed the annual reporting requirement with written reports submitted to DEP

(Appendix B) and project updates on a blog (www.Seagrasssoundings.blogspot.com). The restoration project timeline, as stated in the Amendment to the 401 WQC (Appendix A), considered the length of time necessary to plant, monitor and replant plots if necessary, and set the project to commence in 2010 with planting in 2011 and conclude with a final report by December of 2017. This report is the final report for the Hub3 restoration effort and covers the project from its inception in 2010 to final monitoring activities conducted in 2016. The report includes detailed site descriptions, methods, site selection, test planting, results and discussion.

3.0 Methods

3.1 Permitting

DMF project staff obtained all required local, state and federal permits and authorizations, including Orders of Conditions (OOC) from the municipalities of Beverly, Salem, Boston and Nahant. Federal Army Corps of Engineers Category II permits were also obtained; these receive review by USFWS, EPA, and NOAA as well as CZM and DEP. The application requires notice to the Massachusetts Historic Commission, the Massachusetts Tribes and the Board of Underwater Archeologists. Approvals were for several 9 square meter (m^2) test-plots as well as full-scale planting within two acres total, distributed across sites that rated well in the Battelle and DMF site selection processes.

3.2 Site Selection

In 2009, three sites (Woodbury Point (WP 11), in Salem Sound; Governors Island Flats (GIF) and Deer Island Flats (DI), in Boston Harbor) were identified as potential restoration sites based on a preliminary transplant suitability model (PTSI) conducted by Battelle (Battelle and TRC 2009a) and the success of planted test-plots.

Battelle's site selection model summarized existing information such as historical eelgrass presence, nearshore stressors, wave energy, sediment type and field data in a GIS-based assessment. Field data included substrate composition, observed depth limits of eelgrass growth, coastal morphology and photosynthetically active radiation (PAR) readings that were collected by Battelle during one sampling day in October 2008. Battelle calculated an approximate range of percentage of light reaching the canopy (percentage of surface irradiance or %SI) using an extinction coefficient (Kd) derived from Secchi disk data and depth collected by Massachusetts Water Resources Authority (MWRA), and PAR readings from the October field day (Battelle and TRC 2009a). These data were compared to the 2001 DEP eelgrass GIS layer to identify light at depth in areas where eelgrass was present. Site characteristics and stressors were overlaid in GIS to calculate restoration site suitability ratings. Test-plot sites were identified based on the suitability maps.

Site characteristics measurements

Because planting is very effort intensive, and failure rates can be high, fully characterizing the suitability of potential sites is critical. Therefore, in 2010 and 2011 DMF re-assessed Battelle's site selection model and re-visited the test-plot locations to gather more light and sediment data and note any characteristics that are indicative of restoration potential (Table 1). At the same time, we used towed underwater cameras and divers to survey other areas that rated well in the 2009 PTSI but were never test-plotted by Battelle. Many areas were eliminated from consideration due to factors including depth, sediment type, wave energy and proximity to dense mooring fields. We also screened sites based on established criteria for light (>15% SI, based on a mean of values reported in the literature (Lee et al., 2007, Latimer and Rego 2010) and sediment <35% silt/clay (Leschen et al., 2010). At prospective sites, we collected site characteristics including additional surface sediment and light data (Table 1).

The surface sediment was assessed using diver observations by hand scooping the top few inches of surficial sediment and classifying it as mud, clay, fine-sand, sand, gravel, cobble, boulder and/ or shell hash. Light availability and temperature data were collected using HOBO Pendant continuous data loggers (model UA-002-64) and Li-Cor LI-192 Underwater Quantum 2π PAR sensors with the LI-1400 data logger attached to a 2009S Lowering Frame.

The HOBO loggers are less expensive and can record continuous measurements, so they were used to compare relative light between sites. HOBOs were deployed for two-weeks several times throughout the 2011 through 2015 field seasons. Loggers were affixed in a south-facing orientation one meter above the sediment surface on a screw anchor. One logger was stationed on land (in Gloucester for ease of deployment) for ambient light and temperature conditions. The HOBO data were used to calculate the average percentage of light at the canopy (1-meter off the sediment surface) (% SI) in Lumens/ft^2 by dividing the in-water light measurement by the ambient light measurement. The mean daily percent light at the canopy was calculated and trimmed down to the hours of peak solar irradiance from 10am to 2pm.

Since HOBO logger's range of spectral sensitivity does not include all PAR (photosynthetically active radiation) wavelengths, the percent light calculation is an underestimate of the actual whole-spectrum percent light reaching the bed (Carruthers et al., 2001). Hobos must be calibrated using an exponential decay fit if they are used to estimate PAR (Long et al., 2012), and even then it is only an approximation. Therefore, to directly measure PAR we used a Li-Cor Par light meter. The Li-Cor was used to both obtain a light profile through the water column to calculate the extinction coefficient (Kd), and also to measure the absolute and percent of surface irradiance at the canopy height (1-meter off the sediment surface) (% SI) as µmol photons m^{-1} second^{-1} which is a measure of the photosynthetic photon flux density (PPFD). A surface reading (0.10m depth) was taken, followed by up to eight additional readings with increasing depth. More readings were taken close to the surface while readings were taken every meter as depth increased. PAR measurements were collected at various times during the growing season from 2011 through 2017, at the reference sites: Beverly, West Beach Deep (WBD) (3 measurements) and Shallow (WBS) (7 measurements), Peachs Point (PP) in Marblehead (3 measurements), Nahant Cove (NC) (8 measurements) and Nahant Bay (NB) (2 measurements). PAR measurements were also collected at the restoration sites: Woodbury Point (WP11 and WP12) (2 measurements), Fort Pickering (FP) (1 measurement), Middle Ground (MG) (9 measurements), and Juniper Cove (JC) (7 measurements), as well as at Governor's Island Flat (GIF) in Boston Harbor (2 measurements).

A surface reading (0.10m depth) was taken, followed by up to eight additional readings with increasing depth. More readings were taken close to the surface while readings were taken every meter as depth increased. The PAR attenuation or light extinction coefficient, Kd, and the percent light at one meter above the seafloor (i.e. at the canopy) were calculated using the measured PAR in ambient light above the surface (I_o) compared to at-depth PAR measurements (I_z) using an algorithm developed by the National Park Service (Kopp and Neckles 2009). The normalized PAR attenuation (I_z/I_o) is assumed to follow Beer's law that light intensity decreases exponentially with distance through the water as follows:

$$Iz/Io = exp(-K_d*z) \text{ and } Ln(Iz/Io) = -Kd*z$$

where Kd is the PAR extinction coefficient and z is the measured depth. A larger Kd indicates a higher light attenuation, for example in poorer water quality conditions. Kd is calculated as the negative slope of a regression of ln (I_z/I_o) versus depth. Kd close to zero indicates little light attenuation (i.e. good water quality).

Test-plots

Based on our re-assessment of the Battelle model and our site-specific field data (Table 1) we planted test-plots at Fort Pickering (FP), Juniper Cove (JC) and Middle Ground (MG) in Salem Sound (Figure 2) and Long Island East (LIE), Peddocks Island East (PIE), Lovell Island (LOV), Green Island (GI), Great Brewster Island (GB), Gallops Island (GI), Deer Island Flats (DI) and Governor's Island Flats (GIF) in Boston Harbor (Figure 3) from 2011 to 2013. Test plots were small test plantings, either 3m x 3m plots or 5m x 5m plots at a density of 24 shoots/m^2 or 50 shoots/m^2 in planted squares alternating with unplanted squares (Figure 4). We relied on the test plots planted in 2009 by Battelle at WP11. The test-plots were planted in a checkered pattern. The checkered pattern allows for a larger planted area while requiring fewer shoots to be transplanted and incorporates space for growth and expansion. The checkered planting design has been previously used in several restoration efforts including by the University of New Hampshire in the Piscataqua river (Davis and Short 1997) and in New Bedford (Kopp and Short 2001), Save the Bay (Susan Tuxbury, formerly of Save the Bay, Pers comm. 2011) and DMF in Boston Harbor (Leschen et al., 2010). Harvesting and planting followed methods described in Section 3.3 below.

Test-plots were monitored approximately one month after planting and again at 4-6 months and finally on year for WP, MG and GIF. Monitoring consisted of counting the planted squares, counting shoot density, measuring the area of the plot and assessing general health of plants and site conditions, including epiphytic coverage, presence of invasives and bioturbating organisms, and observations about sediment changes. Monitoring methods are detailed in Section 3.4.

Selection of full-scale restoration sites

A test-plot was considered successful if plants had greater than 35% survival with little to no evidence of damaging bioturbation, epiphytes or disease after the 6 month or one year monitoring event. Where test-plots were successful, full-scale sites were designed ranging in size from approximately 0.06 to 0.8 acres (Table 2), depending on the suitable planting area at the site and the required acreage of the project agreement. Juniper Cove (JC) in Salem Sound and Green Island (GI) in Boston were planted with a smaller site layout, due to the smaller size of the suitable planting area. Woodbury Point (WP11 and WP12) and, Middle Ground (MG), and Fort Pickering (FP) in Salem Sound (Figure 2) and Governors Island Flat (GIF) and Great Brewster Island (GB) in Boston Harbor (Figure 3) were planted in a larger site layout.

Reconnaissance and Restoration Site layout

To prepare for full-scale planting, divers surveyed a large area in the vicinity of the test-plot to ensure obstructions or impediments were not present (e.g. large rocks, hard bottom, ghost gear), and to delineate the best planting locations within the site. The diver survey began by setting two 50 m transect tapes laid parallel 35 m apart. The dive team swam perpendicular lines between the tapes noting any characteristics in order to create a detailed map of the site. Final plot sizes and locations were determined based on the most suitable substrate, avoiding boulders and algae, for example. The selected site was marked with stakes and screw anchors and GPS points were collected at each site corner.

3.3 Transplanting

Donor bed harvesting

Two primary areas were used for harvesting: off of Pride's Beach in Beverly for Salem Sound planting sites (Figure 2) and in Broad Sound (Nahant Main) and a cove in eastern Nahant (Nahant Cove) for the Boston Harbor restoration sites (Figure 3). Donor beds were selected based on the proximity to the restoration site, the characteristics of the meadow (natural meadow established for 10 or more years, with a minimum of one acre of continuous growth and at a density greater than 50% cover) and ease of access to the site (Evans and Leschen 2010). In 2011, DMF divers also harvested plants from near the Logan Airport Light Pier in Boston Harbor to salvage the plants before an FAA-required runway safety improvement at Logan Airport would impact four acres of eelgrass there. The Boston Harbor plants were used in test-plots in Boston Harbor and at Woodbury Point in Salem Sound. Plants used for eelgrass restoration were harvested from donor beds in accordance with DMF's eelgrass restoration guidelines (Evans and Leschen, 2009). Divers harvested individual shoots by hand, picking shoots with two inches of intact rhizome. Divers moved along both sides of a 100 m transect approximately 1-2 meters on either side, minimizing impact to any one location. About 15 shoots (approximately 5%) were harvested from each 1m^2 area until the target number of shoots was reached. GPS coordinates were recorded at each end of the transect to prevent repeat harvesting of the same area.

Harvested shoots were either planted on the same day or stored in a wire mesh cage underwater, tied to a dock in Salem or Winthrop overnight. Overnight storage was only necessary during large planting events (4 volunteer events). All plants were transplanted within 48 hours after harvesting per the restoration guidelines (Evans and Leschen, 2009).

Planting design

Full-scale restoration planting sites consisted of checkered plots of alternating planted and unplanted 1 m^2 squares spaced over an approximately 0.06 to 0.8 acre site, depending on the location (Figures 5-9). In 2011, our site layout at Woodbury Point consisted of four, 18 m x 30 m (0. 13 acre) plots of checkered squares with 24 shoots/m^2. Three full plots and a partial fourth plot were planted, for a total of 0.43 acres total checkered area. The 144 planted squares per plot were planted at a density of 24 shoots/m^2. The fourth plot contained 60 planted squares. All together we planted 11,808 shoots at WP 11 (Figure 5). This was a total planted area of 575 m^2 or 0.14 acre spread throughout a 0.45 acre site.

In 2012, we redesigned our planting plan to include several smaller patches to enhance the edge available for rapid rhizome expansion (Gaeckle 2006). We balanced this with the benefits of mutual protection provided by a larger patch by increasing the shoot density and keeping the plots large enough to continue to provide protection (Olesen and Sand-Jensen 1994). Instead of using a continuous checkered planting as was done at WP11, we spaced out several smaller checkered plots across the site at a new area at Woodbury Point adjacent to the 2011 planted site that we call WP12. The smaller, denser planting plan reduced effort, time and risk, thereby improving efficiency and safety based on our experiences in the field. We planted using this design at all full scale sites. Each site was planted with three to ten smaller checkered plots (Figures 6-9), with thirteen 1m^2 squares per plot. We increased the density of planted shoots from 24 shoots/m^2 to 50 shoots/m^2 for a total of 650 shoots planted per plot. Plots were planted from 2012 to 2015, depending on the site (Table 1). After the initial planting, we abandoned JC due to poor initial success. Based on positive initial success at GIF and MG we increased the originally planted 0.4 acre sites by adding four additional plots at GIF (Figure 8) (North -0, A0, A11, A30) and three to MG (Figure 7) (A-0, A-20, A-40) in 2014 and 2015.

Planting methods

We used three different planting methods: the horizontal rhizome (HR) method, the burlap disk (BD) method, and the rock method, in accordance with DMF Seagrass Standard Operating Procedures (DMF 2014a, DMF 2014b). The HR method entailed planting two shoots together in opposite directions, with bamboo skewers anchoring the rhizomes to the sediment (Davis and Short, 1997). We used the HR method at 24 shoots/m^2 for test-plots and for full-scale planting of the portion of WP site planted in 2011 (WP11). The BD planting method, developed by Chris Pickerell at The Cornell Cooperative Extension, involved weaving 10 shoots into 20 cm-diameter circular burlap disks that were then buried in an approximately 3-5 cm deep hole backfilled with sediment (Pickerell, Cornell Cooperative Extension, pers. com. 2011). To test the relative success of the BD and the HR methods we collaborated with Chris Pickerell in a method comparison study, as part of a larger method test which included sites in Long Island Sound and Rhode Island. Our method comparison study at Fort Pickering included a total of four test-plots; two plots planted with the HR method and two with the BD method at two different depths, shallow (6ft MLW) and deep (12ft MLW) (Figure 10). The BD method was more successful than the HR method in the comparison study both due to shoot survival and density and time efficiency of the method (DMF, 2013). The BD method was used with 50 shoots/m^2 (five burlap discs of 10 shoots each) and was the primary method used for full-scale plantings throughout Salem Sound and Boston Harbor after 2011 (Table 1). A third method, dubbed the 'rock method' was also developed by Chris Pickerell. The rock method entails placing a cobble on top of the buried rhizomes of 4-8 shoots of eelgrass (C. Pickerell, Cornell, pers. com. 2011). The Pickerell team had success with the rock method at Long Island sites (http://www.seagrassli.org/), however our test of this method at Lovells Island was not successful so the method was not used for further planting.

Outreach and Volunteers

Four volunteer events were hosted during the project to involve local environmental groups in the restoration process. In June 2012, one event with adult volunteers from Salem Sound Coastwatch and one event with teenage volunteers from the New England Aquarium Live Blue Ambassadors group prepared eelgrass shoots into BD planting units for divers to transplant to FP and WP restoration sites in Salem Sound. Two volunteer events helped with the planting at Boston Harbor sites, both with the New England Aquarium Live Blue ambassadors group in August 2013, and again in August 2014.

Utilizing volunteers helped accomplish a great deal of work over a short amount of time. Volunteers assisted in preparing 13,000 eelgrass shoots into 1,300 planting units covering four restoration sites. The weaving rate for burlap discs was roughly seven discs per person per hour. A total of more than 40 volunteers were engaged over the course of the restoration project. A summary of the field events with pictures and links to other useful sources can be found on our blog, www.SeagrassSoundings.blogspot.com.

3.4 Monitoring

Donor beds

Our harvesting technique was developed to ensure no adverse impact to donor beds. The potential impacts of this harvesting method have been studied previously by Davis and Short (1997), and shown to have no quantifiable impacts. Fonseca et al. (1994) studied donor bed recovery and concluded that fast-spreading species, including *Zostera marina*, will rapidly recover after harvesting activity with no chronic impact to the donor site. Based on these studies and our personal experience in the field, we decided not to monitor the donor beds except to do qualitative swim-overs after harvesting events. No visible indication of harvesting effects such as holes were observed within days or weeks after harvesting, so we did not monitor further.

Restoration sites

We chose to measure shoot density and plot area because they are easily quantifiable and non-destructive measurements of the structure of an eelgrass bed which can be used as a proxy for its function as fish and invertebrate habitat. We monitored the development of the transplanted bed overtime for shoot density and used these measurements to gage the success of the restoration compared to the same measures at reference beds. We also monitored the plot expansion through diver measurements and total vegetated area through acoustic mapping.

In 2011 and 2012, monitoring at WP11, FP, JC and MG was done at approximately one week, one month, six months, and one year post-planting. WP, MG and WB were also monitored before and after coastal storms to assess impact. In 2011, WP11 was monitored after Hurricane Irene which occurred 2-3 months post-planting. In 2012, MG and WP11 were monitored one week before and one week after Hurricane Sandy, about four months post-planting.

At WP11 divers swam over each plot and noted presence/absence of the originally planted squares. In addition, we monitored eight of the planted squares randomly sampled from each plot to quantify shoot density at the one month and annual monitoring intervals. We did not measure area of the plots with divers at WP11. After 2012 quantitative monitoring was not done again until 2016. In 2016 we changed the monitoring design because the grass had retreated from some areas and expanded into other areas, and the individual plots were no longer distinguishable. We shifted from a random monitoring design throughout the whole plot to a targeted haphazard design where vegetated areas were targeted and sampled by tossing four quadrats haphazardly. This enabled us to quantify shoot density within the vegetated areas of the site.

From 2012 on at all sites other than the portion of WP planted in 2011 (WP11), our monitoring design changed to account for the new site layout and BD planting method. We also reduced the frequency of monitoring, focusing more on the initial one month period followed by annual monitoring for three years after planting. At each site, divers visited all planted plots and noted the presence or absence of each planted square, measuring shoot density at four randomly selected planted squares within each targeted plot. The vegetated extent of each of the plots was measured along three axes (length, width, and diagonal) to determine the overall expansion of the plots through lateral growth and seeding, to calculate the area of the planted plots. We also noted qualitative observations of wasting disease, epiphyte cover and snail and grazing evidence, and sediment observations such as sand waves after a storm. This monitoring method continued for all subsequent years at all transplant sites except WP11.

In the fall of 2016, we mapped the GIF, WP and MG restoration sites using acoustic mapping equipment and analysis. We used a Humminbird 698SI sidescan system with a 455 kHz sidescan sonar and an 83/200 kHz dual beam downward-looking bathymetric sonar to obtain sidescan sonar images. Sonar data were processed with SonarTRX Pro software (64x, Version 16.1.6056.27393) to generate a sidescan sonar mosaic that shows characteristic patterns where eelgrass is present (Figure 11). The eelgrass spatial extent was delineated in ArcGIS 10.4 at a scale of 1:2,000. We drew polygons where we saw the sonar return in the characteristic eelgrass pattern and included all discernible eelgrass with no minimum mapping unit or density threshold. Overlapping sonar images allowed for the highest possible accuracy of detection. The resulting polygons were delineated by combining all mapped patches of eelgrass at or immediately adjacent to each of the planting sites. In-water groundtruthing for presence/absence was done using reeled, towable, live-feed underwater cameras including Doyle Marine's SnakeMate and AquaVu submersible camera (Figure 12). The total area of eelgrass spatial coverage was determined by measuring the area of each delineated polygon in ArcGIS. We cross referenced this with our field measurements of the length, width and diagonal of each planted plot to ground truth the acoustic mapping. We present both the diver area measurements and the acoustically mapped area in this report and use both measurements in our success criteria.

Reference beds

Reference beds were located according to DMF Seagrass Standard Operating Procedures (DMF, 2014c). First, eelgrass maps generated by Mass DEP (MassDEP 2012) were consulted to select a general location. Selected reference sites had continuous, healthy eelgrass and were not previously restored. Reference sites were easily accessible and had similar depth and sediment grain size ranges as the restoration site. The reference beds were checked with a towable underwater camera for verification of eelgrass presence and to confirm that the bed was continuous for at least 5 acres with a shoot density indicative of a persistent meadow in this region (>150 shoots/m^2).

We monitored three reference beds in Salem Sound (West Beach Shallow (WBS), West Beach Deep (WBD) and Peachs Point (PP)). WBS and WBD are protected between Misery Island and West Beach and maintain a dense lush meadow and relatively stable sediment. There have been instances of observed storm impacts, including hurricanes Irene in 2011 and Sandy in 2011 and in 2012, which eroded areas within the meadow. Still, eelgrass recovered quickly after storm disturbance. This bed has persisted consistently since at least 1938 where it is visible in historic MA Department of Transportation aerial imagery (MADOT, 1938). The PP reference transect is within a relatively protected north-facing cove off of Marblehead, with several islands offshore that dampen exposure. The cove contains an active mooring field with roughly 20 moorings and several private docks extending into the shallow edge of the bed. The bed is characterized by dense, continuous grass in silty-sand sediments with shell hash and *Crepidula* sp. shells.

We monitored three reference sites in Boston Harbor (Nahant Bay (NB), Nahant Cove (NC) and Logan Airport (LA)). All three Boston reference sites are relatively protected and have persisted for decades. The meadow at LA is shallower, in siltier sediments, patchier and subject to more epiphytic coverage than the meadows at NB and NC. Its location adjacent to the airport on one side and the federal navigation channel on the other, has left it vulnerable to airport development and harbor dredging impacts. In contrast The NB meadow is very expansive and relatively undisturbed, aside from the presence of nearby navigational channels. The NC meadow is in a small residential cove tucked in along the southeast shore of Nahant. The cove contains a mooring field with roughly 6 moorings but is otherwise undisturbed.

Reference sites were monitored for comparison with our restoration sites (Figures 2 and 3). At each reference site, a transect was established and eelgrass shoot density, percent cover and canopy height were measured at 12 randomly assigned 0.25 m^2 quadrat stations along the transect. Data from the 12 quadrats were averaged to obtain means for the transect. All reference beds were monitored annually within the growing season of July to October each year beginning in 2013. WBS and WBD were monitored twice a year in July and October and the results were pooled and averaged. The reference bed monitoring method used an approach based on SeagrassNet global seagrass monitoring methods (http://seagrassnet.org/) and in accordance with DMF eelgrass technical guidelines and DMF Standard Operating Procedures (Evans and Leschen, 2009; DMF, 2014c). In addition to diver monitoring, we acoustically mapped the reference beds in Salem Sound in 2016 and in Boston Harbor in 2016 and 2017.

3.5 Success Criteria

The restoration goal set in 2009 by DEP and resource agencies was the successful replacement of 1.8 acres of eelgrass, three to five years after initial planting, to mitigate the loss of the same area attributed to the HubLine pipeline project.

To determine if 1.8 acres of eelgrass habitat had been successfully restored and was structurally and functionally equivalent to natural meadows in the region, we compared the shoot density at the transplanted sites with shoot densities measured at reference sites. To do this comparison, a success criterion (SC) was calculated using the mean and standard deviation of shoot densities at three local and representative reference sites (Short et al., 2000). Success is achieved if density measurements fall within one standard deviation of the mean of the reference sites, which accounts for site variability. The success ratio (SR) is the proportion of the mean at the transplanted site compared to the mean at the reference site.

SC = 100*(mean of all reference sites-1 standard deviation)/ mean of all reference sites

SR =100* (mean of restoration site /mean of all reference sites)

The SR approaches 100 as the transplanted site mean gets closer to the reference site mean. When the SR reaches or exceeds the SC, the target is met for that parameter (Short et al., 2000).

A second measure of restoration success used an assessment of the area restored through both diver measurements of plot expansion and acoustic mapping to determine the actual area vegetated. Success for this parameter is achieved when there is expansion and coalescing of planted plots into the site with a planted area equivalent to or greater than the area of the original planting. For example, WP12 was planted using six plots over a 0.4 acre site. The site will be considered successful for area if eelgrass has expanded throughout or beyond the 0.4 acres area after five years as measured through diver plot expansion measurements (plot development over time) and acoustic mapping (total vegetated area at the site).

The expectation is that after three years the measured shoot density should be on a trajectory (i.e. a trend in ecosystem structural or functional development) to reach equivalence with shoot density measured at the reference sites, and aerial coverage should be expanding toward the desired acreage. After five years SC for shoot density should be met and aerial coverage should equal or exceed the target acreage (Evans and Short, 2005).

4.0 Results

From 2011 through 2015 DMF planted a total of 0.5 acres of eelgrass patches spread throughout 3.2 acres in checkered plots across seven sites (Figures 2 and 3). The mean shoot density of the plots was 12 shoots/m^2 (24 shoots/m^2 in the planted squares) for WP11 and 24 shoots/m^2 (50 shoots/m^2 in the planted squares). Each site was planted with spaced checkered plots and sites ranged in size from 0.06 to 0.8 acres (Figures 5-9). Of the seven fully planted sites, three continued to grow and expand. By the end of 2016, our planting effort resulted in a total eelgrass spatial coverage of 2.4 acres at WP11 and 12 (0.42 acres), MG (0.16 acres) and GIF (1.80 acres), exceeding the goal of 1.8 acres restored. MG, WP and GIF all met restoration success criteria for either shoot density or area or both by the end of 2016. Four other test-plot sites were also planted and declined significantly in the first month after planting (e.g. by the second monitoring event) so were not further planted or monitored.

4.1 Salem Sound

Site selection

WP, MG, JC and FP rated well in our site selection process in Salem Sound meeting several key criteria including sediment type (<35% silt/clay estimated by a diver sediment surface observation), light availability (15% or greater using a Li-Cor PAR sensor) (Table 1) and test plot survival (>35%) within the first year. All four sites had 15% light or greater (Li-Cor measured PAR) at the canopy and a mean Kd of 0.41 for Salem Sound sites (Table 1). Woodbury Point (WP) also rated well in the 2009 Battelle site selection model (Battelle and TRC 2009a) and had successful test-plots that were still growing in 2011.

Based on relatively high light, sandy sediments and successful test-plot results (Evans et al., 2013), all four sites were selected for full-scale planting.

Reference sites

Mean shoot density at Salem Sound reference sites (Peachs Point (PP), West Beach Shallow (WBS) and West Beach Deep (WBD)), ranged from 102 to 186 shoots/m^2 between 2013 and 2016.

Seasonal and annual variability in density has been measured at the West Beach reference meadow since 2008 for another project. Before 2012 density was relatively stable, with a mean of 162.5 shoots/m^2. In 2012, after storm events, density decreased to 86.5 shoots/m^2. It took until 2015 to recover to pre-2012 density levels with densities averaging 180 shoots/m^2 with a maximum shoot density of 384 shoots/m^2 and a minimum of 16 shoots/m^2 (Figure 13). In 2016, WBS and WBD had a mean shoot density of 211 shoots/m^2 (235 shoots/m^2 at WBS and 168 shoots/ m^2 at WPD) (Figure 13).

Woodbury Point 2011 and 2012

The WP11 area was planted in June through August of 2011. By October 2011, survival declined to between 5% and 18% at all plots with a mean of 7.5 shoots/m^2 (compared to the 24 shoots/m^2 planted) (Figure 14). In 2012, Plot B2 had rebounded to 71.6% with a mean shoot density of 17.2 shoots/m^2. The other three plots had sparse grass, 1 to 2 shoots/m^2. Between 2013 and 2015 the grass at WP11 persisted in several patchy areas throughout the site as observed during swim-overs but was not quantified until 2016. In 2016, the vegetated areas within plots had a mean density of 93 shoots/m^2 (plots A1 and A2) and 130 shoots/m^2 (plots B1 and B2). Plots A1 and A2 were patchy with a total planted area of 809 m^2 (0.2 acres) and plots B1 and B2 had a total planted area of 202 m^2 (0.05 acres) as measured with acoustics (Figure 15).

The WP12 area was planted with four plots on June 19, 2012 with the help of volunteers. The remaining plots were planted on June 21 and July 3, 2012. Initial one-month monitoring showed a 92% survival of the planted shoots (46 shoots/m^2). By October 24, 2012, the three northern plots (Figure 6) were the most successful with mean survival of 114% at a mean shoot density of 62 shoots/m^2. Seedlings were observed between and among the plots. On 11/6/2012 we monitored after a tropical storm and shoot density had decreased 20-53 shoots/m^2. In 2015, the mean shoot density of all plots was 36.5 shoots/m^2. Between 2012 and 2015, shoot density varied, but all plots increased by the final monitoring event in October 2016 to a mean of 83.3 shoots/m^2 (range of 36 to 164 shoots/m^2).

The planted area of WP12, as measured by divers, expanded in the first and second years from the one-month extent of 153 m^2 (0.037 acres) to 169 m^2 (0.042 acres) by 2014 (Figure 16). By 2016 the total vegetated area was 228 m^2 (0.06 acres). Each year new eelgrass patches were observed between and around the plots but not quantified.

By 2016 the planted grass at WP11 had expanded and shifted shoreward, while the deeper planted portion of the site (deep edge) was mostly lost. Acoustic mapping captured this expansion and we mapped 0.42 acres (1,699m^2), including a shift shoreward of the 0.4 acre restoration site (Figure 15, Table 2).

The shoot density within the areas monitored at Woodbury Point was always below one standard deviation of the mean of the reference sites shoot density (Figure 17). The success criterion for shoot density, based on the mean reference value established by annual monitoring of three reference sites in Salem Sound, was not met at WP11 or WP12 in any of the four years of monitoring (Figure 18). Despite the relatively low density, the planted grass has expanded from the original 0.28 acre planted plot areas (WP11: 0.24 acre and WP12: 0.04 acre) to a total area of 0.42 acres, so at this site the success criterion for area was met based on results of acoustic mapping analysis.

Fort Pickering

Results of our method comparison study showed higher success with the BD method compared to the HR method, and this difference was greater at the deep site. One month monitoring results at the deep site were 81% BD survival compared to 44% HR survival (Evans et al. 2013).

The FP full-scale plots planted using BD method on June 12, 2012 (Figure 6) had a 93% mean survival in the first week with 41 to 50 shoots/m^2 in checkered plots throughout 0.4 acre site. In August, 2 months post planting, survival was 78.3%. By October 24, 2012, at 4.5 months, survival was 49% with shoot density ranging from 0 to 66 shoots/m^2. The northern three plots were covered in macroalgae and the northern middle plot was completely gone. After one year, five of the six plots had no eelgrass and the remaining plot had thinned to 9 shoots total. We noted a lobster trawl across the site and mats of algae and *Crepidula*. In 2014 one plot remained, with a total of 75 shoots in a 250 m^2 area (plot South-20) (Figure 6). The site was not monitored again. The success criteria for shoot density and area of eelgrass restored were not met by 2016.

Juniper Cove

At the time of planting in 2012 (Figure 9), divers noted drift algae in the area. By October 2012, all three plots had dropped to approximately 1% survival with approximately 2 shoots/m^2 and the plots were covered in a thick mat of drift algae. We did not measure the vegetated area. The site was not monitored after 2012. The success criterion for shoot density and area of eelgrass restored were not met.

Middle Ground

Five of the six plots planted in July 2012 at MG had consistently higher density with each annual monitoring event (Figure 19). By July of 2013 five plots had 177.5% survival with a mean shoot density of 89 shoots/m^2 and the sixth plot was not found. By July 2015 mean shoot density for the 5 successful plots was 219 shoots/m^2. By October 2016 (after five growing seasons) the planted squares had coalesced into each plot for a mean shoot density of 245 shoots/m^2 with a range from 194 to 264 shoots/m^2 spread over 5 plots. Three additional plots planted in September 2014, October 2014 and May 2015 had a mean percent survival of 102% approximately one year after planting, with a mean density of 51 shoots/m^2 by July 2015. The following year, two years after they were planted, they had a mean density of 247 shoots/m^2 spread in a checkered pattern over the three 25m^2 plots for a total area of 0.02 acres, a 494% increase from the original planted density in two years (Figure 19).

Plots expanded at MG from 146m^2 (0.036 acres) one-month extent to 252m^2 (0.06 acres) of vegetated area by 2016 (Figure 16), in patches throughout the approximately 3,300m^2 (0.8 acre) site (Figure 7). The total planted plot area initially included only the original five plots with the additional three plots included in the total for 2014, 2015 and 2016 (Figure 7). New seedlings as well as lateral shoots were observed within the plots. Acoustic mapping in the October 2016 delineated the area of planted plots at 0.16 acres of eelgrass in patches throughout a 0.8 acre site. The plots were easily distinguishable and had expanded since planting but had not coalesced with each other (Figure 20).

Shoot density at MG was within 1 standard deviation of the mean of the reference sites by 2014 (Figure 17), exceeding the success criteria for shoot density two years after planting (Figure 18). By 2015, the success ratio dipped just below the success criteria (the standard deviation within the reference sites increased), but by 2016 the success ratio again exceeded the success criteria. The MG restoration was successful as measured by shoot density compared to reference values. Area restored was estimated through diver and acoustic mapping to be 0.06 and 0.16 acres respectively, in patches throughout a 0.8 acre site. The area of eelgrass restored is still patchy and has not yet met the established success criteria for area.

4.2 Boston Harbor

Site selection

Green Island (GI), Great Brewster (GB) and Governor's Island Flats (GIF) in Boston Harbor rated well in our site selection process. Criteria included acceptable light (>15% SI), sediment condition (i.e. <35% silt/clay) and successful test plots (>30% survival). For results from the other sites investigated in Salem Sound and Boston Harbor please refer to Table 1 and our 2012 report (Evans et al., 2013).

On our GIF site survey in 2010 we recorded the presence of some discrete patches of grass near the Battelle test plot site. We surveyed the area along a 50 m transect swimming in diagonals of 10 m on either side of the transect. We noted mostly featureless mud with a layer of surface diatoms and some seedlings and small patches of grass. GIF had a successful test-plot, with Kd and PAR SI values of 0.56 and 15%, respectively (Table 1). While measured mean percent light (15%) was the minimum according to our criteria, the test-plot was successful, so GIF was also selected for full-scale planting. Great Brewster (GB) and Green Island (GI) also had successful test plots, acceptable light and sediment (Table 1).

Reference sites

Mean shoot density at Nahant Cove (NC) and Nahant Main (NM) reference sites showed an overall increase from 2013 (101 shoots/m^2 mean shoot density) to 2015 (204.5 shoots/m^{2}mean shoot density) while Logan Airport (LA) maintained a consistently lower shoot density during the same time period (37.3 shoots/m^2 to 43.3 shoots/m^2) (Figure 17). In 2016 the trends reversed and the Logan airport shoot density increased to 177 shoots/m^2 exceeding the Nahant shoot densities (147.5 shoots/m^2). This increase in shoot density included seedlings, which were observed in abundance during monitoring. A large percentage of the seedlings did not persist, and by 2017 shoot density at the Logan meadow had decreased to 22 shoots/m^2, returning to levels similar to those seen from 2013 through 2015.

The Logan meadow areal extent decreased from 2012 (43.66 acres) to 2016 (34.81 acres), as mapped using DEP's photo-interpreted polygons. The mapped vegetated area in Nahant Cove was 23 acres in DEP's 2012 photo-analysis and increased to 56.3 acres in DMF's 2017 acoustic survey analysis. The greater area mapped in 2017 was due to an increase in the northwest as well as expansion both shallower and deeper throughout. At Nahant Main, DEP 2012 photo-interpreted eelgrass extent was 731 acres. DMF acoustic survey analysis in 2017 shows an increase to 930 acres. Some of these differences may be due to higher resolution mapping provided by acoustics compared to photo-analysis, as well as differences in the Minimum Mapping Unit employed in each survey method.

Governors Island Flats

The seven plots initially planted at GIF had a 63% mean survival approximately one month after planting (September 2013). Mean shoot density was 31 shoots/m^2 in July 2014, the next growing season. After two years (August 2015) one plot was not found due to poor visibility and shoot survival of the six monitored plots was 161% with a mean shoot density of 81 shoots/m^2 (Figure 21). Three years post-planting (September 2016) all seven plots were located and had a mean shoot density of 141 shoots/m^2, and plots had completely coalesced.

The three additional plots planted during the fall of 2014 had a 98% mean survival one year post-planting with a mean shoot density of 49.2 shoots/m^2. After two years, (October 2016) the three plots had rapidly increased to a mean shoot density of 173 shoots/m^2.

The total plot area measured by divers at GIF increased each year of monitoring and was 208m^2 (0.05 acres) in July 2014 (Figure 16). By 2015 the plots had coalesced and there was evidence of seeding observed between plots. The originally planted 25m^2 plots had expanded to a mean plot area of 39.4m^2 in four of the 10 plots measured. One plot could not be located and the five remaining plots had expanded and coalesced beyond 10m perpendicular to the transect tape, and the edges were not distinguishable. In 2016, the five successful plots had expanded out greater than 25m perpendicular to the transect for all remaining plots. Some of the plots expanded further, but divers stopped measuring at 50 m away from the transect. The entire planting and expansion area was completely vegetated and plants had expanded in all directions. Based on an average of 30m diver-measured expansion of the plots we calculated 1.8 acres of continuous meadow indistinguishable from our planted plot in 2016.

Acoustic mapping showed extensive eelgrass throughout the area of our restoration site and beyond. The total acoustically mapped eelgrass extent on Governors Island Flat was 54 acres, surrounding our fully vegetated site (Figures 22 and 23).

The GIF planting was at or within one standard deviation of the mean of the reference sites shoot density by 2015 (Figure 17). The Success Ratio at GIF exceeded the Success Criteria two years after planting (Figure 18). The GIF restoration was successful as measured by shoot density compared to reference values and area of eelgrass restored. GIF eelgrass area exceeded the target expansion area two years after transplanting. The success of this site continued in 2016.

Great Brewster and Green Island
At Great Brewster Island, shoot density declined and plants had a 16% survival one year after they were planted with a shoot density of 8.2 shoots/m^2. Two years after they were planted, plants had a 9% survival and a shoot density of 4 shoots/m^2 overall. Four of the six planted plots had declined to zero, while two (North 30 and North 10) remained at a low density (6.5 and 19.5 shoots/m^2, respectively). No plants were located during August 2016 monitoring.

Only five plots were planted at Green Island during 2013 (Figure 9). Mean percent survival one month after planting was 85% with a mean shoot density of 43 shoots/m^2. One year later one plot was gone and the remaining four plots had a mean shoot density of 22 shoots/m^2. The following year monitoring results showed a 6% survival. A second plot was gone and the three remaining plots had a mean shoot density of 19 shoots/m^2.

The success criteria for shoot density and area of eelgrass restored were not met by 2016 for either Great Brewster or Green Island.

5.0 Discussion

DMF successfully restored 2.4 acres of vegetated area to three sites in Massachusetts Bay, exceeding DEP's mitigation requirement of 1.8 acres of restored eelgrass by 2017 (Appendix A). Each of our restoration sites had a different outcome. One site, GIF, met both success criteria for area and shoot density. Our plantings at GIF expanded into a continuous 1.8 acre area that is now surrounded by greater than 50 acres of eelgrass. Another site, MG, met the success criteria for shoot density and is structurally equivalent to reference eelgrass meadows for that parameter, but has not yet coalesced. The plantings at the site of impact, WP, are low density and patchy. Although the transplant did not meet density success criteria, expansion of the transplant to adjacent areas is a positive indication that mitigation at the site of loss was effective and beneficial. Although each of the sites responded differently to restoration, there were some commonalities discussed below.

The burlap disk (BD) transplanting method proved to be easy to work with and successful at the three restoration sites in a range of sediment conditions (from silty sediments of GIF to the gravelly-sand of MG). In a method comparison study conducted jointly with Chris Pickerell of Cornell Cooperative Extension, The BD method was more successful than the HR method both based on higher shoot survival and density and time efficiency of the method (Evans et al., 2013). In the full-scale restoration, our mean shoot survival rate was 78.3% after 1-2 months. This is greater than shoot survival results reported in other studies using the TERF method (73% shoot survival after one month, Gaeckle, 2006) and the horizontal rhizome method (44% overwintering survival, Davis and Short, 1997).

In general we found that acoustic mapping was an efficient monitoring tool that allowed us to capture the total area vegetated and the structure of the particular meadow compared to the structure of reference meadows. Because the MG plots were still well defined in 2016 we could compare diver measurements to acoustic analysis for plot area. We found that acoustic mapping methods over-estimated the vegetated area through the inherent error and broader scale, while diver measurements underestimated the vegetated area by missing patches outside of the monitored plot and limited view of the diver.   Error in the acoustically mapped edge increases because plants may be fanned down by current, shifting the edge by as much as a meter. In addition, although the SonarTRX Pro software corrects for image distortion and image stretching, some degree of stretching remains. Finally, error is also introduced through the polygon drawing process. Despite the inherent error in the acoustic mapping method, this method provides an important broader scale perspective of a meadow. Focusing only on tenth-of-a-meter resolution from diver measurements, as is common in restoration monitoring, will miss interesting and important spatial patterns in a restored bed's development. For example, we found that eelgrass was moving shoreward out of our defined site at WP but spreading and expanding nonetheless. Because both diver measured and acoustic measured methods have limitations and advantages, we used both in this project to present a range of area data for assessment of restoration success. In future work, we plan to use acoustic maps of restoration sites and reference sites to assess percent cover of vegetated patches at the meadow scale as part of a project's success criteria.

Success criteria are created based on the characteristics of reference meadows. Therefore reference meadow selection is an important and often overlooked step in planning an eelgrass restoration. We recommend more robust reference site selection based on a broader scale assessment of meadow characteristics similar to the transplant site. West Beach (WBD and WBS) in Beverly, a stable and well protected meadow, did not have similar broad scale meadow conditions as the higher energy MG or WP and therefore was not a realistic benchmark for the high energy transplanted areas.

Our transplanted sites ranged in energy, sediment characteristics and light availability and these factors contributed to the differing responses of each site, discussed below.

5.1 Salem Sound

Acoustic habitat mapping conducted by DMF in 2016 characterized 27% of the eelgrass in the Sound as sparse or patchy (Carr and Ford, 2017). The patchy areas are mainly along the exposed coastline, including Aquavitae, just west of MG, and the fringing meadows along Beverly's coast, near WP. The north coast of Salem Sound is exposed to wind, wave and current energy and we regularly observed sand waves at Both WP and MG. Eelgrass grows in smaller, denser patches in high energy exposed environments (Fonseca, 1998; Gaeckle, 2006) and can form characteristic patch mosaics depending on the level of physical exposure (Frederiksen et al., 2004). The two successful restoration sites in Salem Sound have remained patchy, consistent with the nature of eelgrass in the area. In contrast, the reference sites WBS and WBD are protected between Misery Island and West Beach and we do not observe sand waves at these sites. Sites investigated in Salem Sound had sandy or gravelly-sand sediments and high light availability, except the deep edge of the impact site at WP, which had lower light.

Woodbury Point

By 2016 the eelgrass at WP had expanded and met the success criteria for area, although the deep edge of the site did not recover. As we found in our previous work in Boston Harbor (Leschen et al., 2010), historical presence of eelgrass is not always a predictor of transplant success. The HubLine impact site was at the deep edge of the bed, where light limitation can be a challenge for new transplants even when grass grew there before. Eelgrass light requirements vary depending on the depth, water quality and sediment characteristics (Kenworthy et al., 2014). Our measurement of 18% of surface irradiance reaching the canopy at this site is on the lower end of the acceptable range of 15-22% (Latimer and Rego, 2010) and much lower than the optimum 34% measured in mesocosm experiments (Ochieng et al., 2010). In addition, eelgrass is known to be an ecosystem engineer, sustaining its own habitat by stabilizing sediments (van Katwijk et al., 2009). Sediment composition and exposure changed after the HubLine was trenched, potentially making the impact site less suitable for eelgrass. Nonetheless, an effort was made to plant at the impact site. Now, four years after planting, we see a shoreward retreat of grass from our planted site at WP to shallower depths that are less light limited and more stable (Figure 15).

Middle Ground

Although both Salem Sound sites are patchy, planted patches at MG are smaller and more discrete, while WP has longer coalesced patches. This may be in part driven by current circulation in the Sound resulting in poor seed recruitment at MG. High energy, patchy meadows are known to have lower seed retention than continuous beds (Livernois et al., 2017) as energy moves seeds away, limiting inter-patch growth. Current modeling shows an elliptical circulation around Salem Sound (ASA, 2001) that could disperse seeds away from the MG site to a recently documented meadow southeast of Middle Ground (off Coney Island). Low seed retention is likely to slow development of transplanted plots at MG. In contrast, currents at WP are instead pushing seeds shoreward supporting the development of eelgrass in the shallower parts of WP.

Finally, MG was still being planted in 2015 and will need more time to develop. Although shoot densities have already reached parity with reference levels, patches have not fully coalesced. Eelgrass is expected to take three to five years to meet success criteria (Short et al., 2000) and to reach structural and functional equivalence with reference values (Evans and Short, 2005; McGlathery et al., 2012). With more time we expect patches will spread, but remain variable due to the wave and current energy exposure at the site.

Unsuccessful sites

Algae, fishing gear and storms lead to decline of our test plots at unsuccessful sites in Salem Sound. At Juniper Cove, initial one month planting survival was over 100%, but persistent winds throughout the summer blew debris and algae into the cove, smothering the newly planted shoots. Similarly, at Fort Pickering kelp settled over the transplants in the late summer and the following spring we returned to find lobster pots deployed directly over one of our plots, both resulting in smothered, scoured plants. Since we originally planted the test plot in the fall and assessed success the following spring, the test plots were not subject to summer algae conditions. Our experience highlights the importance of monitoring test plots for at least one full year to capture seasonal effects at a site.

Finally, we have not fully quantified the impact of major storms on our restoration sites, as it is often difficult to safely monitor directly before and after a storm. However, we have noted storm impacts at WP11 and WBS/WBD, and consider storm damage an important variable in restoration success.

5.2 Boston Harbor

Once known as the "Harbor of Shame" due to its poor water quality and eutrophic conditions, Boston Harbor is now cleaner than it was more than a decade ago when the MWRA transferred waste water treatment flows from direct discharge to the harbor to offshore diffusion in Massachusetts Bay (Taylor, 2006). Vaudrey et al. (2010) reported eelgrass recovery in 12 to 15 years following removal of wastewater and remediation of nutrient loading in Long Island Sound. Boston Harbor is now 13 years into its recovery and the habitat is similarly responding, with increasing eelgrass coverage to the northern portion of the embayment, particularly Governor's Island Flat, Long Island, Peddocks Island and Nahant Bay (DMF 2016 acoustic mapping). In the first five years after the transfer, total nitrogen dropped 35% (Taylor, 2006). Benthic conditions have improved with increasing dissolved oxygen in the bottom water and sediments and decreasing particulate organic carbon (Taylor, 2015; Pembroke et al., 2016). We expect that the improved water quality has helped improve restoration success and spur a rebound of eelgrass in Boston Harbor, particularly in the North harbor and Nahant Bay. Based on assessment of various mapping techniques, Boston Harbor supported approximately 800 acres in 2006 (DEP 2006 photo-interpretation), and as much as 1,193 acres in 2016 (DMF 2016 and 2017 acoustic mapping analysis; DEP 2016 photo-interpretation and DEP 2012 photo-interpretation for areas not done in 2016). While some of this increase may be attributed to the higher resolution of our acoustic work in 2016 (Boston Harbor) and 2017 (Nahant), which can better detect low-density eelgrass, our dive observations concur that eelgrass is more abundant now in many North harbor locations. However, despite improved conditions, Boston Harbor is still a highly developed urban harbor and eelgrass restoration remains challenging.

Since 2004, 31 sites were test transplanted in Boston Harbor, with only five sites demonstrating success (i.e. persistence after 3 to 5 years) (Long Island North, Long Island South, Peddocks Island and Portuguese Cove from the 2005 DMF-HubLine restoration project and GIF from this project). This points to a lag in recovery of criteria driving eelgrass restoration success, including turbidity (Total Suspended Solids (TSS)), light availability and sediment grain size. TSS in the harbor has increased from an annual average of approximately 3 mg/l in 1996 to 7 mg/l in 2015, due to an increase in inorganic particles (silts and clays) although the contribution of organic carbon has decreased (Taylor, 2006). Increasing shoreline erosion in the South harbor, such as on Sheep Island, is a possible cause of the TSS increase (Taylor, 2015). This could explain why eelgrass has been in decline in the South harbor, and why restoration efforts failed at White Head Flats (AECOM, 2012) and eelgrass disappeared from Crow Point Flats since 2006 (DMF 2017 acoustic mapping).

Governors Island Flats

The GIF plots quickly coalesced and expanded over an acre beyond the original planted area in the third year after planting. Plot expansion and vegetated area was measured by divers in the field. The expansion of the restoration site coincided with a large expansion of eelgrass over the greater Governors Island Flat, mapped using acoustic methods. Eelgrass was not on maps in this area prior to 2016, but small, low density patches had been reported in the area for several years. MWRA has a SPI monitoring station northwest of our site that had eelgrass present beginning in 2008 (Ken Keay, MWRA, Pers com., Nestler et al., 2014). In our second season of monitoring we observed a high number of reproductive shoots, followed by evidence of successful seeding within and around the transplants, and successful recruitment and growth of seed shoots. Transplanting additional eelgrass into this area may have spurred more seeding and facilitated seed retention by slowing currents and trapping seeds (Livernois et al., 2017, Orth et al., 1994) enabling further expansion and melding of smaller patches.

Unsuccessful sites

We mapped increases in eelgrass acreage at some sites in the North harbor (GIF and Nahant Bay) and protected harbor islands (Long Island and Peddock's Island) (DMF 2016 and 2017 acoustic mapping). However, bioturbation, macroalgae and wave energy at the outer island sites and high TSS and silty sediments in the interior harbor and South harbor sites continue to make it difficult to find suitable restoration sites in Boston Harbor.

Test and full-scale sites that did not survive failed due to a variety of site-specific reasons. Great Brewster Island rated well in our site selection process and initial planting was successful but *Cancer spp.* crabs burrowed under most of the disks and shoot density declined over the monitoring period. Similarly, at the six month monitoring at Long Island East we observed a mat of algae and *Crepidula* spp. shells over the entire area that likely moved in during a late winter storm and smothered the plants. These results highlight the importance of seasonal differences in planting success and again underscore the need to assess test plots for at least one full year.

High energy sites in outer Boston Harbor fared poorly. At Gallops Island, the southern shore has sandy substrate with shell hash and some gravel and cobble. The sediment composition throughout the site and the seemingly protected location near a rock spit made it appear favorable. However, our test-plot failed, likely due to high current and wave energy perhaps from passing ferries in the nearby channel.

Substrate and lack of sufficient light was a problem for several sites. Silty sediments and insufficient light contributed to the failure of the test-plot at Deer Island. In the relatively turbid, low light environments of Boston Harbor, eelgrass needs even higher light to off-set stressful sulfide toxicity in the sediments (Duarte et al., 1991, Kenworthy et al., 2014). Unlike the GIF plants, the plants at Deer Island lacked significant lateral expansion and there was no evidence of seeding. Lateral branching is reduced at low light (Colarusso, 2006) explaining the lower shoot densities at this site. Lovell Island had a rocky-cobble substrate and although we anchored the shoots with cobbles, shoots did not sufficiently root into underlying sand. Initial results were promising but after 6 months no shoots remained. Use of the rock method was initially promising at Green Island, but ultimately the macroalgae cover at this site was too high. Grass persisted through 2016 but only in isolated patches where it took root in the finer sediments between rocks and where it was not smothered by macroalgae.

6.0 Conclusions

Hub3 was a six year project (2010-2016) with a total cost of $800,000, paid for by Algonquin Gas Transmission as mitigation for impacts to eelgrass from the installation of the HubLine pipeline. Of the 16 sites that were investigated for this project, seven were selected for full-scale restoration. Three of the seven persisted in 2016 with a total of 2.4 acres of eelgrass, exceeding the project requirement of 1.8 acres by 2017. Furthermore, we expect the restored sites to continue to expand into surrounding suitable habitat. WP eelgrass has expanded into an area equivalent to the impacted site's originally planted area, despite not meeting success criteria for shoot density. MG has a shoot density equivalent to reference sites, despite not yet meeting success criteria for area. GIF has met both success criteria. Shoot density is at reference levels and vegetated area is greater than the area of the original site planted. Our experience over the last five years has led us to the following conclusions:

- The burlap disk (BD) method is our preferred method of transplanting due to the high percent survival, ease of monitoring and reduced dive time required for planting. We recommend the BD method in silty, sandy and gravelly-sand conditions.
- We recommend monitoring test plots for at least one full year to capture seasonal effects at a site before committing to a larger restoration effort.
- We recommend using acoustic mapping methods, in addition to diver measurements, to assess restoration success. Diver measurements provide a finer-scale assessment of plant metrics and plot expansion, while acoustic methods capture broad changes and overall areal development of the meadow.
- More time is needed before concluding success for areal coverage of the MG restoration site as it has not yet been five years since it was fully planted, which is the minimum time expected for transplanted meadows to fully develop (Evans and Short, 2005; McGlathery et al., 2012).
- We found that reference site selection should not only include similar depth, proximity to transplant site, persistence and health of the meadow and ease of access, but also an assessment of the wave, current and sediment characteristics, as indicators of a sites energy and patchiness.
- The Short et al. (2000) Success Criteria method was a helpful tool to determine restoration success. We recommend using diver measurements to assess the survival and areal expansion of the planting units and to assess development of plant parameters using the Short et al. (2000) method. We also recommend acoustic mapping to determine the overall area vegetated and, althought not done for this project, to monitor the percent patch cover at the meadow scale in the restored area compared to a reference area, as part of a project's success criteria.

7.0 References

Aecom (2012) Logan Airport Runway Safety Project Eelgrass (*Zostera marina) Draft* 2012 Annual Monitoring Report East Boston, Massachusetts. September 2012. Submitted to J.F. White contracting Co.

ASA Report (2001) Fate and Transport modeling of contaminants in Salem Sound. Report to the Marine Monitoring and Research Technical Series MMRTS-01-01. 00-031

Battelle and TRC (2009a) HubLine Pipeline Project: Eelgrass Restoration Site Selection Analysis. February 2009. 44pp

Battelle and TRC (2009b) HubLine Pipeline Project: Eelgrass Restoration Test Planting Evaluation. November 2009. 17pp

Carr J and K Ford (2017) Historic eelgrass trends in Salem Sound, Massachusetts. Final Report submitted to the Massachusetts Bays Program. https://www.mass.gov/files/201708/2016_Salem%20Sound%20Eelgrass.pdf 75pp

Carruthers TJB, BJ Longstaff, WC Dennison, EG Abai and K Aioi (2001) Measurement of light penetration in relation to seagrass. *Global Seagrass Research Methods* Short FT and Coles RG editors. Elseveir Science, Amsterdam, The Netherlands

Churchill AC, G Nieves, and AH Brenowitz (1985) Flotation and Dispersal of Eelgrass Seeds by Gas Bubbles. *Estuaries* 8: 254-352

Colarusso P (2006) Natural and stress induced changes in non-structural carbohydrate concentrations in eelgrass (*Zostera marina*). PhD Dissertation, Northeastern University

Davis RC and FT Short (1997) Restoring eelgrass, *Zostera marina* L., habitat using a new transplanting technique: The horizontal rhizome method. *Aquatic Botany* 59: 1-15

Den Hartog C, (1971) The dynamic aspect in the ecology of seagrass communities. *Thalassia Jugoslavia* 7, 101–112

DMF (2014a) Massachusetts Marine Fisheries Standard Operating Procedures. The Horizontal Rhizome Method: planting and monitoring eelgrass (*Zostera marina*). https://www.mass.gov/files/documents/2018/03/07/HR_planting_monitor_SOP_final%20draft.pdf

DMF (2014b) Massachusetts Marine Fisheries Standard Operating Procedures. The Burlap Disc Method: planting and monitoring eelgrass (*Zostera marina*). https://www.mass.gov/files/documents/2018/03/07/planting_Burlap%20Disc_SOP_final.pdf

DMF (2014c) Massachusetts Marine Fisheries Standard Operating Procedures. Monitoring eelgrass (*Zostera marina*) in a reference bed. https://www.mass.gov/files/documents/2018/03/07/ref%20bed%20monitoring_SOP_final.pdf

Duarte CM (1991) Seagrass depth limit. *Aquatic Botany* 40:363-377

Duarte CM, N Marbe, D Krause-Jensen, and M Sanchez-Camacho (2007) Testing the predictive power of seagrass depth limit models. *Estuaries and Coasts* 30(4):652-656

Evans NT and A Leschen (2010) Technical Guidelines for the delineation, restoration and monitoring of Eelgrass (*Zostera marina*) in Massachusetts Coastal Waters. Massachusetts Division of Marine Fisheries Technical Report Series TR-43

Evans NT and FT Short (2005) Functional trajectory models for assessment of transplanted eelgrass, *Zostera marina* L., in the Great Bay Estuary, New Hampshire. *Estuaries* 28(6):936-947

Evans NT, W Dukes and J Carr (2013) Division of Marine Fisheries HubLine Eelgrass Restoration Mid-project Progress Report. Massachusetts Division of Marine Fisheries report submitted to the Massachusetts Department of Environmental Protection. June 2013. 44pp

Fonseca MS, WJ Kenworthy, FX Courtney, and MO Hall (1994) Seagrass Planting in the Southeastern United States: Methods for Accelerating Habitat Development. *Restoration Ecology* 2(3)198-212

Fonseca MS, WJ Kenworthy, and GW Thayer (1998) Guidelines for the Conservation and Restoration of Seagrasses in the United States and Adjacent Waters. *NOAA Coastal Ocean Program Decision Analysis Series* No. 12. NOAA Coastal Ocean Office, Silver Spring, MD. 222pp

Frederiksen M, D Krause-Jensen, M Holmer, and JS Laursen (2004) Spatial and temporal variation in eelgrass (*Zostera marina*) landscapes: influence of physical setting. *Aquatic Botany* 78:147-165

Gaeckle JL (2006) Eelgrass (*Zostera marina L.*) Leaf Growth and Restoration Ecology: University of Vermont, 1993 – BS University of New Hampshire, 2006 - PhD. 228 p

Hosokawa S, M Nakaoka, E Miyoshi, and T Kuwae (2015) Seed dispersal in the seagrass *Zostera marina* is mostly within the parent bed in a protected bay. *Marine Ecological Progress Series* 523:41-56

Kelly JR (1997) Nitrogen flow and the interaction of Boston Harbor with Massachusetts Bay. *Estuaries* 20(2):365-380

Kenworthy WJ, CL Gallegos, C Costello, D Field and G di Carlo (2014) Dependence of eelgrass (*Zostera marina*) light requirements on sediment organic matter in Massachusetts coastal bays: Implications for remediation and restoration. *Marine Pollution Bulletin* 83(2):446-457

Kopp BS and FT Short (2001) Status report for the New Bedford harbor eelgrass habitat restoration project, 1998-2001. Submitted to the New Bedford Harbor Trustee Council and the NOAA Damage Assessment and Restoration Program: 1-64

Kopp BS and HA Neckles (2009) A protocol for monitoring estuarine nutrient enrichment in coastal parks of the National Park Service Northeast Region. *Natural Resource Report* NPS/NCBN/NRR—2009/110. National Park Service, Fort Collins, Colorado

Latimer JS and RA Rego (2010) Empirical relationship between eelgrass extent and predicted watershed-derived nitrogen loading for shallow New England estuaries. *Estuarine, Coastal and Shelf Science* 90(40):231-240

Lee K-S, SR Park, and YK Kim (2007) Effects of irradiance, temperature, and nutrients on growth dynamics of seagrasses: A review. *Journal of Experimental Marine Biology and Ecology* 350: 144-175

Leschen AS, KH Ford, and NT Evans (2010) Successful eelgrass (*Zostera marina*) restoration in a formerly eutrophic estuary (Boston Harbor) supports the use of a multifaceted watershed approach to mitigating eelgrass loss. *Estuaries and Coasts* 15pp

Livernois MC, JH Grabowski, AK Poray, TC Gouhier, AR Hughes, KF O'Brien, LA Yeager, and FJ Fodrie (2017) Effects of habitat fragmentation on Zostera marina seed distribution. *Aquatic Botany* 142:1-9

MADOT (1938) Massachusetts Department of Transportation Survey Department Aerial Photograph Database, Tile Number A-4-N_4-140.accessible via request here http://www.massdot.state.ma.us/highway/Departments/Survey/AerialPhotographsArchive.aspx

McGlathery KJ, LK Reynolds, LW Cole, RJ Orth, SR Marion, and A Schwarzschild (2012) Recovery Trajectories during State Change from Bare Sediment to Eelgrass Dominance. *Marine Ecology Progress Series* 448: 209–21

Nestler E, Pembroke A, and Hasevlat R. (2014) Quality Assurance Project Plan for Benthic Monitoring 2014–2017. Boston: Massachusetts Water Resources Authority. Report 2014-03, 92 pp. plus Appendices

Ochieng CA, FT Short and DI Walker (2010) Photosynthetic and morphological responses of eelgrass (*Zostera marina* L.) to a gradient of light conditions. *Journal of Experimental Marine Biology and Ecology* 382:117–124

Olesen B and K Sand-Jensen (1994) Patch dynamics of eelgrass *Zostera marina*. *Marine Ecology Progress Series* 106:147-156

Orth RJ, M Luckenbach and KA Moore (1994) Seed dispersal in a marine macrophyte: implications for colonization and restoration. *Ecology* 75(7)1927-1939

Orth RJ, SR Marion, KA Moore and DJ Wilcox (2010) Eelgrass (*Zostera marina* L.) in the Chesapeake Bay Region of Mid-Atlantic Coast of the USA: Challenges in Conservation and Restoration. *Estuaries and Coasts* 33:139-150

Pembroke AE, RJ Diaz and EC Nestler (2016) Boston Harbor Benthic Monitoring Report: 2016 Results. Boston: Massachusetts Water Resources Authority. Report 2017-10. 45pp

Pickerell C. Cornell Cooperative Extension, pers. com. 2011

SeagrassNet. Global Seagrass Monitoring Network. http://seagrassnet.org/ Accessed in 2016

Short FT, DM Burdick, CA Short, RC Davis, and PA Morgan (2000) Developing success criteria for restored eelgrass, salt marsh and mud flat habitats. *Ecological Engineering* 15: 239-252

Taylor DI (2006) 5 years after transfer of Deer Island flows offshore: an update of water-quality improvements in Boston Harbor. Boston: Massachusetts Water Resources Authority. Report ENQUAD 2006-16. 77pp

Taylor DI (2015) Boston Harbor Water Quality 1994-2014. Boston: Massachusetts Water Resources Authority. Report 2015-05. 11 pp

Tuxbury S. Formerly of Save the Bay, pers. com. 2011

Van Katwijk MM, AR Bos, VN de Jonge, LSAM Hanssen, DCR Hermus, and DJ de Jong. (2009) Guidelines for Seagrass Restoration: Importance of Habitat Selection and Donor Population, Spreading of Risks, and Ecosystem Engineering Effects. *Marine Pollution Bulletin* 58: 179–88

Vaudrey JMP, JN Kremer, BF Branco, and FT Short (2010) Eelgrass Recovery after Nutrient Enrichment Reversal. *Aquatic Botany* 93: 237–43.

8.0 Acknowledgements

Thanks to all who worked on this project from the initial planning, permitting and budgeting, to the field work, data analysis, presentations and report preparation; particularly, Wesley Dukes, Andrew Weinstock, Vin Malkoski, Kevin Creighton and Ross Kessler, all of DMF, and Alison Leschen and Holly Bourbon, formerly of DMF. Thanks also to the many volunteers who donated their time through the Salem Sound Coastwatch and the New England Aquarium.

Appendix A – Hubline Project Amendment to 401 WQ Cert. and Waterways license

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENERGY & ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
ONE WINTER STREET, BOSTON, MA 02108 617-292-5500

DEVAL L. PATRICK
Governor

TIMOTHY P. MURRAY
Lieutenant Governor

IAN A. BOWLES
Secretary

LAURIE BURT
Commissioner

November 24, 2009

Mr. George McLachlan
Manager, Environmental
Algonquin Gas Transmission, LLC
890 Winter Street, Suite 300
Waltham, MA 02451

Re: HubLine Pipeline Project
Amendment to 401 Water Quality Certificate No. W015087 and
Minor Project Modification, Waterways License No. 9451

Dear Mr. McLachlan:

The purpose of this amendment is to authorize, under 314 CMR 4.00 and 310 CMR 9.00, final conditions and additional performance steps that are necessary for Algonquin Gas Transmission, LLC (the Permittee) to complete the requirements of the 401 Water Quality Certificate No. W015087 (WQC) issued by the Massachusetts Department of Environmental Protection (Department) on August 16, 2002 (as amended on March 27, 2003; August 28, 2003; November 17, 2004; and December 23, 2005) and the Waterways License No. 9451 issued by the Department on September 26, 2002 (License 9451).

The project approved under the WQC and License 9451, the HubLine Pipeline Project, involved the installation of approximately 29 miles of 30-inch diameter pipe through the waters of Beverly Harbor, Salem Sound, Massachusetts Bay, Broad Sound, Quincy Bay, and the Fore River. The pipeline was buried approximately 3 to 10 feet below the seafloor primarily using a plow, but horizontal directional drilling, jetting, and conventional dredging techniques were also used. Armoring over the pipeline was used where the pipeline crossed existing utility lines and in other areas where added protection was necessary, such as the Precautionary Area. Post-construction monitoring of eelgrass and benthic habitat were required in the WQC.

As-built conditions of the project are reflected on the plans referenced in Attachment A and on file with the Department, and in a spreadsheet entitled "Hubline Pipeline Project, Imported

Backfill Lengths based on Profile Signature and OSI Post Construction Survey," provided to the Department on March 3, 2009.

Chapter 91 authorization

License 9451 authorized placement of hard cover material at selected locations to protect the pipeline and pre-existing facilities. Placement of hard cover at additional locations was authorized by a permit under § 404 of the Clean Water Act issued by the U.S. Army Corps of Engineers (USACE) on September 22, 2002, at the request of the U.S. Coast Guard and the Massachusetts Office of Coastal Zone Management (CZM), and by the Department in later amendments to the WQC, in order to protect public safety due to the risk of vessel anchor drops on the pipeline. During construction, as documented by the Permittee's weekly status reports and subsequent filings, the Permittee placed hard cover at additional locations in order to protect the pipeline from insufficient burial depth. The locations of the hard cover materials placed over the pipeline are shown on the as-built plans listed in Attachment A. The additional material shown on the as-built plans is hereby authorized as a Minor Project Modification pursuant to 310 CMR 9.22(3).

Post-construction Impact Evaluation

(a) Recovery of benthic habitat

Condition 11 of the WQC required the Permittee to perform up to four years of post-construction monitoring of benthic habitat disturbed by pipeline construction. The purpose of this monitoring was to assess the recovery of benthic habitat conditions within the pipeline route to pre-construction conditions. The sampling and analytical procedures were detailed in the WQC and in the Comprehensive Marine Environmental Monitoring Plan submitted by the Permittee and incorporated by reference into the WQC. Annual meetings between the Permittee and an inter-agency committee comprising the Department, the USACE, the U.S. Environmental Protection Agency (EPA), the National Marine Fisheries Service (NMFS), the Division of Marine Fisheries (DMF), and CZM (the "inter-agency committee") reviewed the results of the surveys. The Third Post-construction Monitoring Report prepared by the Permittee proposed the use of a Weight of Evidence (WOE) approach to evaluate the likelihood that impacts due to construction were still affecting the benthic habitat.

Beginning in the summer of 2008, the inter-agency committee and the Permittee sought to reach an agreement on quantifying the extent to which changes in the benthic habitat proximate to the pipeline should be attributed to the project. Due in part to difficulties in implementing the approved monitoring plan, and due in part to changes in the sampling and analysis methods adopted by the Permittee, the Permittee and the inter-agency committee were unable to reach concurrence on quantifying the degree of benthic recovery. The Permittee's position, using the WOE approach, is that there are no significant net or negative impacts to benthic habitat. The inter-agency committee evaluated the WOE approach and objected to its adoption as the methodology to evaluate post-construction benthic impacts. The inter-agency committee, using the same data and the agencies' application of the analysis methods set out in the WQC, determined that a significant area of benthic habitat has not recovered.

(b) Hard Cover

There are additional benthic impacts due to placement of hard cover over the pipeline corridor. The Department finds that in excess of 13 acres of hard cover were placed without specific approval in the WQC or any amendments. The Permittee disputes that finding and has provided evidence that the USACE in consultation with cooperating agencies, not including the Department, approved most of this additional material to protect public safety against vessel anchor drops.

Compensatory Mitigation for Post Construction Impacts

Benthic Habitat

Condition 12 of the WQC required appropriate mitigation for habitat found to have not recovered during the monitoring period. The mitigation is to be commensurate with the areas found to have not met the recovery criteria, as determined by the Permittee and the inter-agency committee. Notwithstanding the absence of concurrence by the inter-agency committee and the Permittee on the application of the post-construction impact measurement methodologies, the Department and the inter-agency committee have agreed on the type and amount of compensatory mitigation consistent with their best professional judgment. As it is not practical to replicate the benthic habitat that the inter-agency committee believes has thus far not recovered, the Permittee and the Department, with concurrence of the inter-agency committee, agree that as appropriate mitigation, the Permittee shall provide funding as set forth below for ocean surveys to supplement and aid ongoing data collection for the Ocean Plan under development and later implementation by the Executive Office of Energy and Environmental Affairs pursuant to the Massachusetts Oceans Act of 2008 (Oceans Act surveys). The Oceans Act surveys will collect data on seafloor surface geology that will enable future projects within the surveyed area to conduct suitable alternatives analysis that can help to avoid and minimize future impacts to benthic habitat.

Eelgrass

As required by the WQC, the Permittee conducted pre- and post-construction surveys of eelgrass beds in Beverly Harbor so that any impact of the project to these resources could be determined and mitigated. The inter-agency group and the Permittee reviewed the results of the post-construction surveys in June, 2008 and agreed that a loss of 1.8 acres of eelgrass can be attributed to the HubLine project and requires mitigation.

To implement the mitigation, during the fall and winter of 2008, the Permittee undertook a Site Screening assessment to identify potentially suitable habitat areas to target for restoration planting. The estimated cost of the assessment was $150,000. The Permittee reviewed the results of the Site Screening assessment with the agency committee in early 2009, and the participants agreed upon the scope and proposed locations of a test planting program to determine suitable locations for replicating eelgrass.

During the spring and early summer, 2009 the Permittee completed and provided a progress report on the approved test planting program. The estimated cost of the program was $250,000. The Permittee also provided a final report on the test planting program dated November 2009 and will provide funding as set forth below for an eelgrass planting effort to be conducted by DMF based on locations selected through the test planting program.

Water Quality Certification Amendment

The Department hereby issues this Amended Water Quality Certification with the following conditions:

Amendment Condition # 1:

The Department hereby authorizes all hard cover material placed by the Permittee in locations identified on the as-built plans listed in Attachment A, on file with the Department, and on the spreadsheet entitled "Hubline Pipeline Project, Imported Backfill Lengths based on Profile Signature and OSI Post Construction Survey," provided to the Department on March 3, 2009.

Amendment Condition # 2

The Department accepts the Hubline Pipeline Project Eelgrass Restoration Test Planting Evaluation dated November 2009 as the final report ,and has evaluated the results in accordance with the test plot scope of work approved by the interagency group
Amendment Condition # 3:

Within 20 days of the date of this amendment the Permittee shall provide $700,000 payable to DMF to fund the planting of eelgrass in accordance with the findings of the test program. Within 20 days of the date of this amendment the Permittee shall place an additional $100,000 in an escrow account established by and managed by DMF to be used in the event that replanted eelgrass is unsuccessful and requires additional planting. In the event that the initial planting of eelgrass costs less than $700,000, the remainder of the $700,000 committed shall be placed into the escrow account. The cost to monitor will be paid from the escrowed funds. If during the monitoring period, it is determined that some or all of eelgrass plots need to be replanted or replaced, any costs associated with the harvesting and replanting or replacement of eelgrass will be paid from the escrowed funds. If at the conclusion of the monitoring period, DMF determines that no further replacement planting is necessary, the balance of any funds in the escrow account will be remitted to the Permittee. The inter-agency group has considered the length of time necessary to complete, monitor and replant unsuccessful plot(s) if necessary. It is uncertain at present whether planting would commence in the Spring of 2010, or 2011. The inter-agency group has also discussed the possibility of spreading the initial planting efforts over two years. Following the planting of each plot a 3-year monitoring period will be necessary and then potentially portions of two calendar years will be needed to undertake replanting unsuccessful plots if necessary. Based on these estimated timelines the Permittee's eligibility for a refund of any unspent money will be determined in December of 2017.The completion of Amendment Condition # 2 and payment of all funds in accordance with this condition fully satisfies the Permittee's obligations under the WQC and License No. 9451 for project impacts to eelgrass.

Amendment Condition # 4:

Within 30 days of the date of this amendment the Permittee shall pay $1 million to the Ocean Resources and Waterways Trust Fund to compensate for impacts to benthic habitat resulting from pipeline placement and the addition of hard cover over the pipeline. Said funds shall be disbursed by the Executive Office of Energy and Environmental Affairs to conduct benthic surveys. The payment of all funds in accordance with this condition fully satisfies the Permittee's obligations under the WQC and License 9451 for project impacts to benthic habitat and placement of additional fill material.

Upon full completion of Amendment Conditions # 2 to # 4, the Permittee shall have no further obligations under the WQC or License 9451 to monitor and assess the impacts of the construction of the HubLine Pipeline Project on the ocean and ocean bottom. The Department reserves its authority to require monitoring and assessment of future activities such as operation and maintenance or modifications to the HubLine.

In accordance with the provisions of Section 401 of the Federal Clean Water Act, 33 U.S.C. § 1251 et seq., M.G.L. c.21, §§ 26-53, and 314 CMR 9.00, the Department has determined there is reasonable assurance the project or activity will be conducted in a manner which will not violate applicable water quality standards (314 CMR 4.00) and other applicable requirements of state law.

Please continue to keep the Department informed regarding the progress of the work. If you have any questions on this decision, please contact Alex Strysky at (617) 292-5616.

Sincerely,

Glenn Haas, Acting Assistant Commissioner
Bureau of Resource Protection

Cc: Ted Lento, Regulatory/Enforcement Division, U.S. Army Corps of Engineers
696 Virginia Road, Concord, MA 01742-2751
Bob Boeri, CZM, 251 Causeway Street, Suite 900, Boston, MA 02114
Vin Malkoski, Division of Marine Fisheries, 838 South Rodney French Blvd, New Bedford, MA 02559

ATTACHMENT A

As-built plans entitled "Hubline Pipeline Project" prepared by Duke Energy Gas Transmission/Algonquin Gas Transmission Company:

TABLE 1

Plan Title	Drawing No.	Date
Area Map	M7-L-1000-AB Rev. 6	9/25/01, revised 4/11/05
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1001-AB Rev.3	9/20/01, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1002-AB Rev.4	9/21/01, revised 6/28/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1003-AB Rev.2	9/20/01, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1004-AB Rev.3	9/20/01, revised 4/11/05
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1005-AB Rev.2	9/20/01, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1006-AB Rev.2	9/20/01, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1007-AB Rev.4	9/20/01, revised9/24/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1008-AB Rev.4	9/20/01, revised9/24/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1009-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1010-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1011-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1012-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1013-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1014-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1015-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1016-AB Rev.2	2/6/04, revised 9/24/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1017-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1018-AB Rev.2	2/6/04, revised 4/11/05
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1019-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1020-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1021-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1022-AB Rev.3	2/6/04, revised 4/11/05
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1023-AB Rev.2	2/6/04, revised 4/11/05
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1024-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1025-AB Rev.3	2/6/04, revised 4/11/05
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1026-AB Rev.3	2/6/04, revised 4/11/05
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1027-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1028-AB Rev.1	2/6/04, revised 6/7/04
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1029-AB Rev.3	2/6/04, revised 4/11/05
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1030-AB Rev.3	2/6/04, revised 4/11/05
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1031-AB Rev.3	2/6/04, revised 4/11/05
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1032-AB Rev.1	2/6/04, revised 6/7/04
360 Network Cable Crossing Detail (360 Networks)	M7-D-1001-AB Rev.3	11/13/01, revised 6/7/04
60" Easterly Sewer Outfall 60" Sewer Line Crossing Details	M7-D-1005-AB Rev.3	11/13/01, revised 6/7/04
Area Map	M7-L-1000-AB Rev. 7	9/25/01, revised 3/15/06
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1022-AB Rev.4	2/6/04, revised 3/14/06
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1024-AB Rev.2	2/6/04, revised 3/13/06
30" OD Natural Gas Pipeline Alignment and Profile	M7-A-1025-AB Rev.4	2/6/04, revised 3/13/06

Commonwealth of Massachusetts

Department of Fish and Game

251 Causeway Street, Suite 400
Boston, Massachusetts 02114
(617) 626-1500
fax (617) 626-1505

Deval L. Patrick
Governor
Timothy P. Murray
Lieutenant Governor

Ian A. Bowles
Secretary
Mary B. Griffin
Commissioner

December 23, 2009

Patrick J. Hester
Assistant General Counsel
Spectra Energy Corp.
890 Winter Street, Suite 300
Waltham, MA 02451

Re: HubLine - Amended MassDEP Water Quality Certificate
Deposit of Payments into DMF's Marine Fisheries Research and Conservation Trust

Dear Mr. Hester:

I am responding on behalf of the Division of Marine Fisheries ("DMF") in the Massachusetts Department of Fish and Game. This letter is to confirm that DMF has received two payments from Algonquin Gas Transmission, LLC ("AGT") pursuant to the Amended Water Quality Certificate (the "Amended WQC," copy attached) issued on November 24, 2009 by the Massachusetts Department of Environmental Protection ("DEP") to AGT. Specifically, the payments made by AGT to DMF pursuant to the Amended WQC are as follows:

1. A payment of $700,000 to support a program of eelgrass restoration to be implemented by DMF; and

2. A payment of $100,000 to be held within the Trust for DMF to use on the eelgrass restoration program, if necessary.

DMF has accepted both payments, subject to the terms of the Amended WQC, and deposited them into DMF's *Marine Fisheries Research and Conservation Trust*, an expendable trust established by the Commonwealth pursuant to M.G.L. c. 6A, s.6 and 801 CMR 50.00 (the "Trust"). DMF agrees to provide an annual report to AGT and DEP on the progress of DMF's implementation of the above eelgrass restoration program and its related expenditure of the funds. In addition, in the event that DMF completes the eelgrass restoration program without using the entire $700,000 and $100,000, DMF will return the unused amounts to AGT in accordance with the terms of the Amended WQC.

By your signature below, AGT accepts this letter in lieu of establishing an escrow arrangement as described in the Amended WQC. Thank you for your assistance and cooperation in this matter.

Sincerely,

Richard Lehan

Richard Lehan
General Counsel
Department of Fish and Game
Commonwealth of Massachusetts

Patrick J. Hester

Patrick J. Hester, duly authorized
Spectra Energy Corp.

Attachment (Amended WQC)

cc: Kevin Creighton, CFO, DMF
Kathryn Ford, DMF
Lealdon Langley, DEP
Deerin Babb-Brott, EEA

Appendix B – Links to Hubline eelgrass restoration (Hub3) Annual Reports

HUB3 Fall 2011 Status Report – blog post on SeagrassSoundings.blogspot.com
http://seagrasssoundings.blogspot.com/2011/10/hubline-eelgrass-restoration-fall-2011.html

Hubline Eelgrass Restoration 2012 Annual and Mid-Project Progress Report, June 2013.
http://bit.ly/2oU6L97

DMF Hubline Eelgrass Restoration 2013 Progress Report, July 2014 https://www.mass.gov/files/2017-07/2013-hub3-progress-report.pdf

2014 HUB3 Restoration Field Season – blog post http://seagrasssoundings.blogspot.com/2014/11/2014-hub3-eelgrass-restoration-field.html

Appendix C – Tables and Figures

Tables

Table 1. Site selection and physical characteristics at all sites investigated by DMF from 2010-2012. Light and sediment observations collected by Battelle[‡] in 2009 and DMF* in 2010-2015 and by CZM[x] in 2005. (HR=horizontal rhizome; BD=burlap disk, Rock= Rock method).

Site	Harbor	GPS coordinates	Depth (ft; MLW)	% Light at canopy (HOBO*)	% Light at canopy (1-M off bottom) (Licor*)	Kd (Licor*) Mean 2011-2017	% Light (estimate[‡])	Kd (estimate[‡])	Sediment Obs.	Battelle model	Test-plot (year: method: Survival (days))	Full-scale restoration (year: method)
Reference sites												
West Beach (deep reference) (WBD)	SS	42.55580°N -70.805630°W	12-16	4.2%	32%	0.46	-	-	fine sand	good/ marginal	N/A, reference bed	N/A, reference bed
West Beach (shallow reference) (WBS)	SS	42.55635°N -70.808480°W	6-12	5.6%	32%	0.36	-	-	fine sand / clay	good/ marginal	N/A, reference bed	N/A, reference bed
Peachs Point (PP)	SS	42.518627°N -70.845983°W	6-12	-	39%	0.48	-	-	fine sand/ mud	good / marginal	N/A, reference bed	N/A, reference bed
Logan Airport (LA)	BH	42.354800°N -70.984980°W	<6		27%	0.62					N/A, reference bed	N/A, reference bed
Nahant Bay (NB)	BH	42.426883°N -70.947817°W			30%	0.39					N/A, reference bed	N/A, reference bed
Nahant Cove (NC)	BH	42.418133°N -70.912383°W			35%	0.45					N/A, reference bed	N/A, reference bed
Full-scale restoration sites												
Woodbury Point (WP 11 & WP 12)	SS	42.5418000°N -70.857700°W	12-15	3.4%	18%	0.39	10-20	0.685	gravel/sand / fine sand	marginal	2009: Battelle. High survival	2011: HR 2012: HR&BD
Middle Ground (MG)	SS	42.5314000°N -70.847600°W	6-7	8.13%	20%	0.41	20-35	-	sand / gravel	poor	2011: 2HR deep and shallow. One month 24%, one year 38% survival	2012, 2014, 2015: BD
Fort Pickering (FP)	SS	42.5282000°N -70.866600°W	6	5.17%	26%	0.40	35-50	-	fine sand/ mud	excellent/ good	2011: 2HR+2BD: one month 132% survival	2012: HR & BD
Juniper Cove (JC)	SS	42.5316000°N -70.866800°W	4	12.59%	26%	0.46	35-50	-	fine sand / shell	excellent	2011: 1HR plot. 6 months 68% survival	2012: HR & BD
Governors Island Flats (GIF)	BH	42.3443600°N -70.986570°W	6	2.66%	15%	0.56	10-20	0.576-0.690	mud / fine sand	very good	2009: Battelle. Low survival 2013 June: 1BD plot: four months 46% survival one year 92%	2013, 2014: BD
Green Island (GI)	BH	42.3522910°N -70.893169°W	<6	-	37%	0.46	-	-	patchy sand and boulders	poor	2013: BD, 4 month 74% survival	2013: BD & Rock
Great Brewster Island (GB)	BH	42.3317100°N -70.898370°W	5	-	19%	0.35	-	-	gravel over sand	good	2013: BD. One month 78% survival	2013: BD
Other sites assessed												
Palmer Cove	SS	42.5137530°N -70.882225°W	<6	4.0%[x]	-	-	-		fine sand/ mud	excellent	No, poor visibility, poor water quality, muddy sediments	No

Dead Horse Beach	SS	42.5344270°N -70.874908°W	<6	-	-	-	-	-	sand/ gravel	excellent	No, poor visibility	No
Deer Island (DI)	BH	42.346707°N -70.953088°W	6-12	1.33%	-	-	10-20	0.576-0.690	mud / fine sand	marginal	2009: Battelle. Low survival 2013: DMF. No survival	No – Battelle test plot was lost in 2011, DMF plot was <30% survival, and site is extremely silty
Lovell Island (Lov)	BH	42.327100°N -70.921676°W	<6	-	-	-	-	0.529-0.575	rock/ cobble	poor; adjacent to excellent	2011: Rock method. One month <30%	No – rock method had low survival, high energy site
Long Island East (LIE)	BH	42.328359°N -70.961962°W	6-12	7.4%	-	-	10-20	-	mud / fine sand	good	2011: 2HR plots. One month 54% survival, one year 17% survival	No – crepidula and algae mats
Peddocks Island East (PIE)	BH	42.287052°N -70.941631°W	<6	-	-	-	20-35	0.529-0.575	mud / fine sand	very good	2011: 1HR plot. One month <30%	No –low survival
Thompson Island North	BH	42.318093°N -70.004304°W	<6	-	-	-	-	-	mud / fine sand	good	2005: TERFS as part of HUB1; One month <30%	No – very poor visibility in 3 test attempts in 2011
Gallops Island (GI)	BH	42.325353°N -70.937384°W	4-12	-	-	-	-	-	sand/ shell hash	excellent	2013 – large test plot 5x5m^2 One month 28% survival	No- high wave and current energy
Calf Island	BH	42.344819°N -70.894980°W	8-10	-	-	-	-	-	sand/ gravel	poor	No, very small suitable area	No

Table 2. Planting Results Table (*initial monitoring event was between 1 and 3 month post planting,**see figures 4-10 for site layouts)

Full Scale Restoration Site	Year Planted	Density (Shoots/m^2) and (total shoots planted)	Initial Shoot Density (Shoots/m^2)* and (% Survival)	Final Site Shoot Density (Shoots/m^2) (Last year monitored)	Number of Planted Plots **	Planted Plot Area	Planted Site Area	Final Site Area	Shoot Density Success Criteria	Area Success Criteria
Woodbury Point (WP 11 & WP 12)	June – Aug 2011	24 (11,808 total)	7.5 (31.25%)	111.5 (2016)	3 plots of 144 planted squares & 1 plot with 60 planted squares (492 squares)	3 12x24m & 1 5x24m plot (984m^2)	1836m^2 (0.45 acres)	WP12 Diver Assessment 228m^2 (0.06 acres) WP 11 & WP 12 Acoustic Assessment 1699m^2 (0.42 acres)	Not Met	Met
	June – July 2012	50 (3,900 total)	44.7 (89.4%)	83.3 (2016)	6 plots of 13 planted squares (78 squares)	6 5x5m plots (150m^2)	1650m^2 (0.4 acres)			
Middle Ground (MG)	6 plots in July 2012 2 plots in Sept & Aug 2014 1 plot in May 2015	50 (5,850 total)	2012 plots 61.8 (123.7%) 2014/2015 plots 50.9 (101.8%)	245.6 (2016)	9 plots of 13 planted squares (117 squares)	9 5x5m plots (225m^2)	3300m^2 (0.8 acres)	Diver Assessment 252m^2 (0.06 acres) Acoustic Assessment 648 m^2 (0.16 acres)	Met	Not Met
Fort Pickering (FP)	June 2012	50 (3,900 total)	39.2 (78.3%)	75 shoots total (2014)	6 plots of 13 planted squares (78 squares)	6 5x5m plots (150m^2)	1500 m^2 (0.37 acres)	Not monitored after 2014	Not Met	Not Met
Juniper Cove (JC)	2012	50 (1950 total)	2 (1%)	2 (2012)	3 plots of 13 planted squares (39 Squares)	3 5x5m plots (75m^2)	250m^2 (0.06 acres)	Not monitored after 2012	Not Met	Not Met
Governors Island Flats (GIF)	7 plots between June – August 2013 3 plots in Sept & Oct 2014	50 (6350 total)	2013 plots 31 (63.2%) 2014 plots 49.4 (98.8%)	150.6 (2016)	9 plots of 13 planted squares and 1 plot of 10 planted squares (127 squares)	9 5x5m & 1 5x4m plots (245m^2)	2800m^2 (0.7 acres)	Diver Assessment 7284.3m^2 (1.8 acres)	Met	Met
Green Island (GI)	May – October 2013	50 (3250 total)	42.8 (85.6%)	19 (2015)	5 plots of 13 planted squares (65 squares)	5 5x5m plots (125m^2)	1000m^2 (0.25 acres)	Not monitored after 2015	Not Met	Not Met
Great Brewster Island (GB)	6 plots between May – Sept 2013 1 plot in May 2014	50 (4,550 total)	2013 plots 17.3 (34.7%) 2014 plot 7 (14%)	0 (2016)	7 plots of 13 planted squares (91 squares)	7 5x5m plots (175m^2)	1650m^2 (0.4 acres)	Gone	Not Met	Not Met

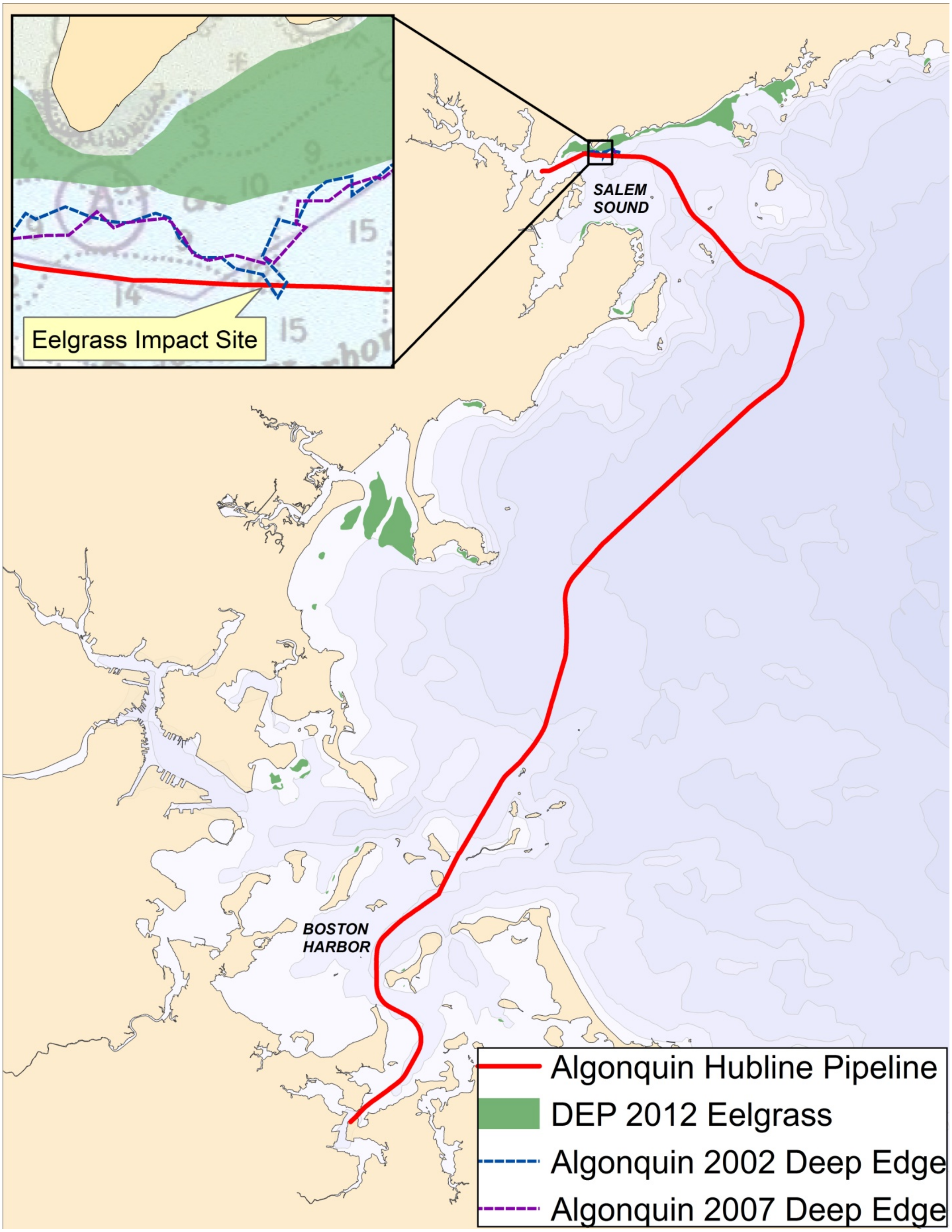

Figure 1. Location of the Algonquin Hubline Liquid Natural Gas Pipeline and the eelgrass impact site.

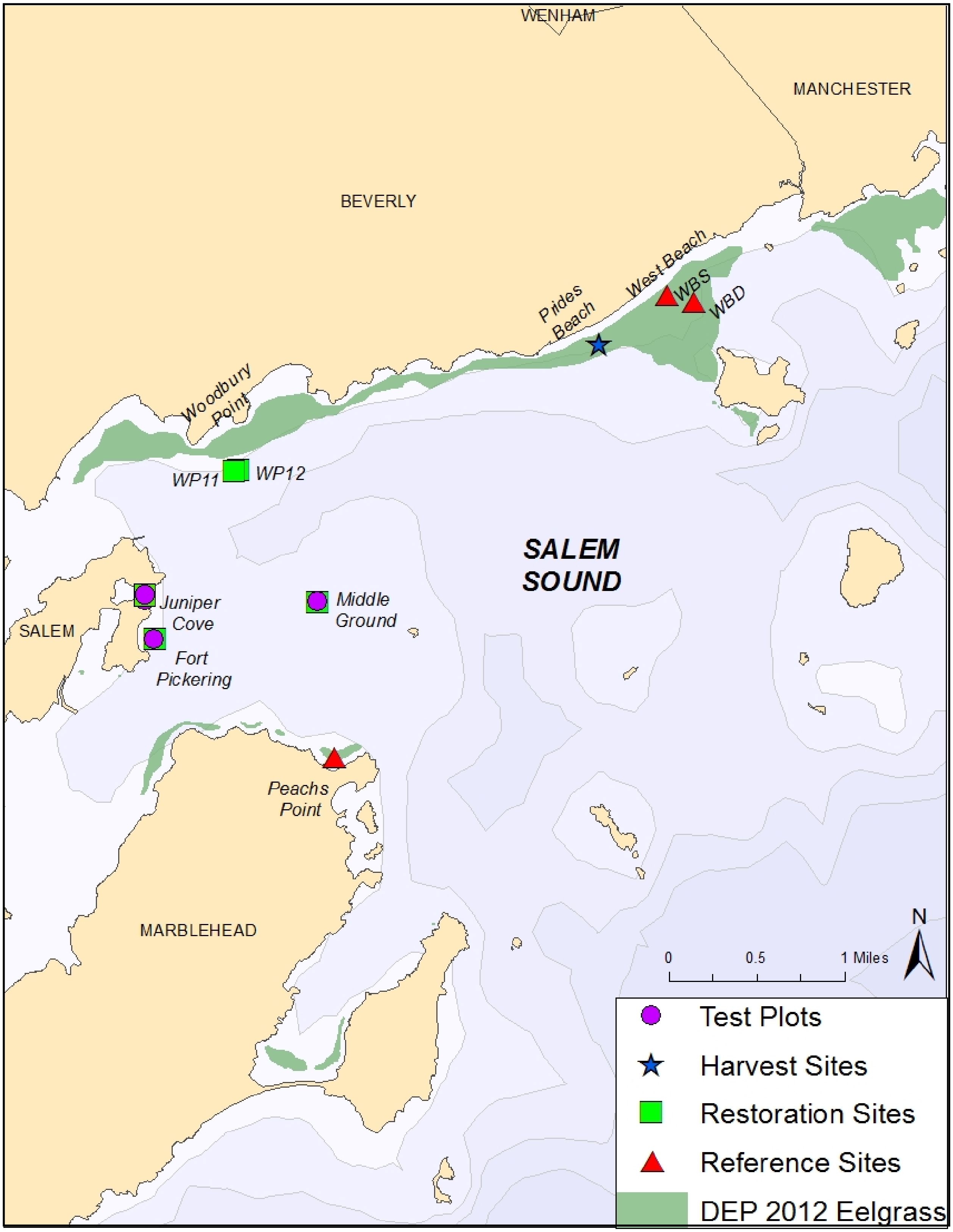

Figure 2. HUB3 Salem Sound Sites: Monitoring, transplant, harvest and reference.

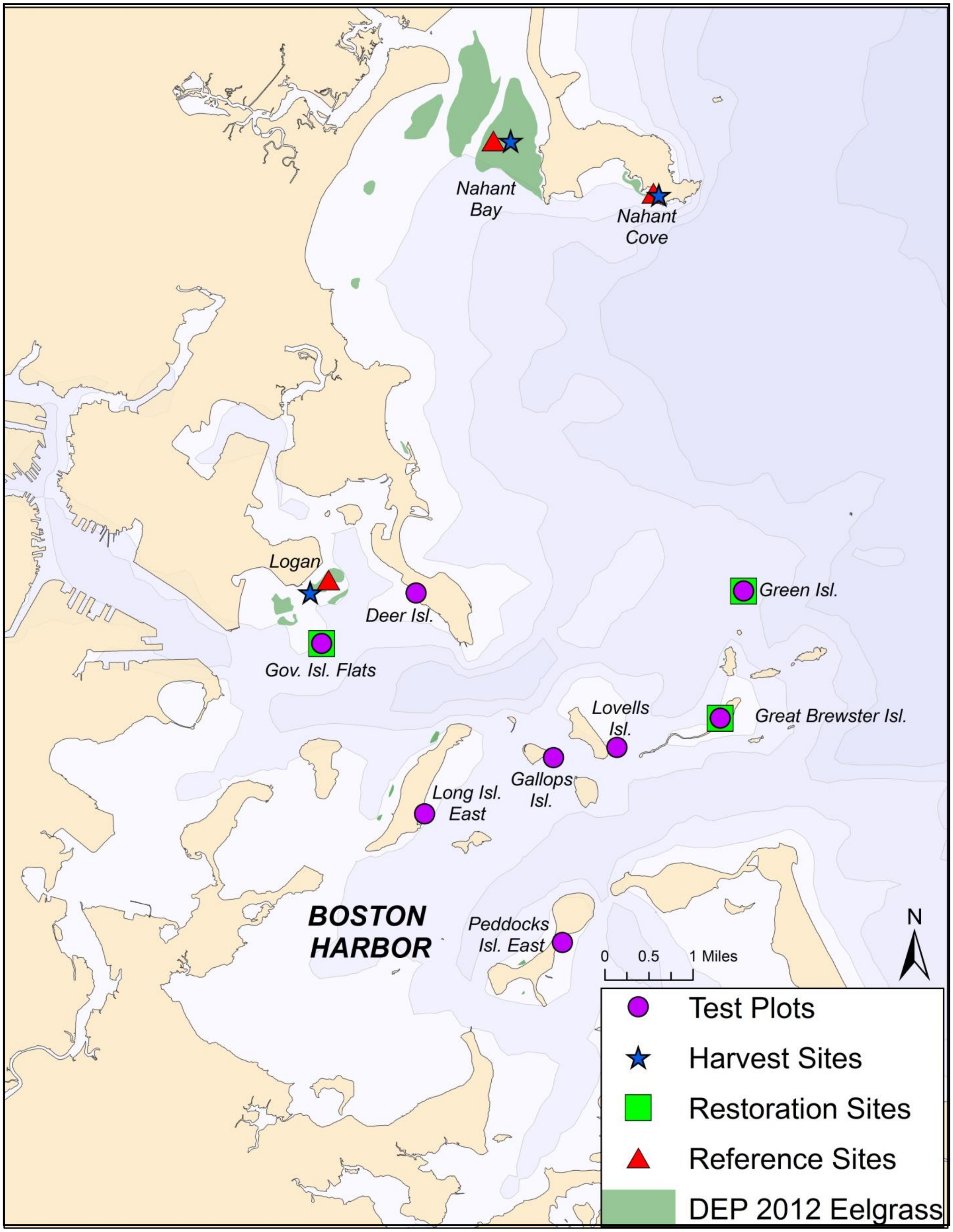

Figure 3. HUB3 Boston Harbor Sites: Monitoring, transplant, harvest and reference.

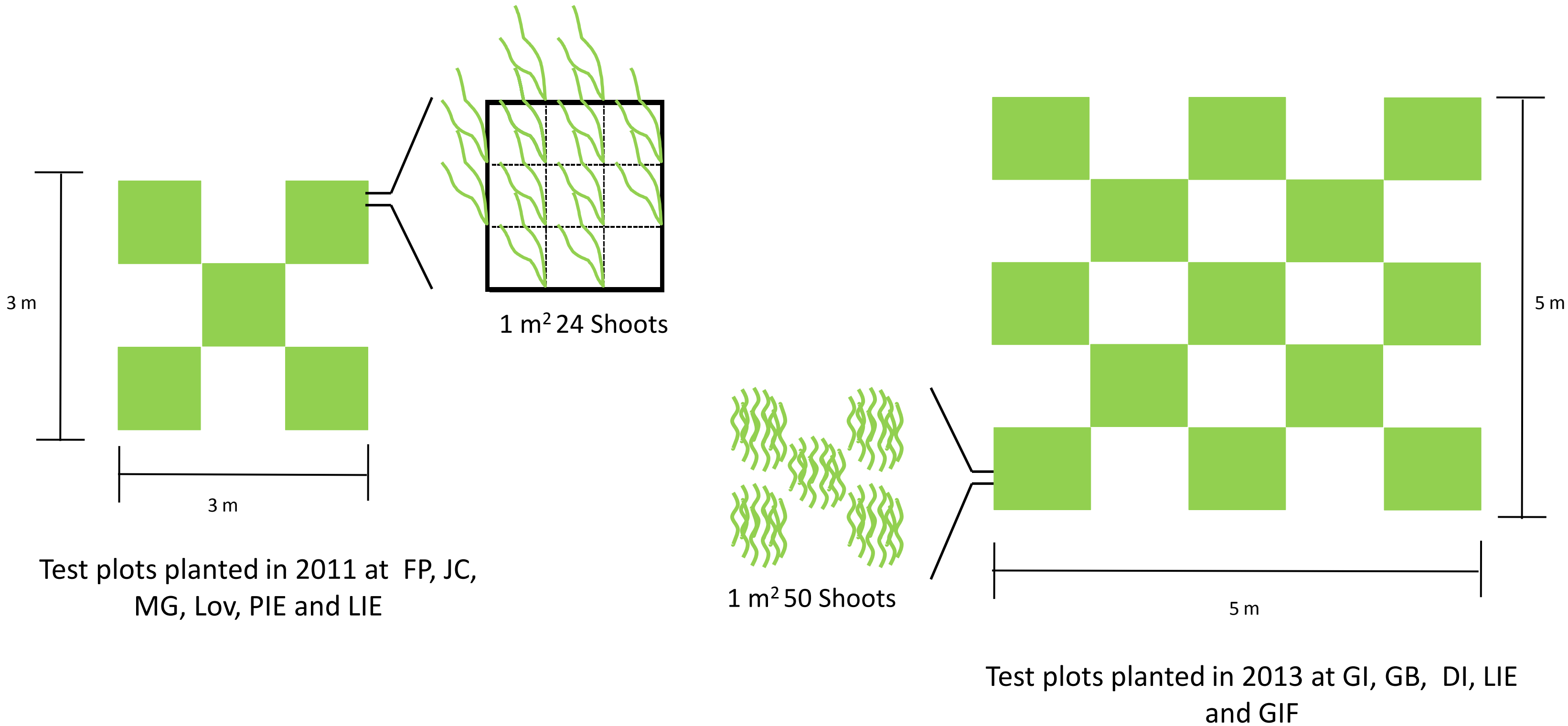

Figure 4. Test-plot transplant layout designs.

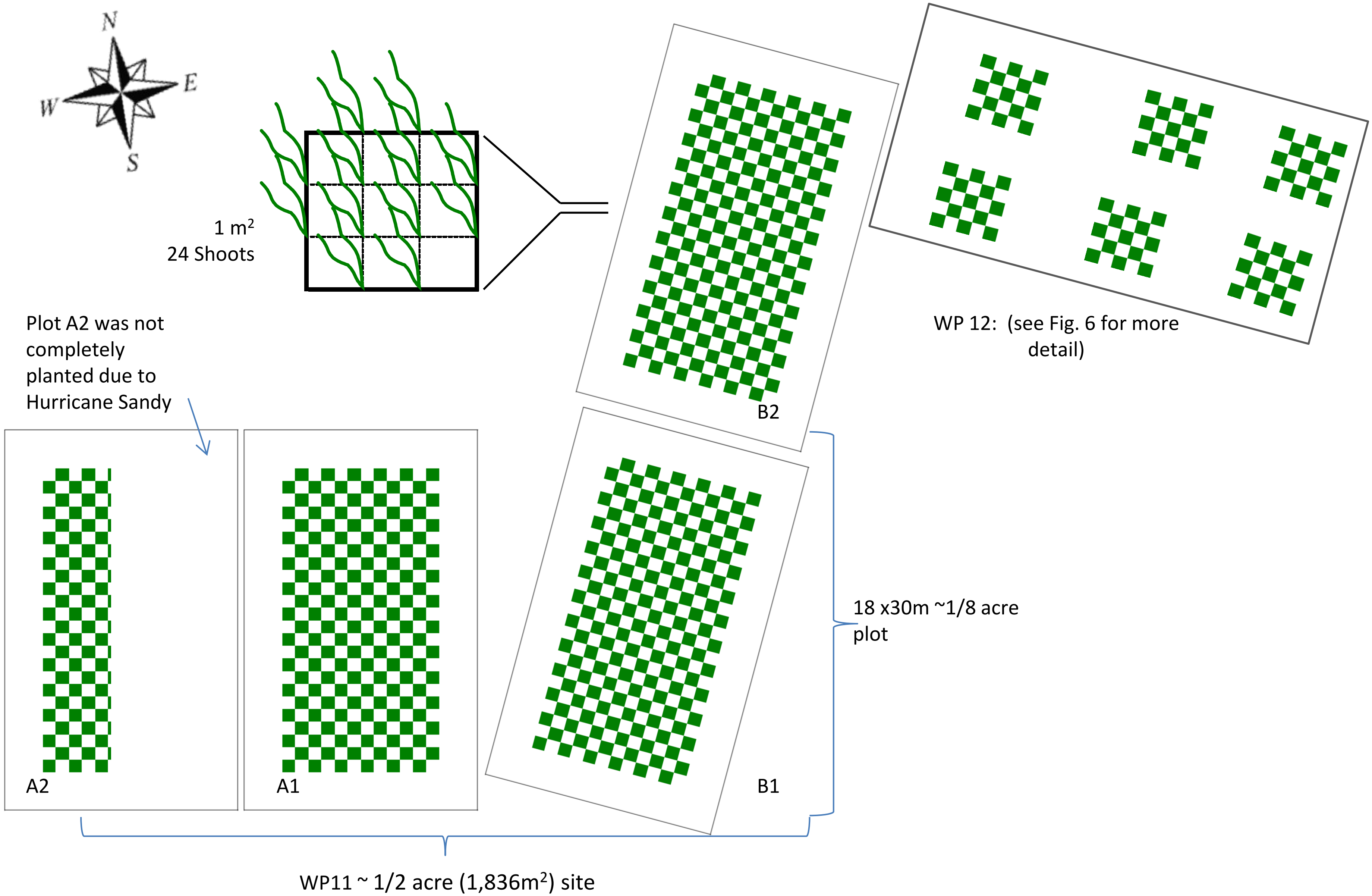

Figure 5. Woodbury Point (WP 11) plots A1, A2, B1 and B2, horizontal Rhizome transplant site plan (50 shts/m2) and WP 12 Burlap disc site (24 shts/m2).

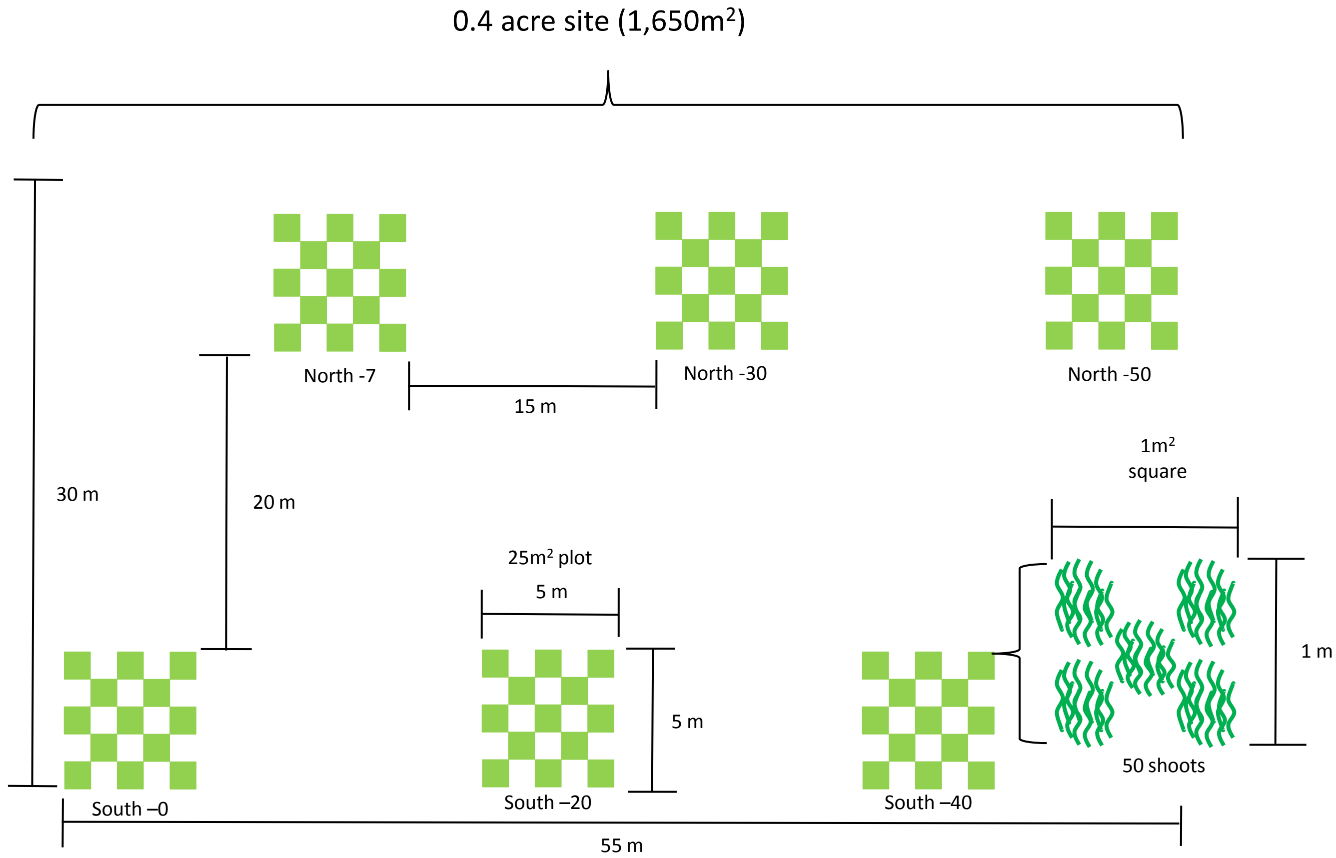

Figure 6. Transplant layout design for Woodbury Point (WP 12), Fort Pickering (FP), and Great Brewster (GB).

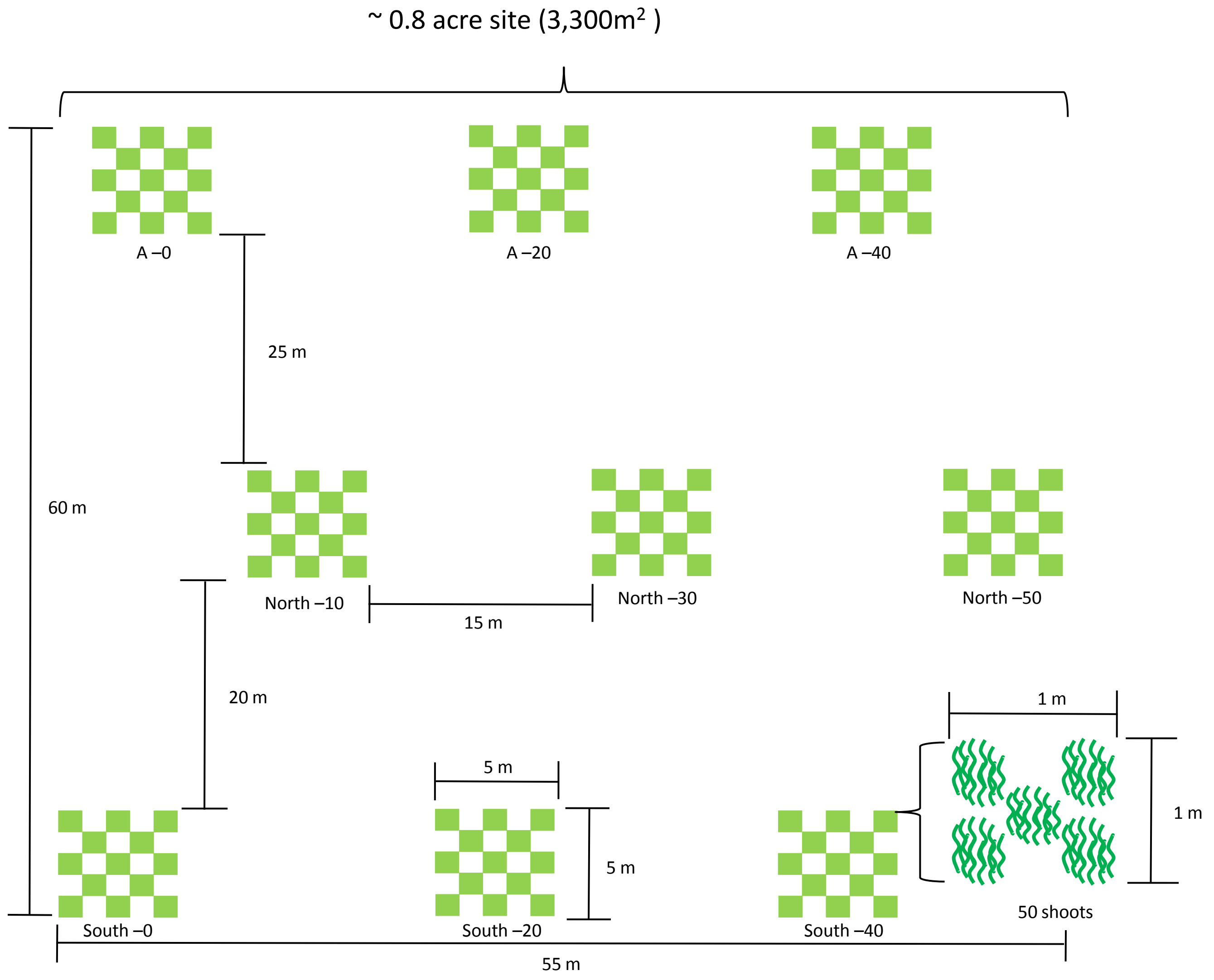

Figure 7. Middle Ground (MG) burlap disc transplant site plan.

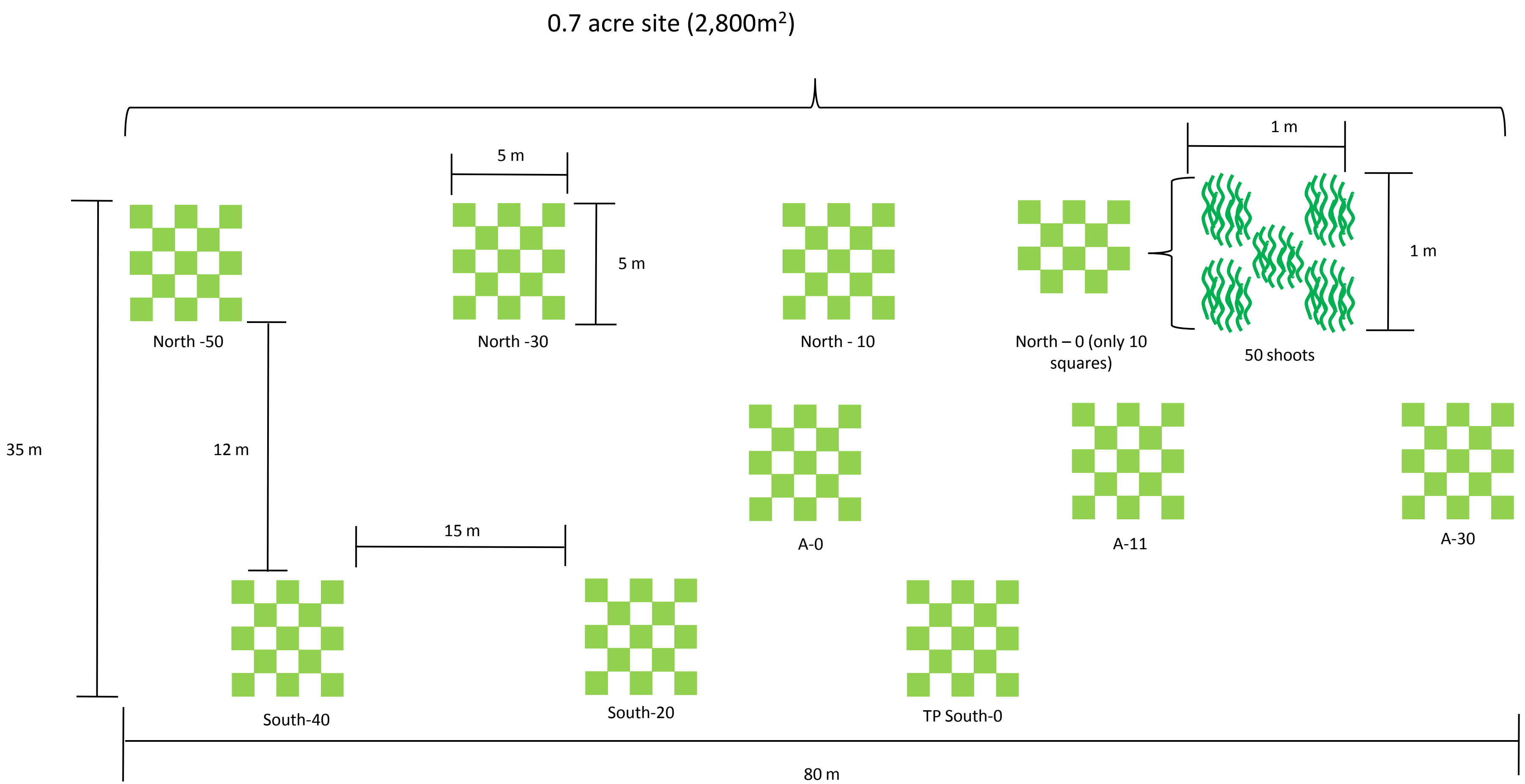

Figure 8. Governors Island Flats (GIF) burlap disc transplant site plan.

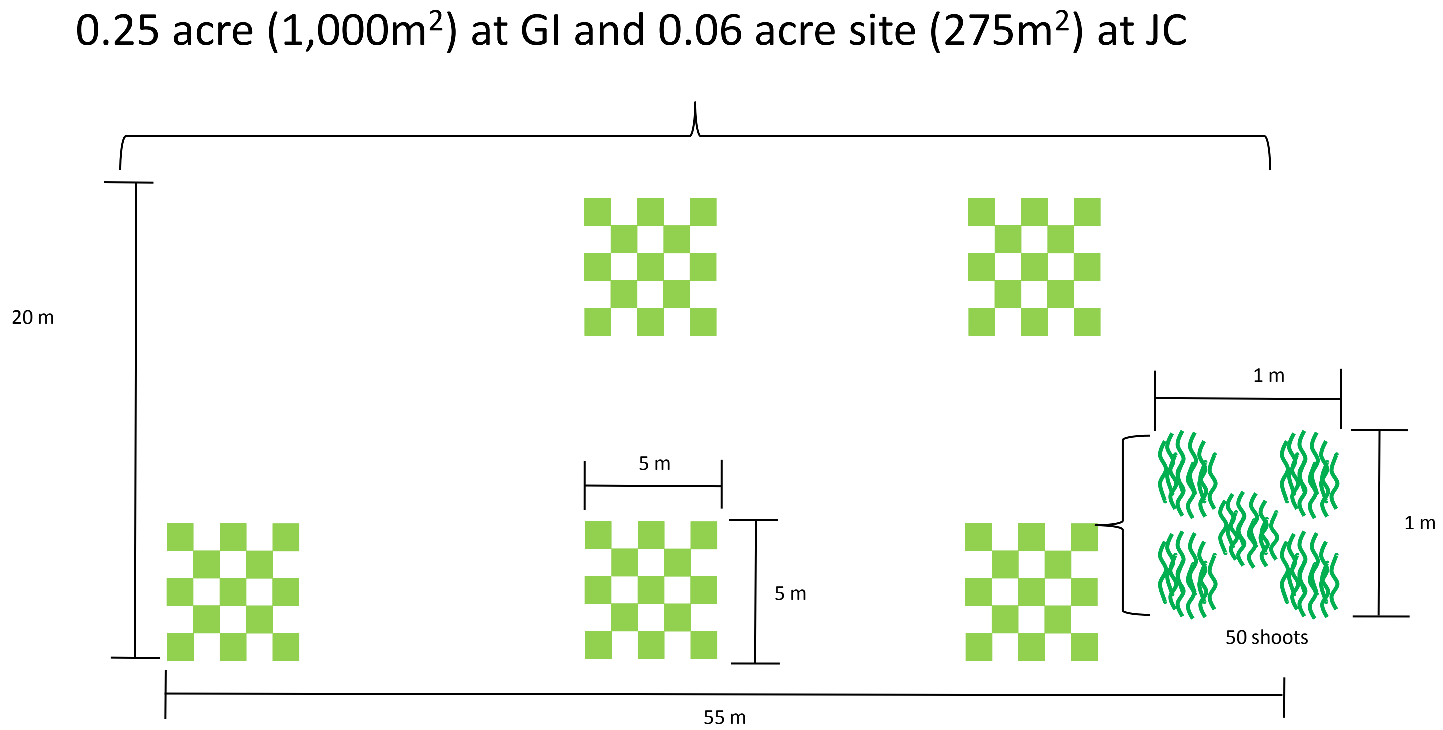

Figure 9. Green Island (5 plots) and Juniper Cove (3 plots) burlap disc transplant site plan.

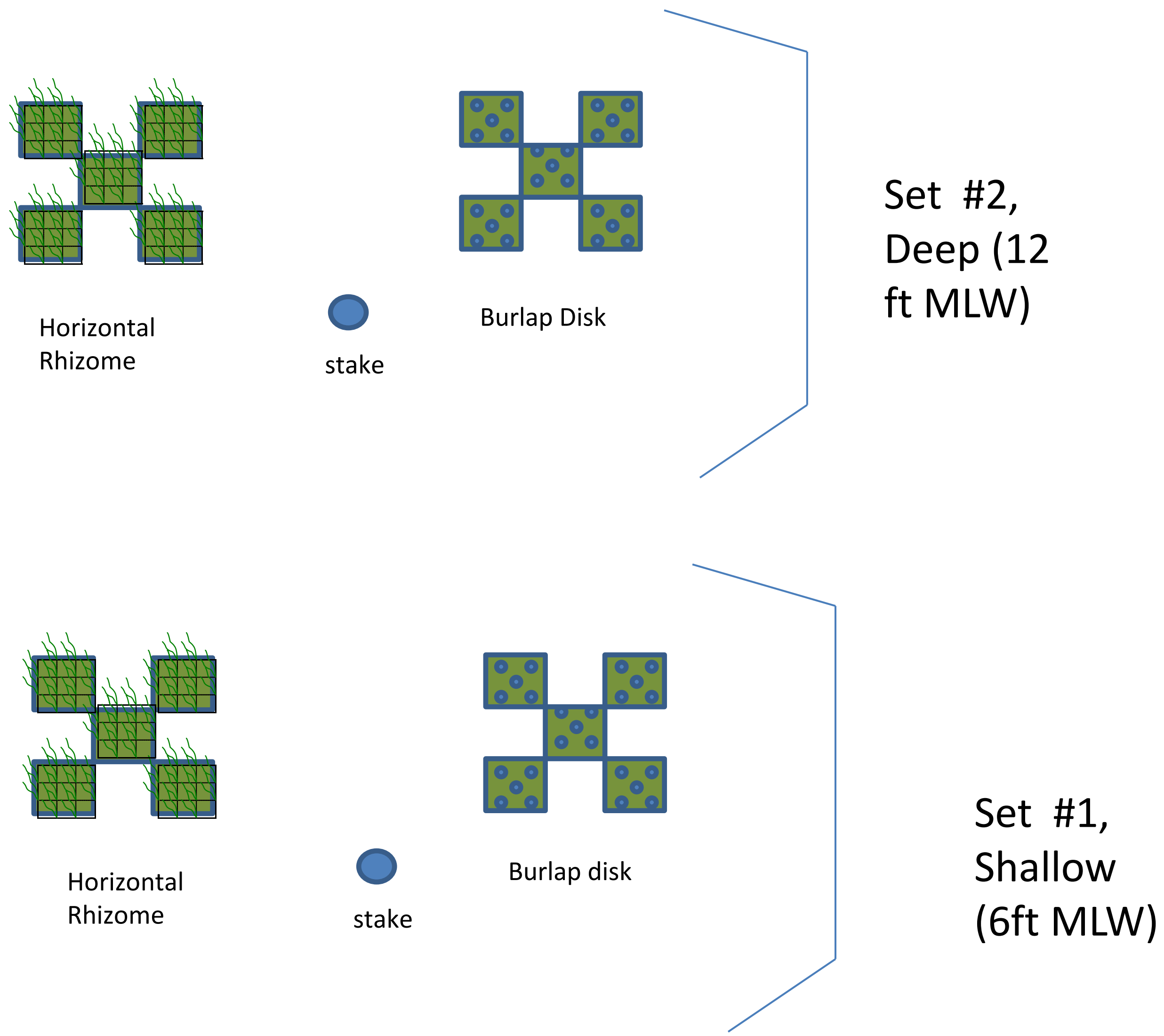

Figure 10. Test plot layout at Fort Pickering. Horizontal Rhizome and Burlap Disk method comparison experimental plots.

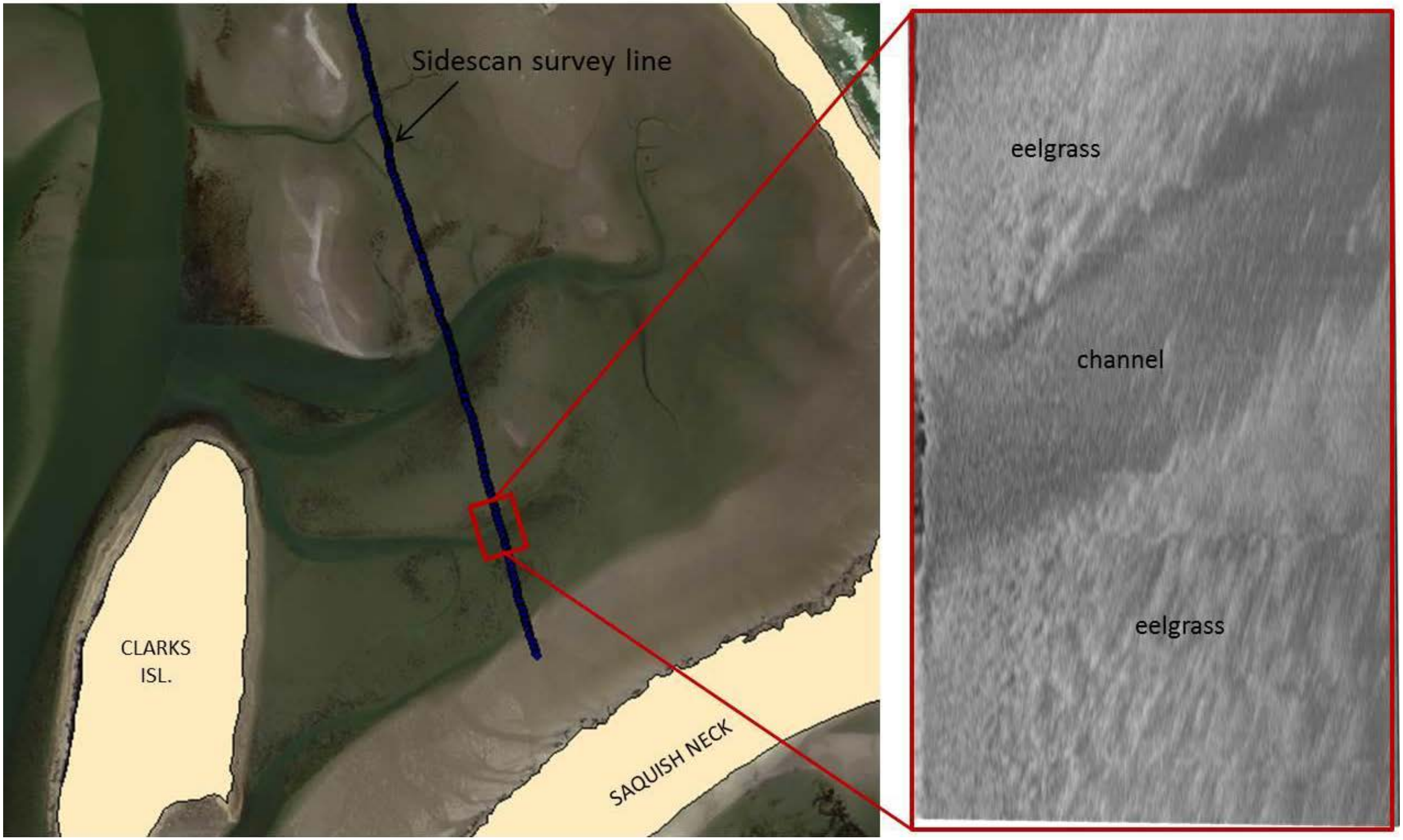

Figure 11. Example in Duxbury Bay of sidescan image output showing the signature of eelgrass versus unvegetated bottom.

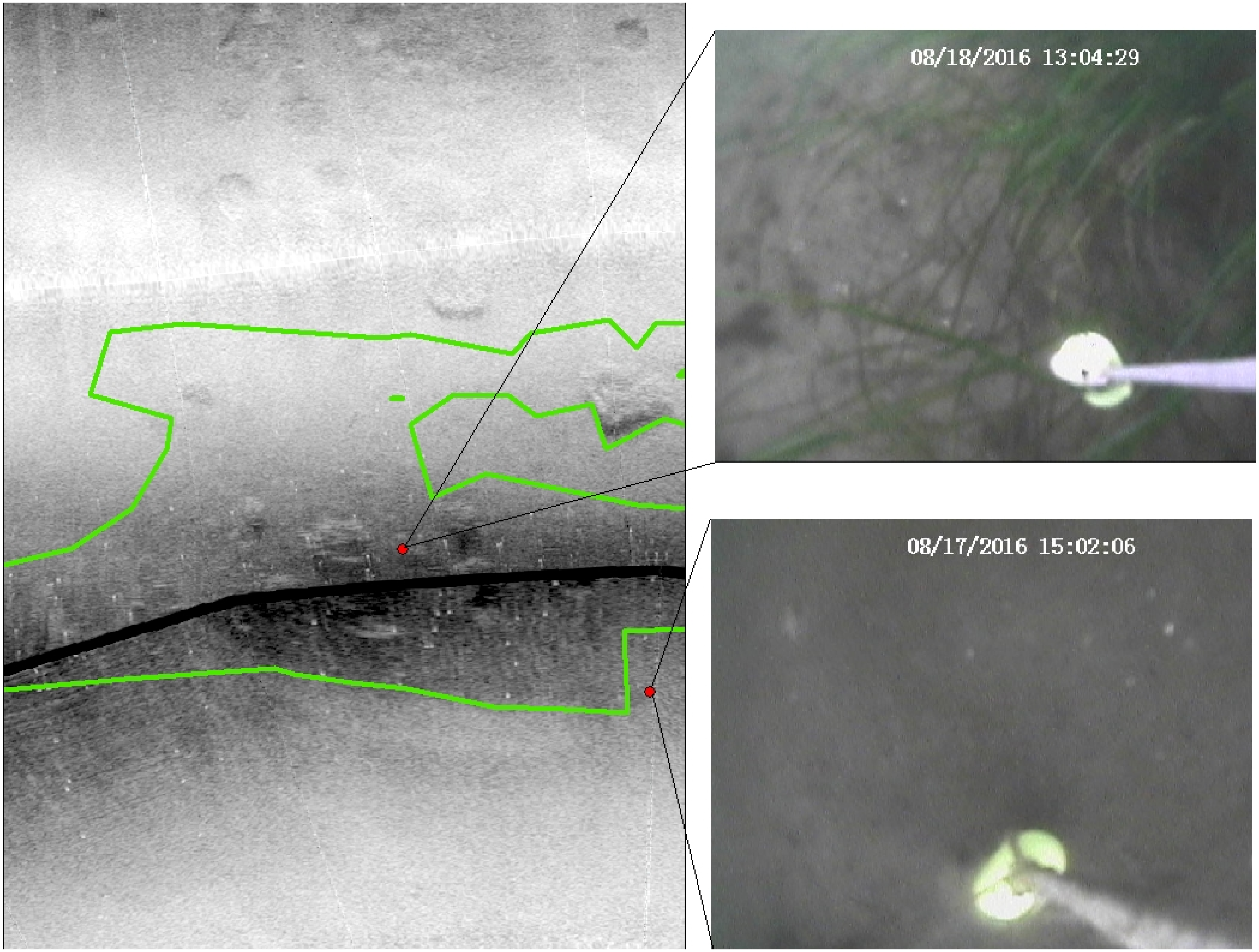

Figure 12. Locations of groundtruth points overlaid on acoustic survey imagery (left) at Woodbury Point in 2016 with corresponding groundtruth images showing an eelgrass patch (top right) and a bare sand patch (bottom right).

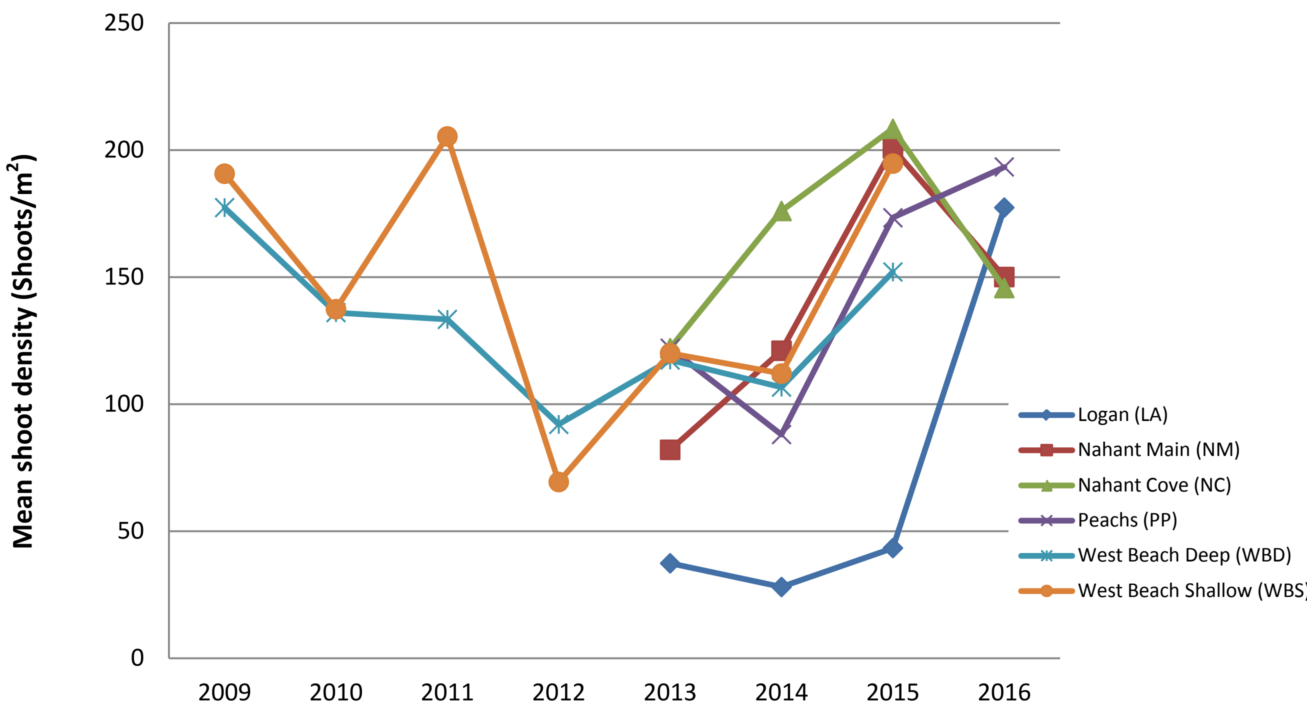

Figure 13. The mean shoot density at all reference sites in Salem Sound and Boston Harbor over time.

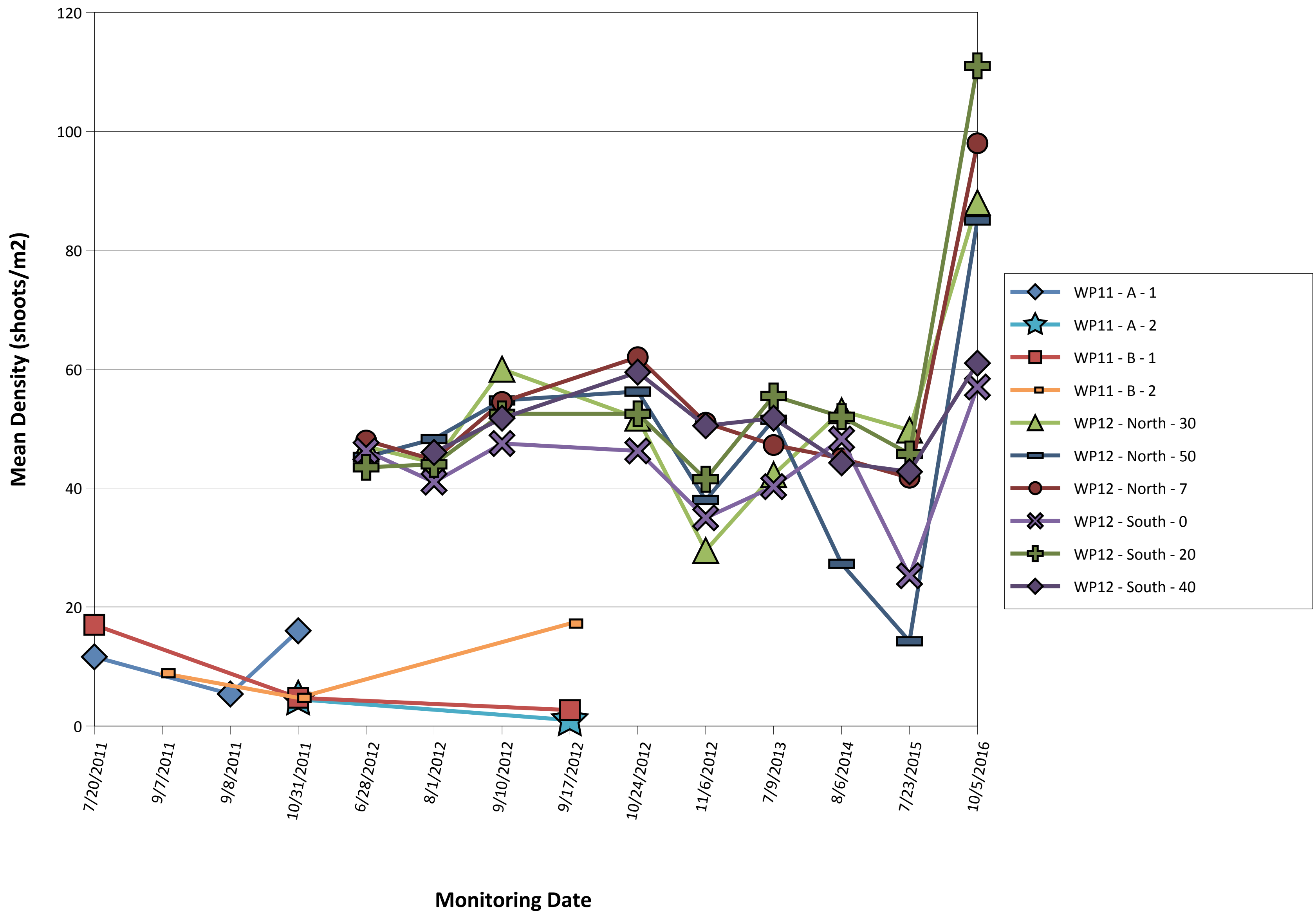

Figure 14. Mean shoot density at Woodbury Point (WP11 & WP12) plots. Note: WP11 was planted at 24 shts/m2 and WP12 was 50 shts/m2. Monitoring method differed in 2016 for WP11 and data are reported in section 4.1.

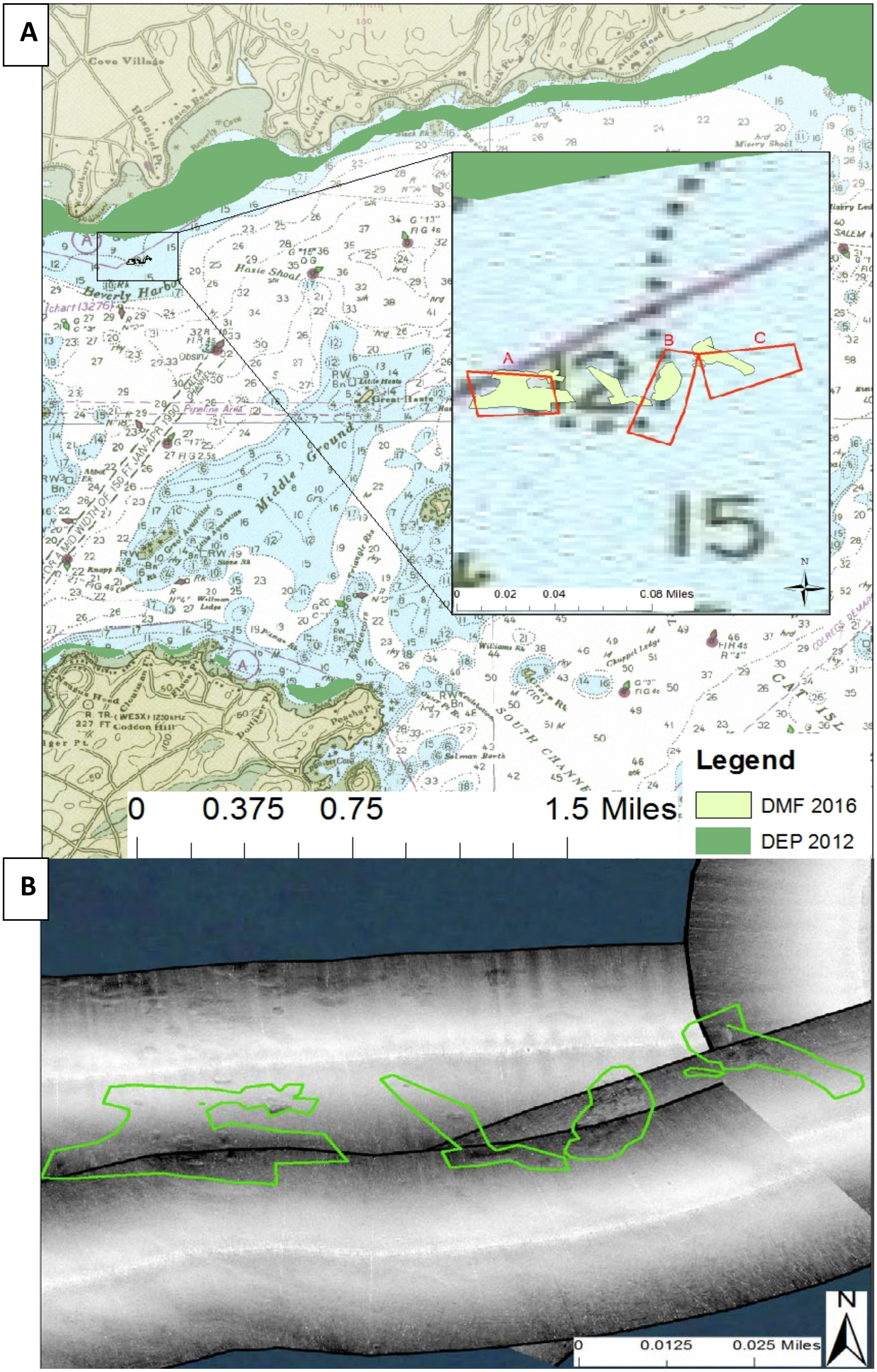

Figure 15. Woodbury Point (WP) A) DMF mapped eelgrass in 2016 showing planted plots in olive, red boxes marking three planting locations (A & B planted in 2011 and C planted in 2012) and large green meadow to north mapped by DEP in 2012, B) acoustic tracks and polygons delineating eelgrass at the Woodbury Point restoration site in 2016.

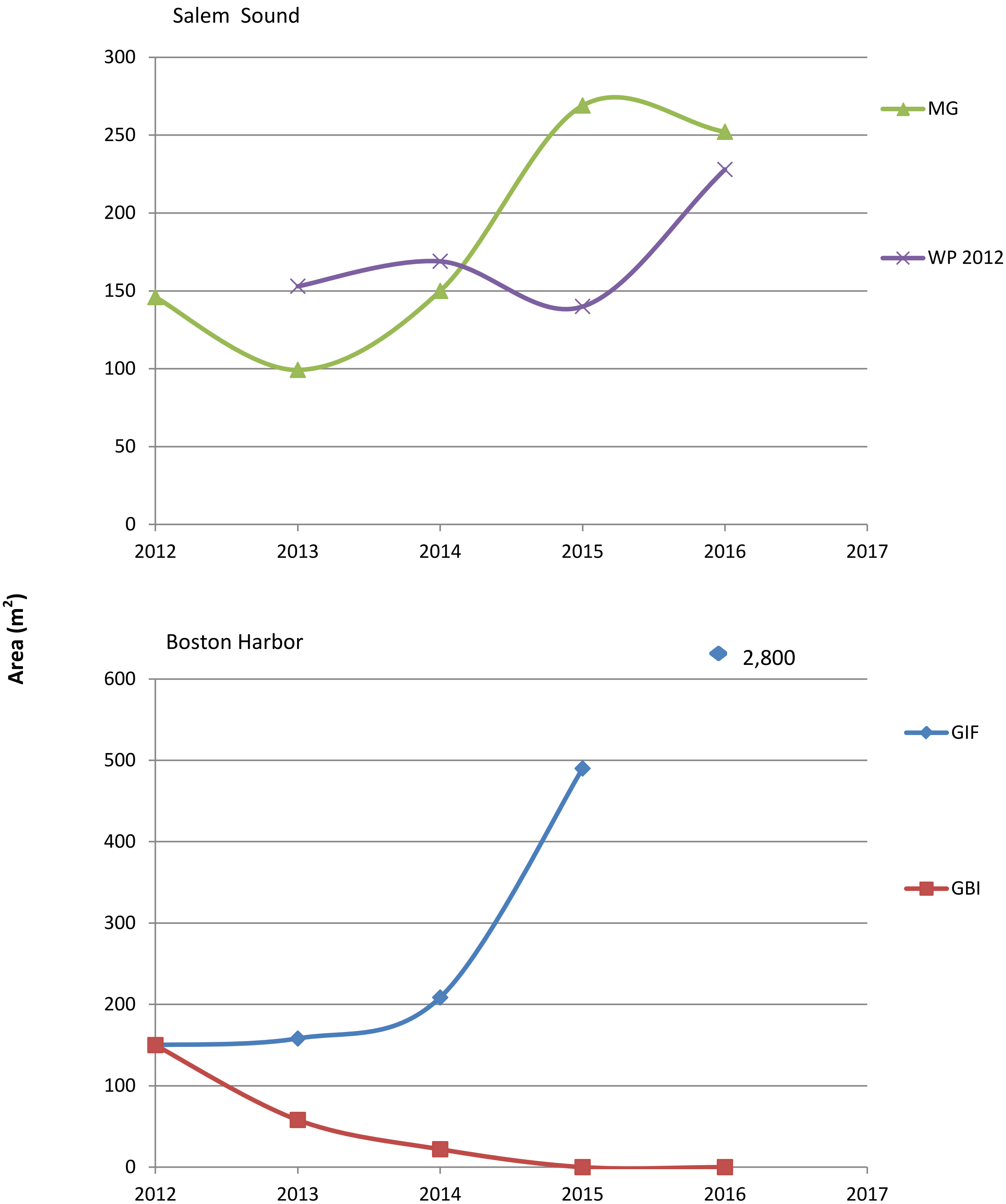

Figure 16. Total vegetated plot area over time at each successful restoration site as measured by divers. Area beginning at one month post planting.

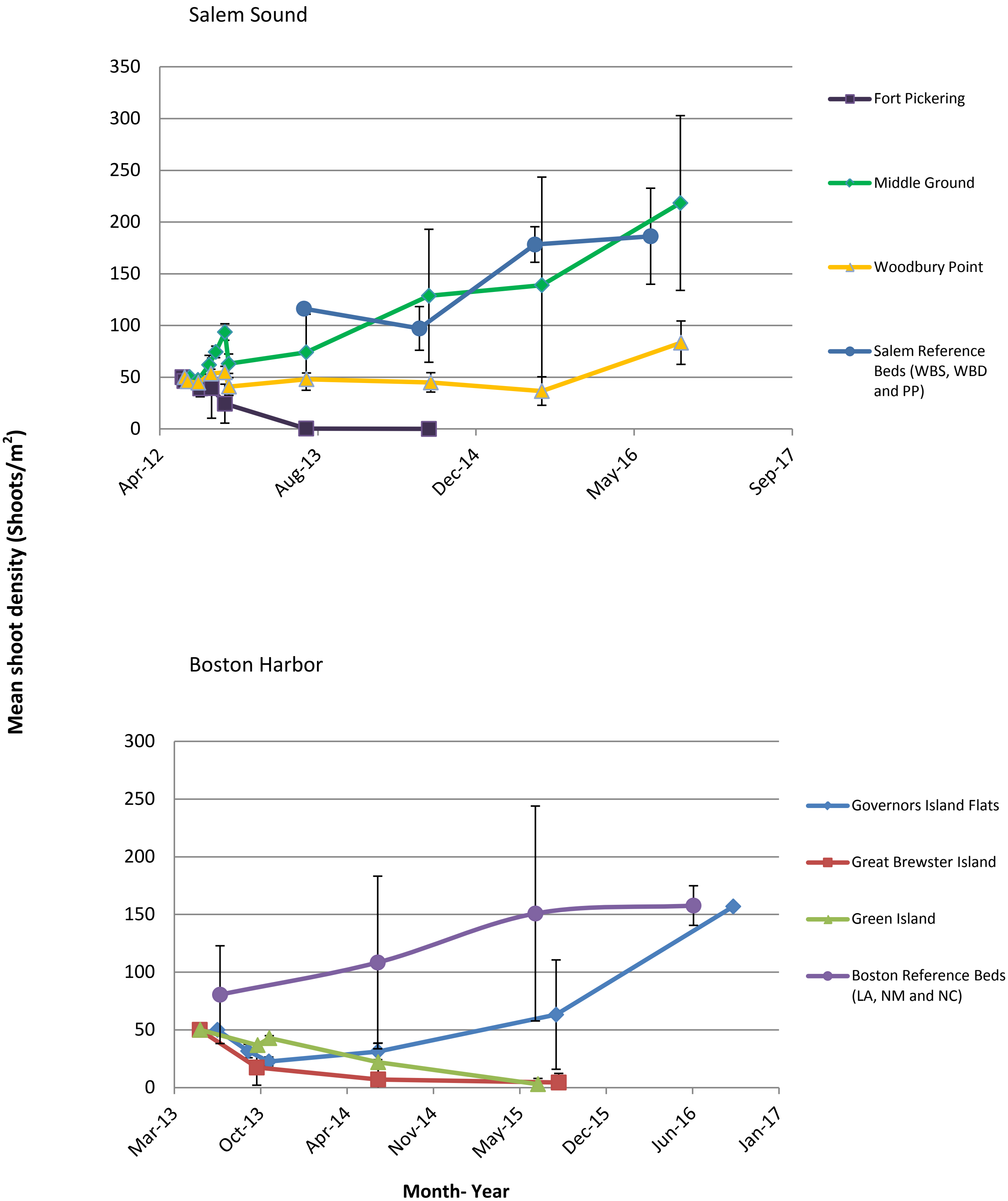

Figure 17. The mean shoot density ±1 SD at Salem Sound and Boston Harbor restoration sites compared to the mean of the selected reference sites for each embayment.

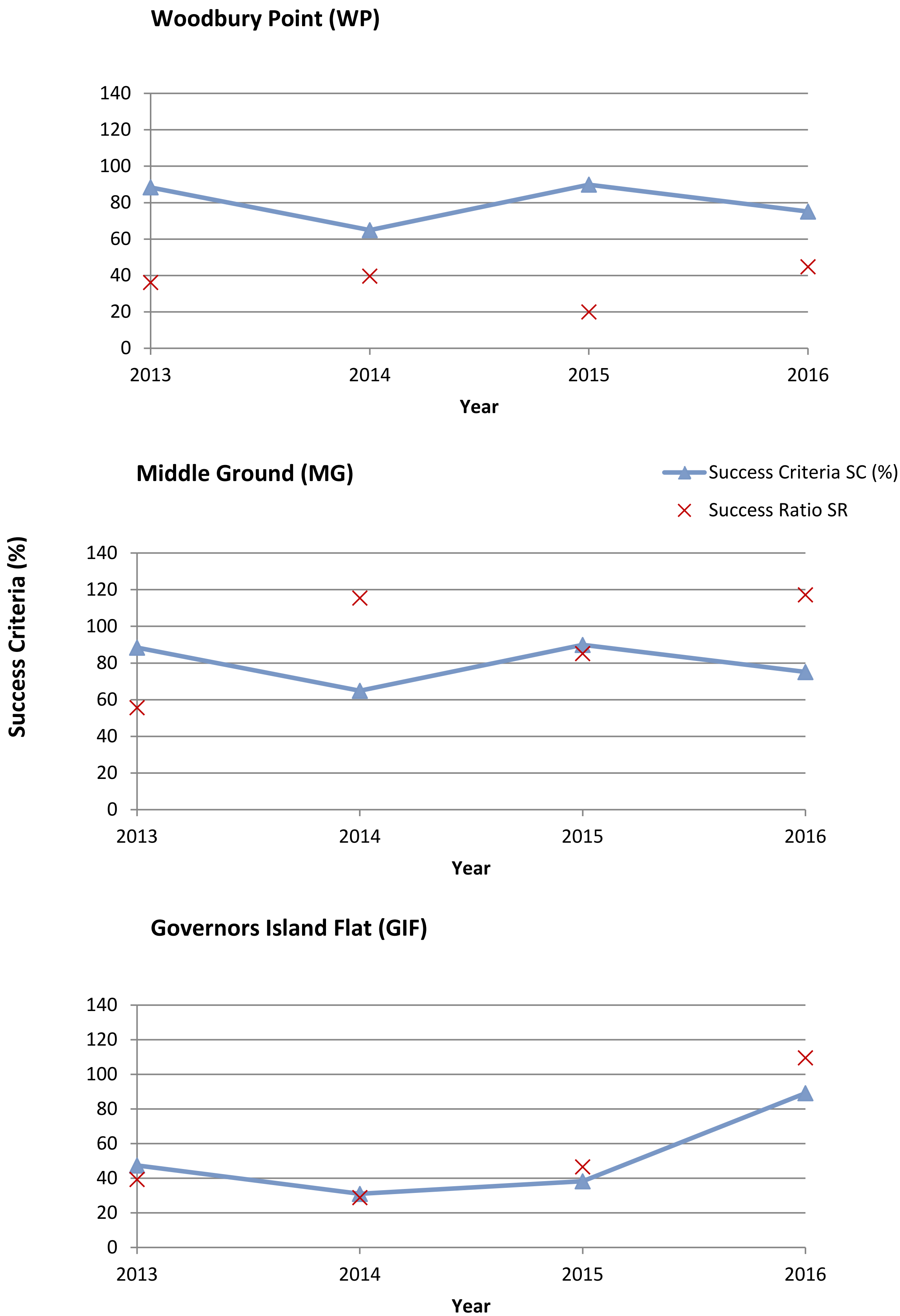

Figure 18: Success ratio compared to success criteria for Woodbury point (WP), Middle Ground (MG) and Governors Island flat (GIF).

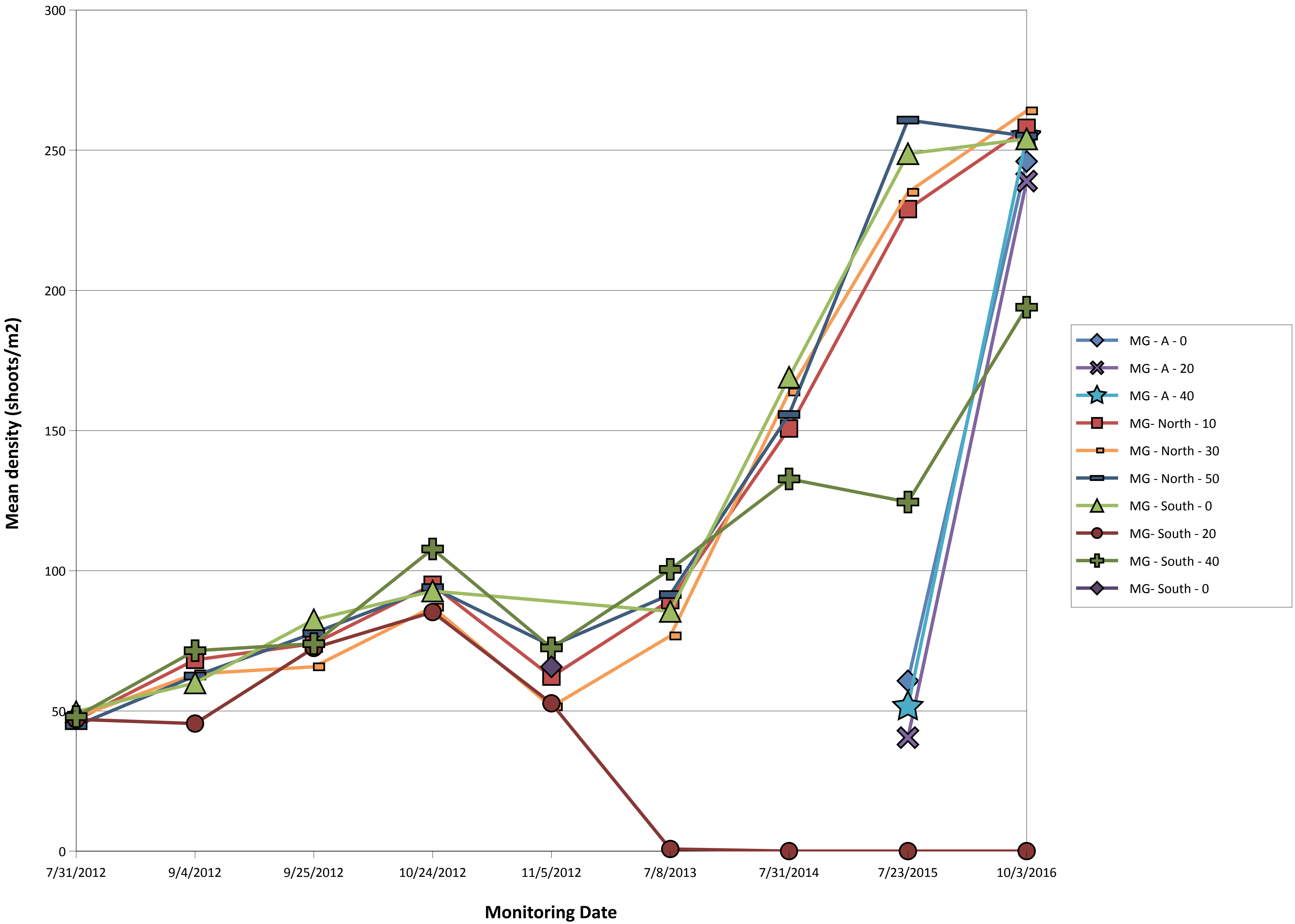

Figure 19. Mean shoot density at Middle Ground (MG) plots.

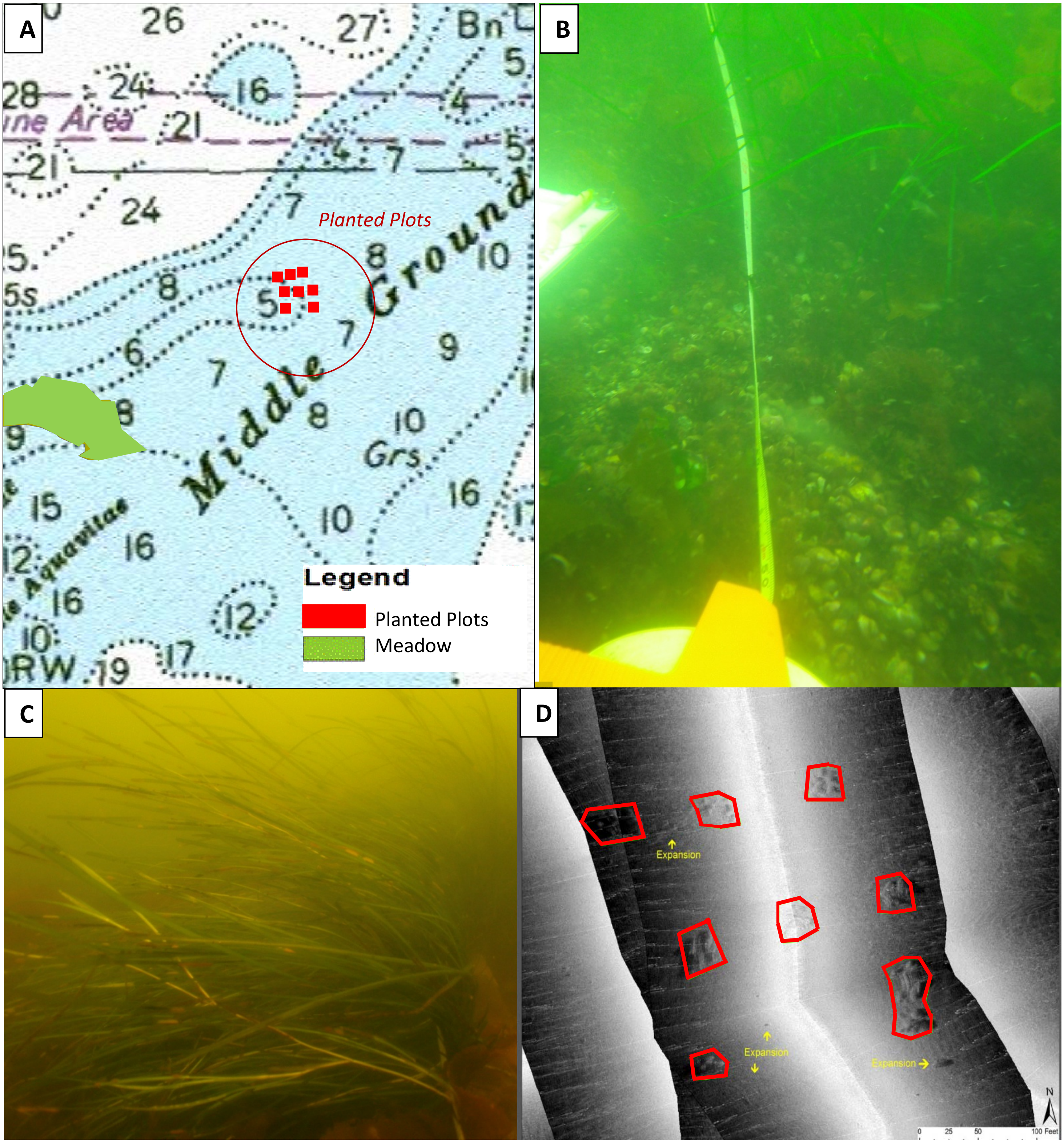

Figure 20. Middle Ground: DMF mapped eelgrass (A) showing planted plots in red and meadow acoustically mapped by DMF in 2016 in green., Eelgrass along transects (B & C) within planted plots at MG in 2016. Acoustic tracks and polygons (D) delineating transplanted eelgrass at the restoration site in 2016.

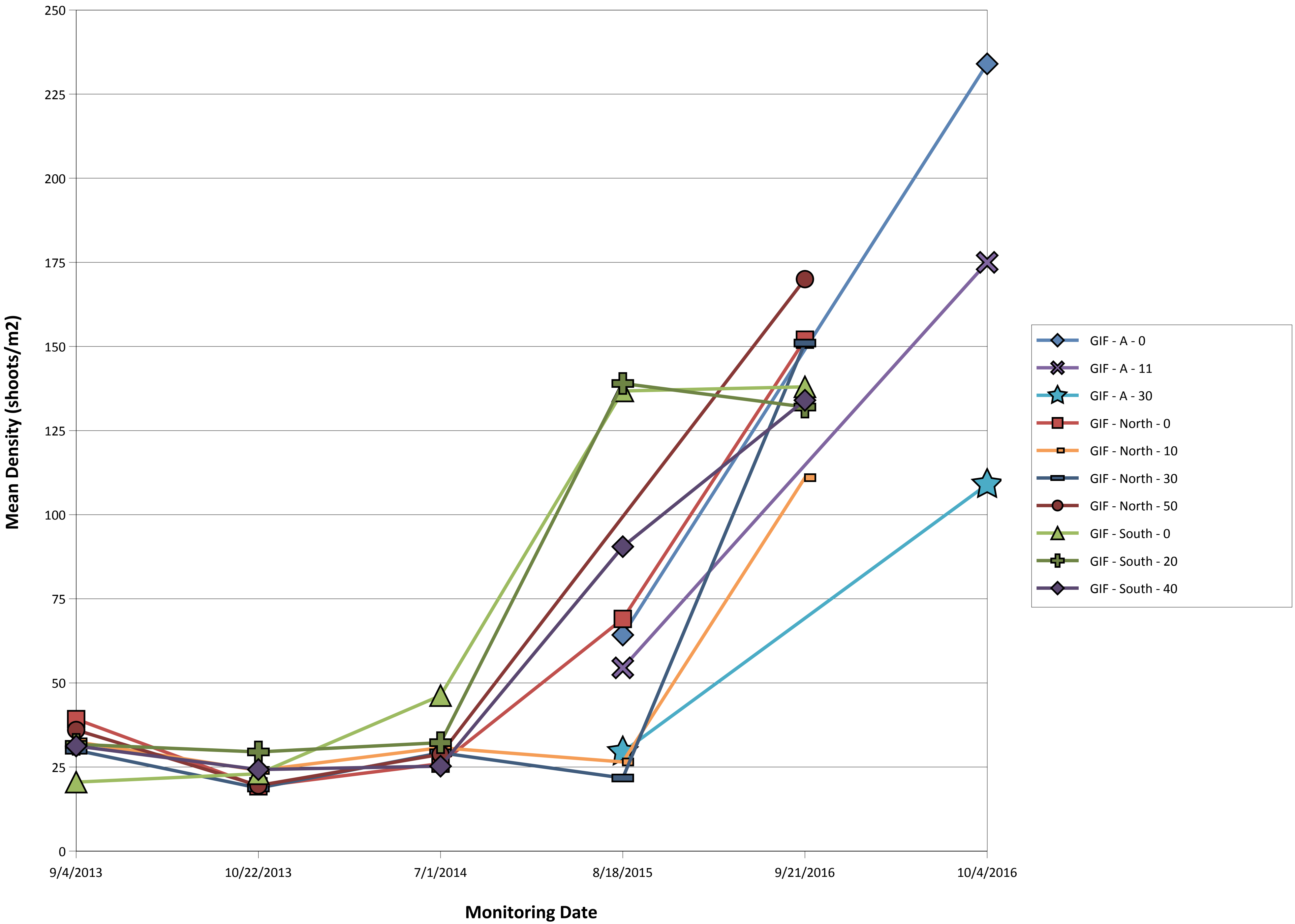

Figure 21. Mean shoot density at Governors Island Flats (GIF) plots

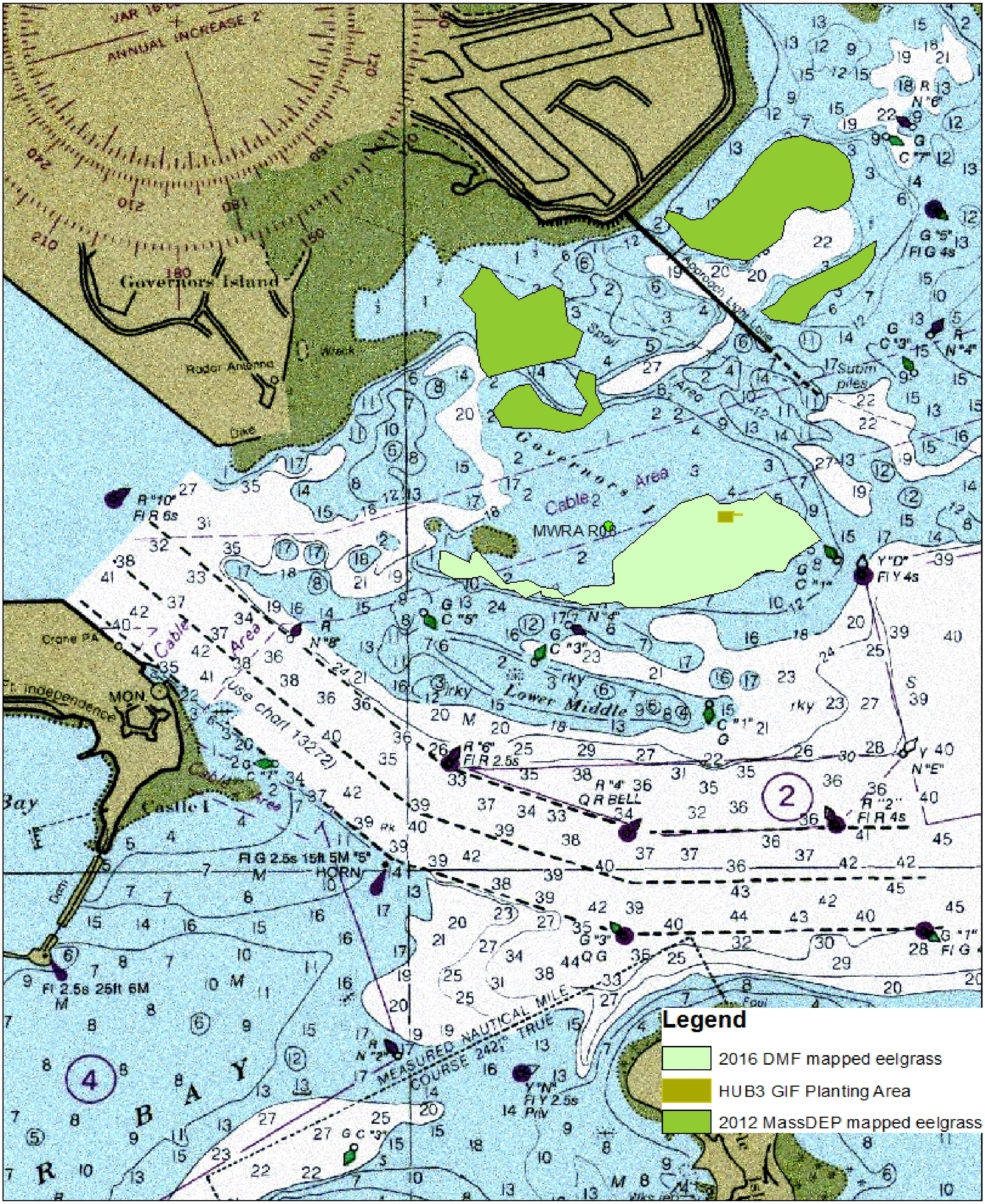

Figure 22.Governors Island Flats: DMF mapped eelgrass showing planted plots in brown, light green area mapped by DMF in 2016 acoustics, green meadow to north mapped by DEP in 2012. B & C) Eelgrass along transects within planted plots at GIF in 2016 D) acoustic tracks and polygons delineating eelgrass at the MG restoration site in 2016

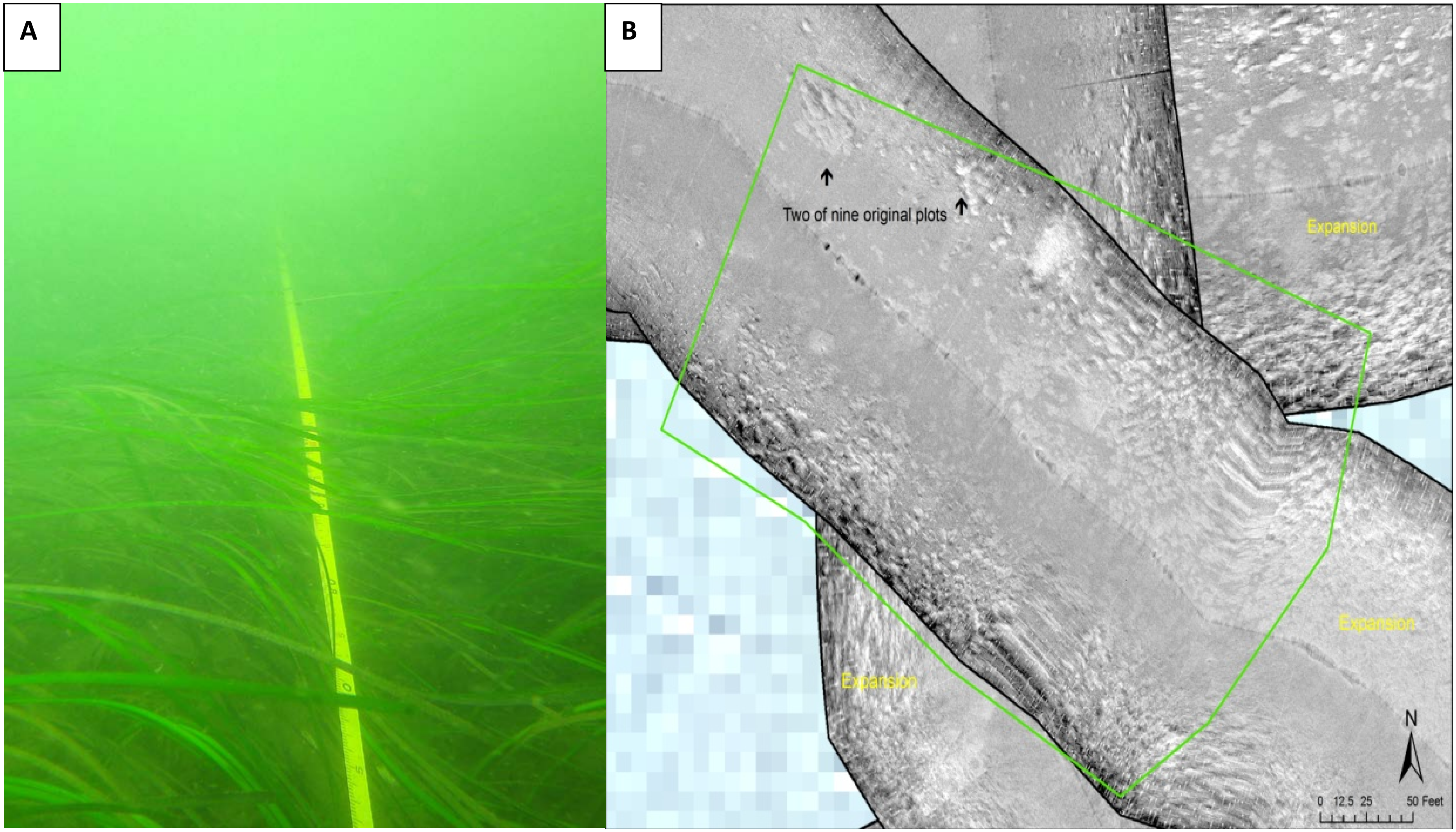

Figure 23. Governors Island Flats: A) Eelgrass along transect within planted plots at GIF in 2016. B) acoustic tracks and polygons delineating eelgrass at the MG restoration site in 2016.