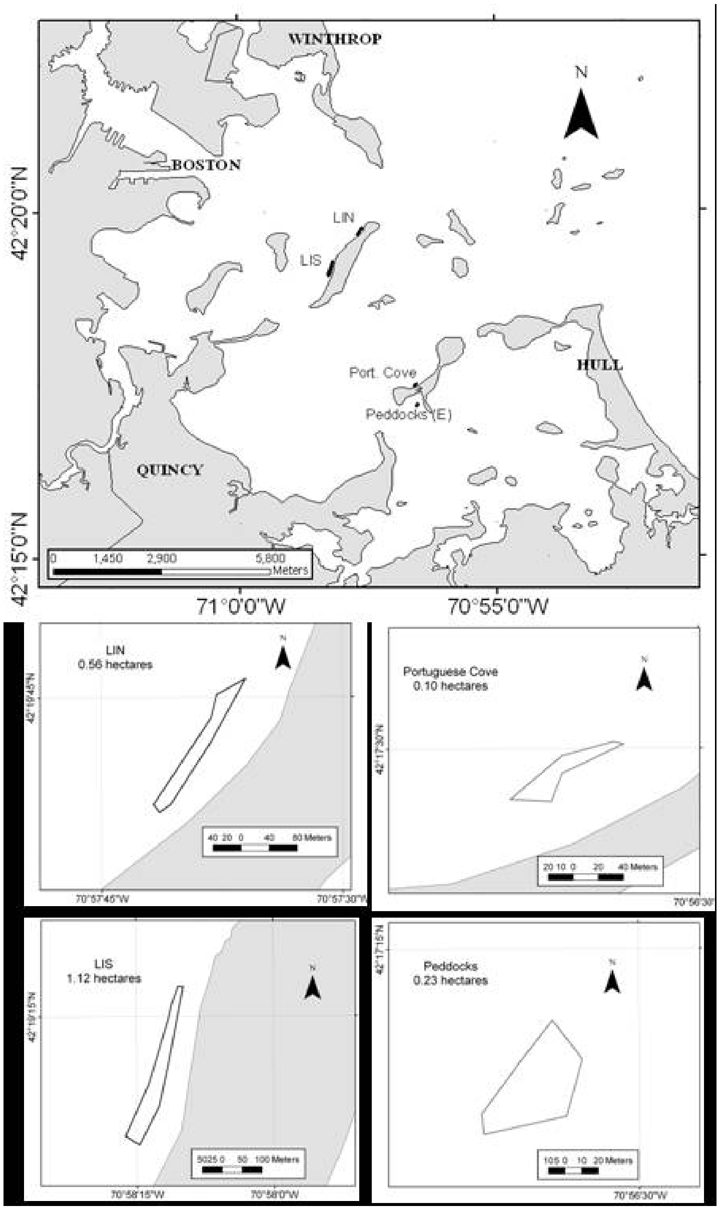
Eelgrass Restoration Project Final Update
February 2008

Introduction
The Boston Harbor Eelgrass Restoration Project was completed during the summer of 2007, and project results have now been analyzed. Four of our sites, Long Island North (LIN), Long Island South (LIS), Peddocks, and Portuguese Cove, now have healthy eelgrass beds (Fig. 1). Total areal coverage is over 5 acres, and beds are spreading on their own by root extension and seed production.

Fig. 1. Planted sites.



Seeds
The seeded area at LIS now covers well over 3000 m^2. A new method of seed dispersal which we tested in 2006 (see 2006 update) was not successful. Therefore, in 2007 we reverted to our 2005 methods, spreading approximately 300,000 seeds by scratching them into the sediment at LIN and Portuguese Cove. The success of our seed planting efforts corroborates that of other projects in New York, Maryland, and elsewhere. Seeding populated far more ground with eelgrass than our shoot transplant efforts, with a much smaller investment of time and resources. Large numbers of seed shoots can be harvested in 1-2 days, and seeds planted in another 1-2 days. Additional time and expense are involved in storing the seeds in a flow-through seawater tank and sieving the contents, but overall effort per area colonized is much less than transplanting shoots. Restoration efforts must still rely upon the site-selection process and test transplant

stages to identify areas where seeds are likely to grow and spread, but seed planting could largely replace laborious shoot transplanting and has the additional advantage of significantly reducing impact to donor beds.

Expansion

We have seen increases in both density and areal cover in almost all plots. Even though planted plots are expanding at LIS 05, most new growth appears to be from seeds, since it is too far from planted plots to attribute to root extension. At the other sites, there is less between-plot spreading, but plots are expanding well in both areal cover and shoot density (Fig. 2). All "checkerboards" plots (see 11/2005 update) have filled in.

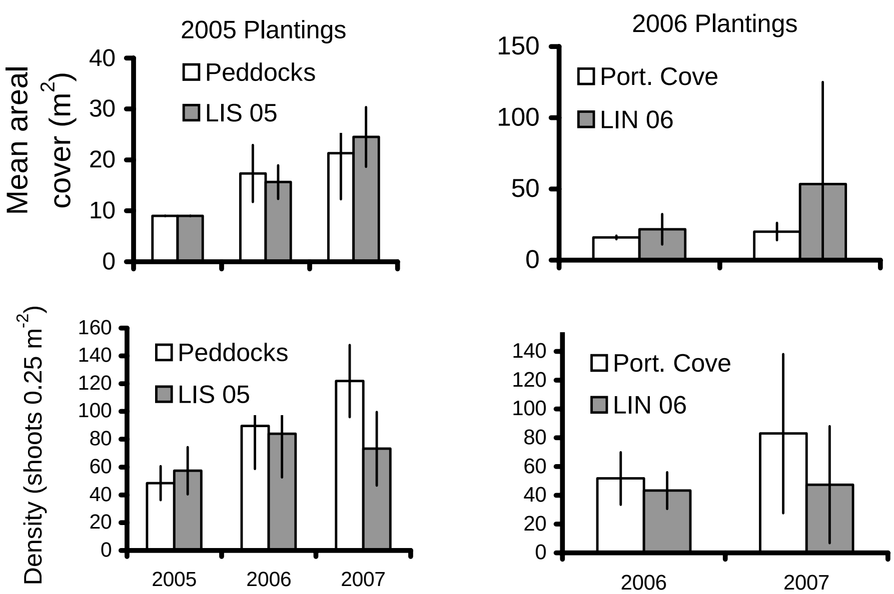


Fig. 2. Mean density and areal cover over the duration of the project (2005-2007) from plots planted in 2005 (LIS and Peddocks SE) and 2006 (Portuguese Cove and LIN).

Habitat Function

The goal of a restoration project is to create a habitat that functions in much the same way as the comparable natural habitat it is replacing. Our biological monitoring was designed to determine how our beds compared after one and two years to: an existing Boston Harbor bed (Hull), our healthy donor bed (Nahant), and an unvegetated Control site near LIS. We looked at habitat structure by measuring eelgrass shoot density, aboveground biomass, canopy height, and leaf area index (LAI = area of leaves x density). Fish, epibenthic invertebrates and benthic infaunal invertebrates were surveyed at each site and enumerated. All were identified and classified by species where possible. Animals were analyzed by several different indices: number of species (S), number of individuals (N), two different diversity indices – Shannon (H') and Simpson (1-D), and evenness (E_H). Generally, more diverse ecosystems are healthier; non-diverse or very uneven ecosystems are more typical of disturbed areas where only one or a few opportunistic species can thrive.

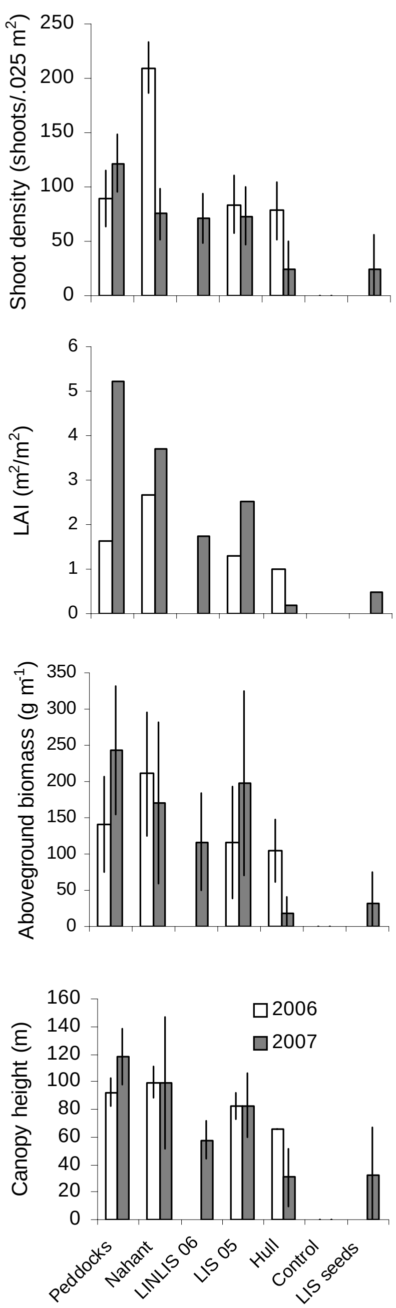


Fig. 3. Measures of habitat structure in 2006 and 2007 at an unvegetated Control site, our healthy donor bed (Nahant), a remnant Boston Harbor bed (Hull), our seed dispersal site at LIS (only measured in 2007), and three of our planted beds. LIS/LIN 06 was planted in 2006, so only 2007 measurements are available. LIS 05 and Peddocks, planted in 2005, were 1 yr old beds in 2006, and 2 yr old beds in 2007. Error bars are ±SD.

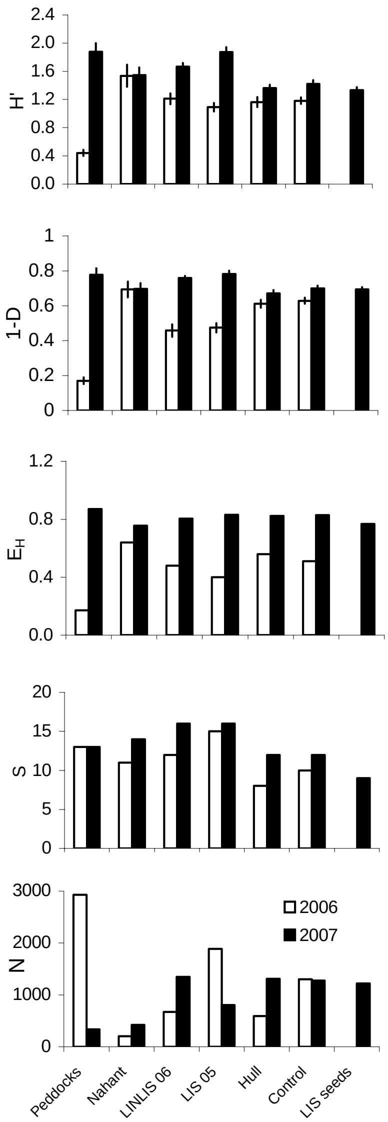


Fig. 4

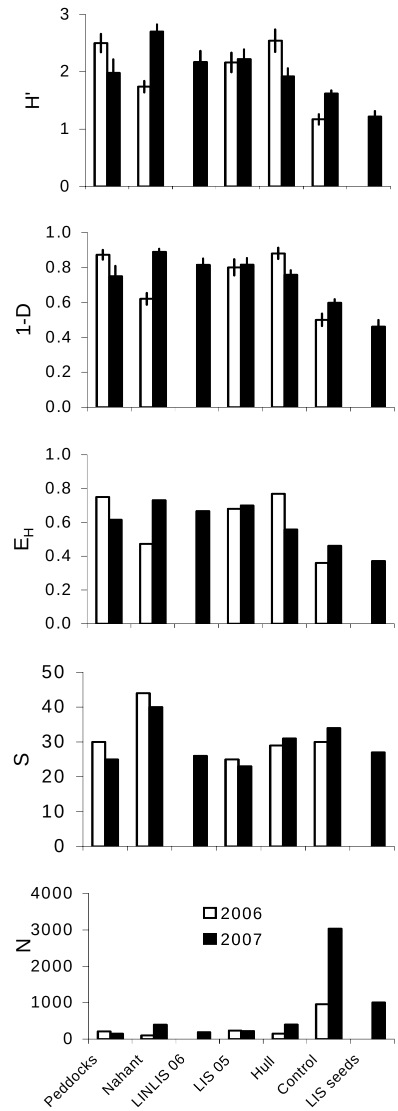


Fig. 5

Fig. 4 and 5. Species number and diversity of epibenthic and demersal fish and invertebrates (Fig. 4) and infaunal invertebrates (Fig. 5) in 2006 and 2007 at: an unvegetated Control site, our healthy donor bed (Nahant), a remnant Boston Harbor bed (Hull), our seed dispersal site (LIS seeds; only measured in 2007), and three of our planted beds. LIS 05 and Peddocks, planted in 2005, were 1 yr old beds in 2006, and 2 yr old beds in 2007. Error bars are ±SD. (N) is number of individuals, (S) is number of species, (E_H) is evenness, (1-D) is the Simpson diversity index, and (H') is the Shannon diversity index.

Results indicate that, after 2 years, our planted beds equaled or exceeded a nearby healthy natural bed in all measures of habitat structure (Fig. 3) and species abundance and diversity (Fig. 4 and 5). The one-year old sites were comparable to the natural beds in some measures, and in-between the unvegetated control site and the natural bed in others.

From 2006 to 2007 Shannon diversity indices (H') for benthic and demersal fish and invertebrates increased at all Boston Harbor sites - substantially at all of our planted sites (Peddocks in particular) and slightly at Hull (natural) and Control sites; they stayed the same at the Nahant donor site. The seed bed was first assessed in 2007. The Simpson diversity index (1-D) showed a similar trend, again with the most marked increases in diversity at our planted sites; 2007 diversity was fairly constant in all areas with our planted sites trending slightly higher than other areas. Evenness, measured by Shannon's equitability (E_H) index, also increased at all sites, and remained fairly level across sites in 2007. Overall, diversity indices at our planted sites are comparable to or exceed those at the natural beds and Control site. Total number of species (S) between years showed less variation than diversity at our planted sites; it did not change at Peddocks, but increased slightly at LI sites. Total number of species at planted sites equaled or exceeded the healthy natural donor bed at Nahant and exceeded Hull and Control sites. Nahant, Hull, and Control site data also exhibited slight increases in species number across years. Total number of individuals (N) declined markedly at Peddocks and LIS 05 which was primarily due to greatly reduced numbers of *Mysis* spp in 2007. The Control site changed little while Hull, Nahant, and LIN/LIS 06 increased slightly. All benthic and demersal species observed are provided in Table 1.

Table 1: Species List - Benthic and demersal fish and invertebrates found at sites in Boston Harbor and Nahant.

Fish	Invertebrates
Cyclopterus lumpus (lumpfish)	*Amphipod* spp.
Myoxocephalus aenaeus (grubby)	*Cancer borealis (Jonah crab)*
Pholis gunnellus (rock gunnel)	*Cancer irroratus (rock crab)*
Pseudopleuronectes americanus (winter flounder)	*Caprella* spp. (skeleton shrimp)
Sygnathus fuscus (Northern pipefish)	*Carcinus maenas (green crab)*
Tautogolabrus adspersus (cunner)	*Cragnon septemspinosa (sand shrimp)*
	Crepidula fornicata (slipper shell)
	Echinaracnius parma (sand dollar)
	Homerus americanus (lobster)
	Libinia emarginata (spider crab)
	Littorina spp. (snails)
	Moon shell spp.
	Mysis spp. *(Mysid shrimp)*
	Mytilus edulis (blue mussel)
	Pagurus spp. *(hermit crabs)*

Sediment

An evaluation of our original test transplant sites revealed that sediment grain size composition was the only factor we found in common among planted sites that failed. Percentage of silt/clay at successful sites was consistently lower than at failed sites (Fig. 6).

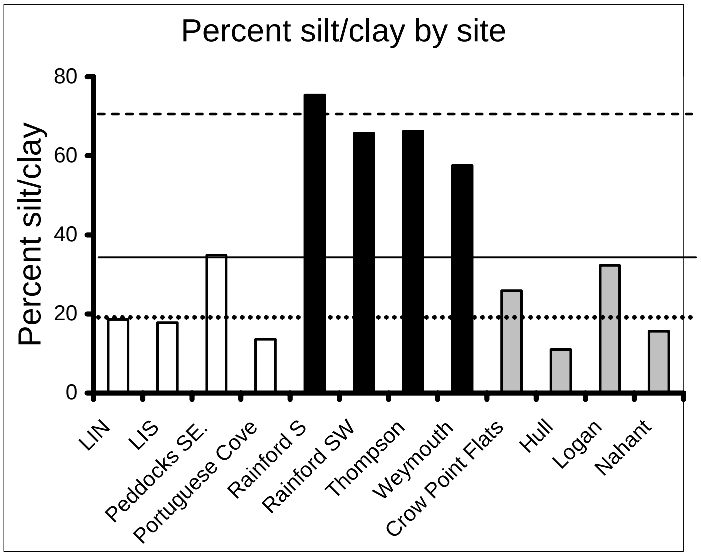


Fig. 6. Percent silt/clay at successful transplant sites (white bars), failed transplant sites (black bars), and existing beds (gray bars). Top (dashed) line is recommended maximum percent silt/clay according to the site selection model we used (Short et al. 2002). Middle (solid) line is maximum found at our successful sites. Bottom (dotted) line is maximum recommended by Koch (2001).

These results indicate that sediment should be carefully considered in restoration projects. Even though eelgrass beds often contain very fine, even anoxic sediment, transplants may not do well in these conditions. In established beds, photosynthesis in the leaves produces oxygen which is transported to the roots for respiration. Some of the oxygen diffuses into the surrounding sediment, neutralizing anoxic conditions, particularly when there is a large biomass of plants and roots contributing in a meadow. However, shoots harvested for transplant may experience shock, thus reducing their ability to photosynthesize. Their survival could be further compromised by the lack of support from other neighboring shoots in the bed. Consequently, a newly transplanted shoot may produce so little oxygen that keeping the roots sufficiently oxygenated for respiration stresses the plant to the point of death.

Much of the sediment in Boston Harbor was muddy silt/clay (Fig. 7) resulting from years of deposition of organic matter when sewage was dumped directly into the Harbor. Even though water quality had improved greatly as a result of the Boston Harbor (wastewater treatment) Project, the prevalence of sediment unsuitable for eelgrass transplanting severely constrained our site selection options. These results have implications for other eelgrass restoration projects in previously degraded estuaries. Sediment may remain an impediment to restoration even years after water quality improvements have been made.

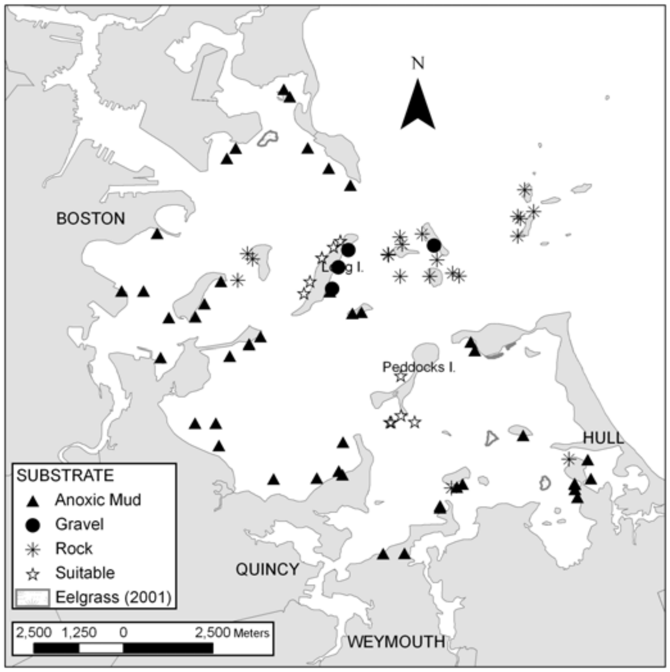


Fig. 7. Sediment type observed in Boston Harbor. Data were gathered using an underwater camera, Ponar grab, or diver-collected cores. Note the prevalence of anoxic mud around the shoreline and the limited areas of sand.

Conclusion

We successfully restored eelgrass to a previously degraded estuary, Boston Harbor, by focusing intensively on site selection, particularly sediment quality. We found a silt/clay content of <35% was consistent among our successful sites. High survival and expansion rates were recorded at 4 of 5 of our large-scale sites (the exception, Weymouth, would have been eliminated under new sediment guidelines). In just two years of monitoring, transplanted sites met and exceeded remnant and donor bed habitat function as measured by species abundance and diversity, and habitat structure. Hand-planting and seeding were most efficient and effective for planting eelgrass. The checkerboard pattern of planting described in previous updates, with plots spaced 30-50 m apart, added to the efficiency of creating larger beds. Our choice of planting locations was severely constrained by unsuitable sediment, which persisted throughout much of Boston Harbor even 5 years after elevated wastewater treatment and improved water quality were realized. These results have important implications for other estuaries where water quality improvement projects may be undertaken. Eelgrass restoration efforts may need to be combined with increasing flushing rates within these areas via dredging or other means in order to clear out accumulated depositional sediment that will impair eelgrass growth. We also integrated an educational/outreach component into the project, in which over one hundred volunteers assisted with harvest and planting and learned about the importance of eelgrass habitat. *MarineFisheries* staff presented our project results to dozens of groups, including school children, citizens organizations, and other scientists. In addition to website updates, an informational brochure, and educational posters, we are currently preparing two manuscripts for publication in peer-reviewed scientific journals.