Shellfish Enhancement for Green Boston Harbor (GBH)

Boston Harbor once teemed with shellfish; colonial records speak of oysters the size of dinner plates. Centuries of development and related pressures (including pollution, resource extraction, and multiple use conflicts) decimated shellfish populations, as well as the water quality essential for their survival and growth. In the past decade, following the placement of a nine mile sewage outfall pipe, harbor water quality has improved to the point where it is nearing suitability for shellfish species and potential aquaculture activities. However, shellfish may not return on their own, but may instead require initial stock enhancement as well as additional improvements in water quality. Perhaps most critically, bringing back depleted shellfish species in Boston Harbor will need to include the involvement of local communities, many of whose members may currently perceive the harbor as an unsuitable place for obtaining seafood.

Our primary goal is to enhance community understanding and participation in multispecies urban shellfish restoration in support of green harbors. A green harbor is a harbor that lives within ecological and human limits, and supports local and place-specific economic production within a regional and global context. Our central hypothesis is that sustainable population of native shellfish species would improve water quality in the Boston harbor, and concurrently improved water quality would support sustainable shellfish stock enhancement and improve urban coastal habitats condition. The proposed project thus includes three objectives: (1) Oyster, blue mussel and soft shell clam stock enhancement at three pilot projects in the Boston Harbor; (2) Monitoring relationships among water quality, circulation patterns and shellfish survival/growth rates; and (3) Research, education and outreach with Boston Harbor communities to support shellfish stock enhancement for better water quality and coastal conditions. Taken together, these objectives will support longer term efforts to develop and sustain multi-species and multi-trophic shellfish restoration by improving the water quality for the Green Boston Harbor.

We have selected Savin Hill Bay, Fort Point Channel and Shipyard Marina as the pilot project sites in the harbor based on the water quality data, suitability data for shellfish enhancement and the fact that we have established excellent relationships at these sites with the local boating and shellfishing communities, as well as with neighborhood associations, Mass Port and the Boston Children’s Museum. At these sites we have chosen to replenish populations of three different shellfish species that occupy different coastal niches. Oysters (*Crassostera virginica*) and blue mussels (*Mytilus edulis*) will be placed at all three sites, while soft shell clams (*Mya arenaria*) will be placed at Savin Hill Bay only. These species have been selected because of their tremendous commercial and ecological value in coastal areas. Stock enhancement will contribute to the shellfish species populations, as well as offer the potential for biomitigation of harbor waters. Although this project will use existing and ongoing monitoring data (MWRA, DMF, EPA), we will perform benthic and water quality testing, as well as hydrological modeling of the sites’ relationships with larger harbor water circulation patterns. These three selected sites represent a mix of development, social, economic and ecological issues that are characteristic of the harbor as a whole. We thus expect that lessons learned here will be applicable in supporting sustainable shellfish stocks, and improving coastal water quality and related habitats (e.g. salt marshes, mud flats, eel grasses) in this and other coastal urban harbors.
Project Description

1. Introduction/Background/Justification

(a) GBH vision and goals
The initial hypothesis for GBH, and the core of this multidisciplinary research, is that the environment sets the limits for sustainable development. Urban harbors can become green harbors if they are managed within environmental limitations, while recognizing strength in ecological and human diversities, and supporting local and place-specific economic production within a regional and global context. The GBH methodology is derived from a 1500 year old Native Hawaiian Ahupua’a approach.

This approach defines sustainable relationships among land, water and humans from the tops of islands to the coral reefs and open-ocean. The main connection - as well as impediment - among the different self-sustaining units in this approach was both the quality and quantity of the water. Land stewardship practices were established to ensure that water used for agricultural purposes higher on the mountains was either unharmed or enhanced for downstream uses. Based on the Ahupua’a approach, the GBH initially envisioned five potential layers or units for a multidisciplinary project (Frankic and Greber 2010; Frankić et al. 2011). This was narrowed to the three layers for the initial years of the project:

1. The City’s and Harbor’s main watersheds – Neponset, Charles, Mystic; the project focus here is on green roofs and other pervious surfaces to restore the watersheds self-sustainability
2. Coastal intertidal areas – a) including the Harbor walk (potential sites for restoring native species of shellfish, e.g. oysters, mussels); b)salt marsh restoration sites; and c) tidal mud flats with soft shell clam restoration sites
3. Eelgrass beds and their restoration in Boston Harbor

Two more potential layers, the Boston Harbor Islands themselves and Stellwagen Bank, although part of the larger vision, are beyond the current scope of the GBH.
(b) Current state of knowledge

Boston Harbor (BH) once teemed with shellfish; colonial records speak of oysters the size of dinner plates (Ingersoll 1881). Although the citizens of communities surrounding Boston Harbor spent over 350 years transforming their harbor from a pristine near-wilderness teeming with fish and shellfish into the nation’s dirtiest coastal environment, over the last 12 years the environmental conditions have improved, largely due to provisions in federal and state clean water legislation (Libby et al. 2007; Libby et al. 2009; Maciolek et al. 2009). Though the water quality has been improved (Taylor 2006; Hunt et al. 2009), shellfish may not return on their own, but may instead require initial stock enhancement as well as additional improvements in water quality. Perhaps most critically, bringing back depleted shellfish species in Boston Harbor will need to include the involvement of local communities, many of whose members may currently perceive the harbor as an unsuitable place for obtaining seafood.

Our primary goal is to enhance community understanding and participation in multispecies urban shellfish stock enhancement in support of green harbors. A green harbor is a sustainable harbor that lives within ecological and human limits, and supports local economic production within a regional and global context. The project hypothesis is that sustainable population of native shellfish species would improve water quality in the Boston harbor, and concurrently improved water quality would support shellfish stock enhancement and improve urban coastal habitats conditions. The proposed project thus includes three objectives: (1) Oyster, blue mussel and soft shell clam stock enhancement at Savin Hill Bay, Fort Point Channel, and Shipyard Marina; (2) Monitoring relationships among water quality, circulation patterns and shellfish survival/growth rates; and (3) Research, education and outreach with a variety of Boston Harbor communities to support shellfish stock enhancement for better water quality and costal habitat conditions. Taken together, these objectives will support longer term efforts to develop and sustain multi-species and multi-trophic shellfish restoration for Boston Harbor and future green harbors.

We have selected Savin Hill Bay, Fort Point Channel and Shipyard Marina as the pilot project sites in the harbor based on the fact that we have established excellent relationships at these sites with the local boating and shellfishing communities, as well as with neighborhood associations, Mass Port and the Boston Children’s Museum (Fig 1). Community participation has been shown to be key in similar efforts to replenish or reintroduce shellfish stock, such as the ‘oyster gardens’ in Chesapeake Bay (Rossi-Snook et al. 2010).

At the selected sites we have chosen to replenish populations of three different shellfish species that occupy different coastal niches. The species have been selected because of their tremendous commercial and ecological value in the New England coastal areas. Oysters (Crassostera virginica) and blue mussels (Mytilus edulis) will be placed at all three sites. Soft shell clams (Mya arenaria) will only be placed at Savin Hill Bay, as this the sole site with appropriate intertidal substrate. Stock enhancement will contribute to the shellfish species populations, as well as offer the potential for bio-mitigation of harbor waters.

Taking a responsible approach to our shellfish stock enhancement will engage community participation as well as relevant state and local agencies (Lorenzen et al. 2010). The overall goal of responsible stock enhancement is to augment the natural supply of juveniles and optimize future harvests by overcoming recruitment limitations (Bell et al. 2008; Lorenzen et al. 2010). The two year project will allow us to estimate the efficacy of our methods, and give us preliminary data that will help us develop strategies for future applications. In addition, we will continue performing water quality testing at all three sites, as well as hydrological modeling of the sites’ relationship with larger harbor water circulation patterns (Fig 5). Our results will complement the annual MWRA reports on BH quality and conditions.
Savin Hill Bay, pilot project site #1
This is a small (1/4 square km) enclosed bay, jutting off the west end of Dorchester Bay in Boston Harbor (Fig. 2). This urban bay and its Malibu beach are intensely used by local residents and day visitors for walking, sun-tanning, and boating. Some visitors swim, while others express concern over water quality and the unpleasant “muck” – the anoxic muddy bottom sediment. Three small patches of salt marsh (predominantly Spartina sp.) dot the beach. Cormorants (Phalacrocorax auritus), snowy egrets (Egretta thula), and the resident Great Blue Heron (Ardea herodias) are common sights, as are a variety of mollusks including soft shell clam (Mya arenaria), periwinkles (Littorina littorea), ribbed mussels (Geukensia demissa), and mud snails (Ilyanassa obsoleta). Notably absent are the oysters that likely were present in pre-colonial times (Ingersoll 1881).
Boston Harbor Shipyard Marina (BHSM), pilot project site #2
We selected this site in conjunction with Mass Port as the area is representative of large marinas throughout the harbor. The BHSM is located on the site of a historic shipyard and consists of 180 slips in deep water (Fig 3). In this project we are going to use G dock for placing oysters and blue mussels.

Fort Point Channel, pilot project site #3
Fort Point Channel is part of the inner BH, highly developed, and plagued by poor water quality due to the presence of several combined sewer overflows (CSO) and surface drains that empty into it (Fig 4). Although our goal at this site is stock enhancement of the oyster population, as at Site #1, oysters as will be placed in both sites for water and at this point strictly forbidden and protected from human consumption.

Shellfish biology supports innovative mitigation and adaptation
There has been a worldwide effort to assess and detect alterations in water quality due to the presence of shellfish (bivalves), specifically addressing questions regarding scale and relevance for “improving water quality” or “exceeding the system's carrying capacity”(Dumbauld et al. 2009). With increasing discharge of nutrients to our coastal waters, shellfish provide an indispensable ecosystem service in mitigating eutrophication (Dame 1996; Rice 1999). However, measurable effects on water properties depend on the
filtration capacity of shellfish relative to their species, size, and the residence time of water in the coastal embayment - the longer the residence time the more opportunity for filter-feeders to remove particles (Prins et al. 1997; Prins and Escaravage 2005; Dumbauld et al. 2009).

**Why oysters** (*C. virginica*)?
Oysters serve as ecosystem engineers: as a suspension feeder, adult eastern oyster filters up to 60 gallons of water a day, and by biodeposition and permanent removal of excess nutrients (N and P) they improve the water quality/clarity for eel grasses and juvenile fish, and play a dominant role in benthic-pelagic coupling (Haven and Morales-Alamo 1970; Kennedy 1996; Kennedy et al. 1996) (Newell et al. 2005; Coen et al. 2007). Only recently have efforts focused on real-life scientific projects about the influence of oysters on nitrogen cycling. We do believe that through this project we will apply present sciences with successful results. This top-down control on phytoplankton through the enhancement of natural oyster population was suggested as a possible management strategy for improving the water quality in Chesapeake Bay estuary, Long Island Sound, the Carolinas, Virginia, New Hampshire, Rhodes Island and Louisiana, and is being considered by the Towns of Falmouth and Mashpee. The use of oysters to help attain water quality goals in Boston harbor is essential – as there are not many options to reduce nutrients once they have entered the coastal waters.

Given the estimated low tide volume of Savin Hill Bay (125 mil gallons) for example, approximately a million oysters could circulate the entire Bay’s volume in few days. We use the low tide value to account for nutrient and contaminant removal through tidal flushing. As discussed in the experimental design section, below, this study plans to continue water quality monitoring of nutrients, coliforms, salinity, oxygen and temperature that began in the summer of 2009 under the auspices of the Green Boston Harbor project (GBH). In addition, monitoring will include sediment analysis of organic material, metals, and other pollutants to evaluate the success of the potential future ‘million oysters’ in the Bay, as we obtain appropriate research permits from MA Department of Marine Fisheries (DMF) for their placement.

**Why blue mussels** (*M. edulis*)?
The blue mussel is one of the most useful bioindicators in the marine field. It is known as a “sentinel species” for both toxicity and ecotoxicity as it can indicate current and historical pollutants present in the water column (Chase M.E. et al. 2001). Since it is a filter-feeding species, over time it bioaccumulates a variety of organic and inorganic contaminants in its tissues (Chase M.E. et al. 2001). Since its biology and physiology are well known, these tissues can be analyzed in the laboratory for both type and concentration of water column contaminants. As it is a sedentary species, living in the same place for more than 10 years, mussels can also be used as bioindicators for spatial and temporal assessment of contaminants.

**Why soft shell clams** (*M. arenaria*)?
Boston Harbor once accounted for more than 75% of the commercial landings of soft shell clams in the state of Massachusetts; today, it represents less than 15% of the total harvest (DMF). Reasons for the decline in productivity within the Harbor are not well understood but decreasing harvests and a large absence of seed clams brings into question the sustainability of current clam stocks and the long term future of the soft shell clam industry within the harbor (DMF). Soft shell clam enhancement efforts in the Boston Harbor currently overseen by the Division of Marine Fisheries have seen great success and have created a strong relationship with industry, residential, and municipal stakeholders throughout the Greater Boston Harbor. In collaboration with the Division of Marine Fisheries we are going to distribute materials and seed clams at the identified site in the Savin Hill Bay (Fig.2).
### Table 1. Shellfish species key indicators. Sources: blue mussels (Newell 1979; Smith 1993); soft shell clams (Stickney 1964; Abraham and Dillon 1986; Funderburk et al. 1991); oysters (Calabrese and Davis 1966; Funderburk et al. 1991; Barnes et al. 2007); all DO (Stickney 1979).

<table>
<thead>
<tr>
<th>Species</th>
<th>Salinity (ppt)</th>
<th>Temperature (°C)</th>
<th>pH</th>
<th>DO (mg/l)</th>
<th>Depth (m)</th>
<th>Turbidity</th>
<th>Type of substrate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oysters (mature)</td>
<td>0-42.4 (optimal: 14-28)</td>
<td>8-49</td>
<td>Spawn: 7.8-8.2</td>
<td>&gt;5</td>
<td>2-10</td>
<td>No high turbidity related to sediments</td>
<td>Oysters shells, calcareous remains of other mollusks, wooden material, rocks, gravel, and solid refuse</td>
</tr>
<tr>
<td>Oysters (larvae)</td>
<td>5-35 (optimal 10-30)</td>
<td>20-30</td>
<td>&gt;7.4 for optimal growth (zebra mussel)</td>
<td>&gt;5</td>
<td>&lt;99</td>
<td>No high turbidity related to sediments</td>
<td>Oysters shells, calcareous remains of other mollusks, wooden material, rocks, gravel, and solid refuse</td>
</tr>
<tr>
<td>Blue Mussel</td>
<td>5-35</td>
<td></td>
<td>&gt;7.4 for optimal growth (zebra mussel)</td>
<td>&gt;5</td>
<td>&lt;99</td>
<td></td>
<td>Hard substrate</td>
</tr>
<tr>
<td>Soft shell clams</td>
<td>10-35 (optimum 16-32)</td>
<td>Optimum 17-23</td>
<td>6.2-8.8 (laboratory experiments)</td>
<td>&gt;5</td>
<td>Intertidal to 16 m</td>
<td></td>
<td>Stiff sand and mud</td>
</tr>
</tbody>
</table>

**Water Circulation Model: Understanding relationships among water quality, water circulation, and shellfish**

Are there relationships among water quality, water circulation, and shellfish survival and growths rates at the three study sites? The Boston Harbor circulation model will be used to explore this question. The model that will be used is based on the Estuarine, Coastal, and Ocean Model (ECOM-si) with Mellor and Yamada 2.5 turbulent closure for vertical mixing (Blumberg and Mellor 1987; Signell et al. 2000). The model domain covers the entire BH and a portion of the Massachusetts Bay (MB) with a grid resolution around 70 m (Fig.5). The model was forced by surface winds and heat fluxes derived from measurements at NOAA buoy 44013 in western MB, and freshwater discharges at the USGS gauges, and boundary forcing (tides, currents, temperature and salinity) derived from the model output of the MB hydrodynamic mode(Jiang et al. 2007). The model is able to capture well the general dynamic processes including tidal cycle, seasonal development of stratification, and wind- and river-driven circulation. A finer grid model will be developed for this project. The model coupled with the data we collect, will allow us to examine the water circulation in the study area, especially the hydrodynamic and likely water quality differences between the three chosen sites. The model has an embedded particle tracking program (see e.g., Jiang e al. 2007), which allows us to understand the connections between shellfish populations at three chosen sites and the larger harbor, and hence assess the impact of our project.
c) Addressing the needs of local communities

Often the economic value of shellfish to human communities is measured by their shellfishing and aquaculture use. In Boston Harbor, however, shellfishing is currently prohibited because of water quality concerns. Economic values of improved water quality may be seen in benefits for tourism and recreation. In Chesapeake Bay, for example, such benefits for clean water legislation have been valued from $3.5 to $18 billion (Morgan and Owens 2001). Due to exacerbated effects from global climate change and sea level rise, coastal ecosystems that provide storm protection and nutrient removal may also benefit the community economically (Lindahl et al. 2005; Costanza and Farley 2007; Gren et al. 2009). Therefore, the oysters, blue mussels and soft clams may also serve as ‘engineers’ for sustainable socio-economic communities by providing ecosystem services and zooremediation (Gudimov 2002). Oyster, blue mussel and soft shell clams stock enhancements and urban aquaculture initiative will also bring together researchers, beach users, and local community members from diverse groups such as yacht clubs, local schools, neighborhood community associations, and religious organizations.

This effort is part of the Green Boston Harbor (GBH) project (founded by PI Frankic in 2008) and its integrated and innovative approach to restoration of eelgrasses (Zostera marina), salt marshes (e.g. Spartina sp.), and shellfish (e.g. C. virginica), which may prove more effective than single species restoration efforts (Kohata et al. 2003; Heck et al. 2008; Wall et al. 2008).

Our primary goal is to enhance community understanding and participation in multi-species urban aquaculture and stock enhancement in support of green harbors. Our proposed study will directly contribute to knowledge related to urban harbor water quality and shellfish population by addressing three critical research needs:

1) Development of a circulation and physical-biological model that can suggest linkages among water quality, water circulation, and shellfish growth and survivability. Such a model might be used to aid site selection for new shellfish aquaculture facilities as well as to evaluate potential related environmental effects.

2) Development of effective strategies for outreach and education, both formal and informal, with a variety of audiences addressing the benefits from sustainable shellfish aquaculture.

3) Finally, our work can directly contribute to the goal of developing sustainable coastal aquaculture. The lack of sustainability in shellfish populations stems in part from the inability of...
a population to generate enough surplus production to meet their own replacement needs as well as the expectations of the fisheries (Folke et al. 1998; Folke 2006). Sustainable shellfish (Frankic 2003; Peharda et al. 2007).

2. Research work plans and milestones

(a) Objectives

Our primary goal is to enhance community understanding and participation in native multi-species shellfish stock enhancement in support of green harbors. To address this goal we have three objectives:

- **Oyster blue mussel and soft shell clam stock enhancement at Savin Hill Bay, Shipyard Marina, and Fort Point Channel**
- **Research and monitor relationships among water quality, water circulation patterns and shellfish survival/growth rates**
- **Research, education and outreach with a variety of Boston Harbor communities to enhance understanding, support, and participation in shellfish stock enhancement and for better water quality and healthy urban coastal environment**

These objectives will support Sea Grant priorities for stock enhancement, steps towards multi-trophic aquaculture, and biomitigation of disturbed ecosystems. Our educational objectives will also support adaptive urban ecosystem management, by fostering communities that are educated about and interested in sustainable coastal ecosystems.

(b) Hypotheses/Research questions

Our central hypothesis is that *sustainable population of native shellfish species would improve water quality in the Boston Harbor, and concurrently improved water quality would support sustainable shellfish stock enhancement and improve urban coastal habitats conditions*. This central hypothesis leads to more specific research questions:

1. Are oysters, blue mussels and soft shell clams able to survive and grow at the selected sites?
2. Is there a difference in the survival and growth rates of shellfish at the three sites and varied treatments?
3. Are the values for the environmental indicators measured, particularly water quality, likely suitable for oyster, blue mussel and soft shell clam health and propagation?
4. Does the hydrodynamic model predict water flows/circulation patterns that are likely to support stock enhancement and water quality at the selected project sites in the harbor?
5. Is there evidence of greater community understanding of, and interest in, sustainable shellfish stock enhancement and water quality in the harbor?
6. How can this approach of using native shellfish species as bioremediators help the establishment of green harbors throughout the urban coastal USA?

(c) Experimental Design

**Monitoring at three pilot project sites will include:**

1. Water quality – bi-weekly (using YSI probe for e.g. salinity, temp, DO, pH, turbidity, nutrients, chlorophyll)
2. Oyster and blue mussels growth and survival measurements – monthly (e.g. shell size)
3. Soft shell clam survival and growth rate measurement after two years
4. Benthic quality – seasonal (4 times per year) sediment samples will be taken at all three pilot project sites (analyses will include heavy metals: Arsenic, Cadmium, Chromium, Lead, Mercury, and Nickel)

5. Beach transects – seasonal assessment of the Bay area biodiversity (Fig 2)

6. Control sample- each of the shellfish placements will have a control sample that will be left undisturbed throughout the course of the study. At the conclusion of the study, we will measure the growth and survival rates of these shellfish.

Site #1: In Savin Hill Bay, about 10,000 oysters from Wellfleet, MA, will be selected with an approximate size of 1 inch in length. Oysters of this size are less susceptible to environmental changes and stress. It will be difficult to find oysters this size in June or July, but we could get the 1”size from a hatchery in August. The startup time for this project will also depend on the permitting process with the MA Department of Marine Fisheries, including a decision on how many oysters we will be able to use in this experiment.

Oyster (A) Place 5000 oysters in 25 netron (polyethylene) mesh ‘stockings’ (200 oysters in each), developed specifically for this project. These will be hung from the Dorchester Yacht Club (DYC) piers. The stockings will be submerged at all times, as the docks move with the tides.

Oyster (B) Place 5000 oysters in the deepest parts (~ 7 meters) of the Bay but outside of the navigational channel. At this site oysters will be placed in 10 netron bags (500 hundred in each) held off bottom on a PVC framed rack. The rack will ensure that the oysters are not placed directly on the bottom where they would likely become covered with silt and suffocate (Fig 2).

Blue mussel (C) Place 5000 blue mussels in 25 netron (polyethylene) mesh ‘stockings’ (200 blue mussels in each). Mussels will be hung from the DYC piers as described for oysters at location A, above. Mussels for this study will be transplanted from areas designated and permitted by MA DMF.

Soft shell clam (D) Place 54,000 soft clams by using 3,600 sq ft nets that are seeded at a density of 30 clams/sq ft. In areas on the North Shore of Mass Bay, wild spat or “larvae” of soft shell clam are easily captured using clam tents or spat nets. Efforts to capture wild seed in the Boston Harbor have proved less fruitful and in the case of soft shell clam aquaculture relays are too labor intensive. For this project clams grown to a size of 10-15mm at the Northeast Massachusetts Aquaculture Center will be transported, seeded, and covered by predator exclusion netting at the chosen enhancement sites. Predator exclusion nets are 52”x14” ¼ inch mesh nets which are secured over the seeded clams to protect them from predators for the first season. Building these nets involves cutting sections from a roll of ¼ inch mesh to the correct size and attaching 20 3”x3” floats to each net.

Site #2: At Shipyard Marina site 5000 oysters and 5000 blue mussels will be placed in 50 (200 hundred in each) netron (polyethylene) mesh ‘stockings.’ ‘Stockings’ will be hung from the pier at one meter intervals. Oysters for this site will be provided by the Wellfleet oyster farm, and blue mussels will be obtained from the DMF designated site.

Site #3: At the Fort Point Channel Site, 5000 oysters will be placed in the same way as at the sites 1-2, of the dock structures so that we can follow their progress without having to dive to the bottom. We will be measuring viability and growth. This activity can also be shared with area schools and other groups such as scout troops through the “Adopt an Oyster” gardening concept. The oysters will be placed in an upweller, a dock-like structure with cage containers beneath the deck where young oysters will grow that will be placed near the Boston Children’s Museum (Fig 6). These containers will be filled with spat oysters and flushed with seawater to facilitate their growth. Initially the oysters will be quite small, measuring 1 millimeter in size. Periodically, they will be run through grates with the largest oysters being moved to adjacent containers. When oysters reach size of 3 cm, they will be introduced into multiple locations in the

Project developed by Anamarija Frankic (GBH), 2011
Fort Point Channel. The upweller can considerably lower the cost of obtaining oysters. It can also be used in subsequent years, so it is important to note that we are installing a lasting resource that will provide benefits for years to come.

EEOS undergraduate and graduate students will be responsible for monitoring the oysters in the upweller. In collaboration with Children’s Museum, we will conduct seminars for visitors to the Children’s Museum as well as local communities. Fort Point Channel will be monitored and assessed to facilitate suitable locations for oyster placements and growth during this project.

(d) Evaluating project success at the three sites
We will evaluate our successes in parallel to our objectives:

- What were the growth and survival rates of shellfish?
- Which locations provided the conditions for survival?
- How many oysters were “adopted”?
- Are the values for the environmental indicators measured, particularly water quality, likely suitable for oyster and blue mussel health and propagation, as compared with expected values in the literature?
- Does the circulation model allow us to examine the water circulation in the study area, especially the hydrodynamic and likely water quality differences between the three chosen sites?

(e) Performance measures

(1) Number of coastal communities that adopt/implement sustainable shellfish enhancement approach
(2) Economic (market and non-market) and societal benefits (jobs created and retained)

Our primary goal, to enhance community understanding and participation in multispecies shellfish enhancement in support of green harbors, is directly aligned with this performance measure. Communities that understand and support sustainable shellfish population enhancement will in turn support related policies. We will measure our success in meeting this goal through the number of community organizations we work with, number of people attending our programs, and the number of people ‘adopting’ an oyster, blue mussel or soft shell clam.

Our project partner and collaborator, Chad Williams, and oyster aquaculturist at Wellfleet Harbor is eager to use a more holistic approach to shellfish aquaculture in which the majority of equipment and gear intensive activities occur within the first year of the species’ life. By nurturing that first crucial year of growth, the juvenile shellfish can be reared to a size and hardiness that will allow them to continue the rest of their cycle though a more natural process than traditional aquaculture. This holistic ecosystem based approach will allow for reduced dependence on gear, including plastic and metal cages and racks as well as nets and mesh bags. Mr. Williams collaborates with other shellfishers through trade
organizations, through the Wellfleet local association, and with the aquaculturists throughout Cape Cod. From seed production, to planting and harvesting, the community that he is part of is one that appreciates collaboration. Many farmers can benefit from the progress and development that is created from opportunities such as the ones this project provides. We all acknowledge that when members of the farming community make advancements the whole industry benefits. In addition, through this project Mr. Williams will directly increase his production; with this increased production he is planning to hire 2-4 new people to help with the work on the farm.

(f) Project Milestone

At the end of the each project year we will hold 2-day workshops at UMass Boston, with a theme “Shellfish for Green Harbors”:

1. Day one will include presentations from researchers, students, and local community members highlighting the year’s research and monitoring results;
2. Day two will include an educational cruise of Boston Harbor, visit to the research sites, and sharing stories, visions and next steps towards a Green Boston Harbor.

(g) Timetable

<table>
<thead>
<tr>
<th>Pilot Site Name</th>
<th>Shellfish</th>
<th>Monitoring Type</th>
<th>Monitoring Frequency</th>
<th>Milestones Year 1</th>
<th>Milestones Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Savin Hill Bay</td>
<td>Oysters, blue mussels, soft shell clams</td>
<td>Water quality</td>
<td>Bi-weekly</td>
<td>1 Day Summer Shellfish festival</td>
<td>1 Day Summer Shellfish festival</td>
</tr>
<tr>
<td>Shipyard Marina</td>
<td>Oysters, blue mussels</td>
<td>Water quality</td>
<td>Bi-weekly</td>
<td>2-day workshop and expo at the end of the year one</td>
<td>2-day workshop and expo at the end of the year two</td>
</tr>
<tr>
<td>Port Point Channel</td>
<td>Oysters, blue mussels</td>
<td>Water quality</td>
<td>Monthly</td>
<td>Shellfish survival/growth</td>
<td>Shellfish survival/growth</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sediment</td>
<td>4 x year (seasonal)</td>
<td>Sediment</td>
<td>Sediment</td>
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3. Outcomes
### Goals/objectives

<table>
<thead>
<tr>
<th>Goals/objectives</th>
<th>Outcomes</th>
<th>Measurements</th>
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<tbody>
<tr>
<td>1. Oyster, blue mussel and soft shell clam stock enhancement at three pilot projects in the BH</td>
<td>1. Adopt an Oyster Results</td>
<td>1. Number of adopted oysters</td>
</tr>
<tr>
<td>2. Monitoring relationships among water quality, circulation patterns and shellfish survival/growth rates</td>
<td>2. Better understanding between water quality, shellfish growth/survival and harbor circulation;</td>
<td>2. Results from water and sediment monitoring, and other ecological data at three selected pilot project sites throughout BH;</td>
</tr>
<tr>
<td>3. Research, education and outreach with BH communities to support shellfish stock enhancement for green harbors</td>
<td>3. Enhanced understanding and participation of local community in multispecies shellfish stock enhancement;</td>
<td>3. Comprehensive survey results of harbor users about ecological knowledge and human behaviors;</td>
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<tr>
<td></td>
<td>4. Number of community members involved in monitoring and research projects (informal science education)</td>
<td>4. Number of local community participants at the workshops and festivals</td>
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<td>5. At least two Community workshops and two summer festivals</td>
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### 4. Outreach and Education Plan

#### (a) Community Outreach

**Educational and Outreach Programs**

Community-based educational and outreach programs are critical to the success of this project. Participants will include undergraduate and graduate students from UMass Boston EEOS, the Massachusetts Oyster Project, visitors to the Boston Children’s Museum, and various local communities in Boston Harbor. Participants at each site will learn about different coastal habitats and related species, specifically shellfish, salt marshes, and eel grass, including these habitats’ importance for the health and quality of our coastal waters, our beaches and our seafood. We have developed IRB certified surveys that will be used as a complement to other project activities. The surveys’ goals are to help us understand the ‘feedback loops’ between individual’s activities and their knowledge and understanding about shellfish and water quality in urban harbors and coastal areas in general.

Programs will include site specific elements. Participants at Savin Hill Bay will learn about the Bay’s past, and imagine its possible futures. How was the Bay shaped prior to the construction of the highway and other development? How did it look like prior to the arrival of the colonists? What plants and animals used to live there? Why did it change? How would we like the beach and bay to be now and in the future? Participants will share their stories and their vision for their bay and beach area. They will learn about the oyster and soft shell clam placements described here, as well as how to restore the nearby salt marsh and eelgrass beds that once flourished in our coastal waters.

At Fort Point Channel, project staff will conduct classes and seminars on oysters and the aquatic community for both visitors to the Boston Children’s Museum and other specially scheduled groups. The Boston Children’s Museum will work with our team in developing the educational content. There will be three educational modules developed discussing runoff and waste management, biodiversity in the channel, and water quality. All of these modules will include hands-on activities such as measuring salinity and water clarity, counting the number of creatures found in a cage, and measuring oyster growth.

“Adopt an Oyster” and oyster gardening concept
“Adopt an Oyster” will further build ownership of water quality and environmental stewardship at these sites. This portion of the program will target school classes, scout troops and other groups for active participation in monitoring shellfish.

Media
Outreach will also include the use of both traditional and new media outlets, including various social networking sites. We will continue to use the Green Boston Harbor web site, Facebook, Twitter and YouTube to share the project information and communicate with project participants (www.gbh.umb.edu).

(b) Graduate and Undergraduate Education
Research, educational and outreach activities for graduate and undergraduate students will include:
1. Build two ‘sea perches’ (MIT Sea Grant’s remotely operated underwater vehicle (ROV) for classroom settings) for basic water quality monitoring as well as community participation and education
2. Assist with biodiversity education and other outreach to local communities
3. Assist with biological surveys
4. Assist with shellfish stock enhancement
5. Collection of biological samples and environmental data in coastal waters perform literature surveys of scientific journals, newspapers, magazines and trade publications.
6. Assist with summarizing and presenting biological and environmental data

(c) Evaluating education and outreach
Evaluation of education and outreach activities will include measuring the achievement of the performance measures described above, as well as:
1. Professional publications and presentations (PIs, undergraduate and graduate student researchers)
2. Meaningful, hands-on experiences for community participants
3. Any change in community presence at the sites, as well as the number of participants at the workshops and summer festivals
4. Media coverage and website traffic
5. Number of adopted oysters

5. Coordinate with other program elements (agency program or other ongoing research)
The Boston Children’s Museum is highly supportive of this initiative as it dovetails with their desire to be a green institution and to bring in more ecological programming. They will be working with us on designing the coursework and activities. Since the upweller facility will abut the museum, we can work together to publicize classes and ensure participation.

The Friends of Fort Point Channel was formed to serve as an advocacy group for the channel. Its membership consists of abutters and other important groups who are dedicated to the health of Boston Harbor. Their agenda calls for increasing use of the water sheet as well as its improvement. This oyster activity lies directly in line with both programs. The Friends membership includes a large community of groups interested in the harbor, such as The Boston Harbor Association and Save the Harbor/Save the Bay. The latter group runs a summer camp for children and we are excited to have them participate in our programming. Soft shell clam enhancement efforts in the Boston Harbor currently overseen by the Division of Marine Fisheries have seen great success and have created a strong relationship with industry, residential, and municipal stakeholders throughout the Greater Boston Harbor. In collaboration with the Division of Marine Fisheries we are going to distribute materials and seed clams at the identified site in the Savin Hill Bay (Fig.2).

References:


Smith, D. G. (1993). The potential for spread of the exotic xebra mussel (Dreissena polymorpha) in Massachusetts. Boston, MA, Massachusetts Department of Environmental Protection