IV D. Shellfish Stock Enhancement Project

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Completion Report - Thomas Shields

Introduction

For more than a decade, Boston Harbor has suffered from declining shellfish harvest due to poor water quality, poor larval recruitment and over harvesting (Shields and Kennedy, 2006). Additional disruptions to native softshell clam (*Mya arenaria*) populations in Boston Harbor that resulted from installation and operation of the "HubLine" natural gas pipeline catalyzed a remediation effort by the Massachusetts Division of MarineFisheries (*MarineFisheries*). In April 2006, a multi-year restoration and enhancement effort was initiated. The main goal of the Shellfish Stock Enhancement Project is to restore and enhance existing populations of softshell clams in five Boston Harbor communities through cooperative programs with local municipalities, commercial shellfishers and Salem State Northeast Massachusetts Aquaculture Center (NEMAC), with funding and technical assistance from *MarineFisheries.*

MarineFisheries' approach to this restoration project began on a pilot scale followed by gradual expansion as team members gained familiarity with the technology and processes of shellfish aquaculture. Proven enhancement methods were developed within specific coastal regions of Boston Harbor along with an understanding of the softshell clam and its habitat within the targeted enhancement areas. We hope to build a sound network of participants within each of the five Boston Harbor coastal communities, who are committed to and capable of carrying on with independent clam enhancement activities.

This report summarizes the status of our enhancement efforts in Boston Harbor from June 2006 through June 2008.

Project Team

The Boston Harbor Shellfish Restoration Project is a collaborative effort involving *MarineFisheries* personnel, local municipalities, commercial shellfishers and Salem State Northeast Massachusetts Aquaculture Center (NEMAC). *MarineFisheries* role consists of project oversight and the provision of technical assistance and funding to its participating partners. Current *MarineFisheries* team members consist of Tom Shields (Shellfish Restoration Biologist) and Sara Turner (Fisheries Technician).

MarineFisheries is working closely with Shellfish Constables in the communities of Hingham, Hull, Quincy and Weymouth, and the Harbormaster in the Town of Winthrop. These individuals are responsible for the selection of enhancement sites within their respective communities, provision of logistic support to *MarineFisheries* personnel and commercial shellfishers, patrolling the enhancement sites, and managing payments to participating commercial shellfishers.

Most of the enhancement activities were carried out by Boston Harbor commercial shellfishers. Master Digger's and their subordinate diggers were involved in all phases of softshell clam enhancement within each of the five participating communities.

Responsibilities of NEMAC personnel included production of the juvenile softshell clams that were out-planted to the Boston Harbor tidal flats. The seed clams were grown within their Cat Cove shellfish hatchery. NEMAC personnel were also responsible for the biological monitoring of the enhancement sites in order to document the survival and growth of the planted clams.

2006 Season Overview

MarineFisheries Shellfish Enhancement Project efforts were initiated in spring 2006 with the inspection of potential softshell clam enhancement sites in three Boston Harbor municipalities; Quincy, Weymouth and Hingham. Stock enhancement and propagation in PROHIBITED/CLOSED areas is contrary to the National Shellfish Sanitation Program (NSSP) due to public health and law enforcement concerns (FDA, 2007). In fact, the Interstate Shellfish Sanitation Committee (ISSC) and FDA recommend stock depletion in long term, prohibited areas (FDA, 2007). For these reasons, shellfish propagation and stock enhancement is limited to OPEN areas of Boston Harbor. Also, due to state regulations, shellfish aquaculture is precluded from existing productive areas. Potential restoration sites within Boston Harbor are therefore restricted to those tidal flats within open areas which are suitable for clam growth but are currently unproductive. Given these constraints, available sites are limited. *MarineFisheries* and NEMAC personnel accompanied by Shellfish Constables from each town visited a number of prospective mitigation sites, ultimately identifying five sites for clam stocking. The selected enhancement sites include the Bathing Beach and World's End Conservation area in Hingham; Moon Head beach in Quincy; and Abigail Adams Park and King's Cove in Weymouth (Figure IVD.1).

Clams were seeded over a 50 x 12 ft area at ~25 or ~50 clams/ft^2. Each seeded plot was subsequently covered with 0.25 inch mesh, extruded plastic netting floated by 11 ounce toggle floats to exclude predators. Predator exclusion netting (52 x 14 ft) was secured in

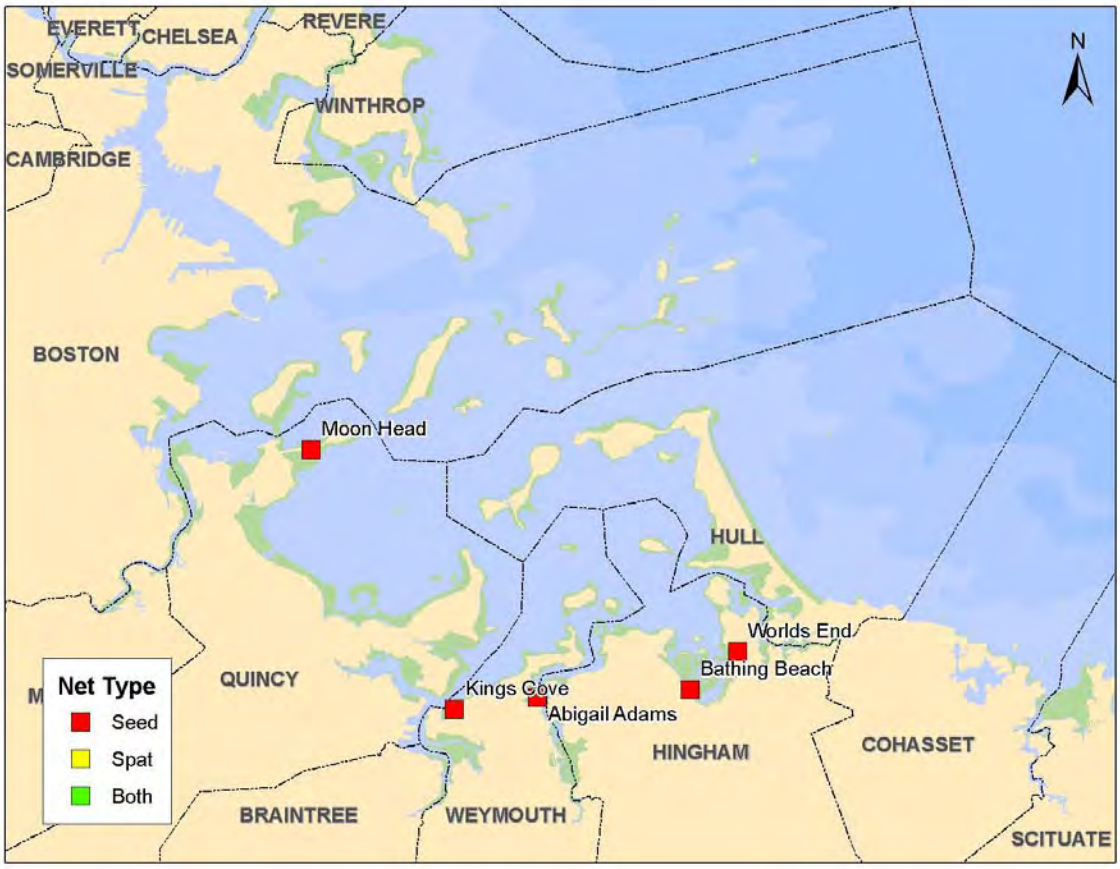

Figure IVD.1. Location of 2006 shellfish enhancement sites in Boston Harbor.

position by a 6-12 inch deep trench dug along the perimeter of each seeded area and back-filled with sediment that provided a 600 ft^2 netted refuge (50 x 12 ft). Between May and August 2006, 41 enhancement plots were installed on the flats, and 1,070,000 juvenile clams, ranging in size from 5.4 to 15.3 mm shell length (SL), were planted within the five propagation sites. The bulk of clam seeding and net installations were carried out by local commercial shellfishers and in one location (Hingham), students from Norwell High School.

GPS coordinates for the corner of all deployed nets were obtained by *MarineFisheries* personnel shortly after installation. All 41 predator exclusion nets were removed in November and December, and enhancement plot corners were permanently marked with ½ inch rebar stakes.

From August through December 2006, Salem State and *MarineFisheries* personnel sampled the enhancement sites for growth and survival of seeded clams, and routinely cleaned and maintained the 41 predator exclusion nets. The 2006 enhancement sites were sampled again in the spring and winter of 2007 and the results are presented within this report.

2007 Season Overview

During summer 2007, *MarineFisheries* and its partners carried out a second year of restoration, enhancement and monitoring of softshell clams (*Mya arenaria*) in Boston Harbor. Information gained during the pilot-scaled 2006 season was used to select more suitable restoration sites and to modify our clam seeding methodology. The number of municipalities participating in the 2007 program was expanded to five with the inclusion of Hull and Winthrop (Figure IVD.2).

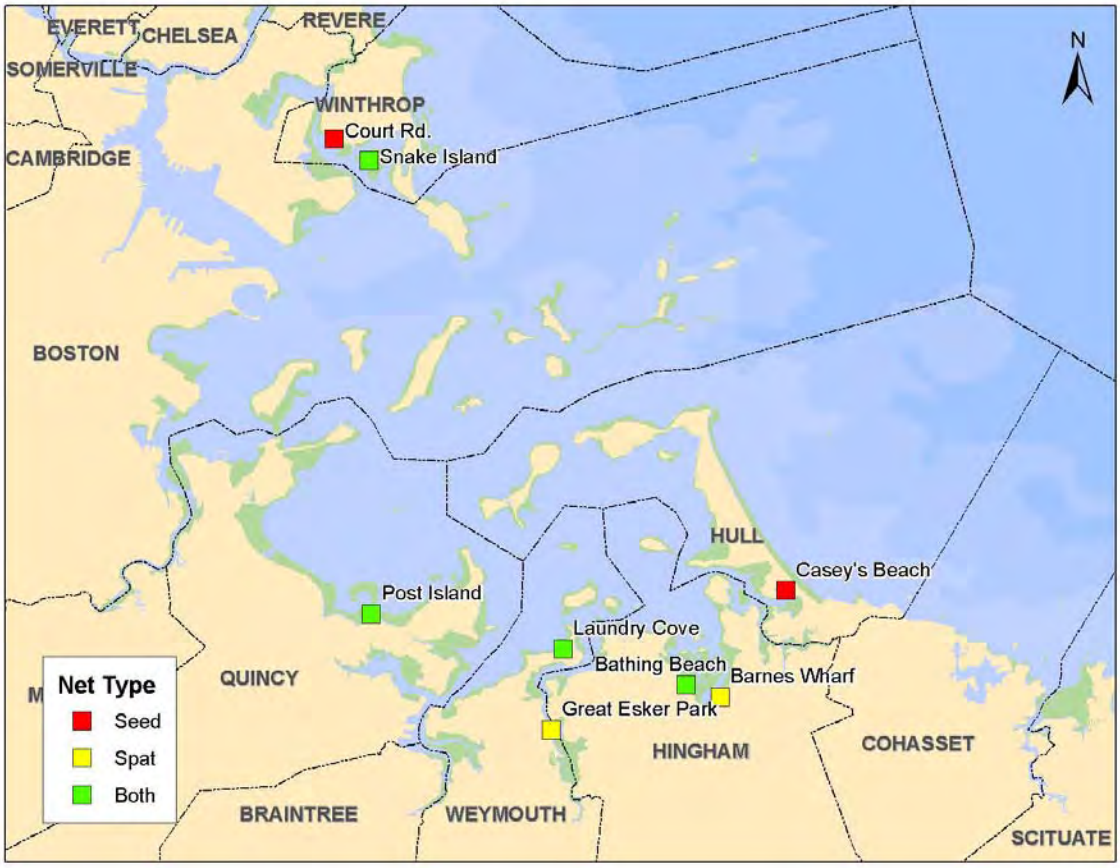

Figure IVD.2. Location of 2007 shellfish enhancement sites in Boston Harbor.

Between 5 June and 5 September 2007, using the methods described for the 2006 seed planting, we stocked approximately 870,000 clams (10.5 to 16.8 mm SL produced at the Cat Cove shellfish hatchery) at eight enhancement sites in Hull, Winthrop, Quincy, Weymouth and Hingham. At each site, 18,000 hatchery-reared juvenile clams were seeded over a 50 x 12 ft plot at a seeding density of 30 clams/ft^2. Each seeded plot was subsequently covered with 0.25 inch mesh, extruded plastic netting (52 x 14 ft). A seventh, smaller net (~20 x 14 ft) was installed in Hingham and seeded with 6,000 clams. In the summer of 2007, a total of 49 enhancement plots were planted with seed clams.

In an effort to entrap naturally occurring wild clam spat, 46 spat collectors were deployed within suitable intertidal locations throughout the study area. The collectors consisted of ¼ inch mesh extruded plastic netting, floated with 11 ounce toggle floats. In some areas the extruded plastic nets were replaced with 30 percent shade cloth which consisted of woven $^1/_6$ to ¼ inch mesh plastic material. Spat collectors were either 25 ft or 50 ft long and varied between 12 and 14 ft in width. GPS coordinates for the corner of all deployed nets were obtained by *MarineFisheries* personnel shortly after installation. Nets covering all seeded and spat collection plots were removed in November and December 2007. Plot corners were then permanently marked with rebar or PVC stakes.

During winter 2007 and again during spring 2008, all restoration sites were sampled for growth and survival of seeded clams. During fall/winter 2007, 44 spat collectors were similarly sampled. Assessment of growth and survival of clams seeded within all 2007 restoration sites along with the success of our spat collection efforts are presented within this report.

2006 Field Season Methods

Clam Stocking and Net Installation

Between May and August 2006, 41 enhancement plots were seeded with 1,070,000 juvenile clams that ranged in size from 5.4 to 15.3 mm SL. Clam stocking and net installation occurred on nine separate dates (Table IVD.1).

Table IVD.1. Stock data for softshell clams planted on tidal flats in the towns of Hingham, Quincy and Weymouth in summer 2006. Parenthesized letters and numbers identify specific plot locations at each site. At the Weymouth site, plot E was seeded with two sizes of clams: 5.9 mm SL clams were planted on the half adjacent the 3-4 side and 7.0 mm SL clams were planted on the half adjacent the 1-2 side.

Enhancement Site & Plot ID	Date	Average length (mm)	S.D.	Number stocked
Hingham (Bathing beach: 1, 2, 3)	18-May	15.3	3.2	20,000
Hingham (Bathing beach: A2, A3, B1, B2, B3)	22-Jun	10.4	2.4	105,000
Hingham (Bathing beach: A1)	22-Jun	9.7	2.8	30,000
Hingham (Bathing beach: C1, D1, D2, D3, E1)	27-Jun	10.2	2.8	105,000
Hingham (Bathing beach: C2,C3)	27-Jun	10.3	2.7	60,000
Quincy (Moon beach, A, B, C, D, E)	10-Jul	10.1	2.9	150,000
Quincy (Moon beach, F)	10-Jul	10.1	2.4	30,000
Quincy (Moon beach: G, H, I, K)	11-Jul	8.6	2	120,000
Weymouth (Abigail Adams Park: A, B, C, E 1-2)	25-Jul	7	1.5	105,000
Weymouth (Abigail Adams Park: D, E 3-4)	25-Jul	5.9	1.7	45,000
Weymouth (King's Cove: A, B, C, D, E)	26-Jul	6	1.7	150,000
Quincy (Moon Beach: K, L)	8-Aug	5.4	1.4	50,000
Quincy (Moon Beach: L, restocked)	13-Oct	20.5	3.9	20,000
Weymouth (Abigail Adams Park: F, G)	9-Aug	5.4	1.4	50,000
Hingham (World's End: A)	9-Aug	5.4	1.4	30,000

Hingham

On May 18, 2006 over two dozen Norwell High School students assisted with the first planting of clams at the Hingham Bathing Beach. This was a trial run to work out the logistics and procedures required to carry out larger scaled planting operations. A total of three plots (1, 2, & 3), measuring 50 ft X 8 ft, were stocked at a density of approximately 22 clams/ft^2 with an estimated 20,000 clams (Table IVD.1; Figure IVD.3).

Following these field trials, set procedures for planting the hatchery reared seed clams were established. Plot installation involved positioning the 52 ft by 14 ft predator exclusion net on the tidal flat, digging a trench around the inside perimeter of the net, raking the area to be covered by the net and removing crabs and debris, seeding the clams and securing the net by backfilling the trench so the outer 1 ft edge of the net was buried to a depth of 6-12 inches.

Full-scaled planting efforts at the Bathing Beach site in Hingham were carried out on 22 – 27 June. A total 320,000 clams were seeded at the Bathing Beach site in Hingham. The clams averaged ~10 mm SL, and were planted at densities of 25 and 50 clams/ft^2 on raked and unraked substrates protected by predator exclusion nets (N = 13; 52 x 14 ft). An additional 30,000 clams (avg. = 5.4 mm SL) were stocked within one plot on 9 August in Martin's Cove at the World's End Conservation site (Table IVD.1; Figure IVD.3).

Quincy

On 10 July, 10 plots (A – J) were established at the Moon Head site in Quincy (Table IVD.1; Figure IVD.4). 180,000 juvenile clams that averaged 10.1 mm SL were seeded at 50 clams/ft^2on raked substrates and protected by predator exclusion nets. On 11 July, four plots (G – J) were seeded with 120,000 clams that averaged 8.6mm SL. On 8 August, Plots K and L were seeded with 50,000 clams that averaged 5.4 mm SL. On 13 October net L was restocked with 20,000 clams that averaged 20.5 mm SL. A total of 370,000 clams were planted and 12 nets installed in Quincy.

Weymouth

Between 25 July and 9 August, 350,000 juvenile clams that averaged 5.4 - 7.0 mm SL were seeded within 12 enhancement plots at two Weymouth enhancement sites; Abigail Adams Park and King's Cove (Table IVD.1; Figure IVD.5). The clams were seeded on raked substrates protected by predator exclusion nets. Eleven of the plots were stocked at a density of 50 clams/ft^2. At Abigail Adams Park site one net (G) was stocked at 33 clams/ft^2. A total of 12 nets were installed; seven at Abigail Adams Park and five at King's Cove.

Biological Monitoring

Concurrent with clam seeding and net installation, two samples (~1 ft^2) were collected from each enhancement plot and transported to the NEMAC's lab. Samples were sieved and aquatic organisms were collected for identification.

Between 17 August and 27 October 2006 the five enhancement sites were monitored and sampled on 13 separate dates. Site monitoring consisted of visually inspecting all nets at a site for damage, repairing any damage and removing debris, mainly green and red algae, from the net. Sampling involved pulling back a portion of the predator exclusion net. Initially, three sides of a net were excavated, folded over and the now exposed netted area randomly sampled. Net excavation required considerable effort and random sampling often yielded few or no clams. Following our initial efforts, a standardized net sampling protocol emerged that involved removing 10 ft of net from one end and using a 1 ft^2 quadrant to collect nine samples from the exposed end. Three samples were obtained from the middle of the exposed area and three from each edge at 1, 4 and 8 ft intervals measured from the edge of the netted area.

Bathing Beach

Martin's Cove

Figure IVD.3. Arrangement of plots at the 2006 Bathing Beach and Martin's Cove enhancement sites in Hingham.

Moon Head

Figure IVD.4. Arrangement of plots at the 2006 Moon Head enhancement site in Quincy.

By late October, it was determined that many of our enhancement sites experienced heavy clam mortalities. Our sampling of the enhancement plots established that there were virtually no clams remaining within the 12 seeded plots at the Moon Head site in Quincy, nor within the 5 seeded plots at the King's Cove site in Weymouth. Similar problems were encountered at the Martin's Cove site in Hingham where no clams were found within the one plot located there, and at the Abigail Adams site in Weymouth where no clams were found within four of the seven seeded plots.

Both random and systematic sampling of enhancement plots in the summer and fall yielded few or no clams. During the winter 2006/2007 and spring 2007sample periods, the sampling methodology was again modified, in order to collect enough clams to adequately define growth and density parameters within each site. Within each enhancement plot, samples were collected from areas with a high density of siphon holes. One ft^2 sediment samples were collected and processed until 60 clams had been obtained. Generally, no more than three samples were collected from each plot. In a few cases, less than three samples and 60 clams were collected because of time constraints (e.g., incoming tide, loss of daylight). In a few cases, less than three samples and 60 clams were collected because of time constraints (e.g., incoming tide, loss of daylight). Clams were separated from sediment and debris by sieving through a 0.375 inch mesh sorting tray. Shell length (SL) of measurable clams was determined to the nearest 0.1 mm in the field with calipers. Number of clams collected and SL of measurable clams were recorded. Sample holes were back-filled and clams, unless excessively damaged during collection, were carefully replaced to their original location.

Abigail Adam's Park

King's Cove

Figure IVD.5. Arrangement of plots at the 2006 Abigail Adams Park and King's Cove enhancement sites in Weymouth.

During the winter 2006/2007 and spring 2007, biological monitoring was limited to the three enhancement sites where clams remained; Bathing Beach site in Hingham (13 nets), Abigail Adams site in Weymouth (3 nets) and Moon Head site in Quincy (1 net). Winter sampling trips occurred on 29 December 2006 and 11 January 2007. The spring sampling occurred between 14 and 20 May, 2007.

2007 Field Season Methods

Clam Stocking and Net Installation

Between 5 June and 5 September 2007, approximately 870,000 clams that averaged between 10.5 to 16.8 mm SL were stocked within 49 plots in Hull, Winthrop, Quincy, Weymouth and Hingham (Table IVD.2; Figure IVD.2). With one exception, stocking procedures were identical at all eight enhancement sites. At each site, a total of 108,000 clams were planted in 6 plots. Within each 50 x12 ft plot, 18,000 clams were seeded at an approximate density of 30 clams/ft^2. Each seeded area was subsequently covered with 0.25 inch mesh, extruded plastic netting (52 x 14 ft) to exclude predators. Predator exclusion netting was secured in position by a 6-12 inch deep trench dug along the perimeter of each seeded area and back-filled with sediment that provided a 600 ft^2 netted refuge (50 x 12 ft). One smaller net (~20 x 14 ft) was installed in Hingham and seeded with 6,000 clams. GPS coordinates for the corner of each net were obtained by *MarineFisheries* personnel shortly after installation.

The eight 2007 enhancement sites are illustrated in Figure IVD.6 (Hull-Casey's Beach East and Casey's Beach West), Figure IVD.7 (Winthrop-Court Road and Snake Island), Figure IVD.8 (Quincy – Terne Road and Post Island Road), Figure IVD.9 (Weymouth – Laundry Cove) and Figure IVD.10 (Hingham – Broad Cove).

Table IVD.2. Stock data for softshell clams planted within eight enhancement sites in the towns of Winthrop, Quincy, Weymouth, Hingham and Hull in summer 2007.

Site	Date	Number of Clams	Number of Plots	Average Size(mm)
Winthrop				
Court Road	6/18/2007	108,000	6	10.5(1.5)
Snake Island	7/1/2007	108,000	6	11.3(1.4)
Quincy				
Terne Road	7/7/2007	108,000	6	10.7(1.8)
Post Island Road	8/5/2007	108,000	6	12.9(1.4)
Weymouth				
Laundry Cove	8/12/2007	108,000	6	12.8(1.4)
Hingham				
Broad Cove	9/5/2007	114,000	7	13.0(1.6)
Hull				
Casey's Beach East	6/6/2007	108,000	6	16.8(3.0)
Casey's Beach West	6/5/2007	108,000	6	16.1(2.6)
Totals		**870,000**	**49**	

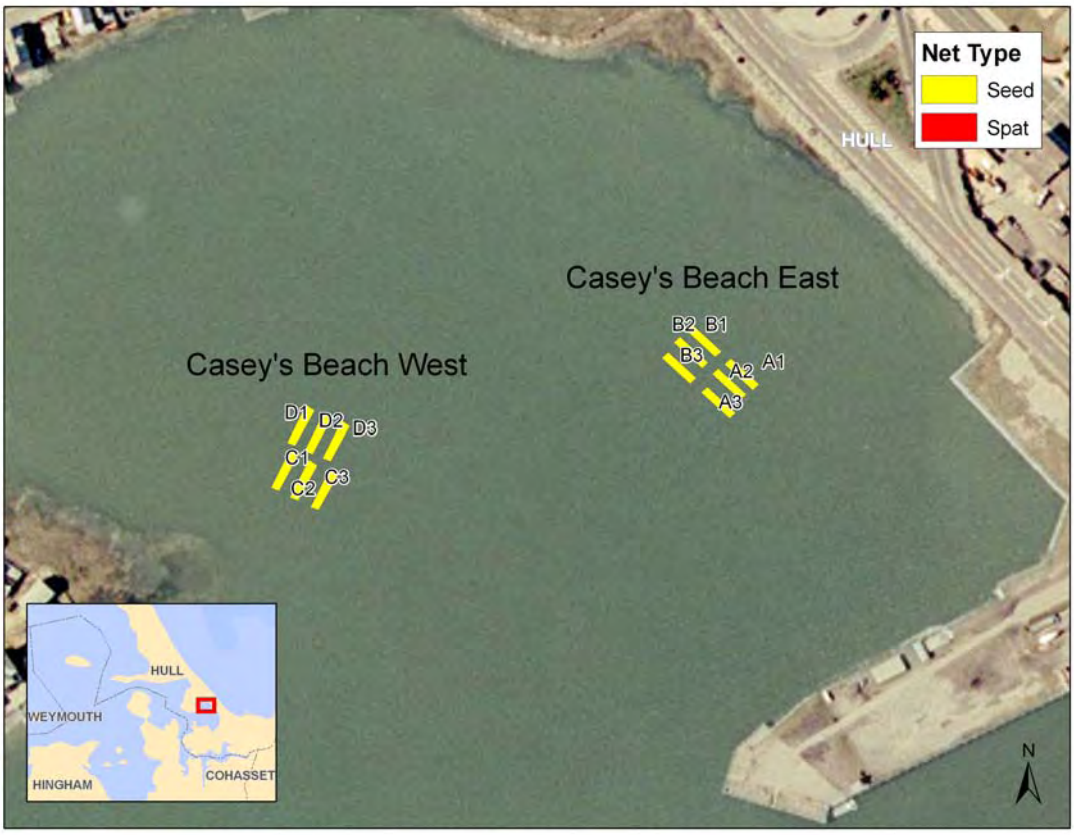

Figure IVD.6. Arrangement of plots at the 2007 Casey's Beach East and Casey's Beach West enhancement sites in Hull.

Wild Spat Collection

In an effort to entrap naturally occurring wild clam spat, 46 spat collectors were deployed within suitable intertidal locations throughout the study area (Figures IVD.7 through IVD.10). Spat collectors were deployed at seven sites; Terne Road and Post Island Road in Quincy, Barnes Warf and Broad Cove in Hingham, Laundry Cove and Great Esker Park in Weymouth and Snake Island in Winthrop. Forty four of the spat nets were deployed in early-June (7th-15th), while two were deployed on July1st (Snake Island, Winthrop). Types of equipment and netting used to collect natural soft shell clams and methods of deploying spat collectors in southeastern Massachusetts have been described by Leavitt (1998 and 2004). Collectors used in this study consisted of ¼ inch mesh extruded plastic netting floated with 11 ounce toggle floats. In some areas the extruded plastic nets were replaced with 30 percent shade cloth which consisted of woven $^{1}/_{6}$ to ¼ inch mesh plastic material. Spat collectors were either 25 ft or 50 ft long and varied between 12 and 14 ft in width. Dates of deployment and retrieval of spat collectors at various locations within the study area are provided in Table IVD.3.

Biological Monitoring

Biological sampling of the 2007 enhancement sites was carried out by NEMAC personnel, with some assistance by *MarineFisheries* personnel. Selected enhancement plots at each site were inspected within one month of seeding to confirm the presence of clams. NEMAC personnel collected samples from all sites during fall/winter 2007/2008 and from most sites in spring 2008. Sampling methods were identical to those that were described for the winter 2006/2007 and spring 2007 sampling of the 2006 enhancement sites (Section 2.2).

Court Road

Snake Island

Figure IVD.7. Arrangement of plots at the 2007 Court Road and Snake Island enhancement sites in Winthrop.

Terne Road

Post Island Road

Figure IVD.8. Arrangement of enhancement plots and wild spat collectors at the 2007 Terne Road and Post Island Road enhancement sites in Quincy.

Laundry Cove

Great Esker Park

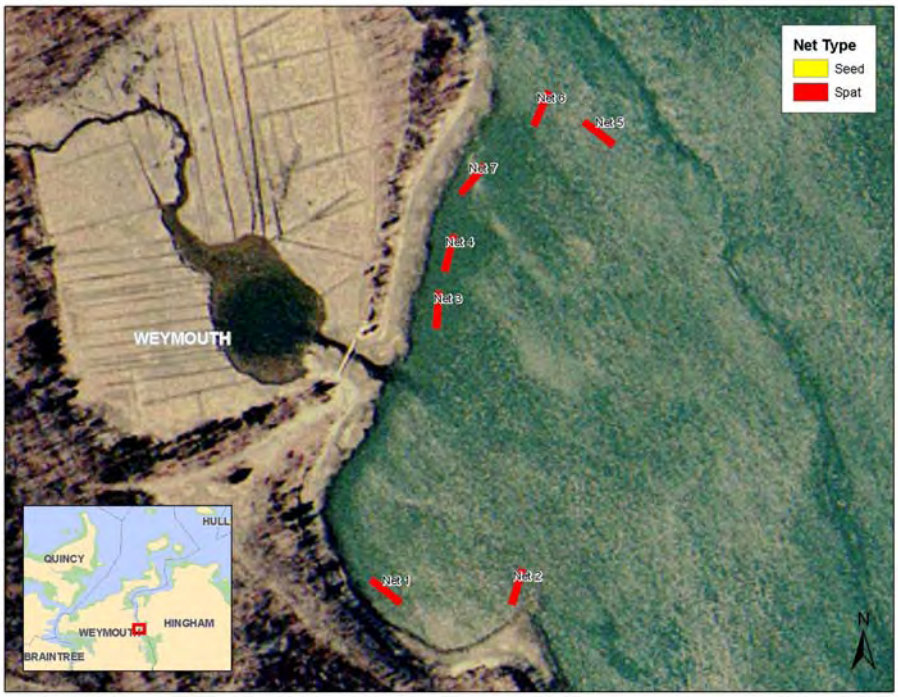

Figure IVD.9. Arrangement of the enhancement plots and wild spat collectors at the 2007 Laundry Cove and Great Esker Park enhancement sites in Weymouth.

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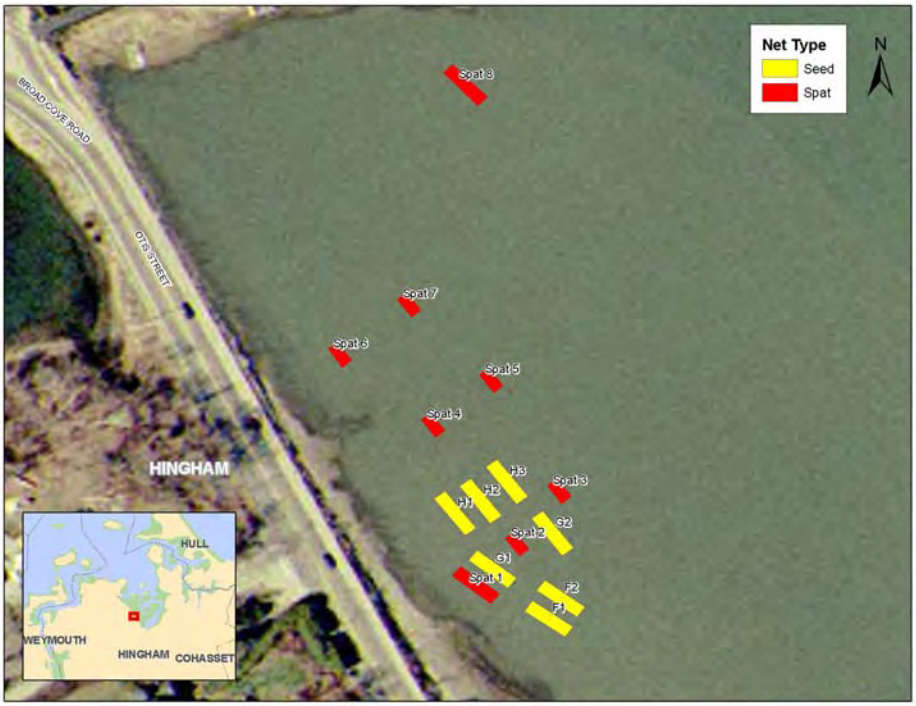
Broad Cove



Barnes Warf

Figure IVD.10. Arrangement of the enhancement plots and wild spat collectors at the 2007 Broad Cove and Barnes Warf enhancement sites in Hingham

Table IVD.3. Summary of wild spat collector deployment and retrieval dates during the 2007 field season.

Site	Date Installed	Date Removed	Number of Nets		
			50'	25'	Total
Terne Road, Quincy	6/14/2007	11/7-8/07	3	4	7
Post Island Road, Quincy	6/15/2007	11/7-8/07	2	6	8
Barnes Wharf, Hingham	6/8/2007	12/28/2007	3	4	7
Broad Cove, Hingham	6/7/2007	12/18/2007	2	6	8
Laundry Cove, Weymouth	6/11/2007	12/19/2007	3	4	7
Great Esker Park, Weymouth	6/12/2007	12/31/2007	3	4	7
Snake Island, Winthrop	7/1/2007	11/21/2007	2	0	2
		Total	18	28	46

Forty four of the 46 spat collection plots were sampled between 20 November 2007 and 11 January 2008. Within each plot, between one and six 1 ft^2 quadrat samples were collected and screened using ¼ inch meshed trays. Shell length (SL) of measurable clams was determined to the nearest 0.1 mm in the field with calipers. Number of clams collected and SL of measurable clams were recorded. Sample holes were back-filled and clams, unless excessively damaged during collection, were carefully replaced to their original location.

The remaining 2006 enhancement plots in Hingham and Weymouth were again sampled by NEMAC personnel between 29 October and 7 December, 2007.

Results and Discussion

2006 Enhancement Sites

A summary of field sampling results for the periods of winter 2006, spring 2007 and winter 2007 are presented in Appendix IVD.A. Sample dates, total number of samples, total number of clams, total number of clams and average length (SL) of the seed clams are presented for each sampled enhancement plot.

Clam Survival

Survival of clams planted at the 2006 enhancement sites was assessed qualitatively since sampling was not random, but directed to portions of the plots where siphon holes were abundant. A qualitative ranking based on average density per ft^2 was developed to generally describe seed clam survival within the enhancement plots: High indicates ≥25 clams; Moderate indicates 15 to < 25 clams; Low indicates 1 to <15; and none indicates no clams found.

Table IVD.4 and Figure IVD.11 summarize seed clam survival within plots at all of the 2006 enhancement sites based on field data collected in the fall and winter of 2007. Sites with no data (Table IVD.4) indicate that no clams survived.

By fall 2006, we established that there were significant problems at four of our five 2006 enhancement sites. No planted clams were found within the 12 nets seeded at Moon Head site in Quincy, the single plot/net planted at the Martin's Cove site in Hingham, the five nets seeded at the Kings Cove site in Weymouth, and four of the seven plots/nets seeded at the Abigail Adams site in Weymouth.

Seed size appears to have played a major role in survival of the planted clams. The average size of clams planted at the two sites that exhibited total failure was between 5 and 7mm (SL). Multiple efforts to find clams at King's Cove in Weymouth (5 nets) and Martin's Cove in Hingham (1 net) revealed that no planted clams survived. Similarly, the four plots/nets at Abigail Adams that were seeded with 5-7 mm clams yielded no clams.

Table IVD.4. Summary of clam survival within the 2006 enhancement sites based on samples collected in the fall/winter 2007. Four survival rankings are based on number of clams/ft2; High (25+), Moderate (15 to <25), Low (1 to <15) and None (0).

Enhancement Site	Sample Date	Plot	Number of Samples	Number of Seed Clams	Sample Density	Average Shell Length	StDev	Survival Estimate
Bathing Beach, Hingham	11/8/2007	A1	1	63	63.0	46.3	3.7	High
Bathing Beach, Hingham	11/28/2007	A2	3	96	32.0	49.7	5.2	High
Bathing Beach, Hingham	11/28/2007	A3	1	55	55.0	51.0	4.6	High
Bathing Beach, Hingham	11/28/2007	B1	4	88	22.0	50.8	5.3	Moderate
Bathing Beach, Hingham	11/28/2007	B2	2	64	32.0	52.9	5.6	High
Bathing Beach, Hingham	11/28/2007	B3	2	55	27.5	52.6	5.3	High
Bathing Beach, Hingham	11/28/2007	C1	1	55	55.0	47.3	3.4	High
Bathing Beach, Hingham	12/7/2007	C2	2	76	38.0	49.0	4.1	High
Bathing Beach, Hingham	12/7/2007	C3	2	62	31.0	51.8	5.0	High
Bathing Beach, Hingham	12/7/2007	D1	3	49	16.3	54.1	5.4	Moderate
Bathing Beach, Hingham	12/7/2007	D2	2	72	36.0	54.2	5.7	High
Bathing Beach, Hingham	12/7/2007	D3	2	72	36.0	55.4	5.9	High
Bathing Beach, Hingham	11/8/2007	E	4	61	15.3	53.9	6.3	Moderate
Martin's Cove, Hingham	N/A	A	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	A	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	B	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	C	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	D	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	E	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	F	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	G	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	H	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	I	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	J	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	K	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	N/A	L	N/A	N/A	N/A	N/A	N/A	None
Moon Head, Quincy	10/29/2007	L(reseeded)	2	28	14.0	50.2	5.4	Low
Abigail Adams, Weymouth	10/31/2007	A	3	6	2.0	33.6	6.0	Low
Abigail Adams, Weymouth	10/31/2007	B	3	19	6.3	40.5	5.0	Low
Abigail Adams, Weymouth	10/31/2007	C	3	39	13.0	39.1	5.8	Low
King's Cove, Weymouth	N/A	A	N/A	N/A	N/A	N/A	N/A	None
King's Cove, Weymouth	N/A	B	N/A	N/A	N/A	N/A	N/A	None
King's Cove, Weymouth	N/A	C	N/A	N/A	N/A	N/A	N/A	None
King's Cove, Weymouth	N/A	D	N/A	N/A	N/A	N/A	N/A	None
King's Cove, Weymouth	N/A	E	N/A	N/A	N/A	N/A	N/A	None

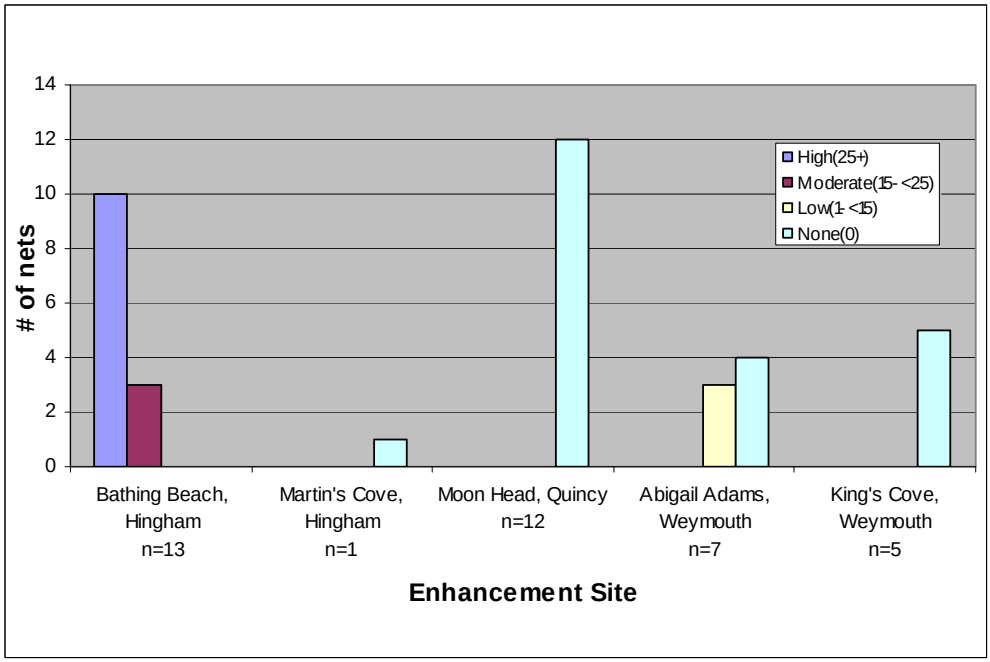


Figure IVD.11. Clam survival at five 2006 enhancement sites based on field data collected in the fall and winter of 2007. Average clam density within individual enhancement plots was used to describe clam survival: High = ≥25 clams; Moderate = 15 to < 25 clams; Low = 1 to <15; and None = no clams found. Number of nets (or plots) and estimated survival of clams within them are presented for each of the enhancement sites.

However, three other nets (A, B and C) seeded with 5-7 mm clams at Abigail Adams did survive at moderate to low densities.

With one exception, all but one of the 13 plots planted at the Bathing Beach site in Hingham were seeded with clams greater than 10 mm SL. Net A1 was seeded with 9.7mm clams. The Bathing Beach site exhibited the highest survival rates, followed by the three nets at the Abigail Adams Park site.

Physical characteristics of the enhancement sites (sediment type and beach kinetics) and human activity also influenced the survival of clams planted in 2006. Despite the teams best effort to select appropriate enhancement sites, Moon Head (Quincy), Martin's Cove (Hingham), King's Cove (Weymouth) and portions of Abigail Adams (Weymouth) sites were not well suited for the seeding and rearing of juvenile softshell clams.

In 2006, juvenile clams were planted in three basic sediment types; silty mud, sand/mud mix and rock/sand/mud mix. Beach kinetics at each of the five 2006 enhancement sites were also variable. Juvenile clams planted at these five sites were exposed to variable degrees of tidal current and stream flows, wind driven waves and vessel wake. In addition, the level of human activities at the five sites was variable and generally involved beach combers and sport fishermen. An assessment of sediment type, beach kinetics (High, Medium Low) and user conflicts (High Medium and Low) is summarized and presented in Table IVD.5 as a site matrix.

As previously stated, clams planted at Kings Cove in Weymouth (5 nets) and within 4 of the 7 plots/nets planted at Abigail Adam's Park in Weymouth did not survive. We believe that this was primarily due to the small size of the juvenile clams (5-7mm). All of these clams were planted in silty mud, which may have contributed to poor clam survival at these sites. We believe that all of the small clams (5.4mm) planted in Martin's Cove(1 net) in Hingham were washed out from under the ¼ inch meshed predator exclusion net by a stream that drains the nearby tidal marsh (Damdee Meadows) during outgoing tides.

Table IVD.5. Assessment of site characteristics (sediment type, beach kinetics, and user conflicts) at the five 2006 enhancement sites.

Enhancement Site	# of Plots	Sediment Type			Beach Kinetics			User Conflicts
		Silty Mud	Sand/Mud Mix	Rock/Mud Mix	Stream/ Tidal Current	Wave Exposure	Vessel Wake	(Anglers)
Hingham								
Site 1	13		**X**		L**	L	L	L
Site 2*	1		**X**		H	H	M	H
Weymouth								
Site 1	7	**X**		**X**	L	L	L	M
Site 2*	5	**X**			H	L	L	L
Quincy								
Site 1*	12		**X**		H	H	H	H

* Shaded areas = sites with no clam survival

* * Ratings for Beach Kinetics and User Conflicts: H = High, M = Medium, L = Low.

Despite the fact that one half of the clams planted at the Moon Head site in Quincy were greater than 10mm SL and that all of the clams were planted in what we thought was optimal substrate (sand/mud mix), none of the 360,000 clams could be found within the 12 seeded enhancement plots. We believe that beach kinetics at this site were the determining cause of the observed poor survival. During an incoming tide, there was a significant long shore current at this site. Moon Head is also exposed to the prevailing southwest winds that occur during the summer in Boston Harbor and to vessel wakes caused by the commuter ferries that run between Boston, Hingham and Quincy. It is likely that the current and wave action at the Moon Head site washed clams away from under the nets.

Recreational fishermen commonly frequented the Moon Head site in Quincy, and most likely contributed to clam mortalities at the site. On numerous site visits, team members found an abundance of fishing lures and tears in the netting covering the plots. Green crabs easily found their way through the tears thus causing significant clam mortalities within some plots. On one occasion, over 200 green crabs were found within an enhancement plot where the netting had been torn by a fishing lure.

Clam survival was highest at the Hingham Bathing Beach Site where the substrate is a sand/mud mix. This site is also exposed to limited tidal current, wave exposure and vessel wake. Despite the fact that the site is adjacent to a public bathing beach, there was limited recreational activity (beach walking and/or sport fishing).

Clam Growth

By winter 2006, only 17 of the original 49 enhancement plots contained seed clams; 13 at the Bathing Beach site in Hingham, 3 at the Abigail Adams site in Weymouth and the one re-seeded net at Moon Head in Quincy. Growth of clams at these remaining sites is illustrated in Figure IVD.12. Although the seed size at time of planting ranged between 8.6 and 20.5mm and growth intervals varied (630 days in Hingham, 448 days in Weymouth and 357 days in Quincy), the growth rates were similar at all three sites.

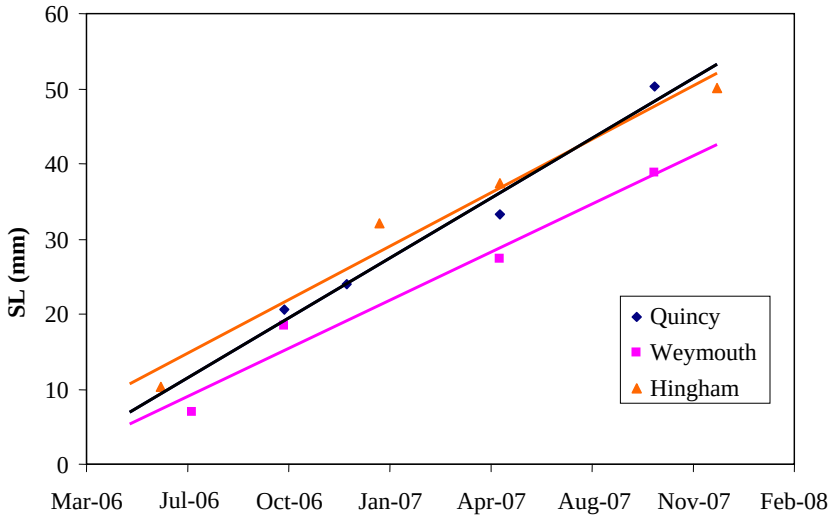


Figure IVD.12. Growth of clams stocked in summer 2006 at the Bathing Beach site, Hingham (r^2 = 0.97); net "L" Quincy (r^2 = 0.97); and Abigail Adams Park, Weymouth (r^2 = 0.97).

Hingham

During winter 2007, all three remaining plots at Abigail Adams Park were dug out by unknown individual(s), thus contaminating the study site. Following the October 2006 sampling trip to Moon Head in Quincy, the team decided to discontinue sampling of this site, since there was only one partial plot remaining at this remote location. Further analysis of growth is restricted to the clams seeded within the 13 plots at the Hingham Bathing Beach enhancement site.

Figure IVD.13 illustrates the size distribution of all clams sampled within the 13 enhancement plots at the Hingham Bathing Beach site following a grow-out period of approximately 90 weeks (1.7 yrs.). Juvenile clam recruits, ranging in size between 15 and 39mm, made up over 10 percent of the population at the site. When considering only the clams that were planted in 2006 (clams $\geq$ 40mm; Figure IVD.14), over 57 percent were of legal size (50.8mm) or greater.

Clams planted at the Hingham Bathing Beach site were subjected to two different experimental treatments; (1) planting at different seeding densities, and (2) planting in raked and unraked sediments. The arrangement of plots receiving different experimental treatments is illustrated in Figure IVD.3. Roughly one half of the plots (7 of 13) were seeded at a density of 50 clams/ft^2. Plots A1 through A3, C1 through C3, and E1 were each seeded with 30,000 juvenile clams. The other plots (6 of 13) were seeded at a density of 25 clams/ft^2. Nets B1 through B3 and nets D1 through D3 were each seeded with 15,000 juvenile clams.

All seed clams were planted in similar mud/sand sediment that was either raked free of crabs and other predators or left untreated. Nets A1 through A3 and nets B1 through B3 were planted in unraked sediment. The substrate within nets C1 through C3, D1 through D3 and net E1 was vigorously raked and all green crabs and other potential predators were removed.

Average clam lengths within each of the 13 enhancement plots at the Bathing Beach site ranged from 46.3 - 55.4mm (Figure IVD.15). Average clam lengths within plots receiving the two experimental treatments are summarized in Table IVD.6 and Figure IVD.16. Overall, clams within the low density plots were larger (53.2mm; SD 7.7) than those within the high density plots (49.2mm; SD 4.8). There was a slight size difference between clams which were planted in raked substrates (52.0mm; SD 5.8) and clams which were planted in sediment that was not raked (50.5mm; SD 5.4).

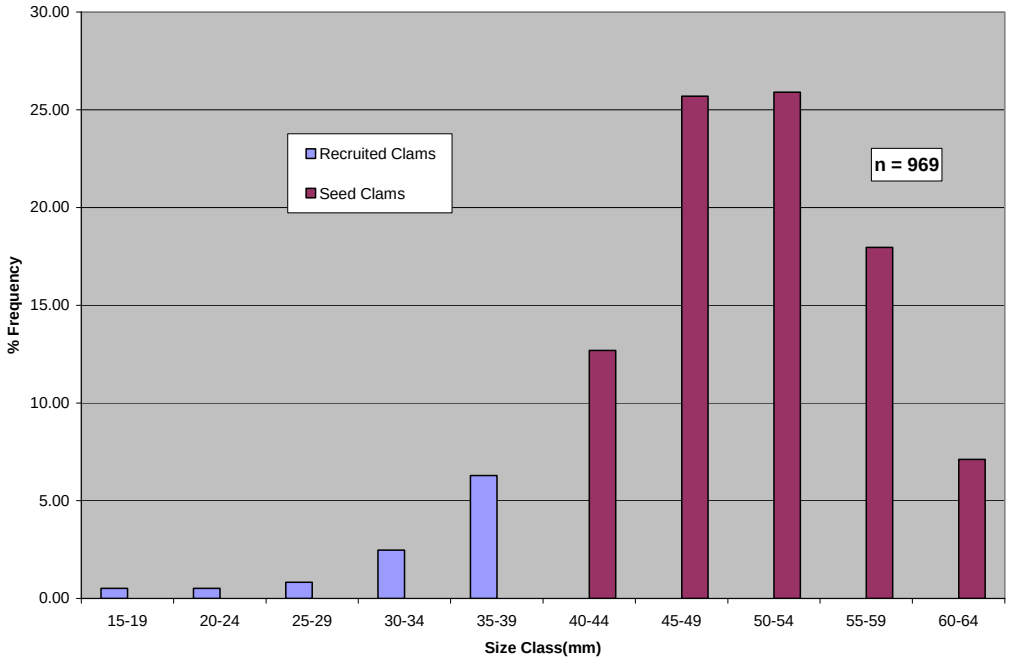


Figure IVD.13. Length frequency of clams within the 2006 Bathing Beach enhancement site in Hingham based on samples collected in October and December 2007. The growth period was 90 weeks or 1.7 years.

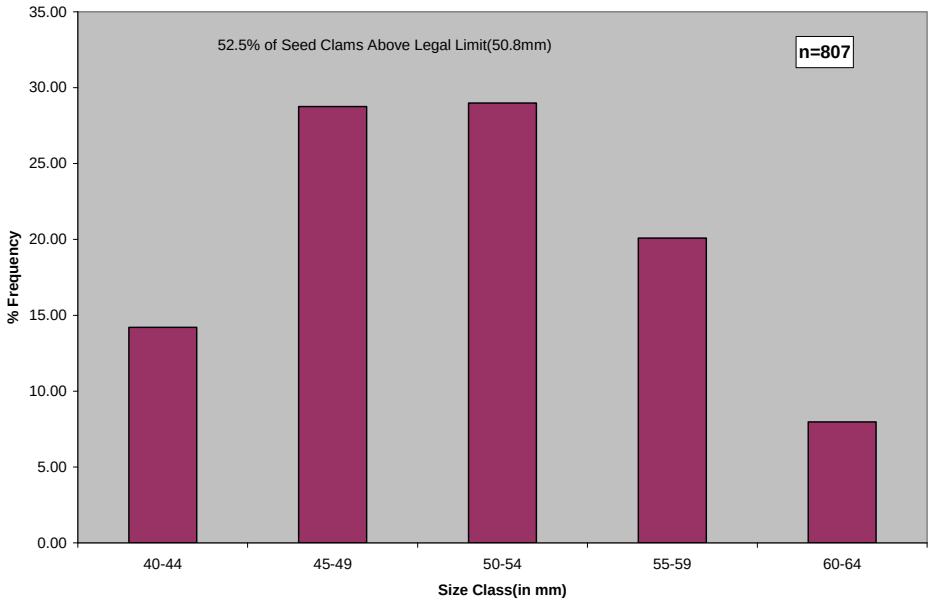


Figure IVD.14. Length frequency of clams that were seeded within the 2006 Bathing Beach enhancement site in Hingham following a grow-out period of 90 weeks or 1.7 years.

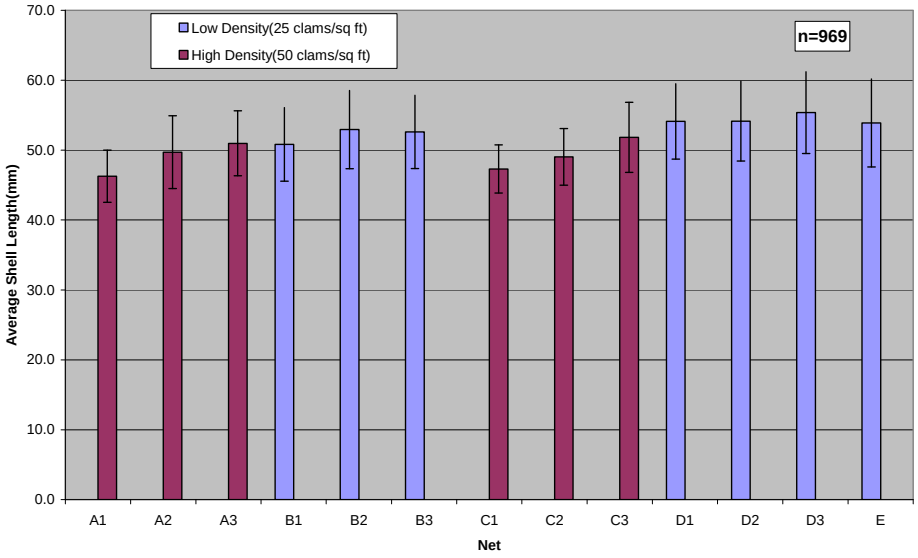


Figure IVD.15. Comparison of the average length of clams planted at low and high densities at the 2006 Bathing Beach enhancement site in Hingham. The grow-out period is 90 weeks or 1.7 years.

Table IVD.6. Summary of average clam lengths within plots receiving different experimental treatments at the 2006 Bathing Beach enhancement site in Hingham following 90 weeks or 1.7 years of growth. Clams were planted at two different densities (A), within raked and unraked sediment (B) and at three different heights on the intertidal flat (C).

A. Comparison of Seeding at Different Densities

Treatment	Average Length (mm)	S.D.	Number of Clams
25 clams/ft2	53.2	5.7	400
50 clams/ft2	49.2	4.8	407

B. Comparison of Raked and Unraked Substrates

Treatment	Average Length (mm)	S.D.	Number of Clams
Raked	52	5.8	386
Unraked	50.5	5.4	421

C. Comparison of Seeding at Different Tidal Heights

Treatment	Average Length (mm)	S.D.	Number of Clams
Series 1 - High	49.6	5.4	255
Series 2 - Mid	51.3	5.6	308
Series 3 - Low	52.9	5.5	244

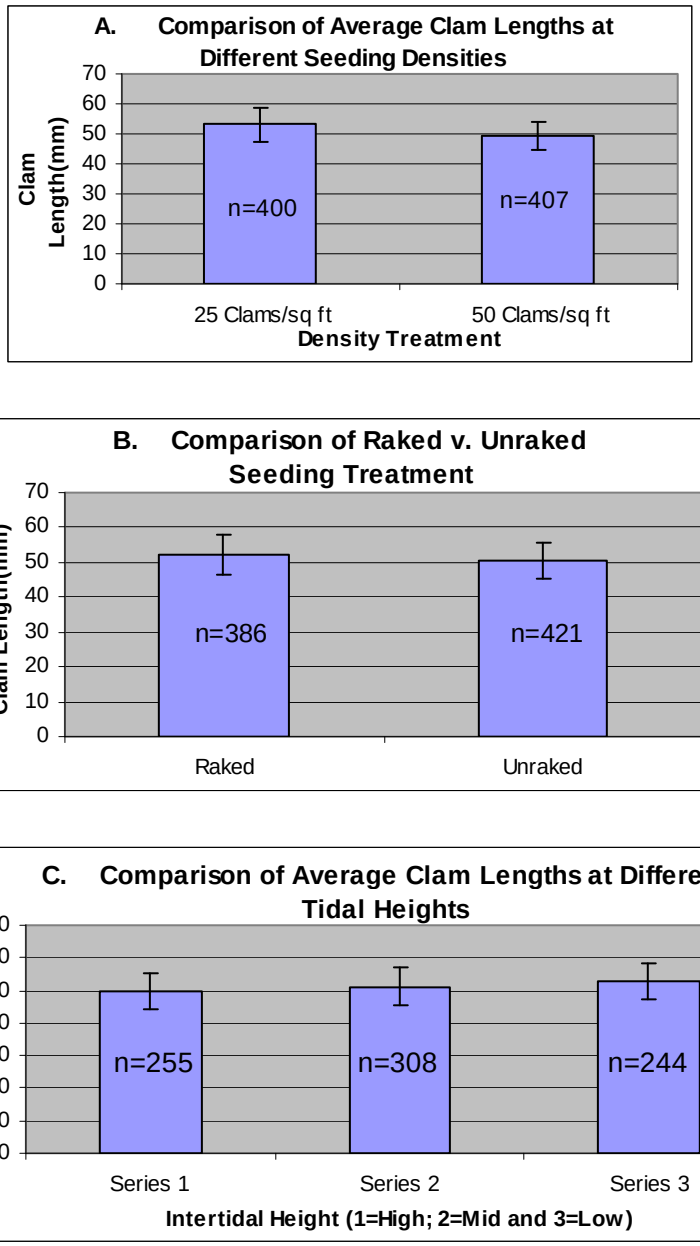


Figure IVD.16. Summary of average clam lengths within plots receiving different experimental treatments at the 2006 Bathing Beach enhancement site in Hingham following 90 weeks or 1.7 years of growth. Clams were planted at two different densities (A), within raked and unraked sediment (B) and at three different heights on the intertidal flat (C).

The slope of the clam flats at the Hingham Bathing Beach site is gradual (Figure IVD.3). With the exception of Plot E1, the remaining 12 experimental plots were laid out in a grid consisting of four rows of three plots. Plots within each row were set at approximately the same height on the intertidal flat and are described as high (1), medium (2) and low (3) intertidal height. Average lengths of clams within high and low density plots at similar intertidal height are presented in Figure IVD.17. Clams within the low density plots were consistently larger than those within the high density plots, regardless of tidal height. Average clam length within both density treatments increased with decreasing tidal height.

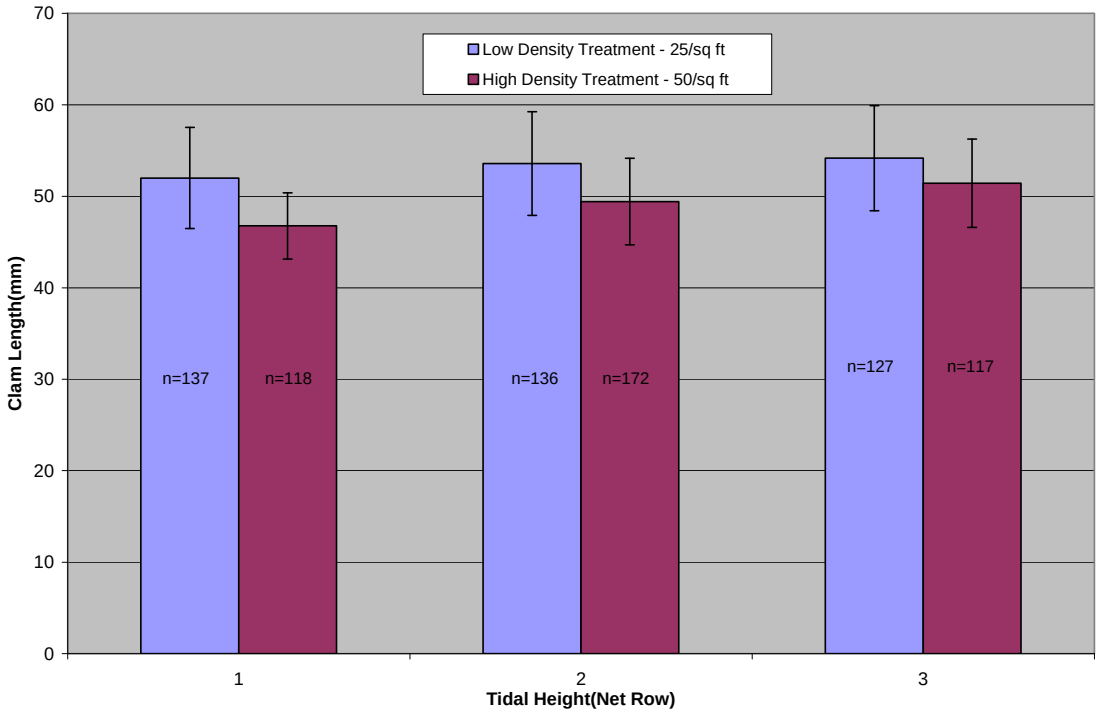


Figure IVD.17. Comparison of average clam lengths at different seeding densities and tidal heights at the 2006 Bathing Beach site in Hingham following 90 weeks of growth.

Benthic Sampling

A summary of benthic fauna identified from samples collected from enhancement plots in Hingham, Weymouth, and Quincy during the summer and fall 2006 is presented in Table IVD.7. Green crabs (*Carcinus maenas)*, mud snails (*Nassarius obsoletus*) and worms (Annelida, Sipunculida, Platyhelminthes and Nemertea) were commonly observed at all 2006 enhancement sites. Many sipunculid worms were observed at Hingham Bathing Beach; few were observed at other locations. Small numbers of other bivalves and worm species were found at all locations.

2007 Enhancement Sites

A summary of the 2007 field sampling results are presented in Appendix IVD.B. Sample dates, total number of samples, total number of clams, total number of seed clams and average length (SL) of the seed clams are presented for each sampled enhancement plot. In order to differentiate between planted clams and resident clams (large and small), length thresholds were established during each sampling period (Table IVD.8). Planted clams within each sampled plot were defined as those with shell lengths within the lower and upper length thresholds. Clams with lengths below the lower threshold are considered wild recruits. Clams with lengths above the upper threshold are considered to have been present at the time of seeding. Only clams that fell within the given length thresholds were used to determine survival and growth parameters of the stocked clam population at each 2007 site.

Table IVD.7. Benthic fauna identified within enhancement plots in Hingham, Weymouth and Quincy in summer and fall 2006.

Bivalves	
Mya arenaria	Softshell clam
Mytilus edulis	Blue mussel
Macoma balthica	Little macoma or duck clam
Mercenaria mercenaria	Quahog
Gemma gemma	Gem shell
Gastropoda	
Nassarius obsoletus	Mud snail
Urosalphinx cinera	Oyster drill
Polinices duplicatus	*Moon snail*
Worms	
Gylcera dibranchia	Clam worm
Nereis virens	Blood worm
Phascolosomas gouldii	Mud worm
Clymenella sp.	Bamboo worm
Capitella sp.	Capitellid worm
Sipunculus sp.	Sipunculan worm
Nemertea	Ribbon worm
Other	
Carcinus maenas	Green crab
Limulus polyphemus	Horseshoe crabs

Table IVD.8. Upper and lower length thresholds of clams seeded in the 2007 enhancement sites. Sampled clams with lengths within the thresholds are considered to have been seeded during the summer 2007. Clams with lengths below the lower threshold are assumed to be recruited to the population after the site was seeded. Clams with lengths above the upper threshold are assumed to have been present at the time of seeding.

Enhancement Site	Sample Month	Lower Threshold (mm)	Upper Threshold (mm)
Winthrop			
Court Road	October '07	none	40
	November '07	none	43
	December '07	none	45
	April '08	20	55
Snake Island	November '07	25	55
	June '08	30	60
Quincy			
Terne Road	August '07	13	35
	January '08	20	45
	May '08	20	55
Post Island Road	September '07	none	35
	January '08	15	40
	May '08	20	55
Weymouth			
Laundry Cove	October '07	15	40
	January '08	15	40
	May/June '08	20	50
Hingham			
Broad Cove	October'07	14	25
	December'07	15	30
	April '08	15	35
Hull			
Casey's East	August '07	15	40
	October '07	20	50
	January '08	25	55
	May '08	25	60
Casey's West	July '07	15	40
	August '07	15	40
	January '08	25	55
	May '08	25	60

Clam Survival

Survival of clams planted in 2007 enhancement sites was assessed qualitatively (as in 2006) since sampling was not random, but directed to portions of the plots where siphon holes were abundant. A qualitative ranking based on average clam density within each plot was applied to generally describe seed clam survival within the enhancement plots. Five survival rankings were used: High = ≥25 clams; Moderate = 15 to < 25 clams; Low = 1 to <15; and None = no clams found.

Table IVD.9 and Figure IVD.18 summarize clam survival at the eight 2007 enhancement sites based

on field data collected in spring 2008. High and moderate clam densities were observed at all 2007 enhancement sites.

Low clam densities were observed in only 5 of the 49 experimental plots seeded in 2007; two at the Laundry Cove site in Weymouth, two at the Post Island Road site in Quincy and one at the Snake Island Site in Winthrop. Physical characteristics (sediment type and beach kinetics) at two of these sites were most likely the cause of low clam survival. At Laundry Cove, the two plots (A3 and B3) with low clam survival were placed in silty mud. Despite the fact that these plots were seeded with larger juvenile clams (12.8mm), the clams did not grow well in a silty mud substrate. Low clam survival within the two plots at Post Island Road in Quincy (Plots D and E) was most likely due to wave exposure. This site is exposed to northeast wind driven waves. At the time of seeding, there was a 10 knot northeast breeze which caused small waves at the site. As the tide rose over the plots, clams could be seen washing around under the nets. It is likely that some of the clams seeded in Plot D and Plot E were washed through the netting shortly following the seeding process.

The observed low clam survival in Plot 2 at the Snake Island Site in Winthrop cannot be explained. This Plot was located in the lower intertidal zone. Although this site is exposed to southwest winds that prevail in Boston Harbor during the summer, Net 2 is only exposed during extremely low tides.

Clam Growth

Average clam lengths on each sample date were calculated for the eight 2007 enhancement sites. Clams lengths collected from all plots sampled at a given site and date were pooled to calculate an average value. The results are presented in Table IVD.10 and Figure IVD.19.

Seeding activities during the 2007 season were protracted over a three month period (June 5 to September 5). This was due in part to the propagation team's decision to plant clams that were greater than 10mm in shell length. The extended seeding schedule was necessary because it takes time to grow large numbers of 10mm seed clams in the hatchery and it allowed us to plant 108,000 clams at each of the eight enhancement sites. However, this protracted seeding schedule exposed clams that were seeded late in the summer to optimal growing conditions (higher water temperatures and plankton availability) for a shorter period of time. Clams that were planted at the three sites in August and September did not obtain an average shell length greater than 36mm (Broad Cove, Hingham; Post Island Road, Quincy and Laundry Cove, Weymouth). Clams planted within the five sites that were seeded earlier in the summer (June and July) ranged between 37 and 44 mm in average shell length (East and West Casey's Beach, Hull; Snake Island and Court Road, Winthrop and Terne Road, Quincy).

Length frequency histograms of clams sampled during three sample periods (spring/fall 2007, winter 2007 and spring 2008) are presented for the eight 2007 enhancement sites: Court Road and Snake Island in Winthrop (Figure IVD.20); Terne Road and Post Island Road in Quincy (Figure IVD.21); Casey's Beach east and Casey's Beach west in Hull (Figure IVD.22); Laundry Cove in Weymouth (Figure IVD.23) and Broad Cove in Hingham (Figure IVD.24). With the exception of the August 2007 sample of Terne Road in Quincy, size distributions during each sample period approximated a normal bell-shaped curve at all sites. The cause of the irregular size distribution at Terne Road is unclear. Clams planted at all eight enhancement sites demonstrated good growth.

A comparison of the average lengths of planted clams at the time of seeding (summer 2007) and at the time of sampling (spring 2008) is illustrated in Figure IVD.25. The grow-out period, or time between seeding and sampling, varied between sites and ranged between 219 days (Hingham) and 352 days (Hull). During the spring 2008, average clam lengths at each site ranged between 22.8mm (Broad Cove, Hingham) and 44.7mm (Casey's Beach- west, Hull). The best growth was observed at sites where larger clams were seeded early in the summer, as was the case at Casey's Beach (east and west) in Hull. Conversely, less growth was observed at sites where smaller clams were seeded later in the season (i.e., Broad Cove, Hingham).

Table IVD.9. Summary of clam survival at the 2007 enhancement sites based on samples collected in spring 2008. Four survival rankings are based on number of clams/ft2; High (25+), Moderate (15 to <25), Low (1 to <15) and None (0).

Enhancement Site	Sample Date	Plot	Number of Samples	Number of Seed Clams	Sample Density	Average Shell Length	StDev	Survival Estimate
Broad Cove, Hingham	4/11/2008	F1	1	75	75.0	22.6	3.2	High
Broad Cove, Hingham	4/11/2008	F2	1	88	88.0	22.0	3.0	High
Broad Cove, Hingham	4/11/2008	G1	1	61	61.0	22.1	2.7	High
Broad Cove, Hingham	4/11/2008	G2	1	88	88.0	24.4	3.3	High
Broad Cove, Hingham	4/11/2008	H1	1	89	89.0	22.4	2.8	High
Broad Cove, Hingham	4/11/2008	H2	3	60	20.0	22.4	3.5	Moderate
Broad Cove, Hingham	4/11/2008	H3	1	109	109.0	23.1	2.6	High
Casey's Beach East, Hull	5/22/2008	A1	1	202	202.0	38.5	4.6	High
Casey's Beach East, Hull	5/22/2008	A2	1	102	102.0	43.7	6.7	High
Casey's Beach East, Hull	5/22/2008	A3	1	119	119.0	42.1	7.3	High
Casey's Beach East, Hull	5/22/2008	B1	1	92	92.0	42.5	5.9	High
Casey's Beach East, Hull	5/22/2008	B2	1	86	86.0	45.7	4.5	High
Casey's Beach East, Hull	5/22/2008	B3	1	77	77.0	44.8	4.6	High
Casey's Beach West, Hull	5/22/2008	C1	1	79	79.0	44.6	6.1	High
Casey's Beach West, Hull	5/22/2008	C2	1	74	74.0	44.1	4.3	High
Casey's Beach West, Hull	5/22/2008	C3	2	68	34.0	48.0	4.2	High
Casey's Beach West, Hull	5/22/2008	D1	1	64	64.0	43.2	5.3	High
Casey's Beach West, Hull	5/22/2008	D2	2	81	40.5	43.2	5.4	High
Casey's Beach West, Hull	5/22/2008	D3	1	71	71.0	45.4	5.4	High
Court Rd., Winthrop	4/23/2008	A1	1	103	103.0	35.2	5.0	High
Court Rd., Winthrop	4/23/2008	A2	1	75	75.0	39.9	6.9	High
Court Rd., Winthrop	4/23/2008	B1	2	83	41.5	41.6	5.7	High
Court Rd., Winthrop	4/23/2008	B2	2	69	34.5	40.4	5.9	High
Court Rd., Winthrop	4/23/2008	C1	2	103	51.5	42.5	5.1	High
Court Rd., Winthrop	4/23/2008	C2	2	96	48.0	42.6	6.2	High
Snake Island, Winthrop	6/3/2008	1	1	163	163.0	44.1	4.5	High
Snake Island, Winthrop	6/3/2008	2	3	40	13.3	51.8	5.5	Low
Snake Island, Winthrop	6/3/2008	3	3	74	24.7	44.3	5.6	Moderate
Snake Island, Winthrop	6/3/2008	4	3	97	32.3	43.5	5.4	High
Snake Island, Winthrop	6/3/2008	5	2	74	37.0	42.6	4.1	High
Snake Island, Winthrop	6/3/2008	6	2	77	38.5	44.0	5.7	High
Laundry Cove, Weymouth	6/11/2008	A1	1	79	79.0	34.6	3.7	High
Laundry Cove, Weymouth	5/21/2008	A2	2	95	47.5	35.1	5.5	High
Laundry Cove, Weymouth	5/21/2008	A3	3	7	2.3	23.0	2.0	Low
Laundry Cove, Weymouth	6/11/2008	B1	1	74	74.0	35.5	5.0	High
Laundry Cove, Weymouth	6/11/2008	B2	1	84	84.0	38.0	5.5	High
Laundry Cove, Weymouth	5/21/2008	B3	3	15	5.0	34.0	8.6	Low

Table IVD.9 (continued).

Enhancement Site	Sample Date	Plot	Number of Samples	Number of Seed Clams	Sample Density	Average Shell Length	StDev	Survival Estimate
Post Island Road, Quincy	5/8/2008	D	3	11	3.7	28.3	3.5	Low
Post Island Road, Quincy	5/8/2008	E	3	1	0.3	32.2		Low
Post Island Road, Quincy	5/8/2008	F	3	71	23.7	32.6	4.2	Moderate
Post Island Road, Quincy	5/8/2008	G	1	75	75.0	33.7	4.0	High
Post Island Road, Quincy	5/8/2008	H	1	68	68.0	34.1	4.3	High
Post Island Road, Quincy	5/8/2008	I	1	94	94.0	33.1	3.6	High
Terne Road, Quincy	5/8/2008	A1	1	78	78.0	34.7	4.1	High
Terne Road, Quincy	5/8/2008	A2	1	110	110.0	34.6	5.4	High
Terne Road, Quincy	5/8/2008	B1	1	99	99.0	38.3	4.3	High
Terne Road, Quincy	5/8/2008	B2	2	81	40.5	39.2	4.1	High
Terne Road, Quincy	5/8/2008	C1	2	90	45.0	38.4	5.5	High
Terne Road, Quincy	5/8/2008	C2	2	86	43.0	40.4	4.5	High

Table IVD.10. Average Clam Length by Sample Date at Eight 2007 Enhancement Sites.

WINTHROP

Court Road

Date	Ave. Length	Std Dev	# of Individuals
6/18/2007	10.5	1.5	seeding
7/6/2007	14.7	2.2	134.0
9/7/2007	32.7	5.7	14.0
10/31/2007	33.1	5.4	58.0
11/14/2007	37.1	3.6	39
12/28/2007	35.8	4.9	472.0
4/23/2008	40.3	6.4	466.0

Snake Island

Date	Ave. Length	Std Dev	# of Individuals
7/1/2007	11.3	1.4	seeding
7/20/2007	14.0	1.7	255.0
9/28/2007	37.5	4.2	16.0
11/21/2007	39.4	6.5	392.0
6/3/2008	44.4	5.5	492.0

QUINCY

Terne Road

Date	Ave. Length	Std Dev	# of Individuals
7/7/2007	10.7	1.8	seeding
8/14/2007	20.6	2.6	452.0
1/7/2008	31.7	4.9	647.0
5/8/2008	37.5	5.2	491.0

Post Island Road

Date	Ave. Length	Std Dev	# of Individuals
8/5/2007	12.9	1.4	seeding
9/14/2007	18.3	1.5	13
9/24/2007	22.1	3.6	57.0
1/11&1/16/2008	26.7	4.4	349.0
5/8/2008	33.2	4.1	309.0

HULL

Casey's Beach East

Date	Ave. Length	Std Dev	# of Individuals
6/6/2007	16.8	3.0	seeding
8/7/2007	32.6	3.4	60.0
10/29/2007	40.4	5.4	213.0
1/18&1/27/08	40.4	5.4	567.0
5/22/2008	42.2	6.2	625.0

Casey's Beach West

Date	Ave. Length	Std Dev	# of Individuals
6/5/2007	16.1	2.6	seeding
7/3/2007	22.8	2.8	55.0
8/2/2007	31.3	3.9	216.0
1/18/2008	39.1	5.3	460.0
5/22/2008	44.7	5.4	404.0

WEYMOUTH

Laundry Cove

Date	Ave. Length	Std Dev	# of Individuals
8/12/2007	12.8	1.4	seeding
10/9/2007	23.2	3.9	113.0
10/30/2007	26.3	4.3	3
1/20/2008	26.4	4.3	286
2/20/2008	30.2	3.7	88
5/21& 6/11/08	35.6	5.4	326

HINGHAM

Broad Cove

Date	Ave. Length	Std Dev	# of Individuals
9/5/2007	13.0	1.6	seeding
10/12&10/25/2007	19.3	3.0	106.0
12/18&12/20/2007	20.3	2.7	705.0
4/11/2008	22.8	3.1	563.0

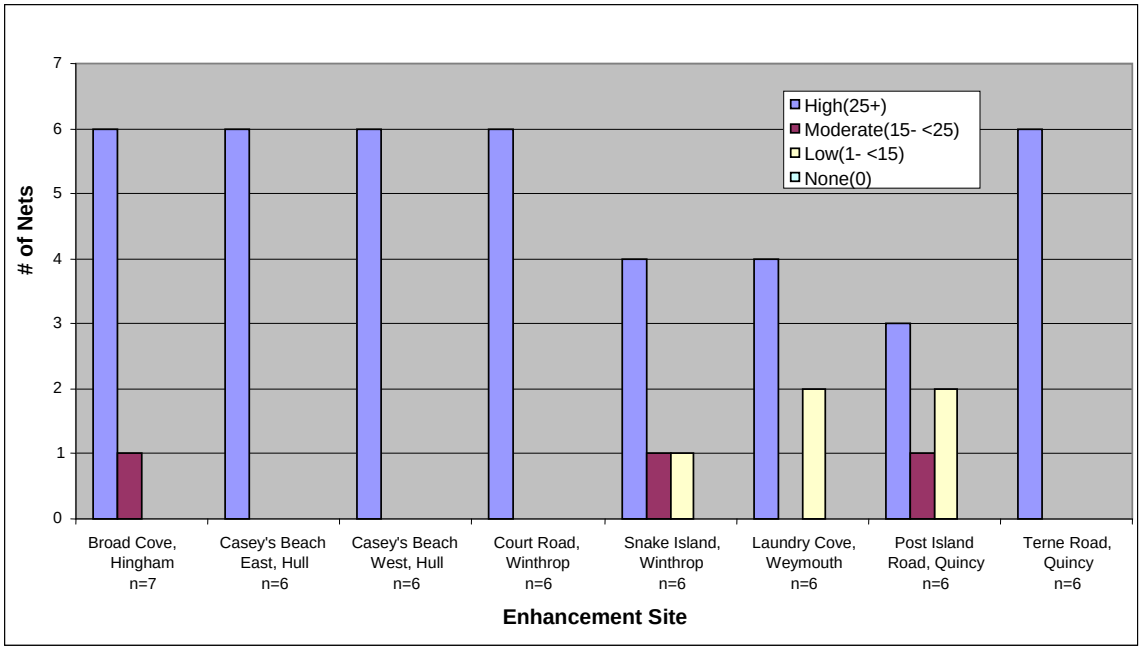


Figure IVD.18. Clam survival at the eight 2007 enhancement sites based on field data collected in spring 2008. Average clam density within individual enhancement plots was used to describe clam survival: High = ≥25 clams; Moderate = 15 to < 25 clams; Low = 1 to <15; and None = no clams found. Number of plots (nets) and estimated survival of clams within them are presented for each of the enhancement sites.

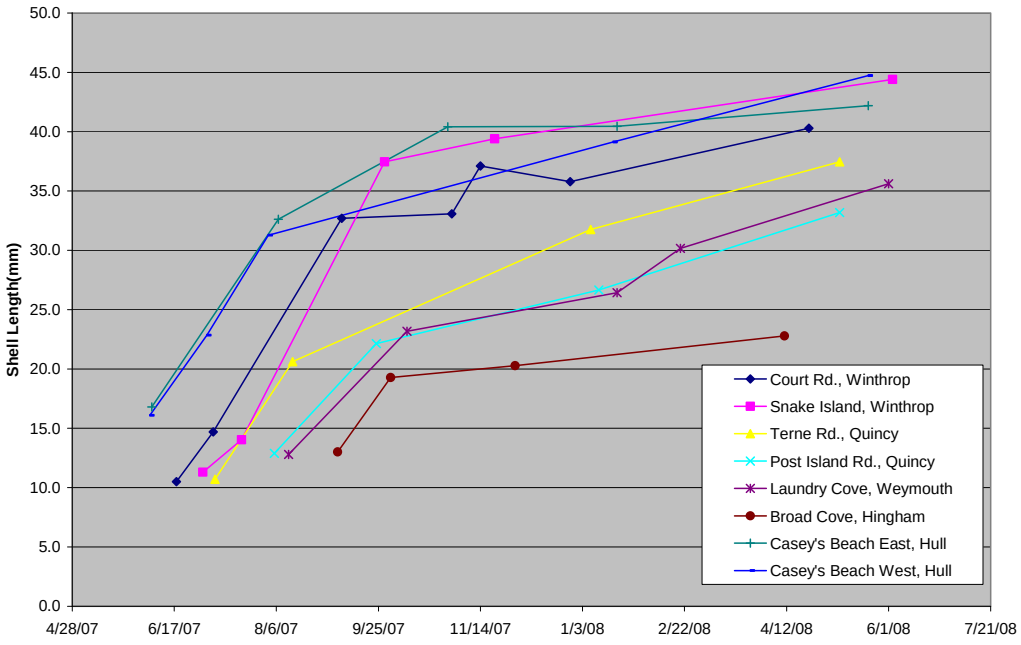
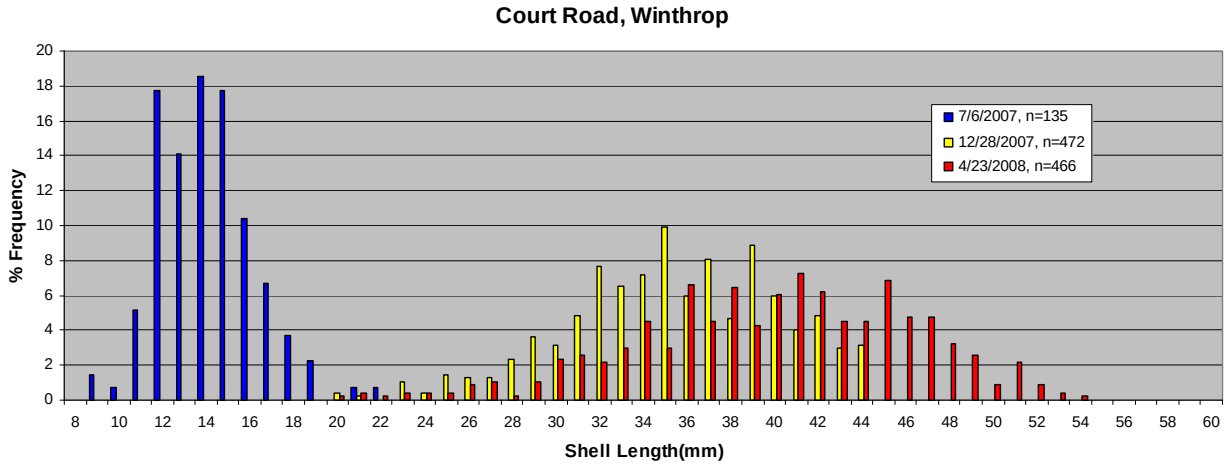


Figure IVD.19. Average clam length by sample date at the eight 2007 enhancement sites.



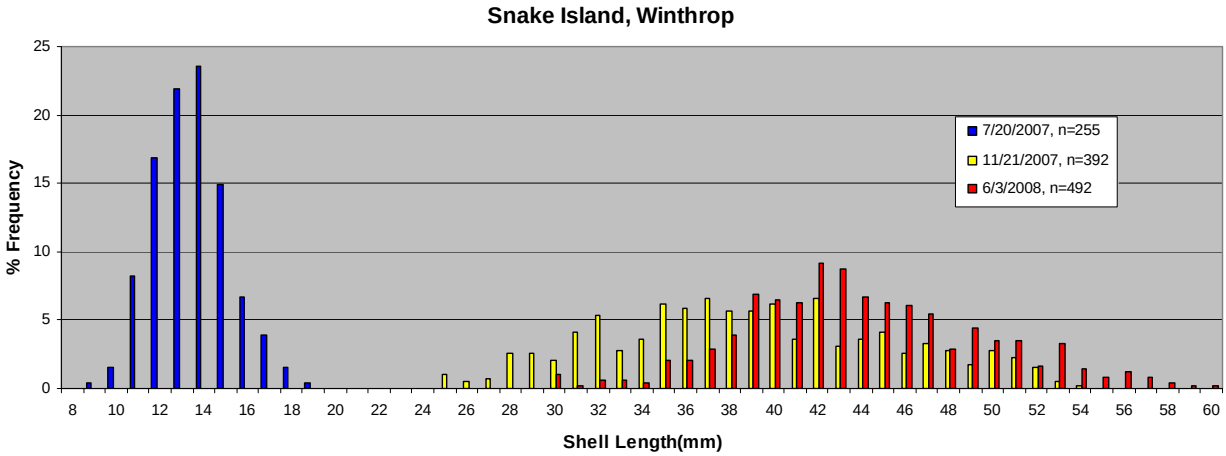


Figure IVD.20. Length frequencies of planted clam populations at the 2007 Court Road and Snake Island enhancement sites in Winthrop during summer/fall 2007, winter 2007/2008 and spring 2008 sample periods.

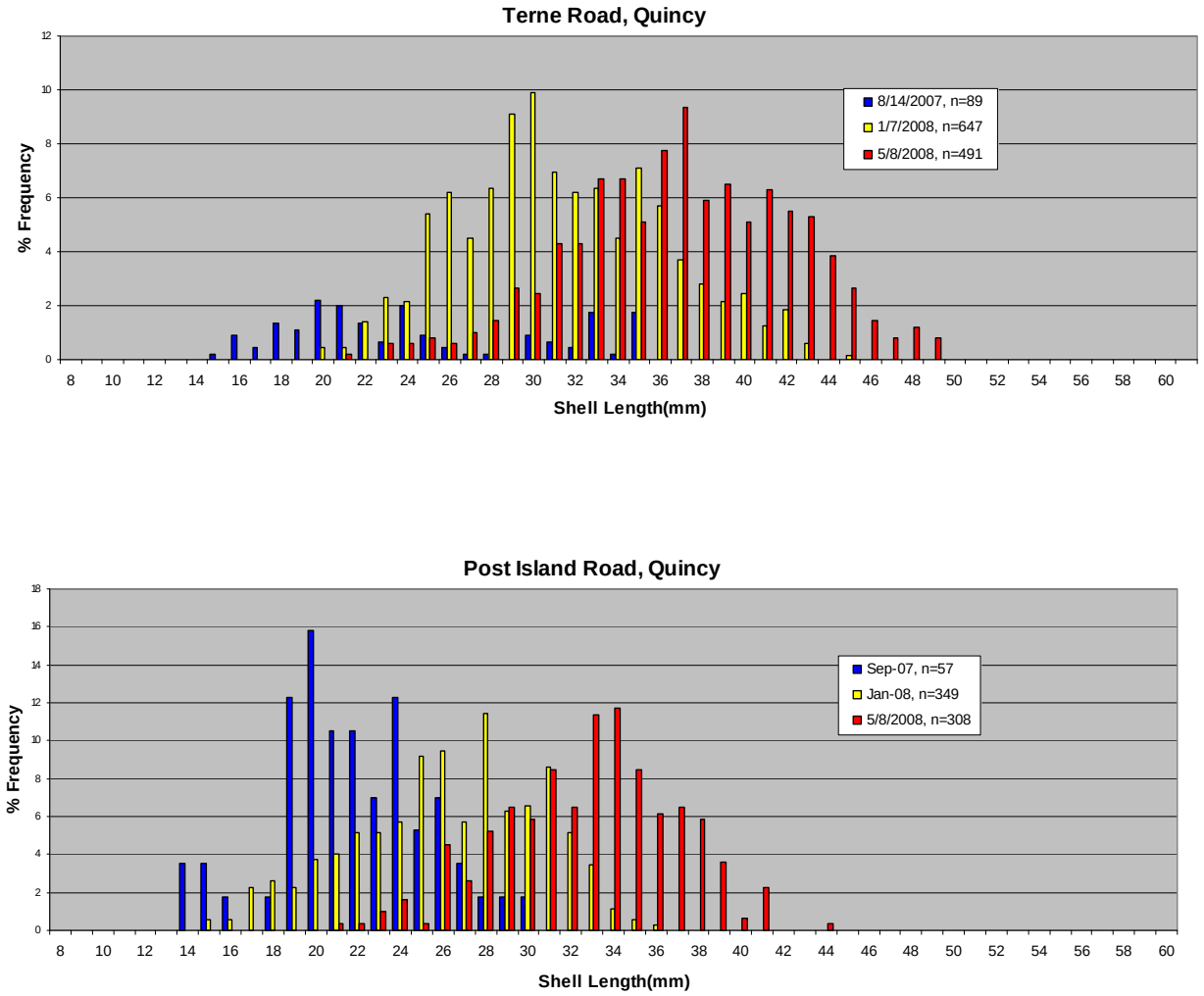


Figure IVD.21. Length frequencies of planted clam populations at the 2007 Terne Road and Post Island Road enhancement sites in Quincy during summer/fall 2007, winter 2007/2008 and spring 2008 sample periods.

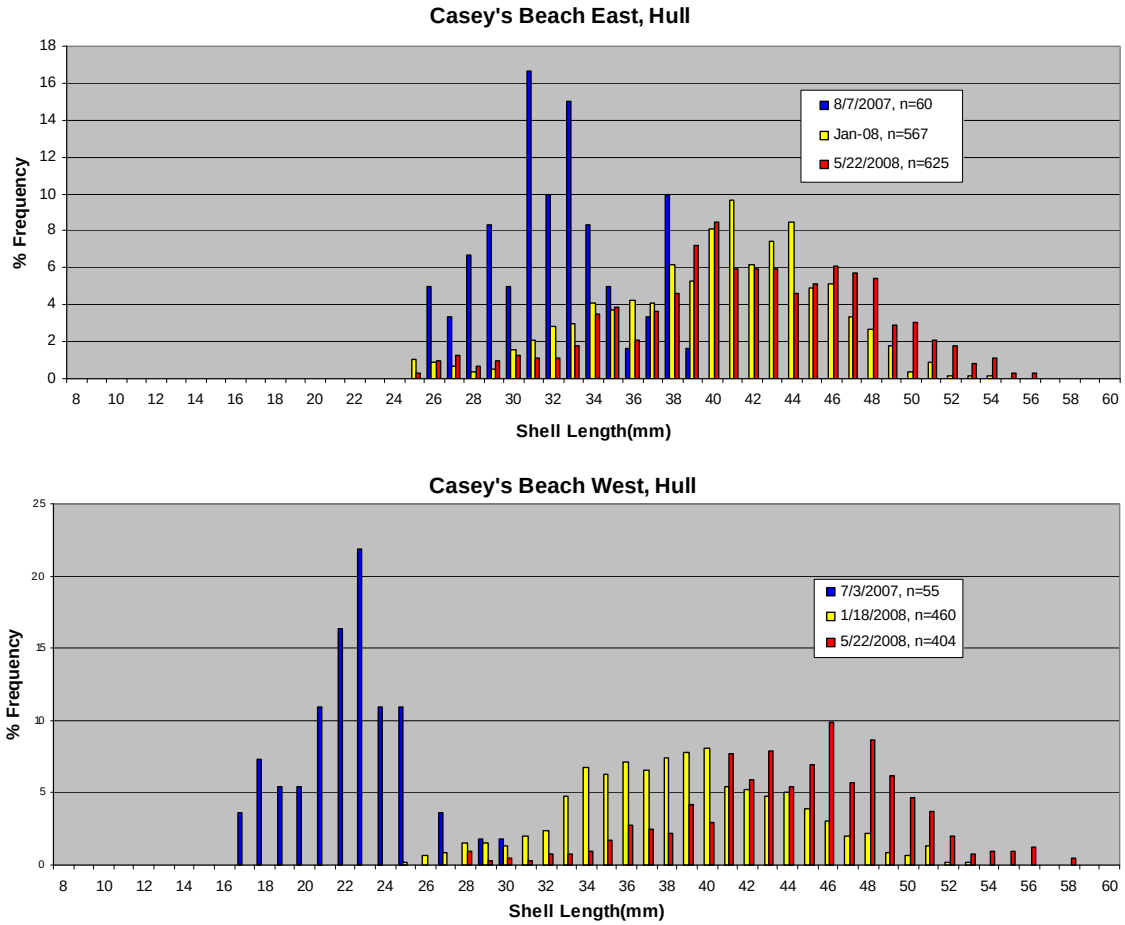


Figure IVD.22. Length frequencies of planted clam populations at the 2007 Casey's Beach East and Casey's Beach West enhancement sites in Hull during summer/fall 2007, winter 2007/2008 and spring 2008 sample periods.

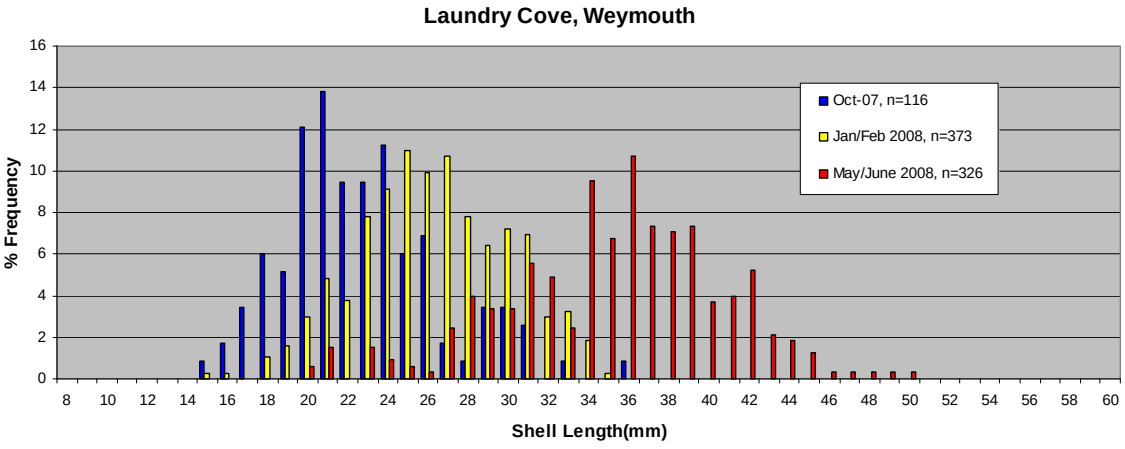


Figure IVD.23. Length frequencies of planted clam populations at the 2007 Laundry Cove enhancement site in Weymouth during fall 2007, winter 2007/2008 and spring 2008 sample periods.

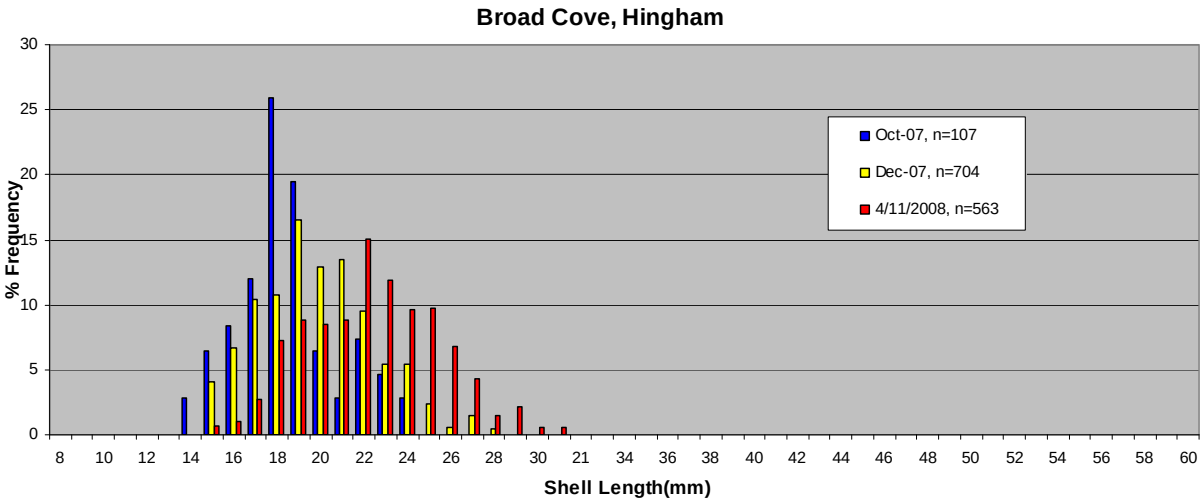


Figure IVD.24. Length frequencies of planted clam populations at the 2007 Broad Cove enhancement site in Hingham during fall 2007, winter 2007/2008 and spring 2008 sample periods.

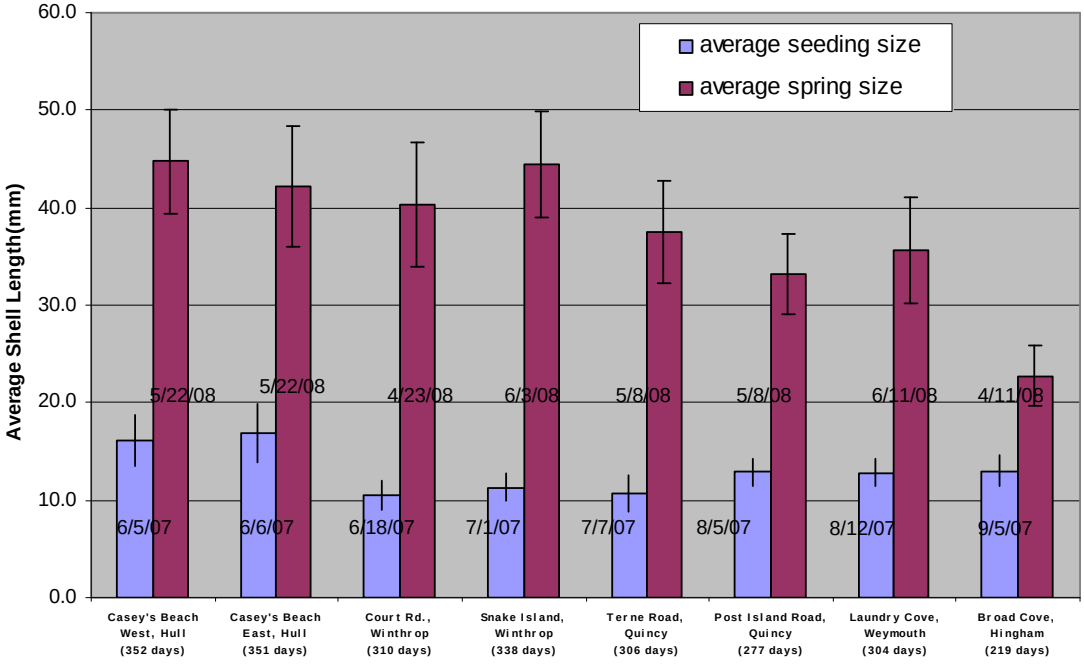


Figure 25. Comparison of average clam lengths at the time of seeding (summer 2007) and at the time of sampling (spring 2008) within the eight 2007 enhancement sites. The grow-out period at each site is indicated within parentheses.

Wild Spat Collectors

Our efforts to collect wild clam spat in Boston Harbor were unsuccessful. Spat collector sampling results are summarized in Appendix IVD.C. Twenty nine juvenile clams (15.1mm, average SL) were sampled within one spat collector (Net A) in the upper intertidal flat at the Snake Island site. No significant numbers of YOY clams were found within any of the remaining 43 spat collectors that were sampled. If there had been any enhanced settlement of clams within the collectors during summer or early fall, YOY clams would have been detected during the team's winter sampling trips. Spat collectors throughout the study area yielded nothing beyond what one would normally expect within the targeted unproductive clam flats. There were very few YOY individuals and sparse numbers of adult resident clams.

Summary

To date, *MarineFisheries* and its partners have made great strides toward restoring and enhancing softshell clam populations within the five targeted Boston Harbor coastal communities. Over the course of two years, a solid working relationship was forged among *MarineFisheries*, commercial shellfishers, Salem State's NEMAC personnel and shellfish constables and harbormasters in Winthrop, Quincy, Weymouth, Hingham and Hull.

In 2006, the study team seeded over one million hatchery-reared juvenile clams within five enhancement sites on tidal flats in Quincy, Weymouth and Hingham. During this first year, the study team acquired a working knowledge of enhancement methods applicable to Boston Harbor clam beds. Commercial shellfishers were quick to learn the proven methods of seeding juvenile clams and installing, maintaining and removing predator exclusion nets. Shellfishers have developed a variety of modifications to field operations in order to facilitate larger scaled seeding operations.

In 2006, the study team developed a better understanding of the importance of seed size. Most of the small juvenile clams (5-7mm) that were out-planted in 2006 did not survive. Larger clams (9.7 to 15.3mm) that were seeded at the Bathing Beach site in Hingham had much better survival rates. After 90 weeks of growth, all 13 enhancement plots at this site supported clam densities between 15 and 25 clams/ft^2.

Physical characteristics of the 2006 enhancement sites (sediment type and beach kinetics) appeared to significantly influence clam survival. Juvenile clams that were planted in silty mud did not survive. Similarly, enhancement sites that were exposed to significant tidal current, stream flows, wind driven waves or vessel wake suffered high levels of clam mortality. It is likely that most of the clams seeded within 12 enhancement plots at the Moon Head site in Quincy were washed away from under the predator exclusion nets by tidal currents and wave action. It is also likely that the clams seeded within the enhancement plot at Martin's Cove in Hingham suffered a similar fate, and were washed away by a tidal stream that drains a nearby tidal marsh

Human activities at the five 2006 enhancement sites were variable, and typically involved recreational fishing and beach combing. Recreational fishermen commonly frequented the Moon Head site in Quincy and most likely contributed to clam mortalities at the site. On numerous site visits, team members found an abundance of fishing lures and tears in the netting. Green crabs easily found their way through the tears thus causing significant clam mortalities within some plots.

The Bathing Beach site in Hingham was the only 2006 site with significant clam survival. Its substrate consists of a sand/mud mix. This site is also exposed to limited tidal current, wave exposure and vessel wake. Despite the fact that the site is adjacent to a public bathing beach, there was limited recreational activity (beach walking and/or sport fishing).

After 1.7 years of growth, 52.5 percent of the clams that were planted at the Bathing Beach site in June 2006 were above the legal size limit of 50.8mm (2 inches). Wild juvenile clams that set within the plots after seeding, ranged in size

between 15 and 39mm, and made up over 10 percent of the total population at the site. Overall, clams from within plots that were seeded at a low density (25 clams/ft^2) were larger (53.2mm) than the clams from within plots that were seeded at a higher density (49.2mm; 50 clams/ft^2). There was a slight size difference between clams which were planted in raked substrates (52.0mm) and clams which were planted in sediment that was not raked (50.5mm). Clams within the low density plots were consistently larger than those within the high density plots, regardless of tidal height. Average clam length within both high and low density plots increased with decreasing tidal height.

Although these observations of size differences by treatment were not based on formal parametric statistical analyses, sample sizes from which the descriptive statistics were generated were large. Also, the consistent size trends associated with each treatment help to support tentative conclusions on the effects of treatments on size.

MarineFisheries and its partners, equipped with a better understanding of enhancement techniques and site selection criteria specific to Boston Harbor tidal flats, carried out a second year of softshell clam enhancement in 2007. Information gained during the pilot-scaled 2006 season was used to select more suitable restoration sites and to modify our clam seeding methodology. The number of municipalities participating in the 2007 program was expanded to five with the inclusion of Hull and Winthrop. During summer 2007, approximately 870,000 juvenile clams that averaged between 10.5 to 16.8 mm SL were stocked at eight enhancement sites in Hull, Winthrop, Quincy, Weymouth and Hingham. Enhancement plots at all sites were seeded at a density of 30 clams/ft^2. A total of 49 enhancement plots were seeded.

During spring 2008, high to moderate clam densities were observed at all eight of the 2007 enhancement sites. Low clam densities were observed in only five of the 49 experimental plots. At Laundry Cove in Weymouth, two plots with low clam survival were placed in a silty mud substrate. Despite the fact that these plots were seeded with larger juvenile clams (12.8mm), the clams did not grow well in a silty mud substrate. Low clam survival within the two plots at Post Island Road in Quincy was most likely due to wave exposure. The observed low clam survival within the one plot at Snake Island in Winthrop cannot be explained.

During spring 2008, average clam lengths at the eight enhancement sites ranged between 22.8mm (Broad Cove, Hingham) and 44.7mm Casey's Beach West, Hull). This range in average clam length is related to the grow-out period, or the time between seeding and sampling. Because seeding activities during the 2007 season were protracted over a three month period (June through September), there was a distinct difference in growth periods at each site. Growth periods ranged between 219 days (Broad Cove, Hingham) and 352 days (Casey's Beach West, Hull). The best clam growth was observed at sites where clams were seeded early in the summer.

Our efforts to collect wild clam spat were unsuccessful. No significant numbers of YOY clams were found within any of the 44 spat collectors that were sampled. Had there been any enhanced settlement of clams within the collectors during the summer or early fall, YOY clams would have been detected during the team's winter sampling trips. Similar methods of wild spat collection have been used successfully in Plumb Island Sound (P. Somerville, pers.com.)* and Cape Cod (Leavitt, 1998), which support significantly larger stocks of softshell clams. Our lack of success in Boston Harbor may be simply due to the presence of too few wild spawning clams within the areas where we deployed our collectors.

Preliminary 2008 Season Summary

In 2008, *MarineFisheries* and its were partners planned to again expand the Boston Harbor enhancement program with the out-planting of 1.62 million juvenile clams (>10mm) to five sites in Winthrop, Quincy, Weymouth, Hingham and Hull. The plan was to seed an additional 90 plots

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at a density of 30 clams/ft^2 within five enhancement sites.

In late August, routine pathology tests of juvenile clams within Salem State's hatchery revealed the presence of an ectoparasite which was preliminarily identified as *Boonea* spp.: a tiny gastropod commonly termed the siphon snail. Because little is known about the life history and distribution of this animal in Massachusetts waters, *MarineFisheries* temporarily restricted any further sale of clams from Salem State's Cat Cove hatchery facility for purposes of out-planting in state waters until a positive identification was secured. This restriction remained in place pending further investigations by *MarineFisheries*. Nevertheless, the study team was able to seed 42 plots with 756,000 seed clams at four enhancement sites in Winthrop, Hingham and Weymouth before the restrictions were put into place. The identification of the ectoparasite was subsequently corrected following the season and normal field activities were resumed.

The 2008 enhancement plots were regularly monitored through the growing season. Predator exclusion netting was removed from the 42 plots and corner stakes were installed in November and December. The 2008 plots will be sampled during spring 2009 to determine clam growth and survival. The 2007 enhancement sites were similarly sampled during spring and fall/winter 2008.

During fall 2008, the study team carried out a controlled harvest of two of the 2006 enhancement plots seeded at the Bathing Beach site in Hingham. Two commercial shellfishers harvested all of the clams within a plot that was seeded with a high density of clams and from one plot that was seeded with a low density of clams. All of the clams were measured in the field. Legal sized clams were taken to the depuration plant in Newburyport and later sold by the Master digger. Sub-legal clams were replanted within the harvested plots. In an effort to determine the accuracy of our current sampling methodology, average clam length and density estimates resulting from the controlled harvest of the two plots were compared to estimates determined by our standard sampling methods.

The study team will analyze all field data as it becomes available in the future and generate updated reports summarizing the enhancement activities and findings.

Acknowledgements

Biological sampling of the Boston Harbor shellfish enhancement sites was primarily carried out by Salem State NEMAC personnel. Dr. Joseph Buttner coordinated the field sampling and assisted in the collation and analysis of the biological data. All juvenile softshell clams planted at the sites were raised at Salem State's Cat Cove shellfish hatchery which is managed by Scott Weston. Shellfish Constables and Harbormasters within the five participating Boston Harbor municipalities contributed significantly to the success of the project to date. Included in this group are Andy Ayer (Quincy), Paul Milone and Ray Nash (Weymouth), John Souther and Ken Corson (Hingham), Kurt Bornheim (Hull) and Charles Famolare (Winthrop). The lion's share of enhancement activities was carried out by Boston Harbor commercial shellfishers. Special thanks go to the Master Diggers Ron Colon, Neil Malluck, Bob Stanley, Wayne Whittler and Chet MacDonald, and to the many subordinate diggers who participated in the project.

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