ADDENDUM TO

HubLine Shellfish Stock Enhancement Project's

2008 Completion Report

Period Covered:

June 2008 to January 2009

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Introduction

2008 Season Overview

During spring 2008, the Massachusetts Division of Marine Fisheries (*MarineFisheries*) and its partners committed to a third year of enhancement and monitoring of softshell clams (*Mya arenaria*) in Boston Harbor. The plan was to out-plant 1.62 million juvenile clams to five sites in Winthrop, Quincy, Weymouth, Hingham and Hull. In late August, routine pathology tests of juvenile clams within Salem State's Northeast Massachusetts Aquaculture Center (NEMAC) 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 plant 42 plots with 756,000 seed clams within four enhancement sites in Winthrop, Hingham and Weymouth before the restrictions were put into place. 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. GPS coordinates were documented in November and December.

MarineFisheries and NEMAC personnel sampled enhancement sites that were stocked during summer 2007 in Hull (Casey's Beach 12), Hingham (Bathing Beach, 7 plots), Quincy (Post Island and Terne Roads, 6 plots per site, 12 plots total), Weymouth (Laundry Cove, 6 plots), and Winthrop (Court Road and Snake Island, 6 plots per site, 12 plots total) to assess survival and growth of stocked clams during their second year of growth. Results of the spring 2008 sampling of the 2007 enhancement sites were reported by Shields (2009). Fall/winter 2008 sampling of the 2007 enhancement sites are reported here.

Sediment samples were obtained by NEMAC personnel from the center of each plot installed in 2007 (n=49) as well as 8 plots stocked in Weymouth and 7 plots stocked in Winthrop (Snake Island) during summer 2008. Sediments were characterized by the Department of Geology at Salem State College.

Sampling of clams and sediments occurred between mid-October 2008 and early January 2009. Sampling efforts were coordinated with local Shellfish Constables and commercial shellfishers.

During fall 2008, two plots stocked in 2006 at the Hingham Bathing Beach enhancement site were completely harvested by commercial diggers. *MarineFisheries* and NEMAC personnel sampled the harvested clams for survival and growth.

2008 Field Season Methods

Clam Stocking and Net Installation

Between 3 July and 5 August 2008, an estimated 756,000 hatchery-reared clams that ranged from 11.8 to 17.1 mm shell length (SL) were stocked at sites in Hingham, Weymouth and Winthrop (Figure 1, Table 1). Clams were quantified volumetrically by NEMAC personnel and stocked at a density of 30/ft^2 within 600 ft^2 plots (50 by 12 ft.). Each plot 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. Stocking efforts were coordinated by *MarineFisheries* personnel with assistance provided by local shellfishers, Town Shellfish Constables, and NEMAC personnel. GPS coordinates for the corner of each plot were obtained by *MarineFisheries* personnel after installation. Plot locations within the Hingham enhancement sites (Rotary and

Figure 1. Location of 2008 enhancement sites in Boston Harbor.

Table 1. Stocking date, number of clams, average seed length and standard deviation for clams seeded at enhancement sites in Hingham, Weymouth and Winthrop during summer 2008.

Enhancement Site	Date	Avg. Seed Size (mm)	Std. Dev.	Number of Clams Planted	Number of Plots
Hingham					
Rotary	3-Jul	17.1	2.7	162,000	9
Rotary	9-Jul	12.7	1.5	90,000	5
Beal Cove	12-Jul	12.7	1.5	72,000	4
Weymouth					
Laundry Cove	19-Jul	11.8	1.6	108,000	6
Laundry Cove	3-Aug	12	1.7	108,000	6
Winthrop					
Snake Isld.- North	22-Jul	11.9	1.6	108,000	6
Snake Isld.- North	5-Aug	11.8	1.4	108,000	6
Totals				756,000	42

Beal Cove) are illustrated in Figure 2. Plot locations within the Weymouth enhancement site (Laundry Cove) and Winthrop enhancement site (Snake Island) are illustrated in Figure 3.

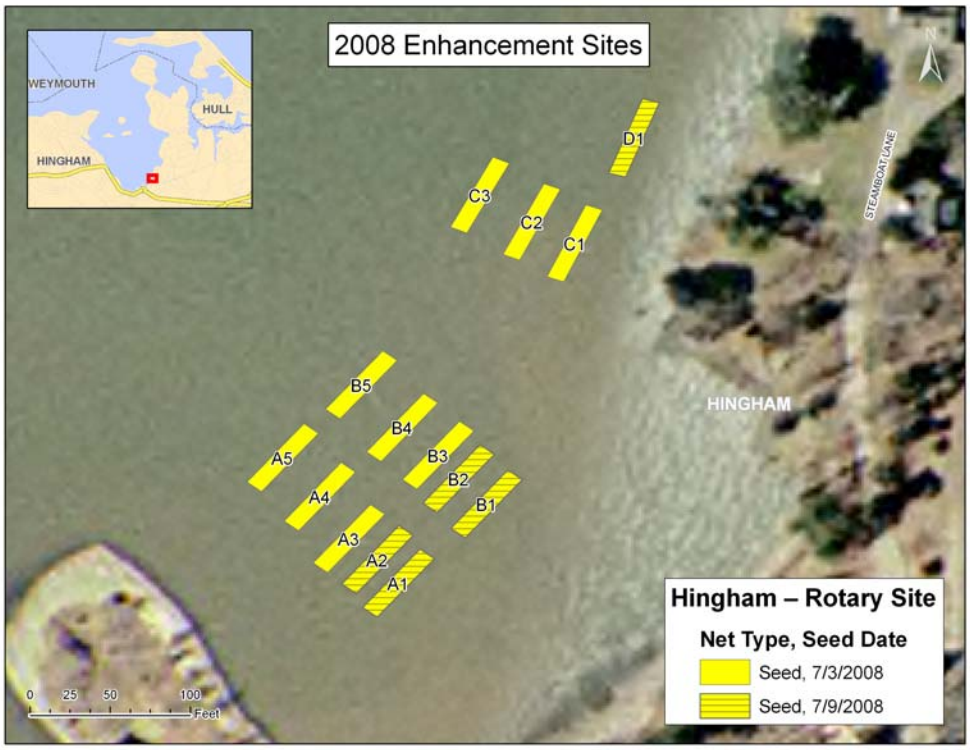
Clam Sampling (2007 cohort)

Sampling of clams stocked within the 2007 enhancement sites was conducted by *MarineFisheries* and NEMAC personnel. Plots were identified and located by PVC and/or rebar rods staked at each corner. 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 or until three samples were collected. Clams were separated from sediment and debris by sieving through a 0.375 inch mesh. Shell length (SL) of measurable clams was determined to the nearest 0.1 mm in the field by caliper. 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. Severely damaged clams were enumerated and discarded immediately after collection at each site. The 2007 enhancement site descriptions, plot locations, and spring 2008 sampling results were reported by Shields (2009). Results of the Fall/ winter 2008 sampling of the 2007 enhancement plots are summarized in Table 2.

Sediment Sampling

Sediment samples were collected by NEMAC staff from each site stocked with clams in 2007 (49 samples) and from two sites stocked with clams in summer 2008 (Laundry Cove, Webb State Park, Weymouth, 8 samples; Snake Island, Winthrop, 7 samples). A total of 64 samples were collected in late fall/early winter 2008/2009 and processed. Samples were collected from near the center of each previously netted area; adjusted to avoid clams as indicated by large numbers of siphon holes. A three inch PVC pipe was pushed and twisted into the sediment until a depth of 12 inches was attained or where further insertion was impossible. Sediment samples were transferred from the pipe to labeled, plastic bags and transported to the laboratory for analysis of grain size, amount of organic matter, and amount of carbonates.

In the laboratory, samples were frozen until analysis. Grain size was determined with American Society for Testing and Materials certified sieves (Folk, 1980). Large shell remnants were removed from the sample by hand. Organic material was removed using hydrogen peroxide (Last, 2001; Poppe *et al.*, 2000), and clays dispersed using sodium hexametaphosphate (Folk, 1980). Clays and silts were separated from sands and gravel by wet



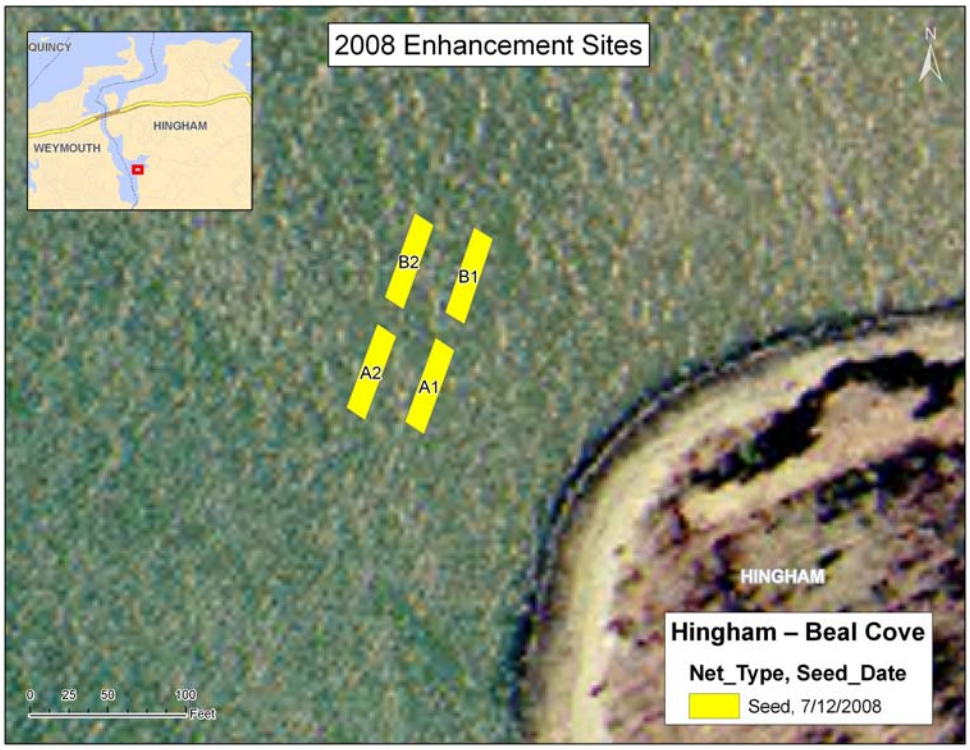


Figure 2. Arrangement of plots at the 2008 Rotary and Beal Cove enhancement sites in Hingham.

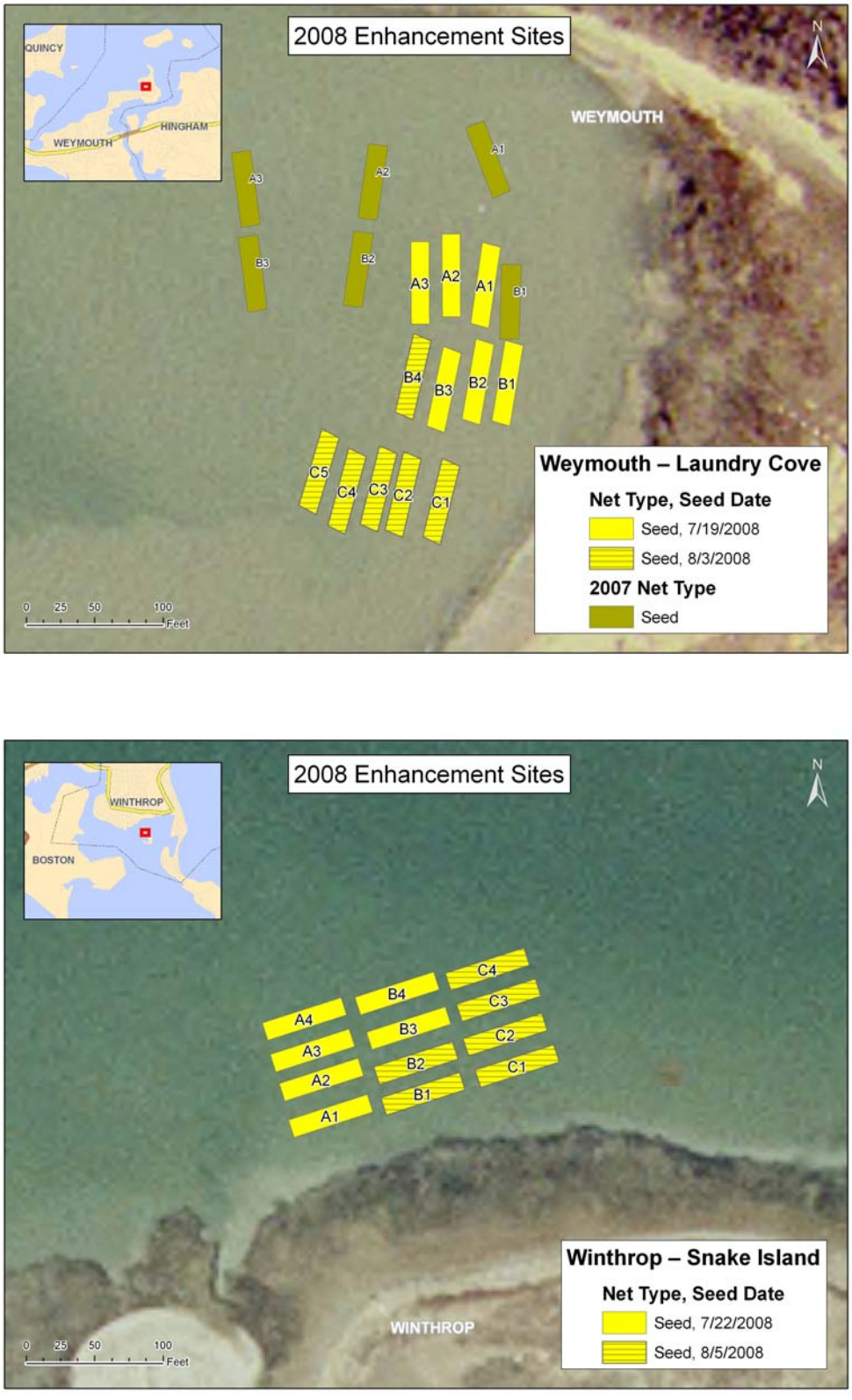


Figure 3. Arrangement of plots at the 2008 enhancement sites in Laundry Cove, Weymouth and Snake Island in Winthrop.

Table 2. Number of 1 ft^2 samples, number of clams collected and measured, and average shell length (SL) and standard deviation (SD) by location for plots sampled in fall/ winter 2008/2009.

Enhancement Site	Plot ID	Date	Number of Samples	Total Number of clams	Number of Measured Clams	Average Shell Length/SD (mm)
Hingham/Rotary	F1	20-Oct-08	3	68	64	47.0/5.2
	F2	20-Oct-08	3	59	55	44.5/5.4
	G1	20-Oct-08	2	70	67	46.7/5.9
	G2	27-Oct-08	2	100	92	46.4/5.4
	H1	27-Oct-08	3	51	45	48.1/5.7
	H2	27-Oct-08	3	34	26	45.0/6.0
	H3	27-Oct-08	3	85	76	47.1/5.9
Hull/Casey's West	C1	10-Nov-08	2	75	67	53.0/7.1
	C2	10-Nov-08	2	90	77	51.9/5.5
	C3	10 Nov 08	2	81	72	56.7/5.9
	D1	9-Dec-08	2	76	67	53.7/6.1
	D2	10-Nov-08	2	67	64	53.0/5.8
	D3	10-Nov-08	2	98	86	54.2/5.6
Hull/Casey's East	A1	10-Nov-08	2	96	80	53.6/5.9
	A2	10-Nov-08	1	86	78	48.6/5.7
	A3	27-Oct-08	2	90	78	49.6/7.1
	B1	10-Nov-08	2	89	81	53.4/6.0
	B2	27-Oct-08	1	125	121	52.1/3.5
	B3	27-Oct-08	2	68	61	52.0/7.4
Quincy/Terne Road	A1	9-Dec-08	1	76	71	51.7/5.2
	A2	9-Dec-08	2	106	94	54.1/5.3
	B1	9-Dec-08	2	93	77	56.4/5.8
	B2	9-Dec-08	2	88	69	57.5/4.9
	C1	9-Dec-08	2	72	60	57.1/6.9
	C2	9-Dec-08	2	82	68	54.5/6.2
Quincy/Post Island	D	24-Nov-08	2	73	68	48.5/6.1
	E	24-Nov-08	3	2	2	47.8/13.1
	F	24-Nov-08	3	74	67	49.2/6.6
	G	24-Nov-08	2	91	83	50.7/6.7
	H	24-Nov-08	2	103	95	52.6/6.2
	I	24-Nov-08	1	67	65	53.1/5.5
Weymouth/Laundry Cove	A1	16-Jan-09	3	52	42	49.6/6.7
	A2	16-Jan-09	3	42	36	51.0/8.6
	A3	16-Jan-09	3	3	3	35.3/2.0
	B1	16-Jan-09	3	98	92	48.7/5.8
	B2	20-Feb-09	3	45	38	52.3/6.8
	B3	20-Feb-09	3	12	12	55.4/8.5
Winthrop/Court Road	A1	12-Nov-08	2	115	97	49.4/6.8
	A2	12-Nov-08	2	81	68	55.7/5.8
	B1	12-Nov-08	2	73	66	54.4/6.3
	B2	12-Nov-08	3	74	62	56.1/8.1
	C1	12-Nov-08	2	81	67	53.0/5.0
	C2	12-Nov-08	2	91	80	54.3/4.4
Winthrop/Snake Island	1	17-Nov-08	2	121	107	57.2/5.8
	2	17-Nov-08	3	40	36	63.7/7.1
	3	17-Nov-08	3	78	65	49.6/12.0
	4	17-Nov-08	2	79	70	50.5/9.2
	5	17-Nov-08	3	79	73	52.0/10.2
	6	17-Nov-08	2	96	92	47.2/8.4

sieving through a 4ϕ mesh sieve (Folk, 1980; Last, 2001; Poppe *et al.*, 2000). Remaining sands and gravels were dry sieved using a RoTap® machine (Folk, 1980; Last, 2001; Poppe *et al.*, 2000) to determine grain size with 1ϕ resolution. To quantify the total organic matter and carbonate content in the sediment, a 1-cc subsample from each sample was obtained and analyzed. Each sample was dried over

night in a drying oven to determine the dry mass of sediment. Organic matter and carbonate content was quantified using the loss on ignition method at Salem State College (Dean, 1974; Heiri et al., 2001). Organic matter present was quantified by calculating the mass lost after igniting the sample at 550°C for one hour. The total carbonate of the sample was determined by calculating the mass lost after igniting the sample at 1000°C for one hour.

Controlled Harvest of Plots

On 9 and 10 October 2008, two plots (A-1 and B-1) within the 2006 Hingham Bathing Beach enhancement site were completely harvested by commercial diggers. Plot locations at the Bathing Beach site are reported by Shields (2009). The sampled plots were seeded at two different clam densities. Plot A-1 was seeded with 30,000 9.7 mm clams (50 clams/ ft^2), and plot B-1 was seeded with 15,000 10.4 mm clams (25 clams/ft^2). The shell length of all clams collected by diggers from the 50 x 12 ft. (600 ft^2) plots were measured by *MarineFisheries* and NEMAC staff. All harvested clams were enumerated and categorized as legal or sublegal size.

Results and Discussion

Evaluation of Enhancement Methods

Shields (2009) reported that, within the 2006 Bathing Beach enhancement site in Hingham, seeding density and raking the substrate prior to seeding influenced average shell length of planted clams. Further analysis of the collected data was conducted in order determine the statistical validity of these findings (Table 3). Independent-samples t-tests assuming equal variance determined that there was a significant difference in shell lengths of clams seeded at two different densities ($p<=0.001$). Following 1.7 years of growth, clams seeded at a density of 25 clams/ft^2 were larger than clams seeded at 50 clams/ft^2 (53.2mm vs. 49.2 mm, respectively).

There was also a significant difference in shell lengths of clams planted in raked and unraked substrates ($p<=0.001$). Clams planted within plots where the substrate was raked prior to seeding were larger than clams that were planted in plots where the substrate was not raked (52.0mm vs. 50.5mm).

Based on these findings, the enhancement team seeded all 2008 plots at the lower density of 30 clams/ft^2. The team also raked the substrate within all of the seeded plots.

Table 3. Comparison of clam shell lengths following 1.7 years of growth and two experimental treatments within 2006 enhancement plots in Hingham. Clam lengths were tested for effects of treatments with Independent-samples t-tests, assuming equal variance.

Comparison of Shell Length at Different Seeding Densities				
Treatment	**Average Shell Length (mm)**	**S.D.**	**Independent Samples T-Tests**	**Number of Clams**
25 clams/ ft^2	53.2	5.7		400
50 clams/ ft^2	49.2	4.8	p<=0.001	407

Treatment	**Average Shell Length (mm)**	**S.D.**	**Independent Samples T-Tests**	**Number of Clams**
Raked Substrate	52	5.8		386
Unraked Substrate	50.5	5.4	p<=0.001	421

A summary of winter 2008 field sampling of the 2007 enhancement plots is presented in Table 2. Sample dates, total number of samples, total number of collected and measured clams, and average lengths (SL) 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 4). 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

Table 4. Upper and lower length thresholds of clams seeded in 2007 enhancement sites. Sampled clams with lengths within the thresholds are considered to have been seeded during 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 (resident) at the time of seeding.

Enhancement Site	Sample Month	Lower Limit (mm)	Upper Limit (mm)	Age (Months)
Court Road	October '07	none	40	
	November '07	none	43	
	December '07	none	45	
	April '08	20	55	
	November '08	35	70	17
Snake Island	November '07	25	55	
	June '08	30	60	
	November '08	40	70	16
Terne Road	August '07	13	35	
	January '08	20	45	
	May '08	20	55	
	December '08	40	70	17
Post Island Road	September '07	none	35	
	January '08	15	40	
	May '08	20	55	
	November '08	30	65	15
Laundry Cove	October '07	15	40	
	January '08	15	40	
	May/June '08	20	50	
	December '08	35	65	16
Broad Cove	October '07	14	25	
	December '07	15	30	
	April '08	15	35	
	October '08	30	60	13
Casey's East	August '07	15	40	
	October '07	20	50	
	January '08	25	55	
	May '08	25	60	
	October '08	35	70	16
Casey's West	July '07	15	40	
	August '07	15	40	
	January '08	25	55	
	May '08	25	60	
	October '08	35	70	16

been present at the time of seeding. Only clams that fall within the established length thresholds were used to determine survival and growth parameters of the stocked clam population at each 2007 site.

Clam Growth and Recruitment

Average clam lengths were calculated for the eight 2007 enhancement sites on each winter 2008 sample date. Clams lengths collected from all plots sampled per site and date were pooled to calculate an average value. The results are presented in Table 5. All length data from clams planted in 2007 (including average clam length data reported by Shields (2009)) were pooled to plot average growth rates at each site (Figure 4). Average clam length at the eight 2007 enhancement sites during seeding, spring 2008 and winter 2008 are illustrated in Figure 5.

Shields (2009). Most clams seeded early to mid-summer in Boston Harbor grow to legal size within 18 months of growth.

The number and percentage of clams sampled during winter 2008, designated as planted, recruited or resident within the eight 2007 enhancement sites, are presented in Table 6. In all cases, over 89% of the clams within the 2007 enhancement plots were planted. With one exception, the percentage of recruited clams within the plots ranged between 0.9 and 4.0. Significant clam recruitment (15.3%) occurred in the Snake Island plots in Winthrop. Percent resident clams within the plots were generally low, ranging between 0.6% and 3.6%. Resident clams were more abundant at the Broad Cove site in Hingham (9.6%) and at the Laundry Cove site in Weymouth (8.0%).

Table 5. Average winter '08' clam lengths at eight 2007 enhancement sites.

Enhancement Site	Seeding Date	Sample Date	Ave. Length (mm)	Std Dev	Number Of Clams	Age (Months)
Court Rd., Winthrop	6/18/2007	11/12/2008	53.3	7.0	425	17
Snake Island, Winthrop	7/1/2007	11/17/2008	55.3	7.2	364	16
Terne Road, Quincy	7/7/2007	12/9/2008	55.3	6.2	417	17
Post Island Road, Quincy	5/8/2008	11/24/2008	50.6	6.6	367	15
Laundry Cove, Weymouth	8/12/2007	12/17/2008	50.0	6.1	206	16
Broad Cove, Hingham	9/5/2007	10/20/2008	46.5	5.7	403	13
Casey's Beach East, Hull	6/6/2007	11/10/2008	49.6	7.2	476	16
Casey's Beach West, Hull	6/5/2007	11/10/2008	54.0	5.8	415	16

Average clam length at four 2007 enhancement sites were above the legal size limit of 50.8 mm (Court Road, Snake Island, Terne Road, and Casey's Beach – West). Clam age at these sites was between 15 and 16 months. Average clam length at the Post Island Road, Laundry Cove and Casey's Beach-East sites were between 49.6 and 50.6mm and ranged between 15 and 16 months in age. Average clam length at the Broad Cove site was 46.5 mm. These clams were smaller because they were planted late in the 2007 season (13 months old). These growth rates are similar to those defined by

Clam Survival

In order to assess the efficacy of our enhancement efforts the study team employed a qualitative method of tracking survival of planted clams. Routine sampling of planted clams was not random, but directed to portions of the enhancement plots where siphon holes were abundant. A qualitative ranking of survival based on average density per ft^2 was developed to generally describe planted clam survival within the enhancement plots: "High" indicates $\geq$25 clams; "Moderate" indicates 15 to < 25 clams;

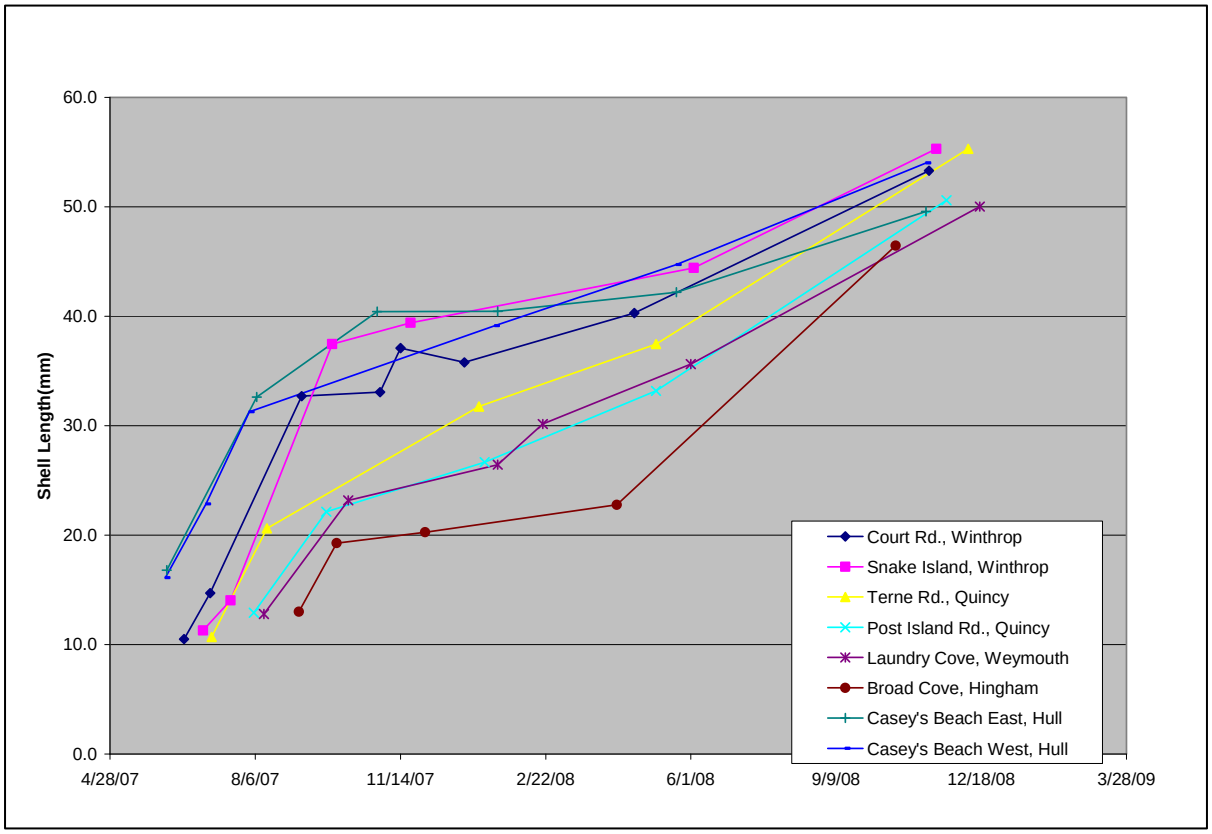


Figure 4. Growth of clams stocked in summer 2007 at eight enhancement sites.

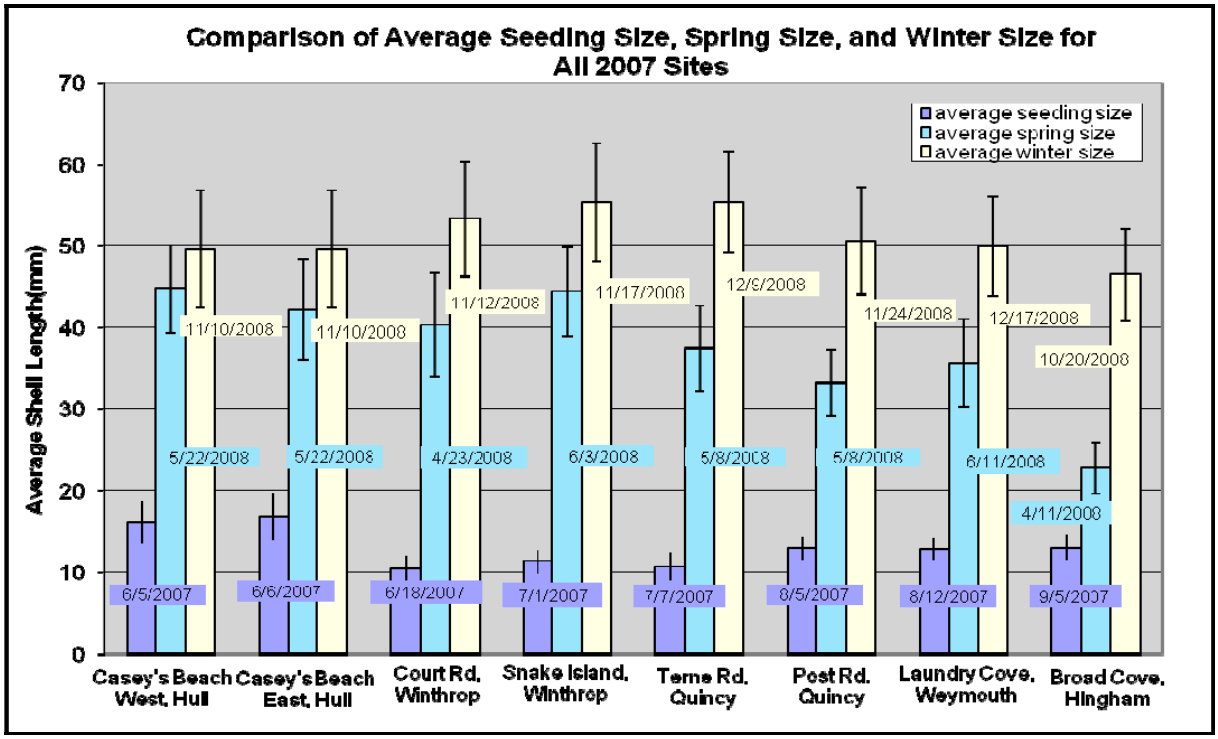


Figure 5. Comparison of average clam length for all 2007 enhancement sites. Sites were sampled at the time of seeding in 2007 and during the spring and winter 2008.

Table 6. Comparison of planted, recruited, and resident clams during winter 2008.

Enhancement Site	Total # Clams	# Planted Clams	% Planted Clams	# Recruits	% Recruits	# Resident	% Resident	# Damaged Clams*
Broad Cove, Hingham	425	379	89.2	5	1.2	41	9.6	40
Casey's Beach East, Hull	499	476	95.4	20	4.0	3	0.6	55
Casey's Beach West, Hull	433	415	95.8	12	2.8	6	1.4	53
Court Road, Winthrop	440	415	94.3	9	2.0	16	3.6	75
Laundry Cove, Weymouth	224	202	90.2	4	1.8	18	8.0	26
Post Island Road, Quincy	380	367	96.6	7	1.8	6	1.6	30
Snake Island, Winthrop	443	364	82.2	68	15.3	11	2.5	50
Terne Road, Quincy	439	431	98.2	4	0.9	4	0.9	74

*Damaged clams not included in total #, seed #, recruit #, or resident #

"Low" indicates 1 to <15; and "none" indicates no clams found. Table 7 and Figure 6 summarize planted clam survival within plots at all 2007 enhancement sites based on field data collected during winter 2008.

Over 85 % of the 2007 plots had moderate to high clam survival during the winter 2008 sample period. The survival of planted clams in the 2007 enhancement sites was considerably higher than that observed within the 2006 enhancement sites during approximately the same time period (Shields, 2009). All plots at the two Casey's Beach sites in Hull and at the Terne Beach site in Quincy had high survival (25+ clams /ft^2). Low clam survival was limited to only one plot at the Bathing Beach site in Hingham, the Snake Island site in Winthrop and the Post Island Road site in Quincy. The only site with significantly low clam survival was Laundry Cove in Weymouth, where there was low clam survival within four of six enhancement plots. Silty sediment is believed to have caused clam mortalities at this site.

Assessment of Controlled Harvest

A summary of the controlled harvest of plots A-1 and B-1 in the 2006 Hingham Bathing Beach site is presented in Table 8. These 600 ft^2 plots were seeded at two different densities; A-1 was seeded with approximately 30,000 juvenile clams (9.7 mm SL) at a density of 50 clams/ft^2 and B-1 was seeded with approximately 15,000 clams (10.4 mm SL) at a density of 25 clams/ft^2. While the high density plot (A-1) yielded more clams (4166 vs. 2878), the percentage of clams that were legal-sized was higher in the low density plot (87% legal in plot B-1 vs. 68% legal in plot A-1). Similarly, the overall size and legal size of clams in the low density plot was greater than those in the high density plot (in plot B-1, average overall size = 57.7 mm, average legal size = 59.6 mm; in plot A-1, average overall size =52.9 mm; average legal size = 56.3 mm). It is important to note that the data presented includes all harvested clams within each plot, including planted (or seeded), resident, and recruited clams.

In order to quantitatively assess the survival of the clams planted in 2006, it is necessary to estimate the number of planted, resident and recruited clams within the sampled plots using upper and lower length thresholds of the planted clams. The upper and lower length thresholds of clams seeded in Plot A1 during the October 2008 sampling period were set at 36 mm and 72 mm, respectively. The upper and lower length thresholds of clams seeded in Plot B-2 during the same sampling period were set at 40 mm and 78 mm, respectively. The estimated number and percentage of planted, recruited, and resident clams and the estimated survival of planted clams within the two sampled plots are presented in Table 9. While the high density plot (A-1) yielded the most clams, the low density plot (B-1) yielded a higher survival rate (18.8% vs. 13.7%).

Insufficient sample size precluded the determination of statistical validity of these controlled harvest observations. However, additional controlled harvesting of enhancement plots during future operations should provide a sufficient number of samples to allow valid statistical analyses.

Table 7. Summary of clam survival at the 2007 enhancement sites based on samples collected in winter 2008. Three survival rankings are based on number of clams/ft2; High (25+), Moderate (15 to <25) and Low (1 to <15).

Enhancement Site	Sample Date	Plot	Number of Samples	Number of Seed Clams	Sample Density	Average Shell Length	StDev	Survival Estimate
Court Rd., Winthrop	11/12/2008	A1	2	109	54.5	49.4	6.8	High
Court Rd., Winthrop	11/12/2008	A2	2	80	40.0	55.7	5.8	High
Court Rd., Winthrop	11/12/2008	B1	2	72	36.0	54.1	6.8	High
Court Rd., Winthrop	11/12/2008	B2	3	69	23.0	56.1	8.1	Moderate
Court Rd., Winthrop	11/12/2008	C1	2	79	39.5	52.9	5.0	High
Court Rd., Winthrop	11/12/2008	C2	2	89	44.5	54.3	4.4	High
Snake Island, Winthrop	11/17/2008	1	2	117	58.5	57.2	5.4	High
Snake Island, Winthrop	11/17/2008	2	3	33	11.0	62.4	6.7	Low
Snake Island, Winthrop	11/17/2008	3	3	57	19.0	55.3	7.7	Moderate
Snake Island, Winthrop	11/17/2008	4	2	67	33.5	53.2	7.2	High
Snake Island, Winthrop	11/17/2008	5	3	65	21.7	55.9	6.4	Moderate
Snake Island, Winthrop	11/17/2008	6	2	75	37.5	50.5	6.3	High
Terne Rd., Quincy	12/9/2008	A1	1	75	75.0	51.7	5.2	High
Terne Rd., Quincy	12/9/2008	A2	2	100	50.0	54.1	5.3	High
Terne Rd., Quincy	12/9/2008	B1	2	85	42.5	56.5	5.9	High
Terne Rd., Quincy	12/9/2008	B2	2	84	42.0	58.2	5.3	High
Terne Rd., Quincy	12/9/2008	C1	2	67	33.5	57.5	7.2	High
Terne Rd., Quincy	12/9/2008	C2	2	80	40.0	54.8	6.5	High
Post Island Rd., Quincy	11/24/2008	D	2	72	36.0	48.5	6.1	High
Post Island Rd., Quincy	11/24/2008	E	3	2	0.7	47.8	13.1	Low
Post Island Rd., Quincy	11/24/2008	F	3	70	23.3	49.2	6.7	Moderate
Post Island Rd., Quincy	11/24/2008	G	2	90	45.0	50.3	7.2	High
Post Island Rd., Quincy	11/24/2008	H	2	71	35.5	51.8	6.1	High
Post Island Rd., Quincy	11/24/2008	I	1	66	66.0	53.1	5.5	High
Laundry Cove, Weymouth	12/17/2008	A1	3	48	16.0	49.2	6.3	Moderate
Laundry Cove, Weymouth	12/17/2008	A2	3	38	12.7	51.2	5.9	Low
Laundry Cove, Weymouth	12/17/2008	A3	3	3	1.0	35.3	2.9	Low
Laundry Cove, Weymouth	12/17/2008	B1	3	95	31.7	48.5	5.5	High
Laundry Cove, Weymouth	12/17/2008	B2	3	39	13.0	52.9	5.8	Low
Laundry Cove, Weymouth	12/17/2008	B3	3	11	3.7	53.3	7.2	Low
Bathing Beach, Hingham	10/20/2008	F1	3	66	22.0	47.0	5.2	Moderate
Bathing Beach, Hingham	10/20/2008	F2	3	59	19.7	44.5	5.4	Moderate
Bathing Beach, Hingham	10/20/2008	G1	2	68	34.0	46.7	5.9	High
Bathing Beach, Hingham	10/27/2008	G2	2	96	48.0	46.4	5.4	High
Bathing Beach, Hingham	10/27/2008	H1	3	48	16.0	48.1	5.7	Moderate
Bathing Beach, Hingham	10/27/2008	H2	3	32	10.7	45.1	6.0	Low
Bathing Beach, Hingham	10/27/2008	H3	3	74	24.7	47.1	5.9	Moderate
Casey's Beach East, Hull	11/10/2008	A1	2	91	45.5	53.6	5.9	High
Casey's Beach East, Hull	11/10/2008	A2	1	83	83.0	48.8	5.5	High
Casey's Beach East, Hull	10/27/2008	A3	2	84	42.0	50.1	7.2	High
Casey's Beach East, Hull	11/10/2008	B1	2	89	44.5	53.5	6.2	High
Casey's Beach East, Hull	10/27/2008	B2	1	121	121.0	43.0	4.5	High
Casey's Beach East, Hull	10/27/2008	B3	2	63	31.5	52.7	6.7	High
Casey's Beach West, Hull	11/10/2008	C1	2	71	35.5	53.7	6.0	High
Casey's Beach West, Hull	11/10/2008	C2	2	87	43.5	51.9	5.5	High
Casey's Beach West, Hull	11/10/2008	C3	2	79	39.5	56.9	6.1	High
Casey's Beach West, Hull	12/9/2008	D1	2	68	34.0	54.4	5.0	High
Casey's Beach West, Hull	11/10/2008	D2	2	66	33.0	53.0	5.8	High
Casey's Beach West, Hull	11/10/2008	D3	2	72	36.0	54.4	5.0	High

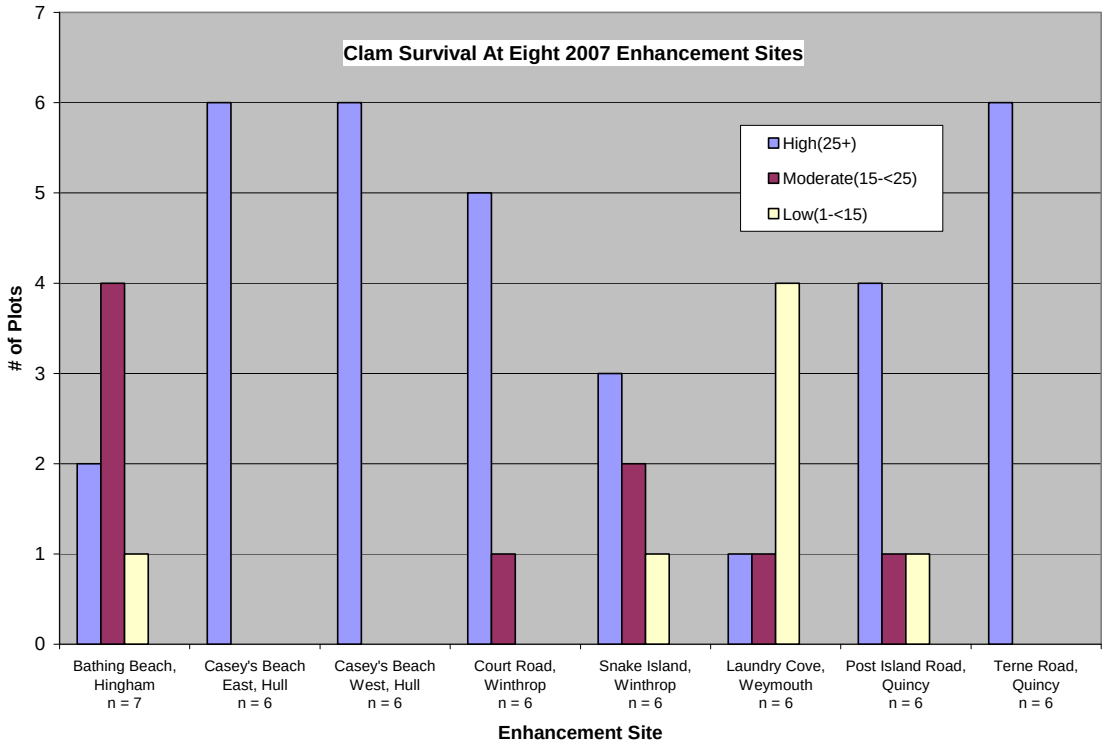


Figure 6. Clam survival at the eight 2007 enhancement sites based on field data collected in winter 2008. Average clam density within individual enhancement plots is used to describe clam survival: High indicates ≥25 clams; Moderate indicates 15 to < 25 clams; Low indicates 1 to <15. The number of plots (n) and estimated survival of clams within them are presented for each of the enhancement sites.

Table 8. Summary of controlled harvest of two plots within the 2006 Hingham enhancement site. 78% of the clams harvested from plot A-1 were measured for shell length (SL). The remainder were counted and sorted into legal and sub-legal categories. All harvested clams were measured in plot B-1.

Plot ID	Size Category	Avg. Shell Length (mm)	Std Dev	Measured Clam Count	Unmeasured Clam Count	Total Count	% Legal
A-1	Overall	52.9	7.8	3159	1007	4166	
	Legals	56.3	4.6	2154	420	2574	68%
	Sublegals	45.6	8.3	1005	587	1592	
B-1	Overall	57.7	7.6	2878	0	2878	
	Legals	59.5	5.8	2503	0	2503	87%
	Sublegals	45.6	7.5	375	0	375	

Table 9. Survival estimates of clams planted in Hingham enhancement site in 2006. Controlled harvest of two plots was conducted during October 2008.

Plot ID	# Clams Seeded	Total # clams Recovered	Recruits		Resident		Planted		Total # Planted Clams	Estimated Survival (%)
			#	Percent	#	Percent	#	Percent		
A1	30,000	4166	10	0%	42	1%	4124	99%	4124	13.7%
B1	15,000	2878	34	1%	29	1%	2820	98%	2820	18.8%

Sediment Analysis

Sediment data analysis and interpretation were conducted by Dr. Joe Buttner (NEMAC) and Dr. Brad Hubeny (Department of Geological Sciences) from Salem State College. Sediment classes were determined by mass and reported as percentages of the sample for selected plots installed in 2007: gravel, sand, and silt/clay (Table 10, Figure 7). Organic matter and carbonate were reported as percentages of the sample for the same plots (Table 11). Clam survival for each plot relative to sediment type, percent organic matter, and carbonate is included (Tables 10 and 11).

Despite limitations associated with collection and interpretation of sediment data, some trends were distinguished. Distribution of sediment grain size for each sample site, as expressed by mass percent gravel, sand, and mud, indicates that all sites were largely dominated by sand (Table 10, Figure 7). Sediments at some sites were more homogeneous than at other sites; for instance, Quincy samples (orange) show strong clustering, while Hull samples (dark blue) display scatter (Figure 7).

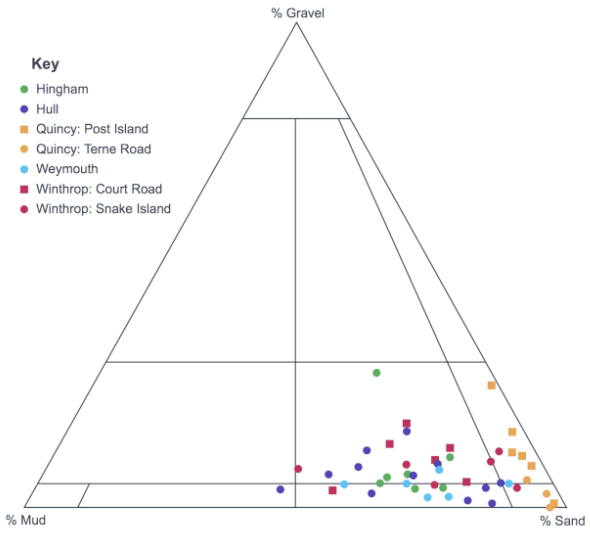


Figure 7. Ternary diagram of sediment grain size for each sample site as expressed by mass percent gravel, sand, and mud.

Summary

Since 2006 *MarineFisheries* and its partners have developed enhancement methods which have resulted in consistent soft shell clam survival at numerous sites throughout Boston Harbor. We continue to build and expand the network of local communities, commercial shellfishers and state agencies with the long term goal of enhancing the softshell clam resource within Boston Harbor.

Clam size, sediment type and beach kinetics were found to significantly influence clam survival. Planted clams larger than 10mm in length exhibited a higher survival rate than smaller juveniles. Smaller 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.

Following the 2006 pilot study, larger juvenile clams (10-15 mm) were planted in more suitable habitats and the restoration team has sampled the sites for clam growth and survival. Although clam growth varied between sites, within 1 ½ years of growth, between 50% and 75% of the planted clams grew to the legal size of two inches (50.8 mm). By year two, virtually all of the planted clams grew to legal size. Because softshell clams reach sexual maturity at a shell length of approximately 35 mm, our growth data suggests that a portion of the planted clams spawn during the late summer of the following year, and that most if not all of the clams spawn during the spring and summer of their second year. It is hoped that clams planted within the restoration sites successfully spawn over the course of two to three years, thus replenishing the clam beds within nearby tidal flats.

Periodic estimates of clam density within restoration plots are a useful tool in gauging the general success of seeding efforts within restoration sites over time. Density of surviving planted clams is difficult to accurately measure due to their natural contagious (clumped) distribution on the tidal flats. Following 14–16 months of growth, clam densities within the 49 restoration plots seeded in 2007 were generally classified as "High" (> 25 clams/ft^2),

Table 10. Sediments were characterized by percent composition for sites sampled between 9 December 2008 and 8 January 2009. Sites were stocked with clams in 2007. Characterization of clams for sites stocked in 2007 and assayed in fall/winter 2008 is indicated. Three survival rankings are based on number of clams/ft^2 ; High (25+), Moderate (15 to <25), and Low (1 to <15).

Enhancement Site	Plot	Gravel (%)	Sand (%)	Silt/Clay (%)	Sediment Class	Estimated Survival
Hingham						
Broad Cove	F1	10.4	73.2	16.4	Gravelly sediment	Moderate
	F2	27.6	51.2	21.2	Gravelly sediment	Moderate
	G1	4.9	63.1	32	Silty-sand	High
	G2	4	75.2	20.8	Sand	High
	H1	6.9	67.3	25.8	Silty-sand	Moderate
	H2	6.1	63.8	30.1	Silty-sand	Low
	H3	3.8	70.1	26.1	Silty-sand	Moderate
Hull						
Casey's East	A1	5.2	85.1	9.8	Sand	High
	A2	9.2	71.5	19.4	Sand	High
	A3	6.7	68.3	25.1	Silty-sand	High
	B1	1.6	80.9	17.5	Sand	High
	B2	4	82.7	13.2	Sand	High
	B3	0.6	85.8	13.6	Sand	High
Casey's West	C1	3	62.6	34.4	Silty-sand	High
	C2	8.7	57.1	34.3	Silty-sand	High
	C3	11.9	57.1	31.1	Gravelly sediment	High
	D1	15.6	62.5	21.9	Gravelly sediment	High
	D2	3.8	45.2	51	Sandy-silt	High
	D3	7.1	52.4	40.5	Silty-sand	High
Quincy						
Post Island Rd.	D	15.8	82	2.2	Gravelly sediment	High
	E	25.4	73.4	1.2	Gravelly sediment	Low
	F	11.5	84.2	4.2	Gravelly sediment	Moderate
	G	1	97.1	1.9	Sand	High
	H	8.7	89.2	2.1	Sand	High
	I	10.9	86.4	2.7	Gravelly sediment	High
Terne Rd.	A1	0.7	96.8	2.5	Sand	High
	A2	0.2	96.4	3.4	Sand	High
	B1	3	94.6	2.4	Sand	High
	B2	0.1	97.5	2.4	Sand	High
	C1	5.9	89.6	4.5	Sand	High
	C2	0	97.4	2.6	Sand	High
Weymouth						
Laundry Cove	A1	3.4	75	21.6	Sand	m
	A2	7.5	72.6	19.9	Sand	Low
	A3	5	74.2	20.8	Sand	Low
	B1	4.6	86.8	8.6	Sand	High
	B2	4.8	67.9	27.3	Silty-sand	Low
	B3	2.1	73.3	24.6	Sand	Low
Winthrop						
Court Rd.	A1	12.4	72.2	15.4	Gravelly sediment	High
	A2	5.5	78.7	15.8	Sand	High
	B1	10	70.6	19.4	Sand	High
	B2	17.6	61.4	21	Gravelly sediment	High
	C1	3.5	55.1	41.4	Silty-sand	High
	C2	13.3	60.5	26.2	Gravelly sediment	High
Snake Island	1	8.9	66.1	25	Sand	High
	2	8.1	46.5	45.4	Silty-sand	Low
	3	11.7	81.5	6.9	Gravelly sediment	Moderate
	4	9.3	81.6	9.1	Sand	High
	5	4	88.9	7	Sand	Moderate
	6	4.7	73.5	21.8	Sand	High

Table 11. Percent of organic and carbonate matter were determined for sediments from plots sampled between 9 December 2008 and 8 January 2009. Sites were stocked with clams in 2007. Characterization of clam survival for sites stocked in 2007 is indicated. Survival is categorized based on number of clams/ft^2 ; High (25+), Moderate (15-<25), and Low (1to <15).

Enhancement Site	Plot	Organic (%)	Carbonate %	Estimated Survival
Hingham				
Broad Cove	F1	2.01	0.73	Moderate
	F2	2.1	0.82	Moderate
	G1	1.55	0.92	High
	G2	1.46	1.16	High
	H1	2.49	1	Moderate
	H2	2.55	1.78	Low
	H3	2.51	1.37	Moderate
Hull				
Casey's East	A1	1.68	0.9	High
	A2	1.25	1.64	High
	A3	2.16	1.49	High
	B1	1.97	1.5	High
	B2	1.54	0.94	High
	B3	2.1	2.51	High
Casey's West	C1	2.75	0.9	High
	C2	3.63	1.25	High
	C3	2.44	2.41	High
	D1	1.74	2.56	High
	D2	3.2	1.56	High
	D3	3.79	1.19	High
Quincy				
Post Island Rd	D	1.09	2.02	High
	E	0.98	1.36	Low
	F	1.03	0.65	Moderate
	G	0.88	0.5	High
	H	1.02	0.51	High
	I	0.99	0.57	High
Terne Rd	A1	1.49	0.72	High
	A2	1.69	1.96	High
	B1	1.64	2.15	High
	B2	1.43	1.69	High
	C1	1.64	3.76	High
	C2	1.6	0.88	High
Weymouth				
Laundry Cove	A1	2.42	2.16	m
	A2	3.02	1.29	Low
	A3	3.45	2	Low
	B1	1.98	3.7	High
	B2	3.62	1.4	Low
	B3	3.51	4.15	Low
Winthrop				
Court Rd	A1	1.49	0.72	High
	A2	1.69	1.96	High
	B1	1.64	2.15	High
	B2	1.43	1.69	High
	C1	1.64	3.76	High
	C2	1.6	0.88	High
Snake Island	1	5.26	2.79	High
	2	2.95	1.64	Low
	3	1.1	3.72	Moderate
	4	1.12	4.05	High
	5	0.91	6.3	Moderate
	6	1.16	1.49	High

"Medium" (15-25 clams/ft^2) and "Low" (1-15 clams/ft^2). Sixty-eight (68) percent of the plots contained "High" clam densities, 18 % contained "Medium" densities and 14 % contained "Low" clam densities.

Survival of planted shellfish is probably the most important parameter that restoration teams need to assess in order to gauge the success and impact of a particular program on shellfish resources within the targeted area. In order to obtain accurate survival estimates of clams planted in Boston Harbor, the restoration team conducted controlled harvests of two restoration plots seeded in 2006. Clam survival within these enhancement plots was markedly lower than anticipated (13.7% and 18.8%).

In 2009, *MarineFisheries* and its partners will continue their soft shell clam enhancement efforts in Boston Harbor by applying the successful methods developed to date. The team will continue planting juvenile clams at suitable sites within the five participating communities. The monitoring of clam growth at all enhancement sites and controlled harvests of enhancement plots will also continue in order to develop a more comprehensive assessment of clam survival throughout this Boston Harbor study area.

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