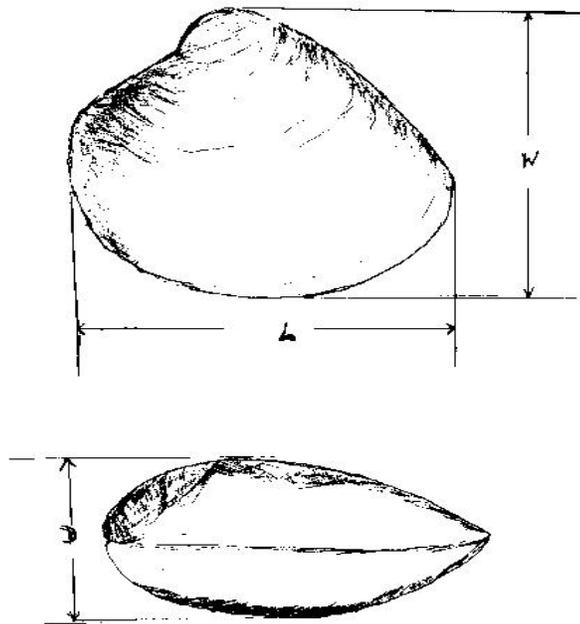




ATLANTIC COAST OF LONG ISLAND, FIRE ISLAND INLET TO MONTAUK POINT, NY
SHORE PROTECTION AND STORM DAMAGE REDUCTION REFORMULATION STUDY

MORICHES BAY
HARD CLAM GROWTH RATE STUDY REPORT



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1.0 INTRODUCTION

The Army Corps of Engineers, NY District (District) is conducting a reformulation of the shore protection and storm damage reduction project for the south shore of Long Island, New York, from Fire Island Inlet to Montauk Point. The project area includes the barrier islands, the Atlantic Ocean shorelines and adjacent back-bay areas of the Great South Bay, Moriches Bay, and Shinnecock Bay. Historically documented breaches resulting from major storm events have occurred along the project shoreline (USACE 1995). The Hurricane of 1938 created several openings to Moriches and Shinnecock Bays. During January 1980, a breach formed about 1,000 feet east of the eastern jetty of Moriches Inlet. Other locations along the study area have experienced breaching, overwash, or shoreline/dune recession sufficient to suggest that future storms could result in severe overwash or breach formation (USACE 1995).

The purpose of this study was to simulate the change in water parameters in the bay that could occur if the barrier island separating Great South Bay from the ocean were breached and the effect the resulting increase in salinity would have on the growth rate of the hard clam (*Mercentaria mercenaria*). The hard clam is harvested recreationally and is the most extensively distributed commercial clam in the United States (Ritchie 1977). According to Stanley (1983), the absence of hard clam populations is an ecological indicator of disturbance; changes in the population and recruitment of this species can be an indicator of the overall viability of coastal ecosystems. Adult clams do not move, and re-population of depleted hard clam beds requires larval settlement and several years of growth.



2.0 METHODS

This study had two major components:

- To establish three hard clam grow-out stations with different mean salinities and monitor monthly growth rates of clams at each station.
- To monitor water parameters (salinity, temperature, dissolved oxygen, pH, specific conductivity and turbidity) in the grow-out area of the bay on a bimonthly basis during the course of the study.

2.1 SITE DESCRIPTION

The study area was located on the south shore of Long Island in Suffolk County, New York, in the townships of Brookhaven and South Hampton and within the waters of Moriches Bay (the bay). The bay is connected to the Atlantic Ocean through Moriches Inlet (MI) and by narrow channels to Great South Bay in the west and Shinnecock Bay to the east. Moriches Bay is a shallow coastal lagoon, nearly 13 kilometers (km) long, and 1.5 – 4 km wide and has a depth at mean low water of 0.5 – 1.2 meter (m) with a mean tidal range of 0.2 m (Turner 1983). Open ocean water entering the bay through MI has a major influence on the hydrography of the bay. The inlet effectively divides the bay into eastern (Moriches Bay) and western (Narrow Bay) halves.

2.2 WATER QUALITY

Bi-monthly monitoring was conducted during eight sampling periods from late June to early October at each grow-out location and at four additional locations in the bay using Hydrolab Datasonde units (Figure 1). The units were secured in place with 15-pound (lb) mushroom anchors and suspended in the water column with 9-inch round buoy markers. They were programmed to take readings every 20 minutes and were left in the water for 24 – 48 hour intervals. Upon retrieval, data were downloaded onto a laptop computer and entered into spreadsheet data files.



Figure 1. Site Location Map.



2.3 GROWTH RATES

2.3.1 Background

The growth rate of adult hard clams slows with increase in length; clams 35 – 39 millimeters (mm) in length grow about three times faster than clams that are 65-69 mm long (Pratt and Campbell 1956). As described in greater detail below, hard clams 20 – 40 mm in length were used for this study. In New York, clams in this size range are reported to be 2 years old (Ansell 1968). Local variation in annual growth is extreme and the extent of variation is more or less the same throughout the continuous range of the species; based on observed growth increments of clams in two locations in New York, annual growth rates of 40 mm clams were predicted to be 5 and 16 mm (Ansell 1968). A similar variation was reported for 40 mm clams in New Jersey. In the northern part of its range (including New York), growth takes place only in the warmer months of the year (Ansell 1968). Growth between ages 2 and 5 is linear (Stanley 1983).

Temperature is the most important factor in growth and reproduction of the hard clam; optimum temperatures for hard clam growth vary from approximately 20 – 23 degrees Celsius (°C) (Stanley 1983). Predicted monthly summer growth increments of 40 mm clams ranged from 2.9 – 5.4 mm in Rhode Island at mean temperatures of 22.5 – 23.5°C, but only 1.1 – 2.1 mm in Virginia at mean temperatures of 24.8 to 28°C (Ansell 1968). Shell growth ceases below 9 and above 31°C (Ansell 1968).

Unlike temperature, salinity does not have a major influence on growth (Rice and Pechenik 1992). The hard clam is found in salinities ranging from 10 – 35 parts per thousand (ppt), but growth is reported to be optimal between about 26 and 27 ppt (Davis, undated, as cited in Rice and Pechenik 1992). Turner (1953) reported that growth of hard clams was optimal between 24 – 28 ppt. Laboratory studies show that the optimum salinity range for siphon extension in adult and juvenile hard clams is 24 – 32 ppt (Van Winkle 1976).

Within the limits set by temperature, other factors which may affect the growth of hard clams include salinity, current velocity, the presence or absence of vegetation (especially *Spartina*) on the clam beds, dissolved oxygen concentration, and various aspects of the bottom material in which the animals are living (Ansell 1968). Food availability, which is affected by the density of phytoplanktonic food organisms in the water and their nutritional quality, and the current speed that transports them, is known to be an important factor affecting growth (Ansell 1968, Rice and Pechenik 1992).

Predation is the primary natural control of hard clam populations (Virstein 1977). Predators include fish, birds, starfish, crabs, and other mollusks. The clam's defenses are burrowing and setting among shells or rocks. Without shell, rock, or other cover, the juvenile hard clam is nearly exterminated by predators (Kraeuter and Castagna 1980).



2.3.2 Study Design

Three grow-out sites were chosen based on salinity data collected in May using a corded Hydrolab Datasonde H₂O probe unit that was deployed at a number of locations at varying distances from the inlet. These locations were in MI, east of the mouth of the Forge River (FR) and north of Masury Point, and east of MI (Figure 1). Clams used for the study were acquired from the Cornell Cooperative hatchery in Southold and were put into bottom culture grow-out cages in order to control predation and provide access for monthly measurements (Figure 2).

The growth study was conducted from early June to mid-October, 2000. Because a number of cages were either destroyed or lost during June and July, the experiment was started over in mid-July with additional clams that were added to those remaining at the end of the first six weeks of the study. One of the grow-out locations was moved during the second part of the study. Due to the addition of new clams to the grow-out cages in mid-July, data from the first and second study periods were treated separately.

All clams were measured by length, width and depth (Figure 3) at the start and end of the first and second growth periods. All measurements were made using calipers that measured to the nearest 0.1 mm. Sub-samples from each cage at each site were measured on two sampling occasions during the second growth period.

Growth Period I (June 3 - July 12)

The original experimental design consisted of five replicate cages of 50 clams each and two control cages, one with 50 clams and one with 32 clams, deployed at each of the three grow-out locations. The control cages of 50 and 32 were established to test for differences in growth that could be caused by clam density. The five sample cages were set in line and secured to each other with a 5-ft length of rope with a 15 lb mushroom anchor at each end. The two control cages were set up in the same manner and set parallel to the sample cages. The cages used were Coastal Aquaculture (CA) model OBC-3 cages with a 5/8 inch square mesh. The three original grow-out sites were the original MI site (high salinity), FR (medium salinity), and a low salinity site located approximately 1 mile east of the inlet (Figure 1).

Cages at the original MI site were lost or destroyed in June, presumably as a result of heavy recreational boating in the area. In addition, the site east of the inlet (EI) was disturbed in July when cages were dislodged from the bottom during an extreme weather event. At this time (July 12, 2000) the study was terminated and clams were collected, consolidated by site, and measured. The shells of the clams that died were also measured. The clams that survived were then combined with additional clams provided by Cornell Cooperative to restart the study.

Growth Period II (July 15 – October 11, 2000)

The sampling design was modified during the second part of the study. Three sample cages and one control cage, each containing 50 clams, were deployed at each grow-out location (MI, FR, and a new low salinity site located near Smith Point (SP), just east of the Fire Island bridge, (Figure 1).



Figure 2. Coastal Aquaculture Shellfish Growout Cages.

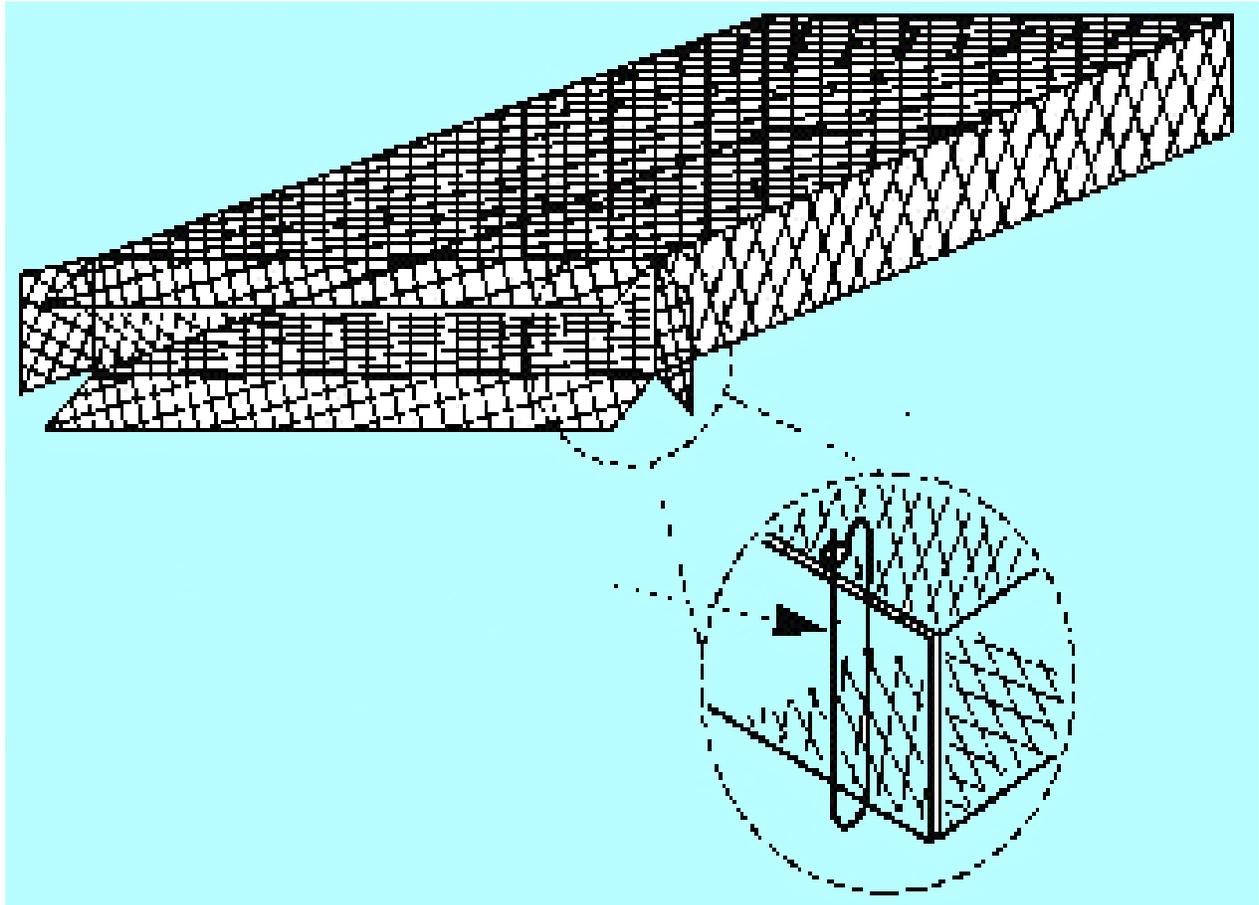
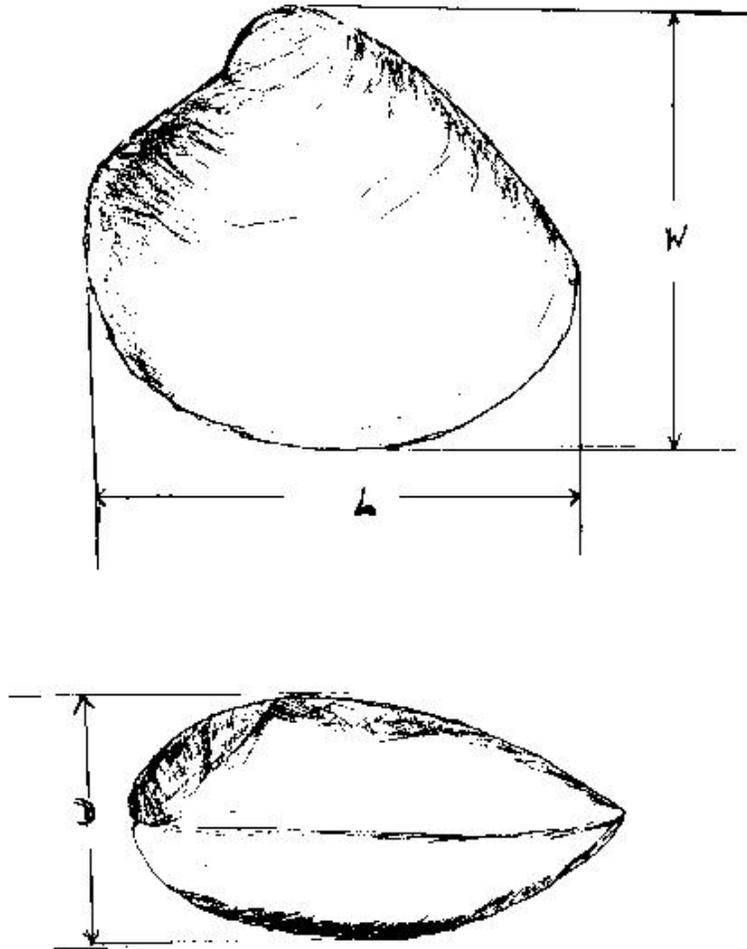


Figure 3. Length, width, and depth measurements of hard clams, *Mercenaria mercenaria*.



Clam growth in the sample cages was monitored in August and September by measuring the sizes of a randomly selected sub-sample of 25 clams from each cage, and at the end of the experiment in October, by measuring all clams. In order to avoid some of the recreational boat traffic believed to have destroyed the original MI site, the new MI site was established slightly to the northeast of the original site, out of the main boat channel. Cages used for this part of the study were 3/8 inch CA model OBC-2 cages. The smaller mesh was used to reduce problems with predation by starfish experienced previously.

2.4 DATA ANALYSIS AND PRESENTATION

2.4.1 Water Quality Data

Water quality data collected during the course of the experiment were downloaded from the Hydrolabs and entered into spreadsheet data files. Minimum, maximum, means, and standard deviations were calculated for each parameter for each 24 – 48 hour sampling period. Mean temperature and salinity data were plotted for all eight sampling dates for each grow-out site. In addition, all temperature and salinity data recorded at 20 minute intervals were plotted for each site and sampling period, along with vertical lines indicating the times of high and low tide at the inlet (Appendix A, Figures A1 – A16). The August 9 FR temperature and salinity data were lost due to an instrument malfunction.

2.4.2 Growth Rates

May 31/June 3 – July 13

Size measurements for all the clams placed in each treatment cage (n=50) and the two control cages (n=50 and 32) taken at the beginning of the experiment were averaged to estimate an overall mean length, width, and depth for each cage. All measurements were recorded in tenths of mm and means were rounded off the nearest 0.1 mm. Overall means were calculated for each site from all the clams (treatments plus controls) put in the water at the beginning of the experiment and removed from the water at the end. Clams removed at the end were not differentiated by cage, but live clams were differentiated from dead ones.

Phase 2 (July 15 – October 11)

Mean sizes were calculated for all clams (n=50) placed in each cage at the beginning and end of this growth period. During August and September, randomly selected sub-samples (n=25) from each replicate cage were measured. All measurements were recorded in tenths of mm and means were rounded off the nearest 0.1 mm. Mean size estimates for the beginning and end of the experiment included clams from the control cages. Dead clams were differentiated from live ones on each date. Dry weight measurements from each sampling date at each site (two clams from each cage) were averaged for growth rate analysis.

Seasonal growth rates were determined for each grow-out site from the differences in mean size between July 15 and October 11 (88 days) and from differences in mean dry weights between August 9 and October 11 (62 days) and by fitting linear regressions to mean length, width, depth



and dry weight estimates for each grow-out site on each sampling date. Separate regression analyses were performed with July – September and July – October data. Only those regression equations with statistically significant slopes (*i.e.*, slopes that were not equal to zero) were used to estimate growth and to compare growth between sites. Mean monthly summer growth rates were calculated for all three sites using both methods. Differences in non-zero slopes between sites were tested for each size measurement using analysis of covariance (ANCOVA) to determine if there were statistically significant differences in growth rate between sites.



3.0 RESULTS

3.1 WATER QUALITY

Average temperatures varied by as much as 5.3°C between grow-out sites in the summer and by as little as 1.2°C in the fall (Figure 4). As expected, the mean temperature began to drop as the seasons progressed from late summer to early fall. Mean temperatures peaked at 26.8°C during August 9 at SP, at 23.9°C on July 14 at FR, and 21.4 and 21.7°C on August 9 and September 13 at MI. The highest summer temperatures were consistently recorded at SP throughout the summer and the lowest at MI. During late September and early October, the lowest mean temperatures were recorded at SP.

Average salinities were highest throughout the entire monitoring period at the MI site, ranging from 30.1 ppt in August to 33.2 ppt in early October. Mean salinities at SP were consistently the lowest, ranging from 23.8 ppt on August 9 to 27.3 ppt on August 2 and 27.5 ppt in late September. Mean salinities at FR were intermediate, ranging from 27.6 ppt in mid-July and early August to 31.3 ppt in October.

3.2 OBSERVED GROWTH RATES

Results presented in the following two sections were based on observed changes in mean size and dry weight recorded at the three grow-out sites between the initial deployments of clams on May 31/June 3 and July 15 and their removal on July 13 and October 11.

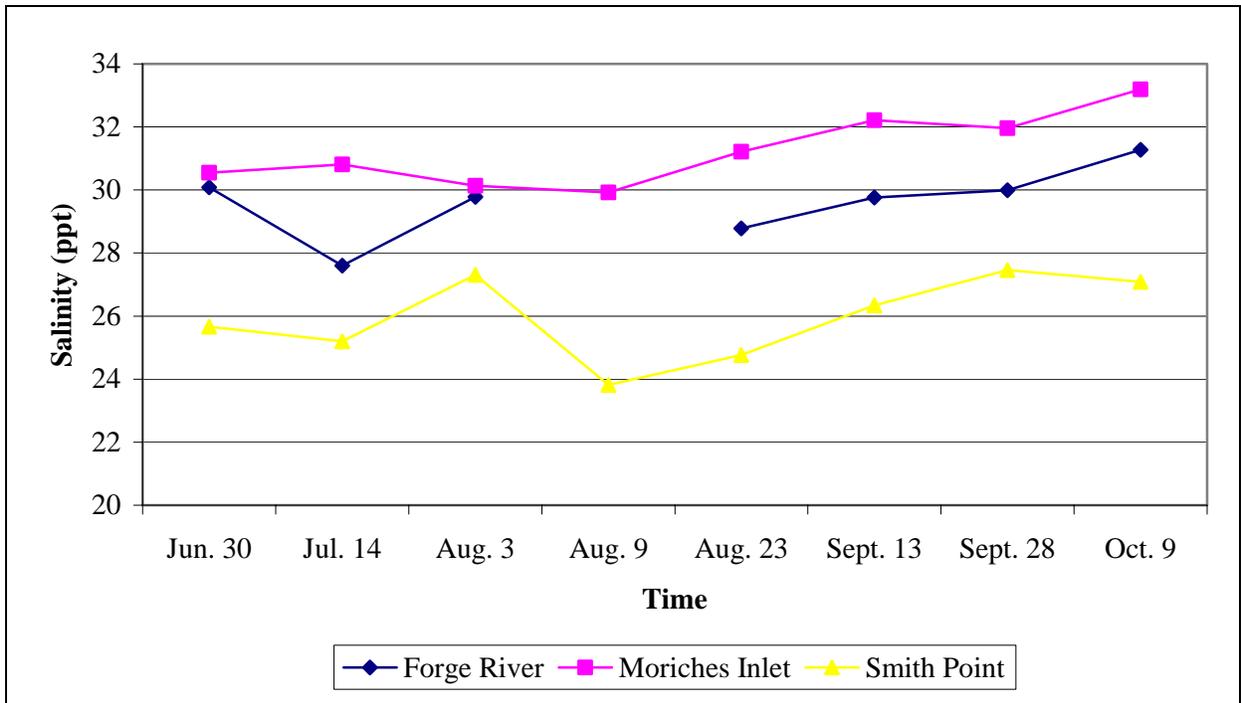
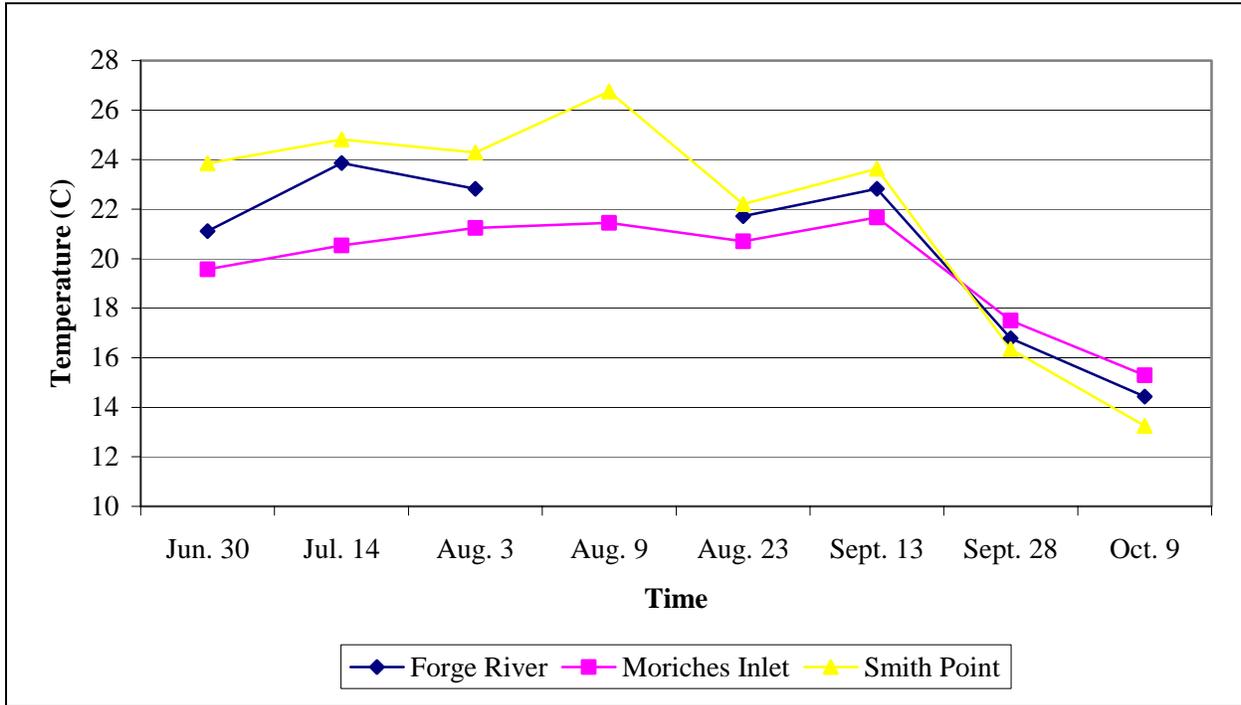
3.2.1 May 31/June 3 – July 13

The mean sizes (length, width, and depth) of clams initially deployed in each of five cages at the three sites between May 31 and June 3, plus the controls, are shown in Table 1. Also shown are the mean sizes of the surviving clams at each site on July 13. Length frequency distributions of clams that were put in the water initially and the live and dead clams that were taken out of the water six weeks later are shown in Figure 5. In general, length frequencies were skewed to the right at the beginning and end of this first growth period (*i.e.*, there was a higher proportion of larger clams with modal lengths of about 35 mm).

Small increases in mean size (<1 mm) were noted at MI and EI, but mean length, width, and depth actually decreased at FR during the six week period. The heavy losses of clams (13% at EI, 44% at FR, and 75% at MI) caused severe reductions in the number of clams that were re-measured on July 13. For this reason, differences in mean size at the beginning and the end of this growth period did not produce reliable growth data.



Figure 4. Mean temperature and salinity recorded at three grow-out sites, June 30 – October 9, 2000.



Note: August 9 data were deleted from plots due to equipment malfunction.

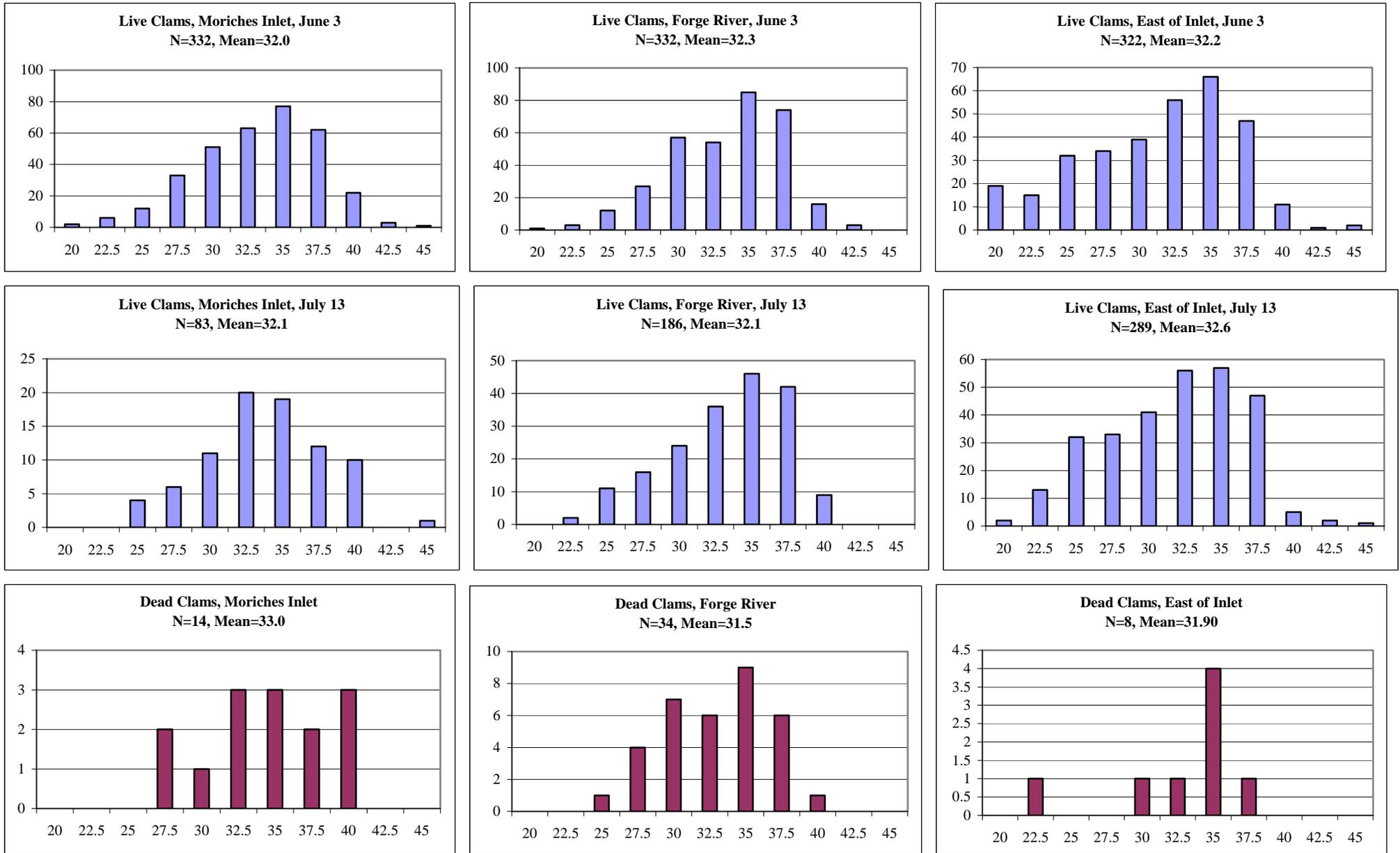


Table 1. Mean lengths, widths, and depths for clams measured from all cages and sites on May 31/June 3 and July 13, 2000.

Site	Date	Cage	# of Clams Measured	Mean Length	Mean Width	Mean Depth
Moriches Inlet	3-Jun-00	A	50	32.7	27.3	18.3
		B	50	32.9	28.8	18.4
		C	50	32.6	28.9	17.8
		D	50	33.0	28.1	18.9
		E	50	33.5	28.7	18.9
		Controls	82	29.1	25.2	16.3
	Total	332	32.0	27.6	17.9	
13-Jul-00	Total	83	32.5	28.3	18.8	
Forge River	3-Jun-00	A	50	31.5	27.5	17.4
		B	50	31.7	27.9	17.9
		C	50	33.1	27.6	18.4
		D	50	32.6	27.0	18.2
		E	50	33.0	27.4	18.3
		Controls	82	32.0	27.2	17.8
	Total	332	32.3	27.4	18.1	
13-Jul-00	Total	186	32.1	26.9	17.7	
East of Inlet	3-Jun-00	A	50	31.5	26.3	17.5
		B	50	32.7	28.9	18.1
		C	50	30.2	25.0	16.8
		D	50	29.5	25.9	16.3
		E	50	28.4	23.8	15.7
		Controls	82	29.0	25.3	16.4
	Total	332	30.2	25.9	16.8	
13-Jul-00	Total	289	30.6	26.1	17.2	



Figure 5. Length frequencies of live and dead clams measured at three grow-out sites in Moriches Bay, June 3 and July 13, 2000.



3.2.2 July 15 – October 11

The mean sizes of all clams deployed in each cage at the three grow-out sites on July 15 (including controls) are shown in Table 2 along with the mean sizes of sub-samples (n=25) on the three subsequent occasions when clams were removed from the water for measurement. Length frequency distributions of clams that were put in the water on July 15 and live and dead clams that were removed from the water on August 10, September 11, and October 11 are shown in Figures 6-8. Length distributions were slightly bi-modal with one mode at 25 – 27.5 mm and a second one at 32.5 – 35 mm. Length distributions were bi-modal at MI at each re-measurement and at FR in September and October, but not at SP. A higher percentage of smaller clams were put in the water at MI in July than at the other two sites, causing the mean sizes at this site on July 15 to be notably lower than at the other two sites (Table 2). The loss of one cage at MI in September and of two more cages (one replicate and the control cage) at this site in October severely reduced sample sizes.

One-way analysis of variance (ANOVA) revealed no significant ($P=0.05$) differences between mean lengths in replicate cages at either MI or SP, but the clams in cage A at FR were significantly smaller on three of the four dates (Table 3). Based on these results, size measurements from all cages were combined at MI and SP, but the measurements from cage A at FR were excluded from the overall mean size calculations for each sampling date. With this exception, clams in the control cage were not significantly different in size from the clams in the experimental cages at any site and were therefore included in the overall mean size estimates for each site at the beginning and end of the experiment. The absence of any difference in the mean size of clams in the control cages in October at FR and SP indicates that there was no effect of handling and removal from the water on the growth of clams that were measured over the course of the study.

Shell growth at MI was about twice as fast as at the two interior sites. Growth in length between July 15 and October 11 was 3.0 mm at MI, 1.6 mm at FR, and 1.7 mm at SP, producing average monthly growth rates of 1.0, 0.53 and 0.57 mm, respectively. Growth in width was 3.1, 1.0, and 1.4 mm at the same three sites and averaged 1.03, 0.33, and 0.47 mm per month. Growth in depth was 2.4, 1.7, and 1.2 mm and averaged 0.80, 0.57, and 0.40 mm per month. Monthly summer length increments of 0.5 – 1.0 mm are low compared to growth data reported for most other North American sites by Ansell (1968).

The mean lengths of the dead clams were consistently 2.5 – 3.5 mm smaller than the mean lengths of the survivors, indicating that the mortality rate was higher for smaller clams. Of the original 200 clams deployed at each site, 15% died at FR during the experiment and 20% died at SP. Mortality over the course of the study could not be calculated at the inlet because of the lost cages, but mortality rates between July 15 and August 10 were similar at all three sites (12 – 15% of the 150 clams in the three experimental cages). Because differences in the mean sizes of the survivors were used to estimate growth rates and the smaller clams suffered higher mortality rates than the larger ones, the growth rates reported in this study are slightly over-estimated. However, as long as the mortality rates were about the same at each site over the summer (*i.e.*, 15 – 20%), the differences in growth between sites were not affected.



Table 2. Mean lengths, widths, and depths for clams measured from all cages and sites on July 15, August 10, September 11, and October 11, 2000.

Site	Date	Cage	# of Clams Measured	Mean Length	Mean Width	Mean Depth
Moriches Inlet	15-Jul-00	A	50	28.0	24.2	15.7
		B	50	27.7	24.1	15.4
		C	50	28.2	24.2	15.7
		Controls	50	29.4	26.1	16.3
		Mean	200	28.4	24.6	15.8
	10-Aug-00	A	25	30.0	26.3	17.5
		B	25	27.6	24.6	15.8
		C	25	29.8	26.2	16.8
		Mean	75	29.1	25.7	16.7
	11-Sep-00	A	25	30.6	27.9	17.5
		B	25	30.4	27.2	17.2
		C	Cage destroyed			
		Mean	50	30.5	27.6	17.3
	11-Oct-00	A	25	31.4	27.7	18.2
		B	Cage destroyed 11-Oct-00			
		C	Cage destroyed 11-Sept-00			
Controls		Cage destroyed 11-Oct-00				
Mean		25	31.4	27.7	18.2	
Forge River	15-Jul-00	A	50	27.3	24.6	15.5
		B	50	30.3	26.7	17.0
		C	50	30.9	27.3	17.2
		Controls	50	30.2	27.3	16.7
		Mean	150	30.5	27.1	16.9
	10-Aug-00	A	25	29.5	25.9	16.6
		B	25	30.6	26.6	17.4
		C	25	30.9	26.6	17.7
		Mean	50	30.7	26.6	17.6
	11-Sep-00	A	25	28.8	25.9	16.5
		B	25	32.0	29.0	18.1
		C	25	32.5	29.3	18.5
		Mean	50	32.2	29.2	18.3
	11-Oct-00	A	25	28.7	25.2	16.5
		B	25	32.2	28.4	18.5
		C	25	31.7	28.1	18.7
Controls		25	32.5	28.5	18.6	
Mean		75	32.1	28.3	18.6	



Table 2. Mean lengths, widths, and depths for clams measured from all cages and sites on July 15, August 10, September 11, and October 11, 2000.

Site	Date	Cage	# of Clams Measured	Mean Length	Mean Width	Mean Depth
Smith Point	15-Jul-00	A	50	29.5	26.0	16.5
		B	50	29.7	26.8	16.8
		C	50	29.7	26.5	16.6
		Controls	50	29.0	25.3	16.2
		Mean	200	29.5	26.1	16.5
	10-Aug-00	A	25	30.1	25.8	17.0
		B	25	29.7	25.4	16.6
		C	25	29.8	25.7	16.8
		Mean	75	29.8	25.6	16.8
		11-Sep-00	A	25	31.0	27.3
	B		25	31.9	28.7	18.3
	C		25	31.5	28.3	18.0
	Mean		75	31.4	28.1	18.0
	11-Oct-00		A	25	31.1	27.0
		B	25	31.9	28.8	18.4
		C	25	31.6	27.4	18.0
Controls		25	30.3	26.6	17.0	
Mean		100	31.2	27.5	17.7	

Note: Mean lengths from cage A (shaded) were not included in the overall mean for Forge River.



Table 3. Results of one-way analysis of variance test (F test) for equal mean lengths among cages (including controls) at each grow-out site and sampling date.

	7/15	8/10	9/11	10/11
Moriches Inlet	1.39	1.93	0.03	- -
Forge River	6.26*	0.62	4.15*	3.30*
Smith Point	0.29	0.06	0.26	0.61

Note: * indicates significant differences between cages at P = 0.05. Only two cages remained at Moriches Inlet on 9/11, and one on 10/11.



Figure 6. Length frequencies of live clams (left) and dead clams (right) at Moriches Inlet, July 15 – October 11, 2000.

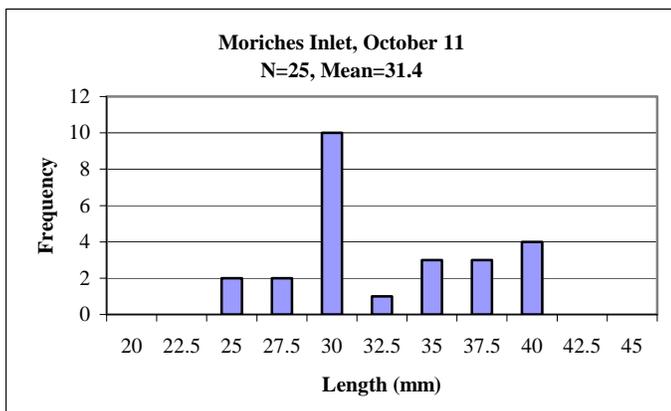
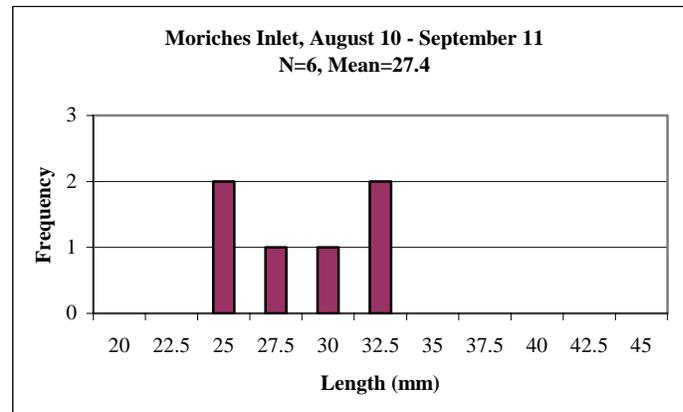
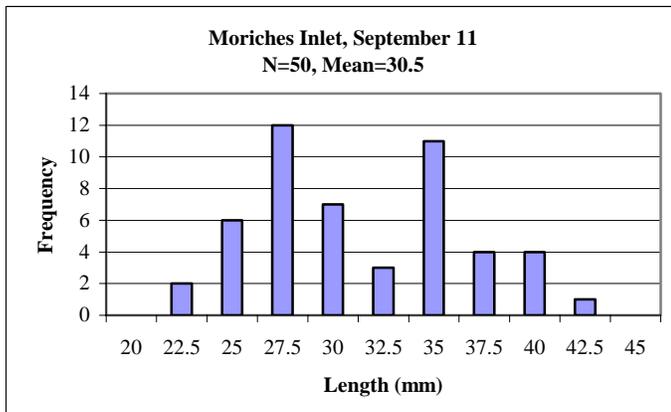
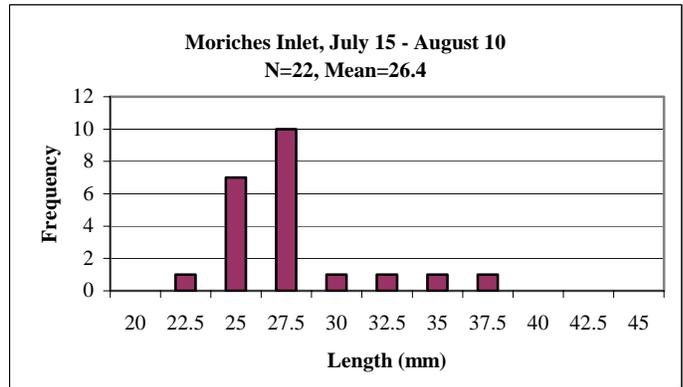
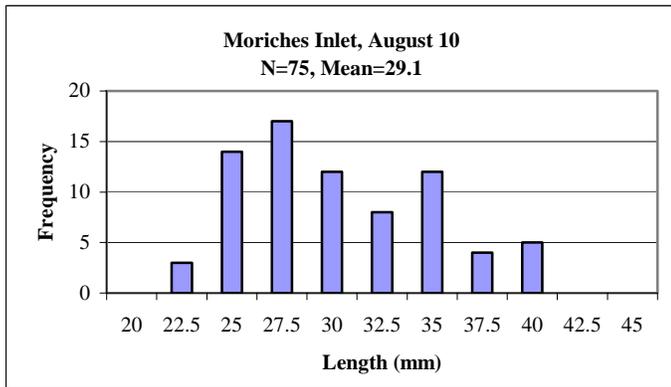
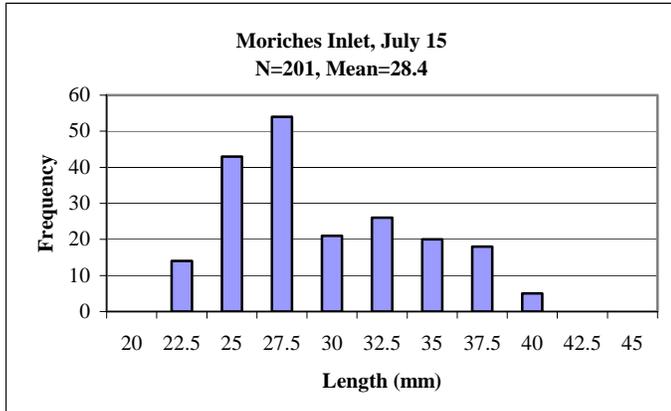


Figure 7. Length frequencies of live clams (left) and dead clams (right) at Forge River, July 15 – October 11, 2000.

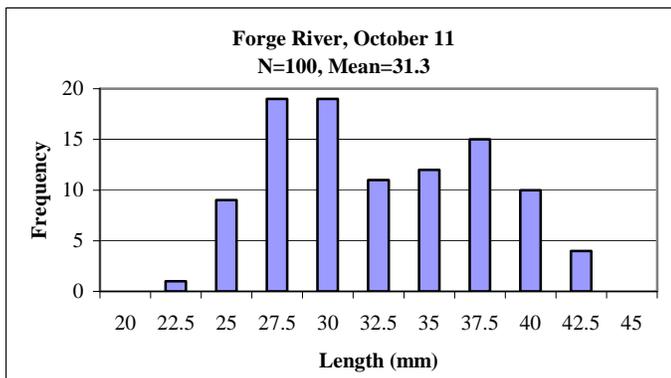
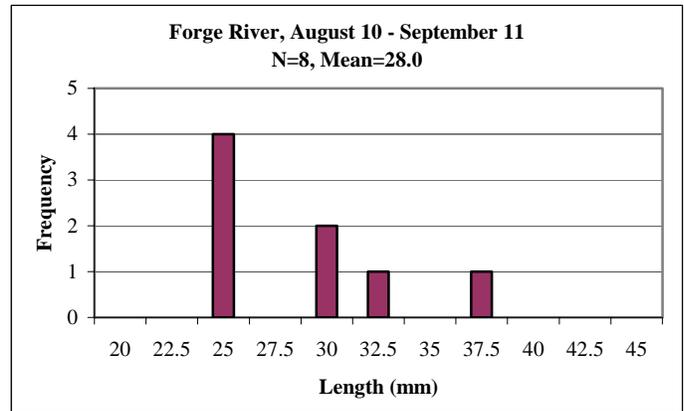
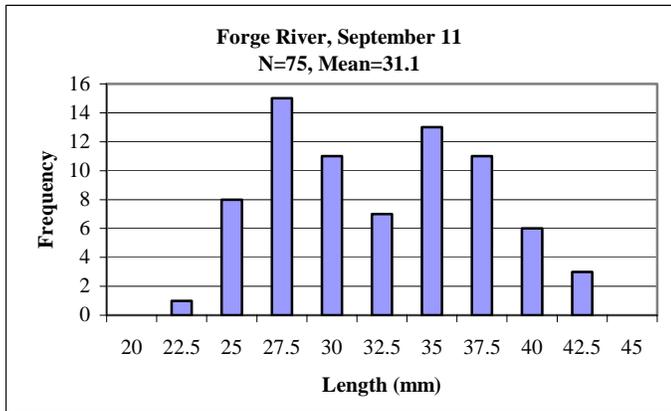
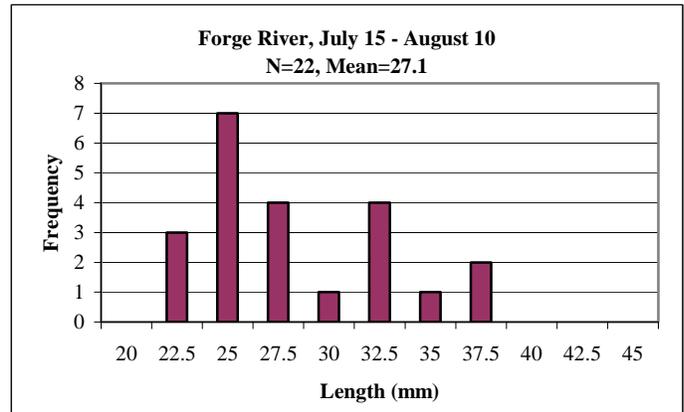
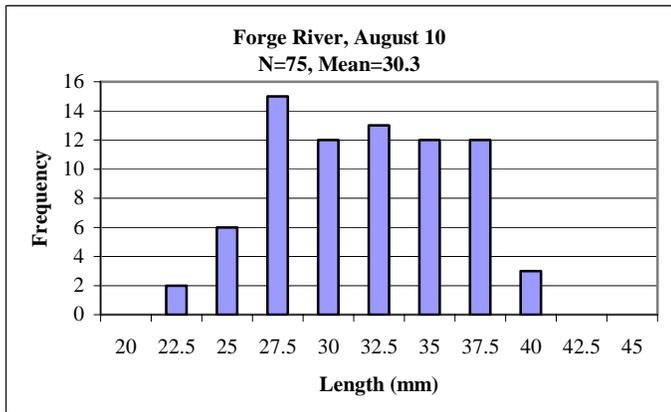
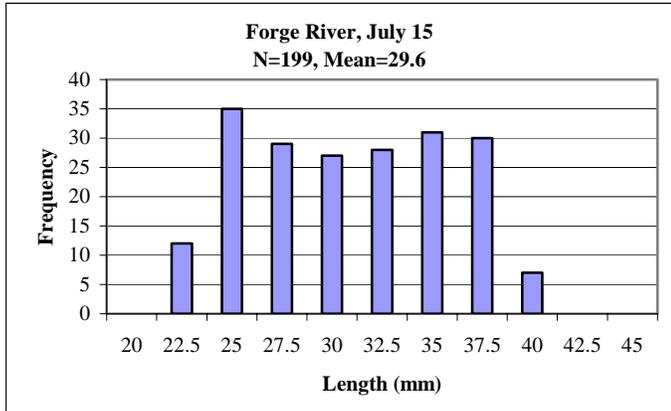
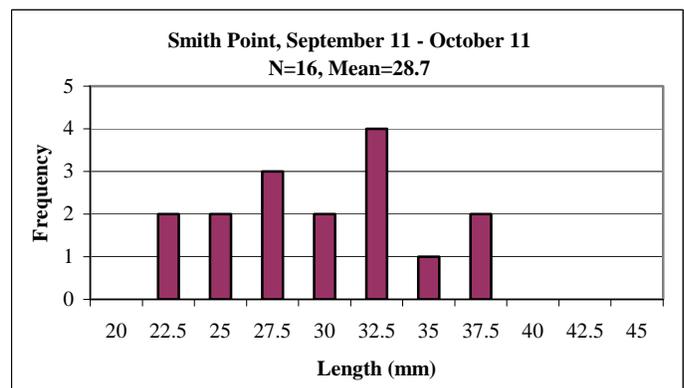
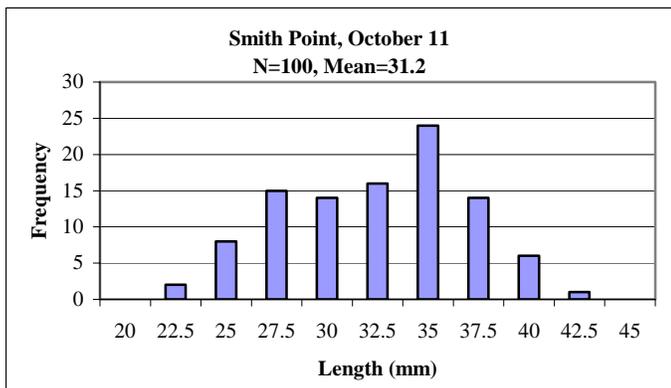
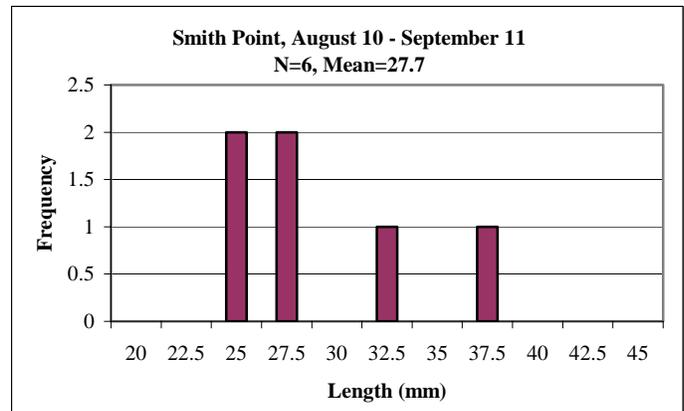
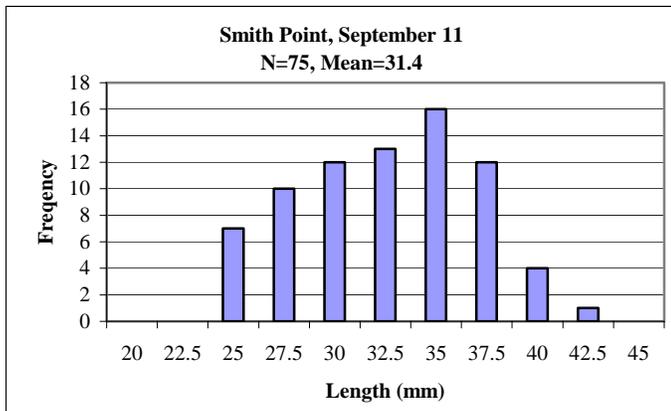
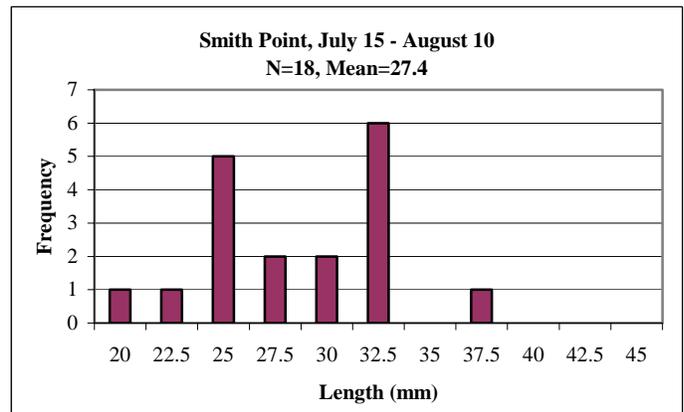
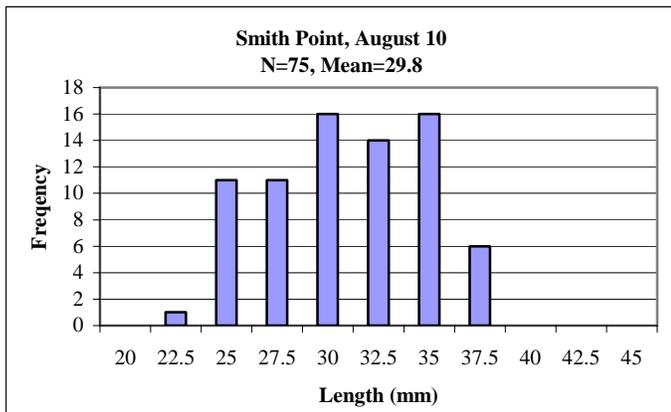
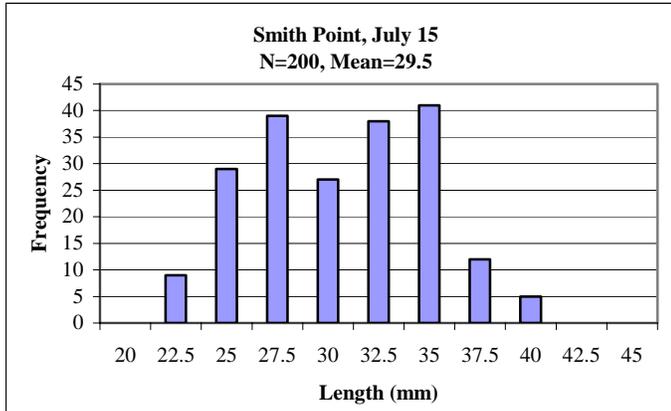


Figure 8. Length frequencies of live clam (left) and dead clams (right) at Smiths Point, July 15 – October 11, 2000.



Dry weights of individual clams selected at random from each cage (two per cage) at each site after the first, second, and third months of the study are shown in Table 4, along with means for all six clams collected at each site on each date. Increases in dry weight over the 62 day time period were noted at each site. The largest relative increase was at the inlet (65% increase compared to 32% at FR and 44% at SP). Note that the mean dry weights were based on very small sample sizes. These results are consistent with the shell growth results.

3.3 GROWTH RATE MODELS

This section summarizes the results obtained from linear regression analysis of the changes in mean size and dry weight at each site during the study.

For each site, linear regressions were fit to mean length, width, and depth estimates from each site for two time periods: July 15 – September 11 and July 15 – October 11 (Figures 9 and 10). Linear regressions were also fit to mean dry weight data from each site for August, September, and October (Figure 11). Because mean sizes declined between September and October, the July – September regressions may produce a more reliable summer growth rate estimate than the July – October regressions. Reductions in growth can be expected in the fall when average temperatures dropped from 22 – 24°C to 13 – 15°C at all three sites. On the other hand, it is equally likely that the July – October regression analyses are more reliable since they were based on four data points instead of three and included data from the beginning and end of the study when all the clams were measured, not sub-samples. It appears that the mean size estimates at FR and SP may have been under-estimated in August and over-estimated in September.

Regression coefficients (slope and intercept), and R^2 values for each analysis are shown in Tables 5 – 7 along with the computed monthly growth rates for each statistically significant regression. Differences in the mean sizes of the clams deployed at each site at the start of the experiment caused the y intercepts of the regressions to be different.

Growth in length:

Both regression lines fit MI mean shell length data extremely well (R^2 of nearly 1.0). Least squares fits to mean length data from the two interior sites were not so tight, but all six length regressions were significant at $P = 0.10$. Average monthly growth rates calculated from regression statistics ranged from 0.94 – 1.10 mm between July and September and from 0.67 – 1.05 mm between July and October. There were no significant differences in growth (slopes) between sites during either time period.

Growth in width:

The only significant linear regressions for mean width shell data were at MI. Average monthly growth at the inlet was 1.54 mm during July – September and 1.12 mm during July – October.



Table 4. Dry weight measurements for individual clams sampled during August, September, and October, 2000.

Site	Date	Clam	Dry Wt. (g)	Site	Date	Clam	Dry Wt. (g)	Site	Date	Clam	Dry Wt. (g)			
Forge River A	9-Aug-00	1	0.43	Moriches A	9-Aug-00	1	0.56	Smith Pt. A	9-Aug-00	1	0.43			
		2	0.24			2	0.40			2	0.30			
Forge River B		1	0.57	Moriches B		1	0.56	Smith Pt. B		1	0.43			
		2	0.61			2	0.22			2	0.32			
Forge River C		1	0.53	Moriches C		1	0.72	Smith Pt. C		1	0.35			
		2	0.62			2	0.46			2	0.34			
		Mean	0.50			Mean	0.49			Mean	0.36			
Forge River A		11-Sep-00	1	0.91		Moriches A	11-Sep-00	1		0.62	Smith Pt. A	11-Sep-00	1	0.35
			2	0.57				2		0.58			2	0.70
Forge River B			1	0.50		Moriches B		1		0.34	Smith Pt. B		1	0.61
			2	0.61				2		0.50			2	0.17
Forge River C			1	0.44		Moriches C		1		cage destroyed	Smith Pt. C		1	0.29
	2		0.79	2				2	0.13					
	Mean		0.63		Mean	0.51			Mean	0.38				
Forge River A	11-Oct-00		1	0.80	Moriches A	11-Oct-00		1	0.78	Smith Pt. A	11-Oct-00		1	0.42
			2	0.64				2	0.84				2	0.48
Forge River B			1	0.82	Moriches B			1	cage destroyed	Smith Pt. B			1	0.45
			2	0.89				2					2	0.67
Forge River C			1	0.38	Moriches C			1	cage destroyed	Smith Pt. C			1	0.40
		2	0.43	2				2	0.72					
		Mean	0.66		Mean		0.81		Mean	0.52				



Figure 9. Linear regression analysis of mean shell length (top), width (middle) and depth (bottom) at three grow-out sites in Moriches Bay, July – September, 2000.

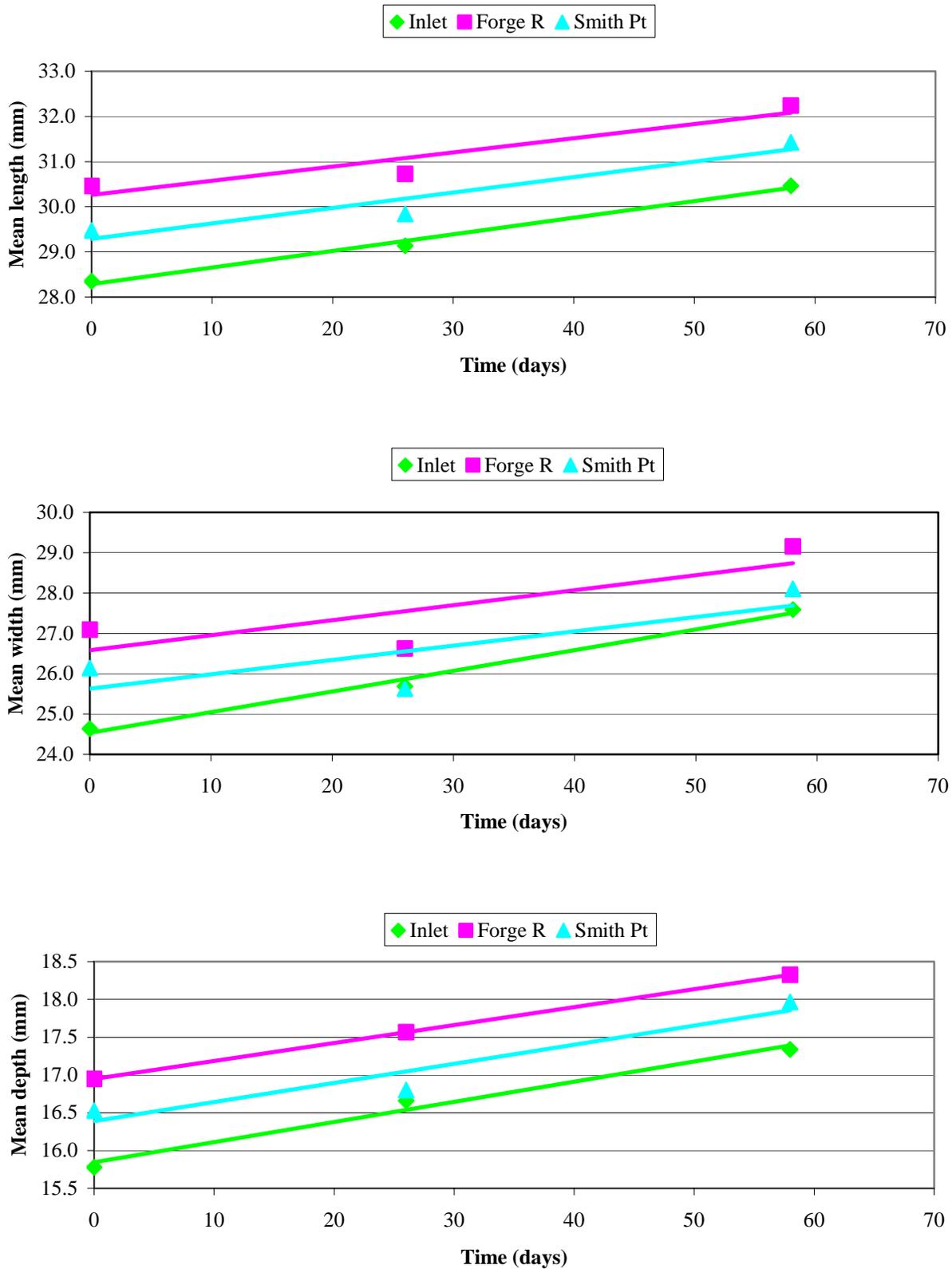


Figure 10. Linear regression analysis of mean shell length (top), width (middle) and depth (bottom) at three grow-out sites in Moriches Bay, July – October, 2000.

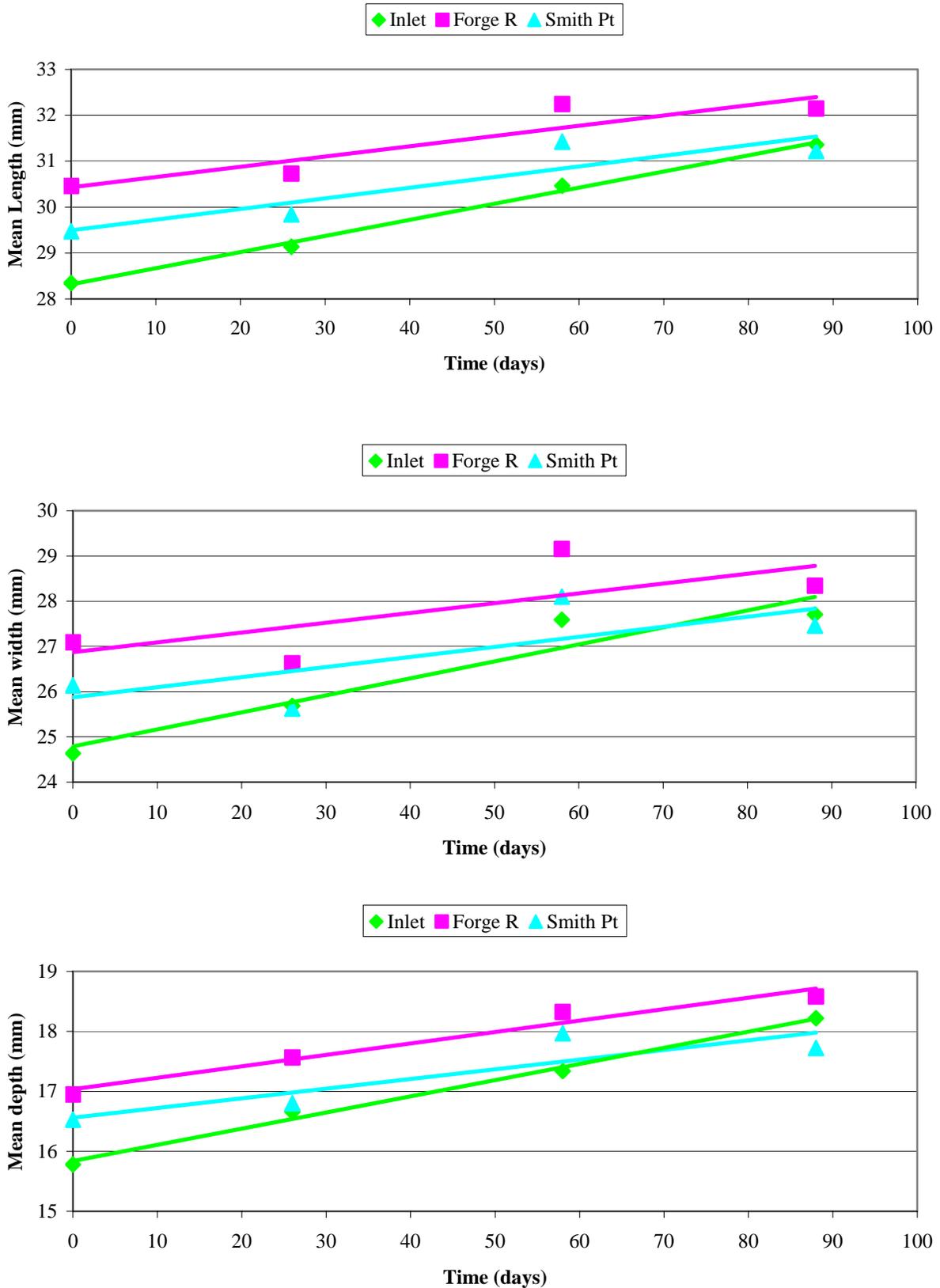


Figure 11. Linear regression analysis of mean dry weight estimates at three grow-out sites in Moriches Bay, August 9 – October 11, 2000.

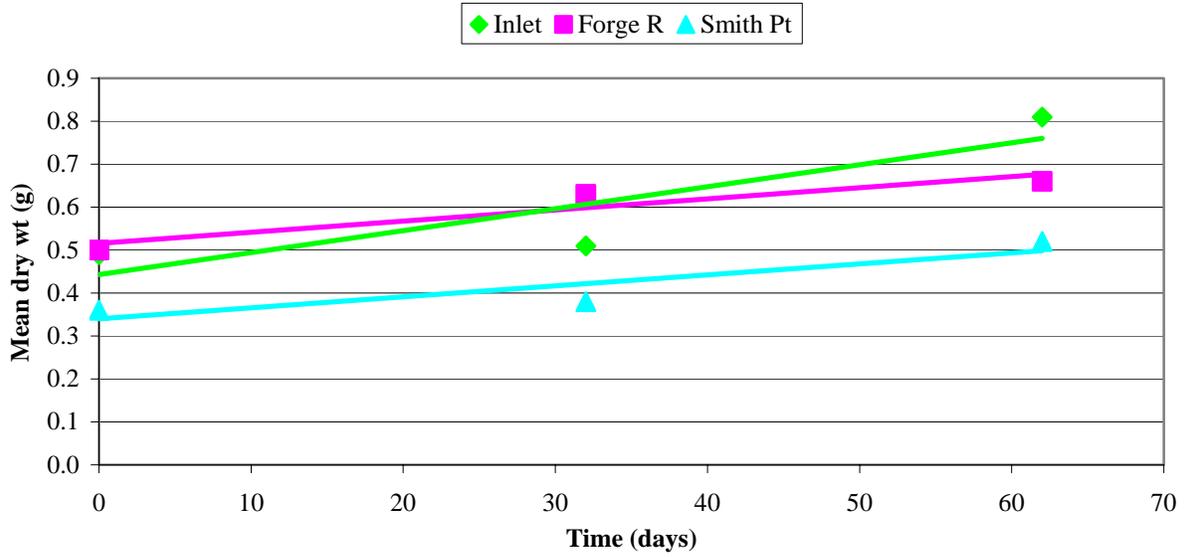


Table 5. Regression coefficients and estimated monthly shell growth rates (mm) for clams at three grow-out sites in Moriches Bay, July 15 – September 11, 2000.

Site	Variable	Intercept	Slope	R ²	Significance	Monthly growth
Moriches Inlet	Length	28.29	0.0367	0.9926	S (0.10)	1.10
	Width	24.54	0.0513	0.9891	S (0.10)	1.54
	Depth	15.85	0.0266	0.9821	S (0.10)	0.80
Forge River	Length	30.26	0.0314	0.8996	S (0.10)	0.94
	Width	26.58	0.0372	0.6462	NS	
	Depth	16.95	0.0237	1.0000	S (0.01)	0.71
Smith Point	Length	29.29	0.0342	0.9204	S (0.10)	1.03
	Width	25.63	0.0355	0.6232	NS	
	Depth	16.39	0.0253	0.9206	NS	

Note:

- S = significant
- NS = non-significant
- R² = correlation coefficient
- number in parenthesis indicate probability level.



Table 6. Regression coefficients and estimated monthly shell growth rates for clams at three grow-out sites in Moriches Bay, July 15 – October 11, 2000.

Site	Variable	Intercept	Slope	R ²	Significance	Monthly growth
Moriches Inlet	Length	28.32	0.0351	0.995	S (0.01)	1.05
	Width	24.79	0.0375	0.916	S (0.05)	1.12
	Depth	15.90	0.0290	0.950	S (0.05)	0.87
Forge River	Length	30.43	0.0223	0.842	S (0.10)	0.67
	Width	26.87	0.0217	0.514	NS	
	Depth	17.11	0.0183	0.935	S (0.05)	0.55
Smith Point	Length	29.49	0.0232	0.823	S (0.10)	0.70
	Width	25.87	0.0223	0.551	NS	
	Depth	16.71	0.0151	0.721	NS	

Note:

- S = significant
- NS = non-significant
- R² = correlation coefficient
- number in parenthesis indicate probability level.



Table 7. Regression coefficients for clam dry weights at three grow out sites in Moriches Bay, August 9 – October 11, 2000.

Site	Intercept	Slope	R ²	Significance
Moriches Inlet	0.443	0.0051	0.781	NS
Forge River	0.515	0.0026	0.896	NS
Smith Point	0.339	0.0026	0.828	NS

Note:

NS = non-significant
R² = correlation coefficient



Growth in depth:

Fits to mean shell depth data were significant at MI and FR between July and September and between July and October. Average monthly growth rates calculated from regression statistics were 0.80 mm at MI between July and September and 0.87 mm between July and October, and 0.55 mm at FR between July and October. There were no significant differences in growth (slopes) between sites during either time period. Growth in shell depth at FR averaged 0.71 mm a month between July and September and 0.55 between July and October.

Growth in dry weight:

None of the linear regression analyses of average mean weight data were statistically significant.



4.0 CONCLUSIONS

- Growth rates could not be determined during June and the first two weeks of July because too many clams were lost.
- Summer growth rates of 25-40 mm hard clams based on differences in mean shell length, width, and depth and on differences in dry weight were consistently about two times higher at Moriches Inlet than at either of the two sites inside the bay.
- Average monthly growth in shell length was low at all sites (approximately 0.5 – 1.0 mm per month), lower than most published estimates for slightly larger (40 mm) hard clams at other U.S. Atlantic coast locations (Ansell 1968).
- It is not clear whether temperature affected clam growth. Average temperatures remained within the 20 – 23°C optimum growth range at the inlet between late June and mid-September and also at Forge River on most sampling dates. Lower growth increments at FR may have been temperature-related since average temperatures there were 1 – 4°C higher than at MI. However, water temperatures at FR only exceeded 23°C for extended periods of time on July 14 (Appendix A, Figure A_), suggesting that other factors (possibly brown tide) may affect growth in this location. Water temperatures at Smith Point were considerably higher: averages exceeded 23°C on 5 out of 6 occasions between late June and mid-September. Growth rates at FR and SP were similar, however.
- Salinity did not seem to be a factor affecting hard clam growth rates in Moriches Bay. The higher growth rates at the inlet were associated with average salinities that remained above 30 ppt on all eight sampling occasions, well above the reported upper limit for optimum growth of 28 ppt. Mean salinities at FR also remained above 28 ppt most of the time. The salinity regime at SP was much more favorable for clam growth and may have compensated for the high temperatures that prevailed at that site.
- In summary, higher shell growth at the inlet appears to be related to a lower, more favorable, temperature regime and prevailed despite the fact that salinities exceeded 28 ppt. Faster shell growth at the inlet may be related to a more available food supply. Strong tidal currents at the inlet may increase the supply of phytoplankton that is removed from the water by the clams.
- Despite the larger increases in shell size observed at the inlet, linear regression growth models failed to show any statistically significant differences in growth rates between sites when applied to mean length and depth estimates for either the July – September or July – October growth periods. In fact, the slopes of many of the linear regressions that were applied to shell size and dry weight data were not significantly different from zero, indicating that there were not enough mean size estimates available (i.e., not enough sampling dates) to compensate for the variances associated with each mean size estimate.



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Appendix A:
Temperature and Salinity Plots