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Assessment of Shellfish Survival and Growth at Cape Cod Aquaculture Sites

Report prepared for the Southeastern Massachusetts Aquaculture Center

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Introduction

Although there is wide recognition that shellfish survival and growth vary among aquaculture sites and among years, it is difficult to determine how much of this variation is due to intrinsic differences among sites versus other factors that can be changed by shellfish farmers (e.g., inherent differences in seed stock, culture practices and techniques, etc.).

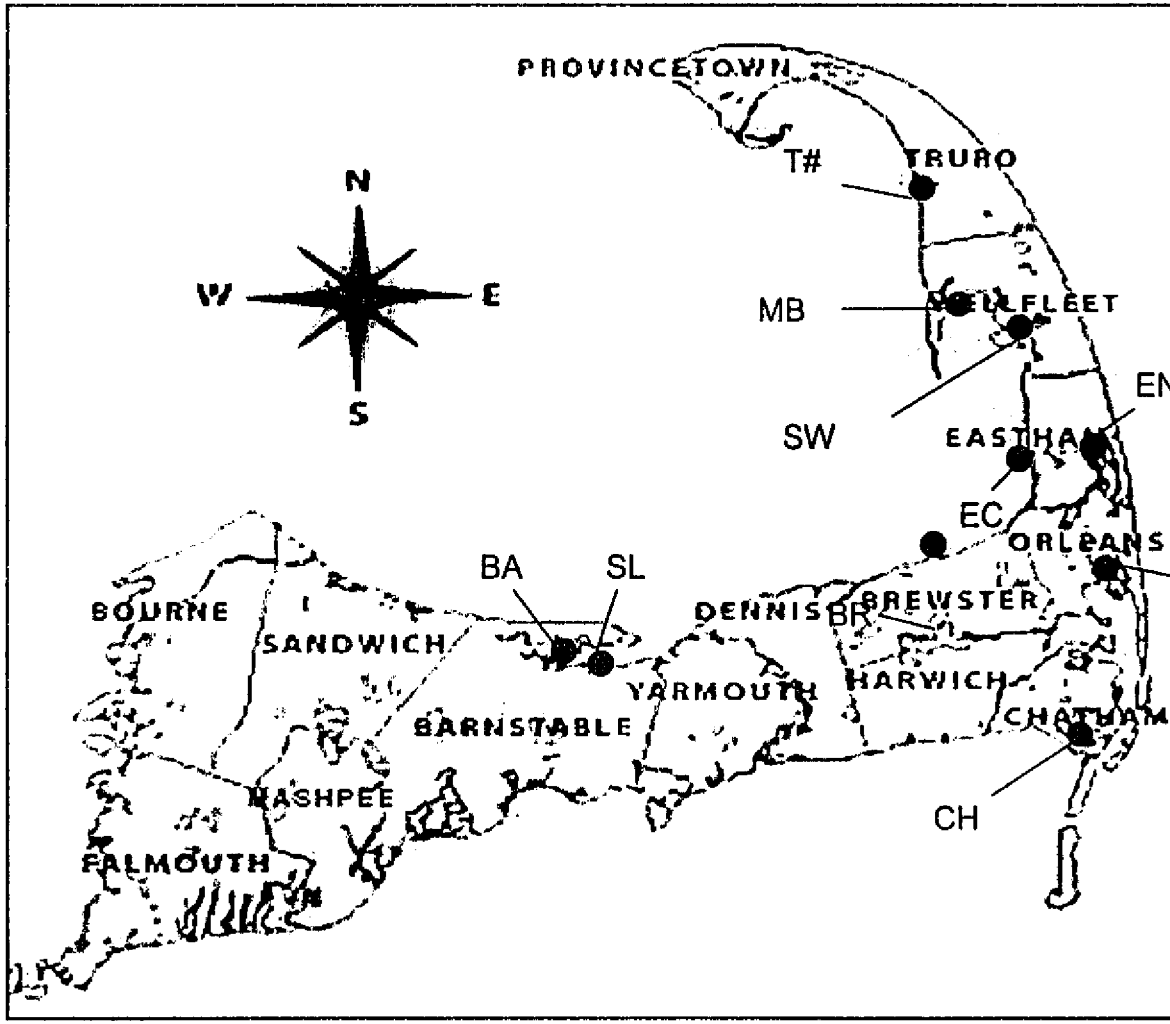
To make this determination, Barnstable County's Cape Cod Cooperative Extension (CCCE) Marine Program staff devised a standardized assessment of site-specific shellfish survival and growth to allow a relative comparison of sites. Specifically, we conducted short-term (2 month) assessments of the growth and survival of oysters (*Crassostrea virginica*), quahaugs (*Mercenaria mercenaria*), and soft shell clams (*Mya arenaria*) at up to eleven intertidal locations around Cape Cod, of which nine are currently being cultivated. At each site, we used similarly sized juvenile shellfish supplied from the same hatchery and cultured identically, to provide a standard, or 'yard stick', that would allow a relative comparison of sites.

It is our hope that, should this 'yard stick' be deemed an acceptable measure, that we could pursue questions of even greater interest to the region's shellfish growers, such as whether farmers suffer from the establishment of nearby farms, whether seed stocks vary substantially in terms of performance, and whether there are any trends over time in shellfish growth and survival.

Methods

Across Cape Cod, we identified 8 private shellfish farms, 1 public propagation site, and 2 uncultured sites where we could conduct this study (Fig. 1). Although all the sites were intertidal and relatively high salinity, the sites varied in terms of substrate and tidal height, and are described qualitatively as follows (sites in Pamet River varied depending on species):

BA: central Barnstable Harbor among farms, low intertidal, firm mud
BR: Brewster flats, mid-intertidal, sandy
CH: semi-enclosed embayment, low intertidal, sandy mud
EC: Eastham bay flats, mid-intertidal, sandy
EN: Nauset Marsh, mid- to high intertidal, firm mud
MB: northern Wellfleet Harbor among Mayo Beach farms, mid-intertidal, firm mud
PB: northern Pleasant Bay among farms, low intertidal, firm mud
SL: near Scudders Lane at town propagation site, mid-intertidal, firm mud
SW: southern Wellfleet Harbor among farms, mid-intertidal, firm mud
TA: southern Pamet River Harbor in creek, mid-intertidal, sandy
TD: middle of Pamet River Harbor, mid-intertidal, sandy, jetty nearby
TF: northern Pamet River Harbor in creek, high intertidal, sandy with rocks
TG: eastern Pamet River Harbor in main river channel, mid-intertidal, sandy


PROVINCETOWN
TRURO
T#
N
W
E
S
MB
SW
EN
EC
ORLEANS
PB
BA
SL
BOURNE
SANDWICH
DENNIS
BREWSTER
BR
YARMOUTH
HARWICH
BARNSTABLE
CHATHAM
CH
FALMOUTH

To minimize confounding variation among shellfish, we purchased shellfish of each species as a single batch; juvenile oysters and quahaugs, called seed, were obtained from the Aquaculture Research Center in Dennis, MA, while seed soft shell clams were purchased from Beals Island Regional Shellfish Hatchery in Beals, ME. Due to logistic constraints, however, the shellfish were deployed in batches with significant differences in initial shell length (Tables 1-3); any batch sharing a letter under 'statistical group' did not substantially differ. This was taken into account at the conclusion of the experiment by determining the average amount of shell length added per day.

Table 1: Size of oyster seed upon deployment in 2003

Batch	Shell Length (mm)	SD (mm)	Statistical Group
7/1 – Truro Sites	8.47	± 1.50	A
7/2 – BR, CH, EN, MB, SW	8.10	± 1.85	A
7/3 - EC	8.64	± 1.36	A
7/7 – BA, SL	9.83	± 2.31	B
7/11 - CH	13.01	± 1.55	B

Table 2: Size of quahaug seed upon deployment in 2003

Batch	Shell Length (mm)	SD (mm)	Group
7/1 – Truro Sites	6.72	± 0.74	A
7/2 – BR, CH, EN, MB, SW	7.18	± 0.90	B
7/3 - EC	7.26	± 0.74	B
7/7 – BA, SL	7.25	± 0.64	B
7/11 - CH	7.90	± 0.79	C

Table 3: Size of soft shell clam seed upon deployment in 2003

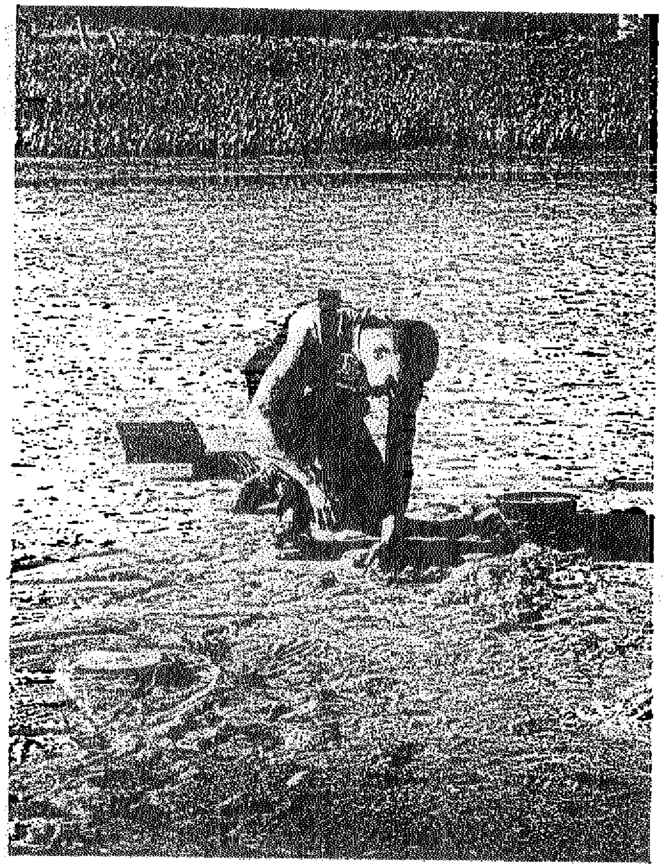
Batch	Shell Length (mm)	SD (mm)	Group
7/1 – Truro Sites	7.34	± 0.71	A
7/2 – BR, CH, EN, MB, SW	7.74	± 0.82	A
7/3 - EC	7.76	± 0.96	A
7/7 – BA, SL	7.93	± 1.14	A
7/11 - CH	12.2	± 2.70	B

For oysters, we placed three vinyl-coated trays (0.5" x 0.25" mesh) at each site, and propped up on 2" PVC pipe with the intent to keep them above the sediment (Fig. 2). Each tray was stocked with 25 oysters. Due to their small size, these oysters were initially enclosed in 3 mm mesh pouches within the cages. After 1 month, we released the oysters from these pouches to allow greater flow of seawater.

For both quahaugs and soft shell clams, at each site we placed six plastic plant pots (10" diameter and 10" deep, or 0.55 ft^2) in the substrate (flush with the bottom) and filled each with the removed sediment, including any infaunal organisms residing in the sediment. For the quahaugs, each pot was stocked with 50 individuals, while the soft shell clam pots were stocked with 25 clams. To test the effects of predators, half of these pots were protected from predation by the addition of predator-exclusion netting over the top of the tray (held by a rubber band). Due to an inadequate supply of soft shell clams, these were only deployed at two sites, sites F and G.

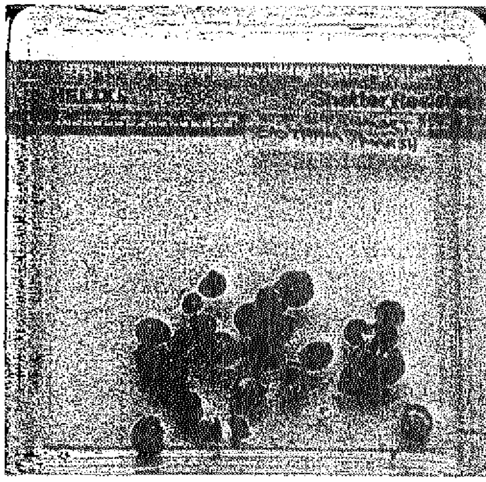
Upon collection of the shellfish on August 29th, surviving oysters were counted and measured. Any signs of predation were noted. Similarly, surviving quahaugs and clams were retrieved by sieving the contents of each pot over 3 mm mesh screen. Survivors and any natural set of shellfish were counted and measured. Again any signs of predation were noted. See Figure 3 for samples of retrieved shellfish.

The survival and growth data were assessed statistically (using general linear models and Fisher's LSD post-hoc test to compare means) and graphed. In many of the graphs comparing sites, the following convention is used: sites that do not vary significantly from one another are connected by a commonly colored horizontal line. This means that although the averages did vary some (as evidenced by the different bar heights), this difference could be accounted for by what is called natural variation and did not amount to 'true' differences among sites.

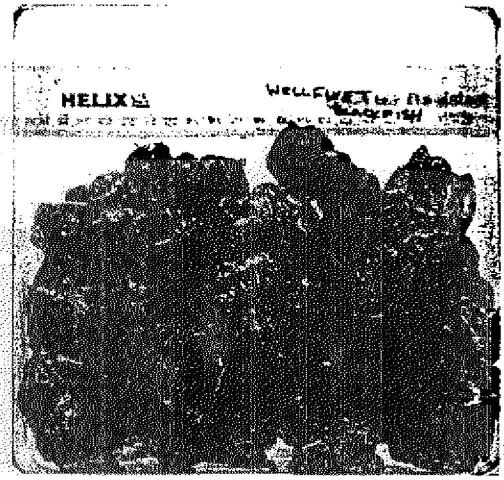


Lucas Drake, a Cape Cod Community College intern, helps set up the experimental units.

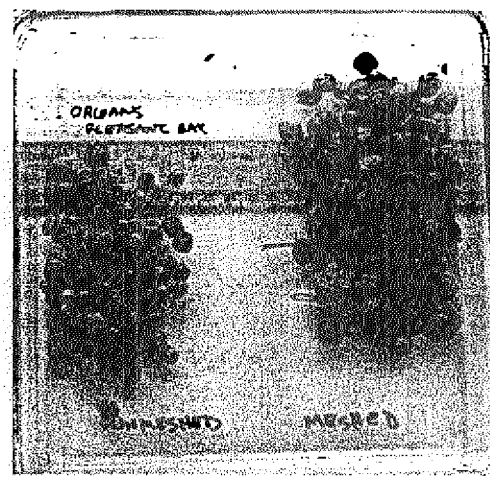
Figure 2



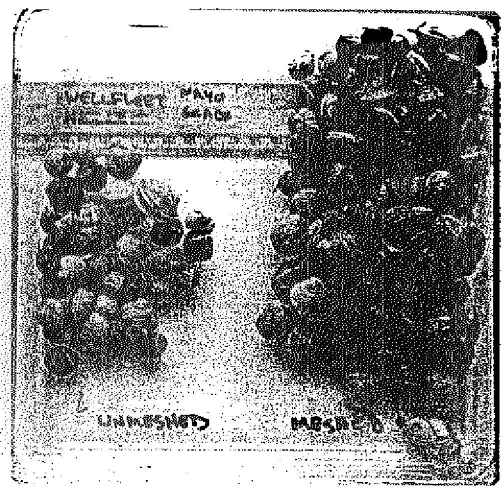
EN (Nauset Marsh)



SW (South Wellfleet)



PB (Pleasant Bay)



MB (Mayo Beach)

TF (Pamet River)

BA (Barnstable Harbor)

Figure 3

Oyster Results and Recommendations

In terms of survival (Fig. 4), the eleven sites[1] examined broke into four overlapping groups, with Pleasant Bay (PB) showing the worst survival and Chatham (CH) having the best. The results for Chatham suggest either initial overstocking or noted recruitment with survival averaging over 100%. Aside from this anomaly, survival of oysters was generally 80% or above at all sites other than PB and Eastham's Nauset Marsh (EN).

The poor survival in Pleasant Bay was explained in part by loss to oyster drills (Fig. 5), with an average loss of 16-20% (4-5 drilled of 25). Drilled oysters were also observed at Scudder's Lane (SL) and Mayo Beach (MB), but the mortality was not significant (Fig. 5). Increased mortality at PB and EN was likely the result of smothering by mats of drifting algae, observed to be common in both Pleasant Bay and Nauset Marsh in 2003.

Oyster growth was more complicated (Fig. 6), breaking into 6 distinct tiers. The average daily growth rate was lowest in PB, followed by EN and Boat Meadow (EC) with average growth below 2.5 mm/day. Relative growth was intermediate at the Pamet River sites (T1 and T2), and Brewster (BR) and CH. The best growth was observed at the four Barnstable Harbor and Wellfleet Harbor sites, with growth of over 0.5 mm/day recorded at South Wellfleet (SW).

Therefore, in terms of oyster aquaculture, Pleasant Bay and Nauset Marsh seemed to pose a particular challenge to aquaculturists in 2003. Oysters were lost to smothering by algae and drill predation, and exhibited slow growth. While these obstacles can be overcome by oyster growers, it is important to note that they add risk and cost to this business. Interestingly, the two harbors noted for their established shellfish culture, Wellfleet and Barnstable, performed quite well in this comparison, setting the standard for all other sites.

Lastly, if this work were repeated, we would recommend modifying the oyster cages so that the animals are suspended at least 6" off the bottom, for two reasons. First, over the course of the experiment, we found that the 2" PVC pipes often buried essentially resting the cages on the sand. Second, at some sites, particularly where there is a great deal of sand transport, this may have inhibited growth. In particular, at EC oyster seed cared for on nearby farms grew much better over the same time period.

[1] For oysters, the Truro sites are as follows: T1 = TA, and T2 = TG

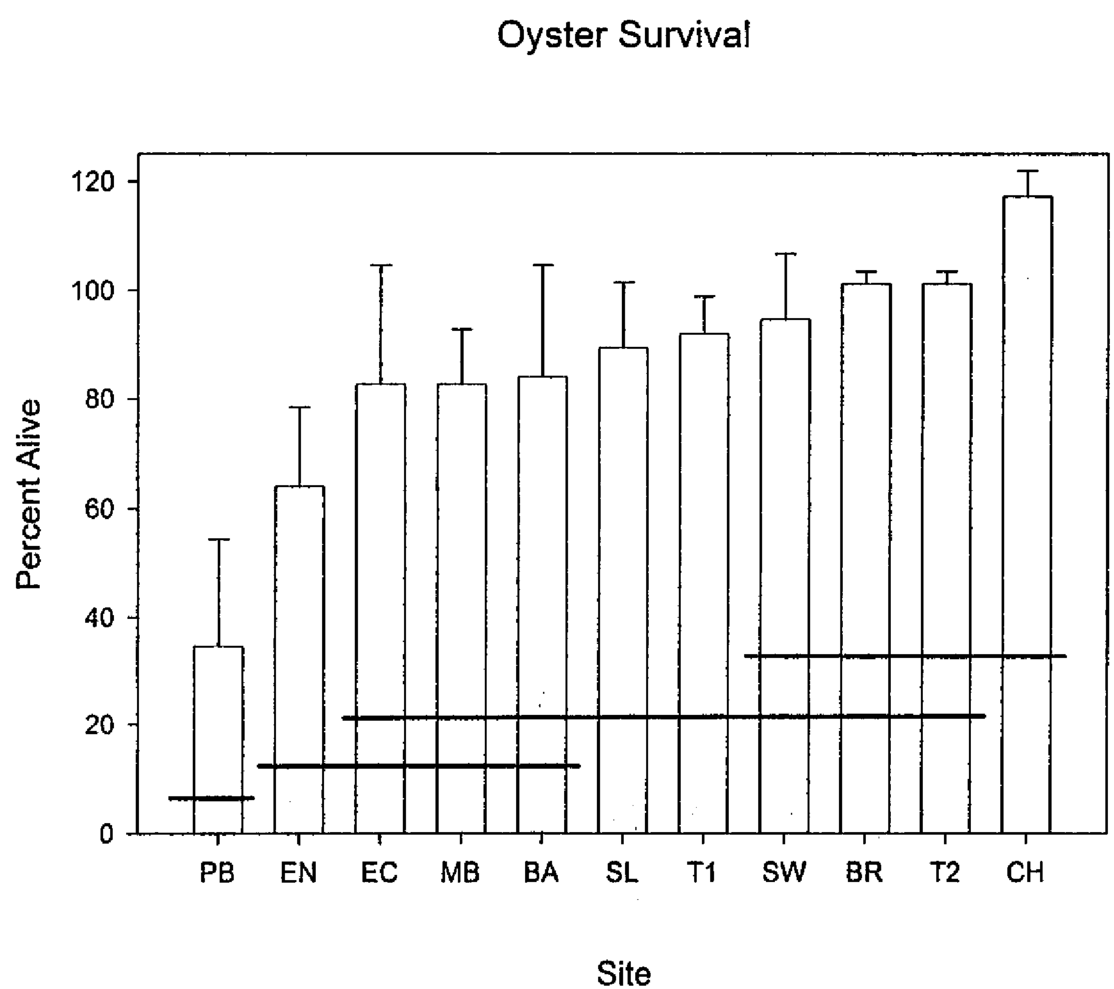

Oyster Survival
Percent Alive
120
100
80
60
40
20
0
PB
EN
EC
MB
BA
SL
T1
SW
BR
T2
CH
Site

Figure 4

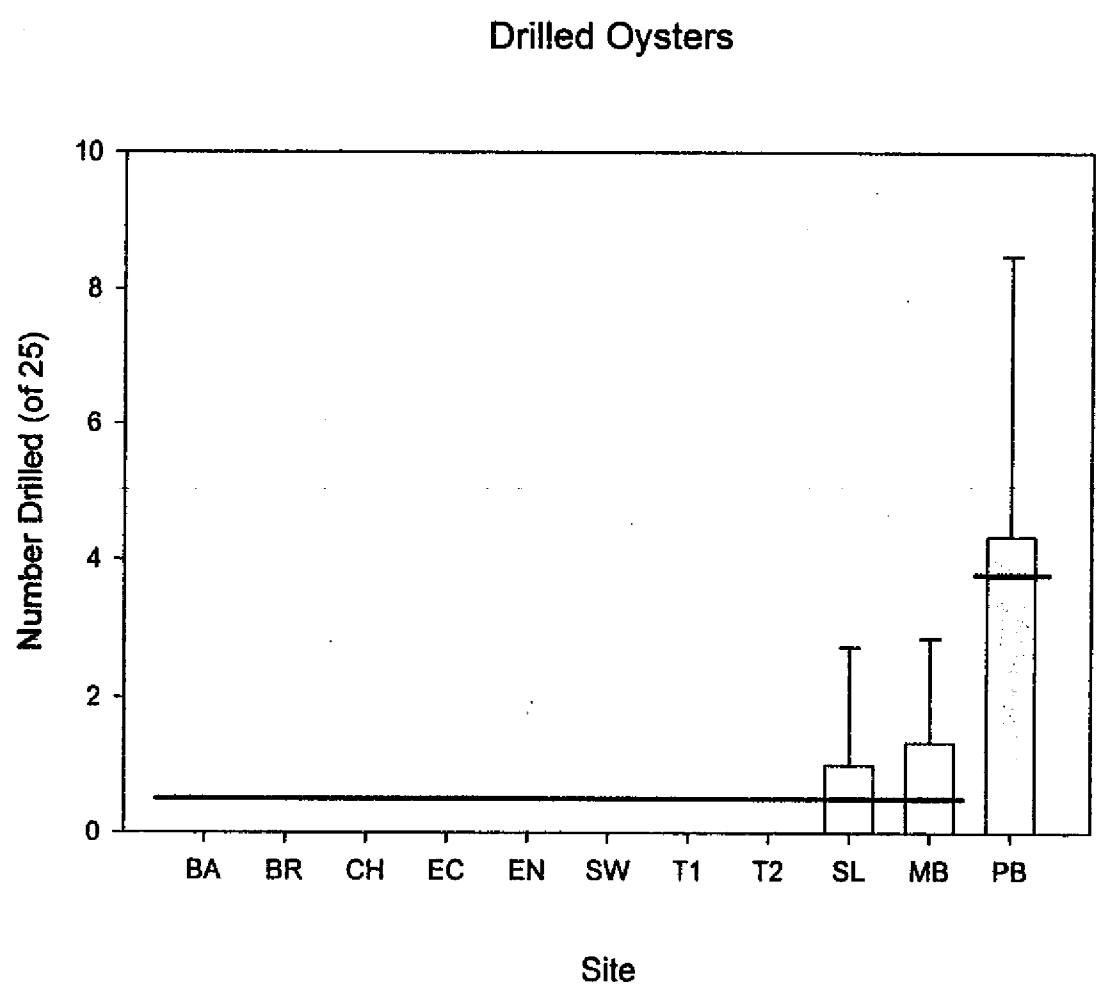

Drilled Oysters
Number Drilled (of 25)
10
8
6
4
2
0
BA
BR
CH
EC
EN
SW
T1
T2
SL
MB
PB
Site

Figure 5

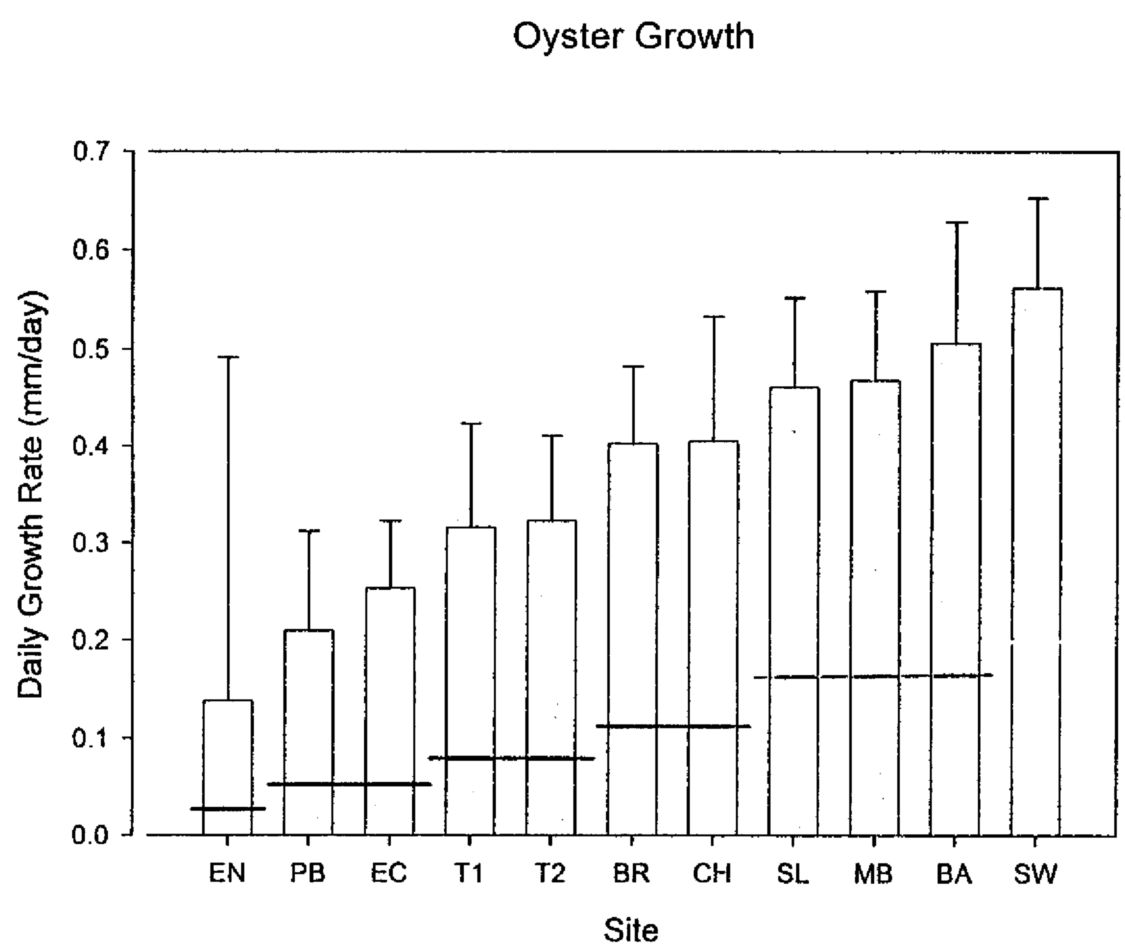

Oyster Growth
Daily Growth Rate (mm/day)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
EN
PB
EC
T1
T2
BR
CH
SL
MB
BA
SW
Site

Figure 6

Quahaug Results and Recommendations

In terms of quahaug survival (Fig. 7), it will come as no surprise that over all eleven sites tested[1] meshed quahaug seed survived significantly better than unprotected seed. More interestingly, when the effect of mesh is examined in terms of each site (Fig. 8), we found three sites where there was no difference in quahaug survival between meshed and unmeshed treatments: Pleasant Bay (PB), Truro 1 (TD) and Scudder's Lane (SL). This suggests that predation was not particularly important at these three sites during the course of the study, but was at all others.

Despite the varying importance of predation (as indicated by comparing meshed to unmeshed quahaugs), survival varied among sites when the mesh treatment is held constant (Fig. 9). Quahaugs protected under mesh (Fig. 9, top) survived least well at Boat Meadow (EC), PB and Nauset Marsh (EN); such differences are likely the result of smothering by drift algae, poor food, etc. Among unprotected seed (Fig. 9, bottom), survival was best at PB, Brewster (BR), TD and SL. Interestingly, the results for Brewster indicated relatively high survival of unprotected quahaugs despite the apparent importance of predation (see Fig. 8).

As with survival, growth among sites was complicated by overlap among sites (Fig. 10). Despite this variation, it is apparent that the best growth was observed in Wellfleet Harbor (South Wellfleet [SW] and Mayo Beach [MB]), Barnstable Harbor (Barnstable Aquaculture Area [BA] and SL), and the Brewster flats. Conversely, growth was slowest in Nauset Marsh (EN), Pleasant Bay (PB) and the Pamet River in Truro (TD & TG).

Interestingly, meshing generally improves the growth of quahaugs (Fig. 11), presumably by allowing the quahaugs to feed without interference by predators. Notably, however, this effect depends on the site (Fig. 12); in the figure, in pairs marked by a black asterisk the quahaugs under mesh grew significantly faster than those unprotected, while in the pair marked by the blue asterisk (TD) the opposite was true. At this site, meshing may have led to greater burial under shifting sands.

Lastly, a set of quahaugs was found at Boat Meadow (EC) but only in the protected treatments (Fig. 13). The quahaug set would not have been observed without the meshed treatments.

Therefore, in terms of quahaug culture, Wellfleet Harbor, Barnstable Harbor and the Brewster flats were the best places to grow quahaugs under net this past year. Generally, meshing improves survival and, perhaps surprisingly, growth, though these effects are somewhat site-dependent.

[1] For quahaugs, the Truro sites are as follows: T1 = TD, and T2 = TG

Effect of Meshing on Quahaug Survival

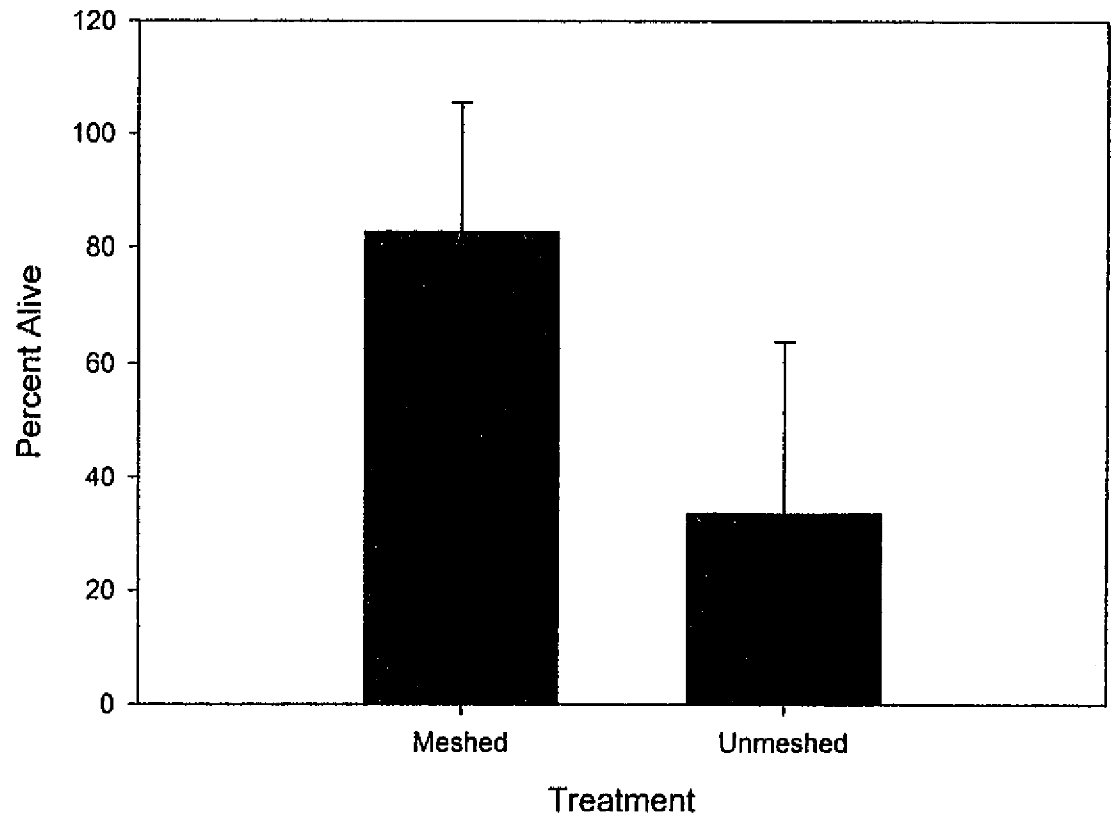


Figure 7

Quahaug Survival: Protected and Unprotected

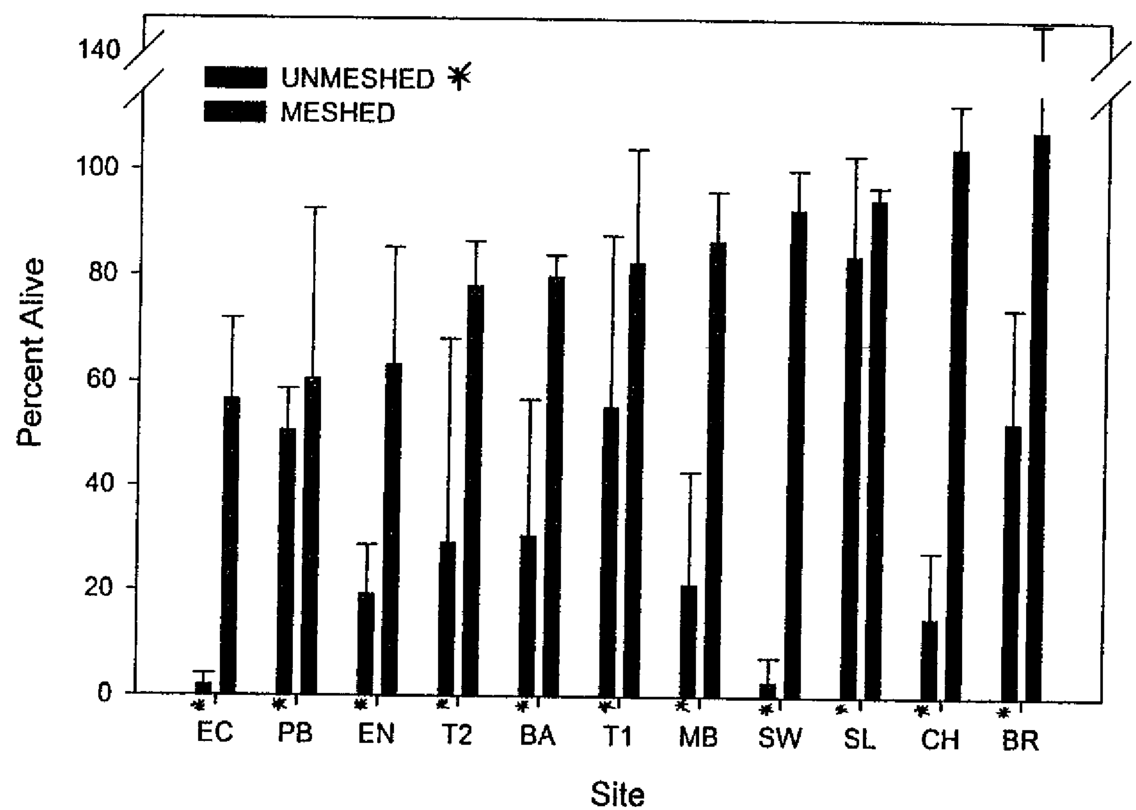
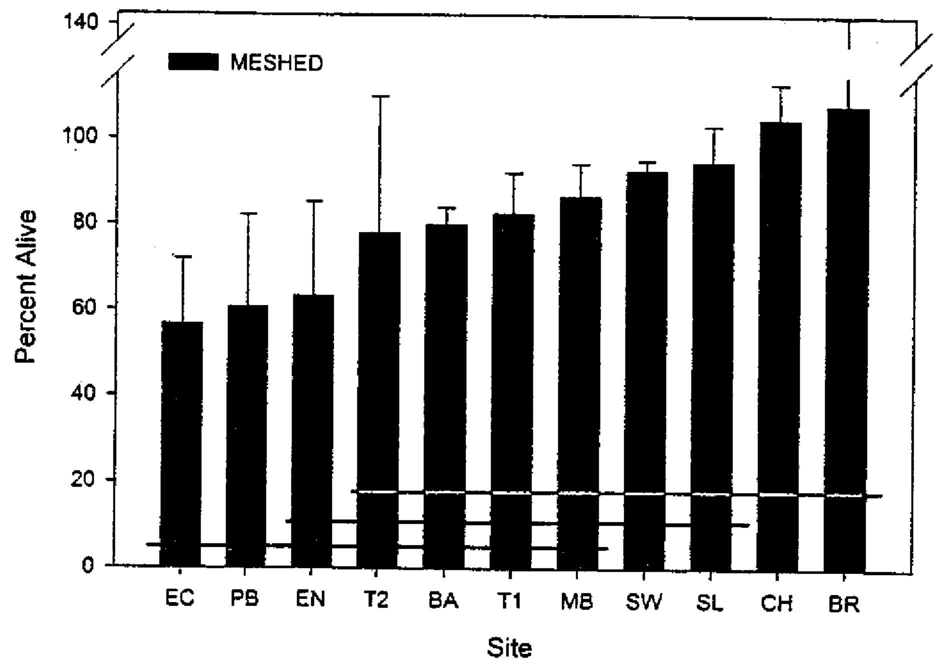


Figure 8

Protected Quahaug Survival



Unprotected Quahaug Survival

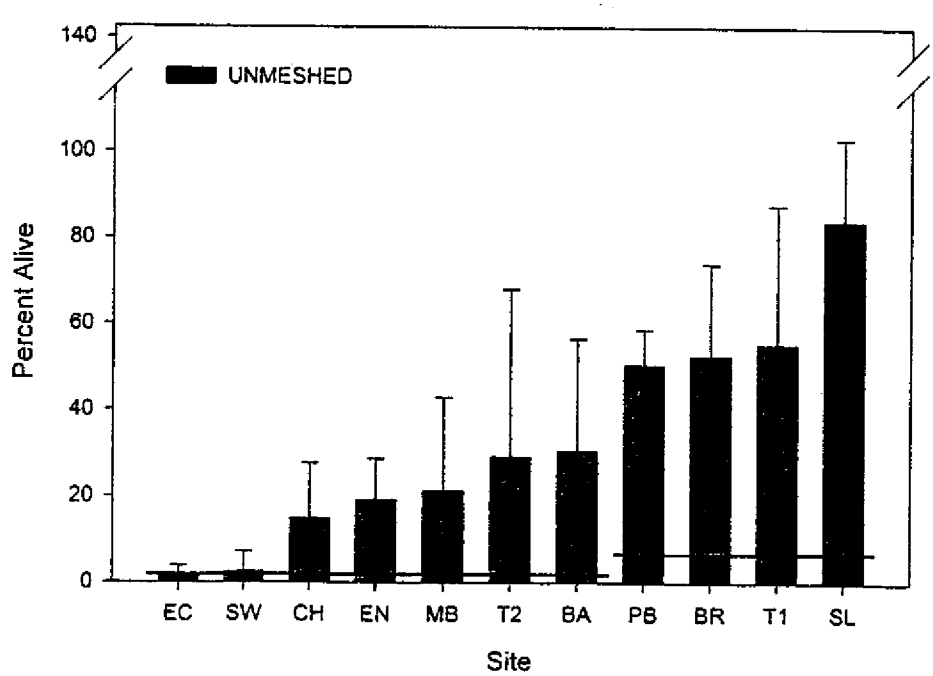


Figure 9

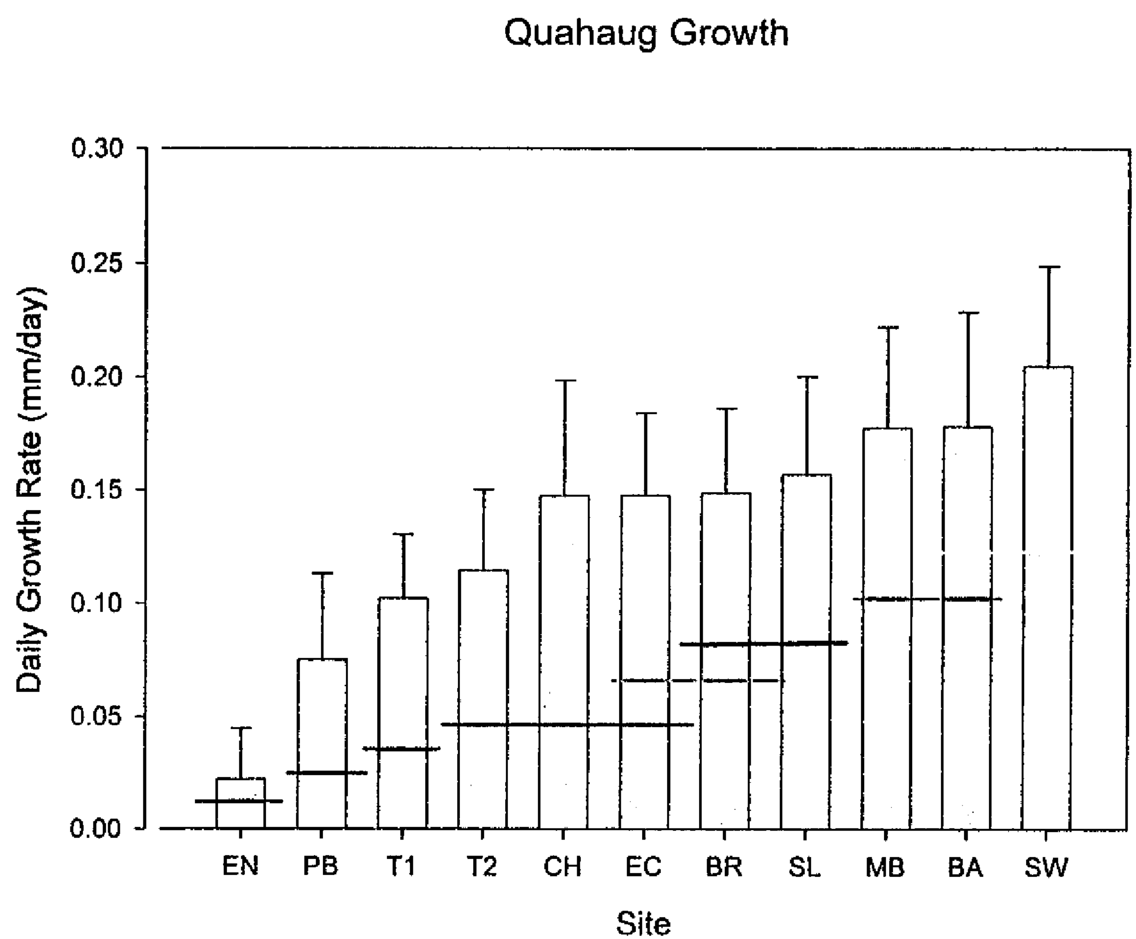

Quahaug Growth
Daily Growth Rate (mm/day)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
EN
PB
T1
T2
CH
EC
BR
SL
MB
BA
SW
Site

Figure 10

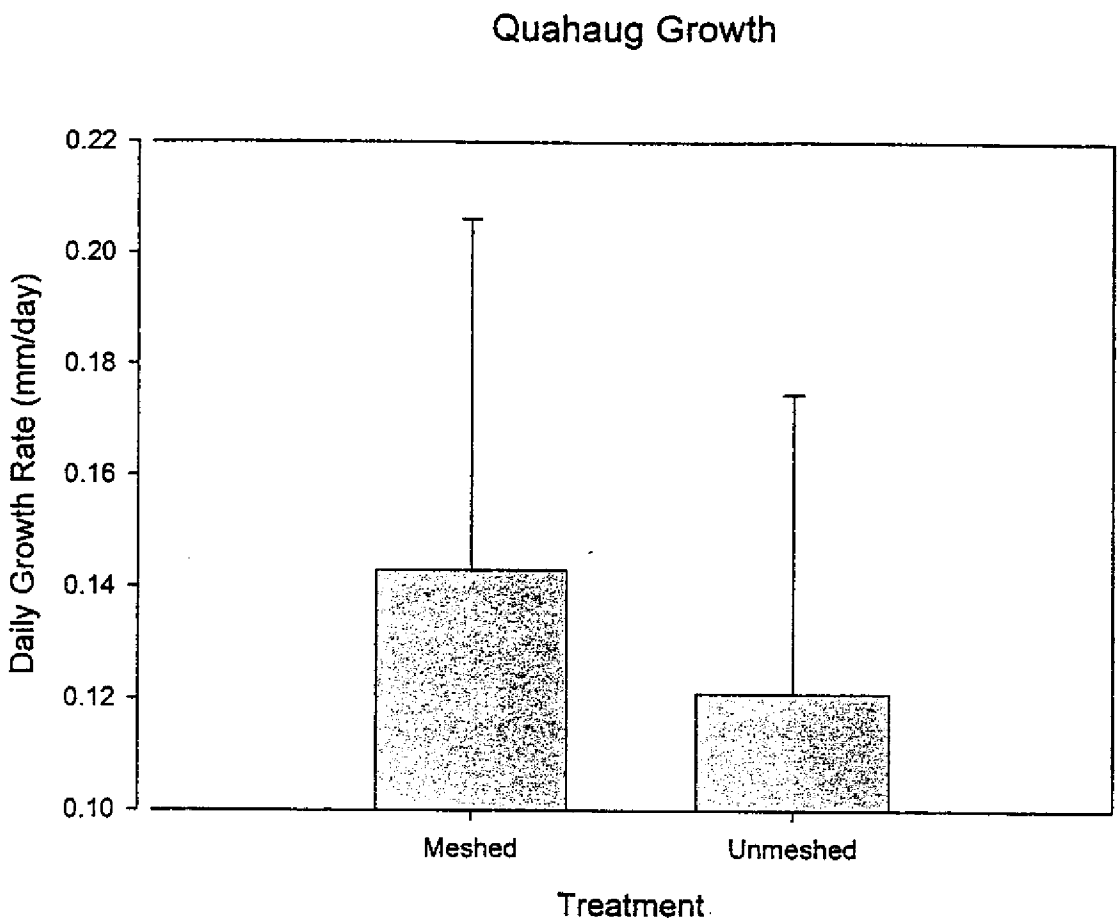

Quahaug Growth
Daily Growth Rate (mm/day)
0.22
0.20
0.18
0.16
0.14
0.12
0.10
Meshed
Unmeshed
Treatment

Figure 11

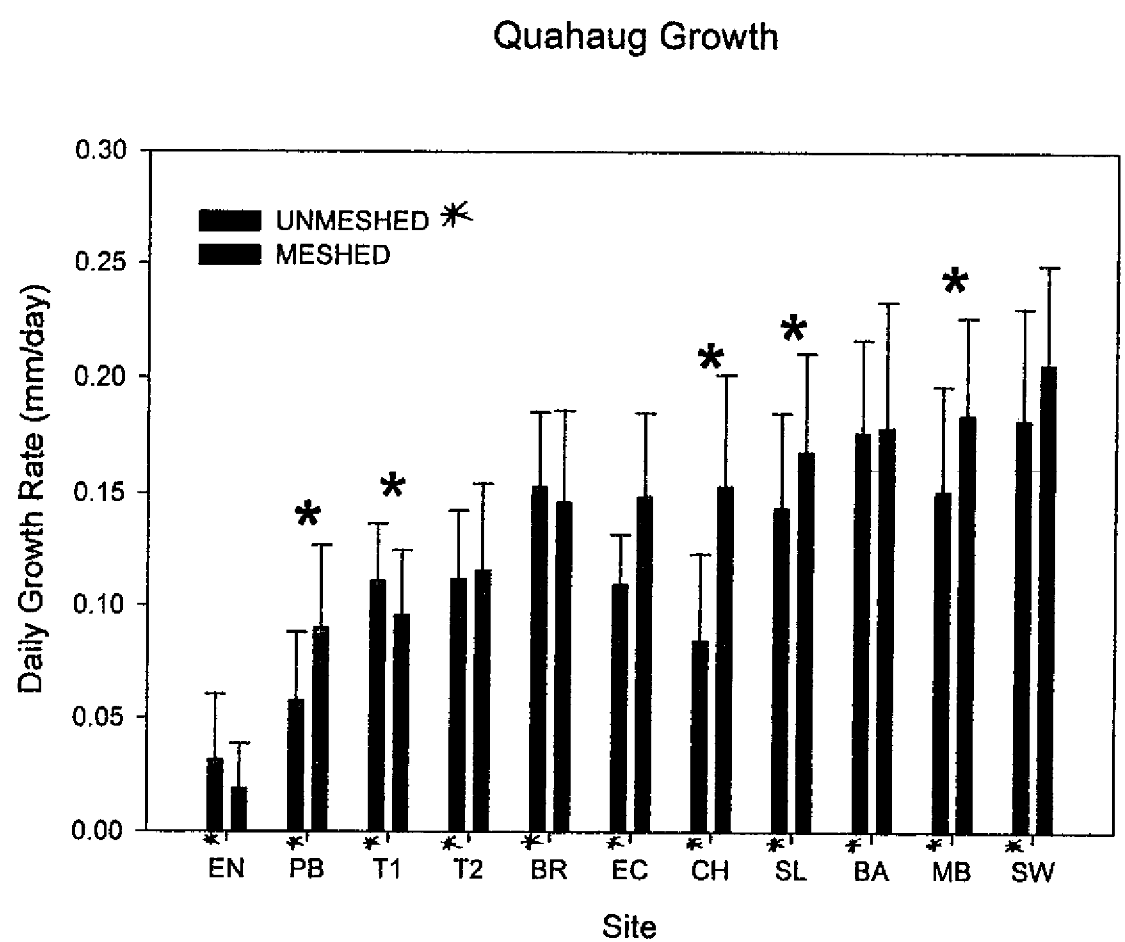

Quahaug Growth
UNMESHED
MESHED
Daily Growth Rate (mm/day)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
EN
PB
T1
T2
BR
EC
CH
SL
BA
MB
SW
Site

Figure 12

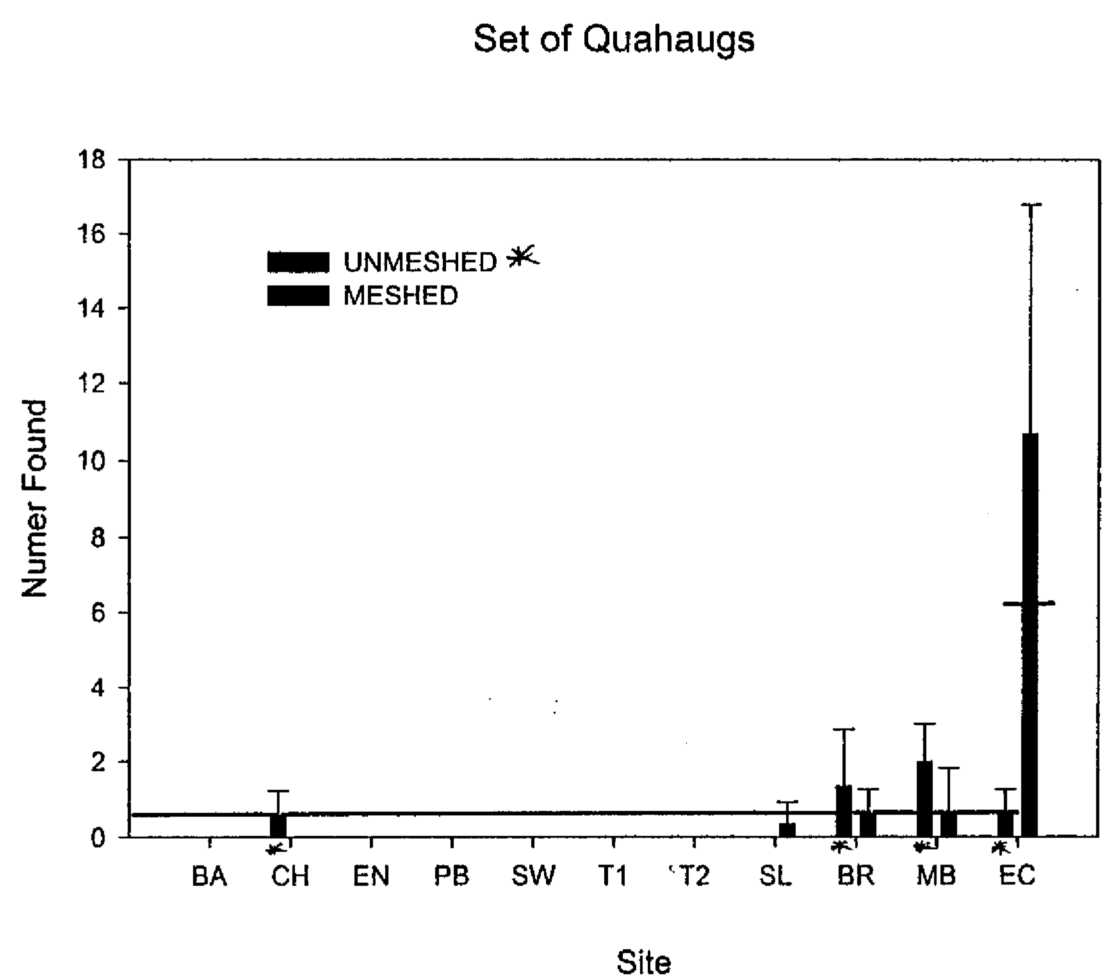

Set of Quahaugs
UNMESHED *
MESHED
Numer Found
0
2
4
6
8
10
12
14
16
18
BA
CH
EN
PB
SW
T1
T2
SL
BR
MB
EC
Site

Figure 13

Soft Shell Clam Results and Recommendations

Soft shell clam survival was generally lower than that for quahaugs, but did not significantly differ among sites nor among site*protection (Fig. 14). Survival, however, was significantly lower in the unprotected treatments than the protected treatments (Fig. 15).

Growth of soft shell clams (Fig. 16) was best by far at the Barnstable Aquaculture area (BA) site, followed by Boat Meadow (EC). Though sites varied, this was complicated by the addition of meshing (Fig. 17); in the figure, in pairs marked by a black asterisk the clams under mesh grew significantly faster than those unprotected, while in the pair marked by the blue asterisk (BA) the opposite was true.

Lastly, a set of soft shell clams was observed in the quahaug pots at one site (Fig. 18), with the set observed at TG in the Pamet River in Truro. Interestingly, protection did not yield a significantly greater recruitment. Despite this, as demonstrated above, netting may be expected to improve the survival of any recruited clams.

Based on these results, culture of soft shell clams in the aquaculture area of Barnstable Harbor appears promising given the fast growth and the ability to protect the seed. It is conceivable that ½" (12 mm) seed could be planted in the early summer and harvested before the end of the year under similar growth conditions.

[1] For soft shell clams, the Truro sites are as follows: T1 = TF, and T2 = TG

Soft Shell Clam Survival: Protected and Unprotected

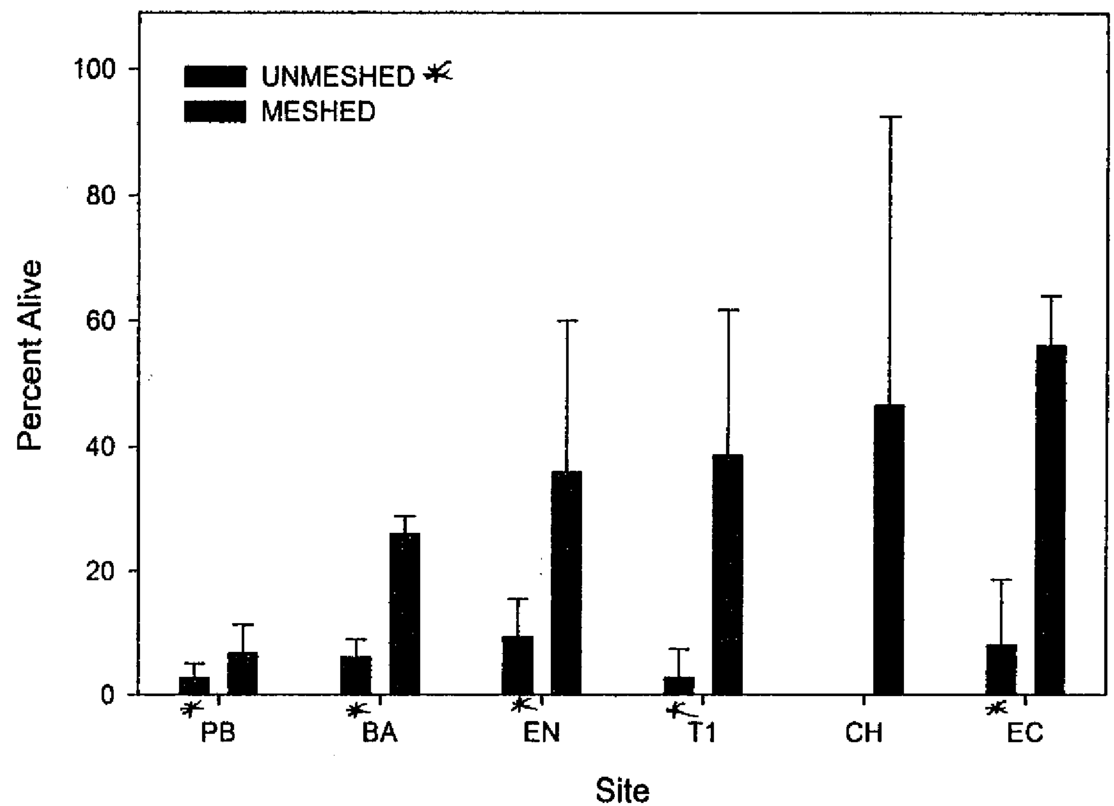


Figure 14

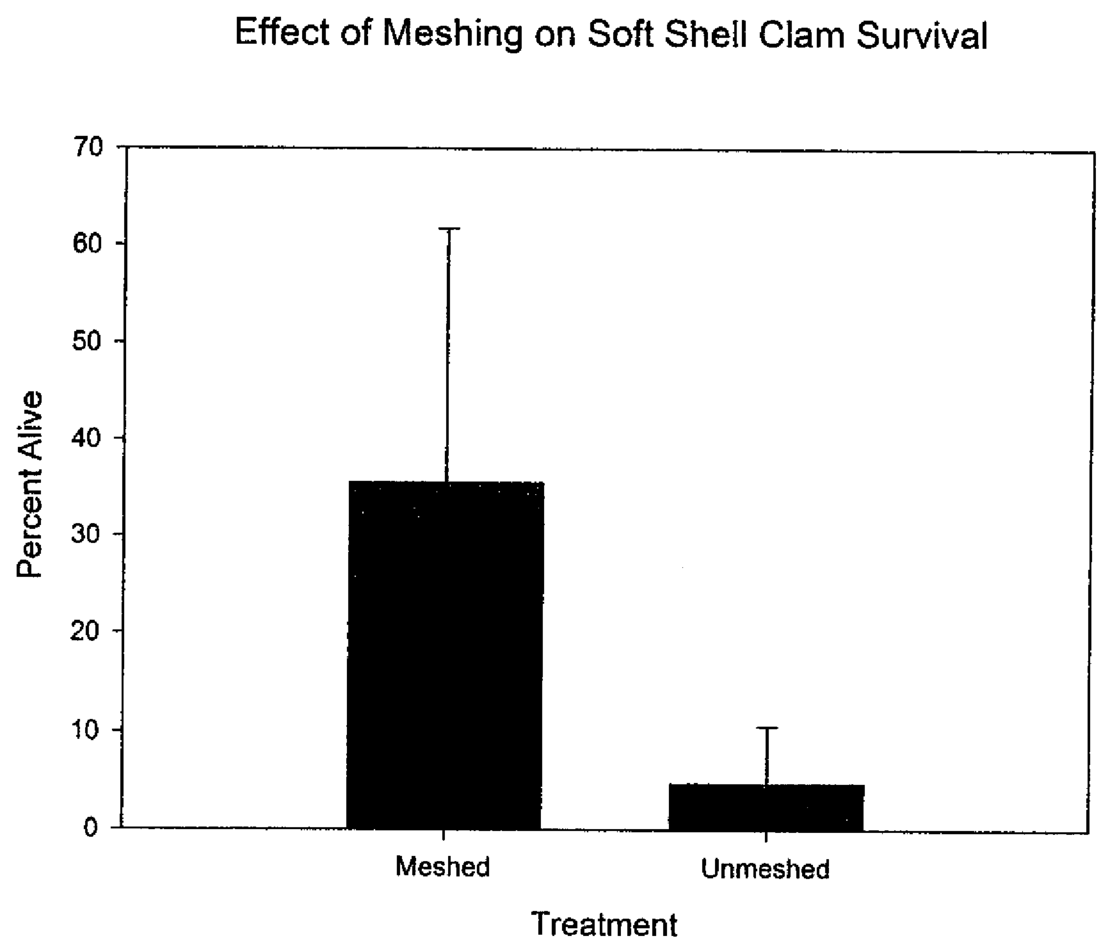

Effect of Meshing on Soft Shell Clam Survival
Percent Alive
70
60
50
40
30
20
10
0
Meshed
Unmeshed
Treatment

Figure 15

Soft Shell Clam Growth

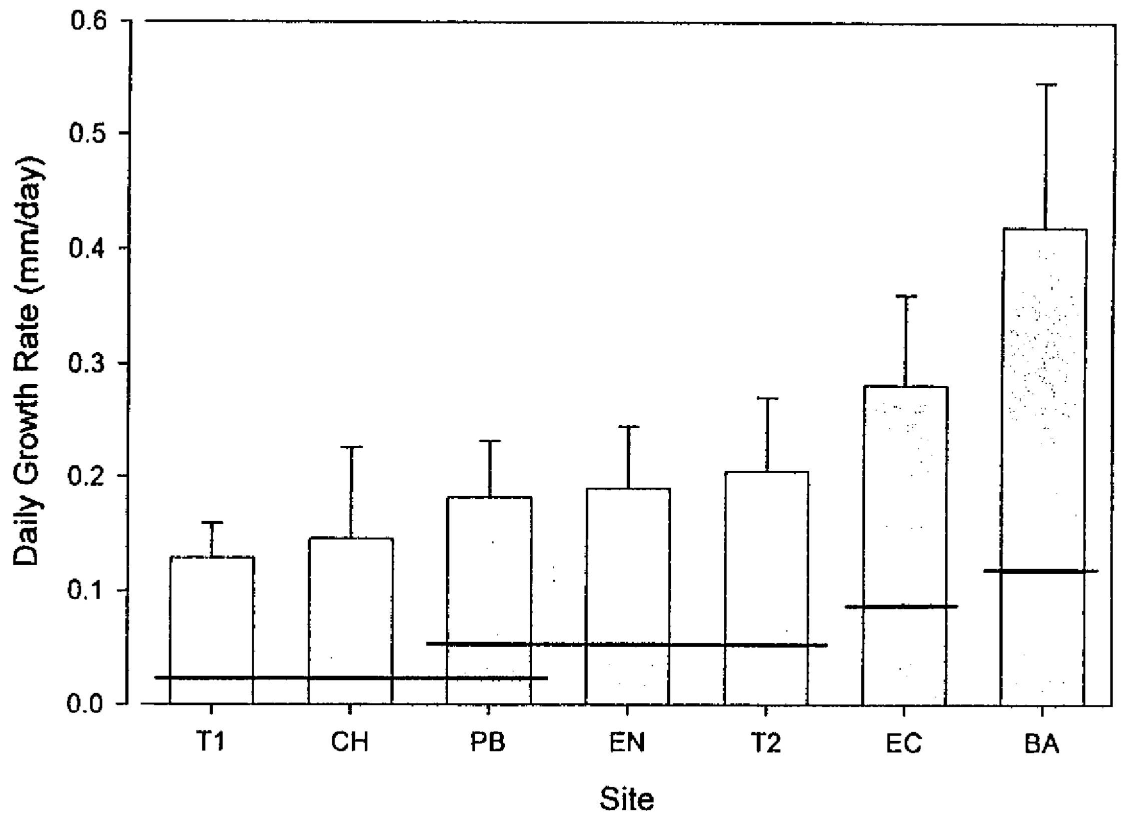
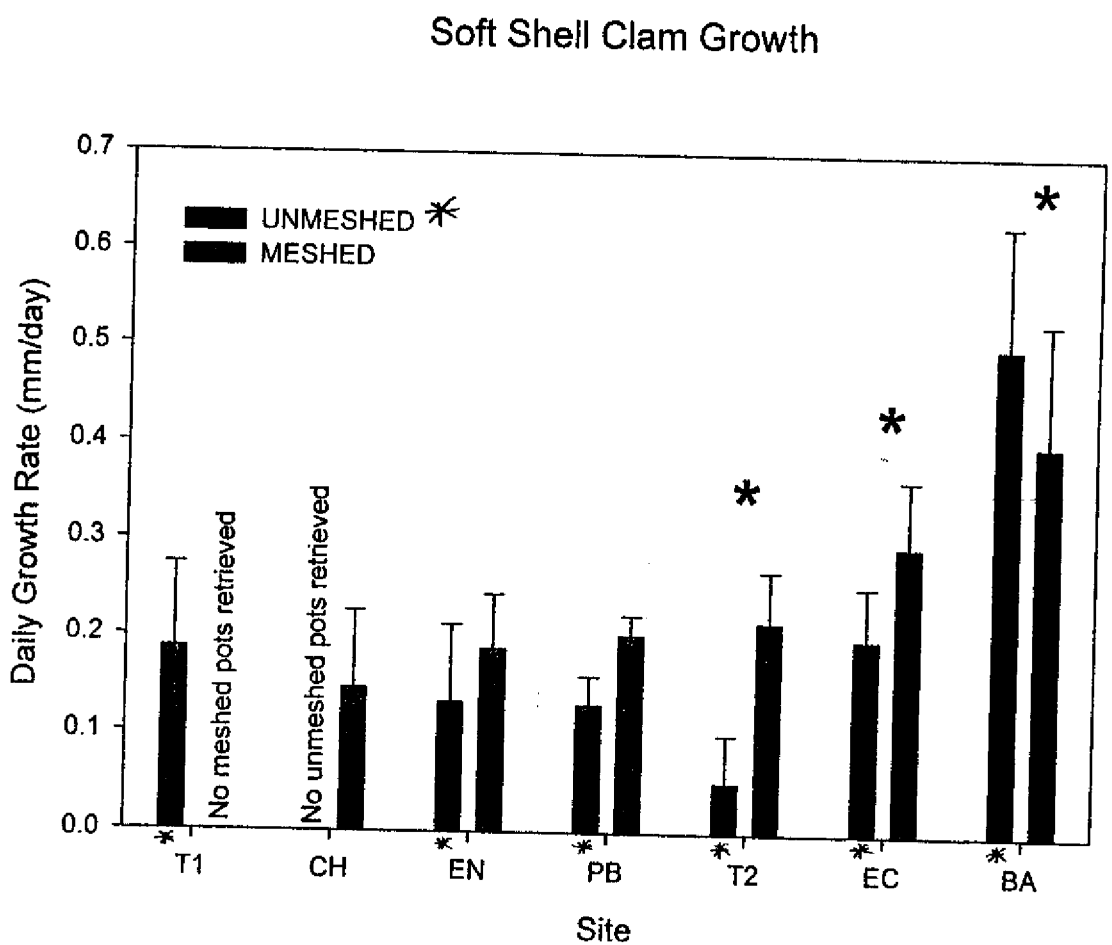


Figure 16



Soft Shell Clam Growth
UNMESHED
MESHED
Daily Growth Rate (mm/day)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
No meshed pots retrieved
No unmeshed pots retrieved
T1
CH
EN
PB
T2
EC
BA
Site

Figure 17

Set of Soft Shell Clams

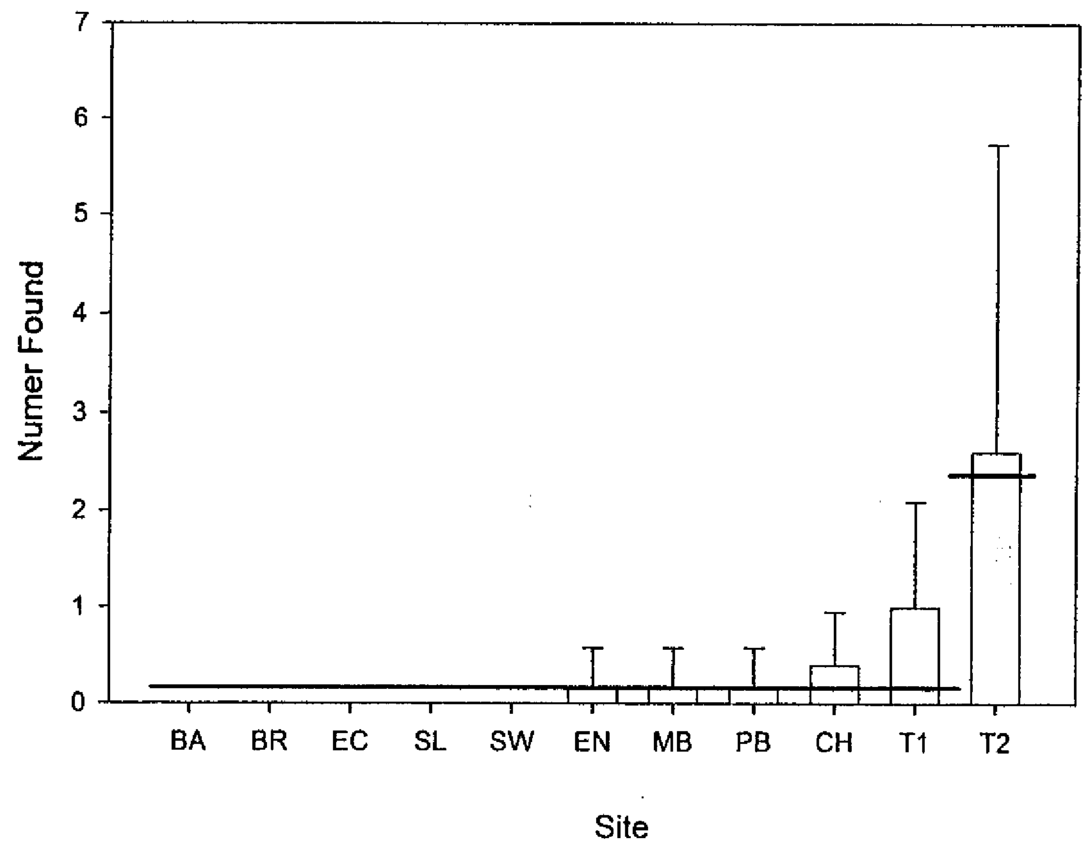


Figure 18