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THE EFFECTS OF CAGE MESH SIZE AND TIDAL LEVEL PLACEMENT ON THE GROWTH AND SURVIVAL OF CLAMS, *Mercenaria mercenaria* (L.) and *Spisula solidissima* (Dillwyn), IN THE COASTAL WATERS OF GEORGIA

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ABSTRACT: This work reports on the effects of cage mesh size and tidal level placement upon the growth and survival of the hard clam, *Mercenaria mercenaria* (L.), and the surf clam, *Spisula solidissima* (Dillwyn), in the coastal waters of Georgia. Surf clams (N = 50 per cage) and hard clams (N = 100 per cage) were each planted in replicated (N = 2) cages constructed of 3 mm, 6 mm, 13 mm and 19 mm mesh vexar plastic at various tidal levels. Cages were deployed by partial burial at the mean and the spring low water marks. At termination of the surf clam trial (6 months), there were no significant differences in survival determined for clams planted in different mesh cages at either tidal level or for clams grown in equivalent mesh size cages between tidal levels. There were significant differences in clam size with surf clams at the spring low water growing significantly larger than those at the mean low water mark. There were also significant differences in surf clam growth between different mesh size cages. Surf clams from 6 mm cages were smaller than those from other cages, while the largest clams reared were in the 13 mm and 19 mm mesh cages. Hard clam trials (15 month duration) illustrated that cage mesh size induced significant differences in survival of hard clams. Significantly fewer clams survived in 19 mm mesh cages than in cages of smaller mesh at both tidal levels. No significant differences in hard clam survival were detected among other mesh sizes nor between tidal levels; neither were significant differences between tidal levels determined for equivalent mesh sizes. Significant differences in hard clam growth were determined for clams grown in different mesh size cages and between tidal levels. Clam growth was greater at the spring low water mark. Clams grew larger in 3 mm mesh cages, least in 13 mm mesh cages with no significant differences in growth in the 6 and 19 mm mesh cages. Statistical analyses (t-tests) illustrated differences in clam growth among replicates at the spring low water mark. Growth may have been reduced in one set of cages as a result of cage excavation by currents.

In Georgia, hard and surf clam growth was found to be dependent upon cage mesh size. Clam survival was independent of cage mesh size as long as the initial size of the seed animals was greater than the mesh size of the cage.

Controlling mortalities and growing a crop to marketable size in as short a time period as possible are the essential ingredients for a successful (clam) mariculture operation. Many methods of protecting juvenile clams from predators have been developed. For instance, innumerable sizes, shapes and types of cages or boxes, tent structures, baffling devices, fencing, gravel or shell aggregate, or various combinations of these have been employeed in an attempt to control clam predation (*e.g.*, Castagna and Kraeuter, 1981; Kraeuter and Castagna, 1980; Menzel *et al.*, 1976). Most of these methods are site specific in their effectiveness. For instance, the use of gravel aggregate has proven very successful in the eastern shore area of Virginia (Castagna and Kraeuter, 1977); whereas, it was not successful in the waters of Long Island, New York (Flagg and Malouf, 1983), Chesapeake Bay (Haven and Loesch, 1973) or in Florida (Menzel *et al.*, 1976). Cage culture, either floating, placed on the bottom or partially buried into the bottom, is the common method of growing clams. Yet, there are no reports on the optimum mesh size of the cage.

The purpose of this research was to determine the effects of cage mesh size upon the growth and survival of the hard clam, *Mercenaria mercenaria* (L.) and the surf clam, *Spisula solidissima* (Dillwyn) for environmental conditions in the coastal waters of Georgia. Hard clams are of commercial importance and are presently being farmed in the coastal waters of Georgia, while the surf clam has shown potential as an aquaculture species (Goldberg, 1980; Krzynowek and Wiggan, 1982).

METHODOLOGY

Hard clams at a mean shell length (longest possible measurement, *i.e.*, anterior-posterior) of 19.5 ± 0.2 (SE) mm were obtained from Aquaculture Research Corporation, Dennis, Massachusetts, and surf clams at a mean shell length of 41.5 ± 0.3 mm were obtained from Mercenaria Manufactors, Inc., Millsboro, Delaware. Hard clams and surf clams arrived in Georgia via air freight on October 5 and 23, 1985, respectively. All clams were temporarily held in raceways at the shellfish hatchery building on Skidaway Island until field planting on October 24/25, 1985.

Each test cage was 30 × 30 × 30 cm in size, constructed of either 3 mm, 6 mm, 13 mm or 19 mm mesh vexar plastic netting. The only exception was for the 3 mm mesh cages. These cages had an outer skin of 19 mm mesh netting with an inner lining of 3 mm mesh netting. Previous work showed that cages constructed of 3 mm mesh netting did not withstand field conditions for any prolonged period of time (personal observation). Eight frames (270 × 30 × 90 cm) were constructed with 6 mm reinforcement rods (Fig. 1). On each frame, a 30 × 30 × 30 cm cage of each mesh size was attached with a 30 cm interval between cages. A piece of 6 mm mesh plastic was attached at both ends in an attempt to make each cage equal in treatment (see Fig. 1). Four frames with cages of each mesh size were buried to a depth of 25 cm into the sandy-mud substrate at the mean low water mark at the southern end of Cabbage Island, Georgia (Fig. 2). The remaining frames were buried as above at the spring low water mark.

On October 24/25, 1985, replicates of 100 hard clams ($\bar{x}$ = 19.5 mm) per cage were placed within cages attached to two frames at the spring low water mark and two frames at the mean low water mark. The remaining frames were seeded with 50 surf clams ($\bar{x}$ = 41.5 mm) per cage. Cages were sealed with tops of equivalent mesh sizes. All cages were sampled seasonally, with clams being removed from individual cages, counted, measured for shell length to the nearest

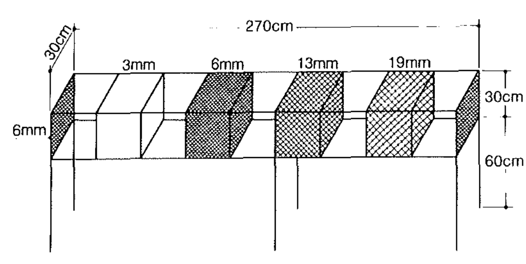

Figure 1. Frames constructed of 6 mm diameter reinforcement rods onto which test cages of each mesh size were attached. Frames and cages were buried so that approximately one-half of the cages were exposed to the tides.

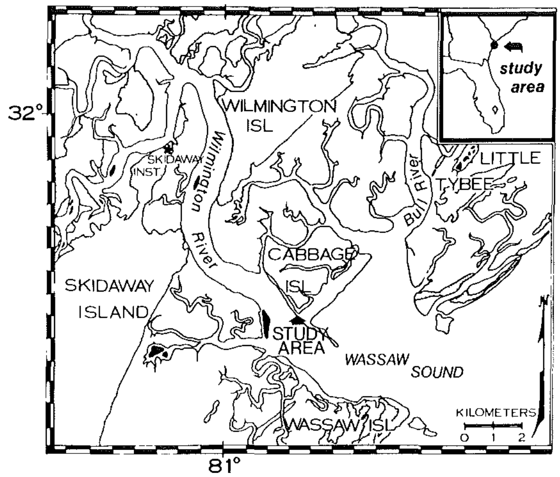

Figure 2. Test site location for the growing of *Mercenaria mercenaria* and *Spisula solidissima* at the southern end of Cabbage Island, Wassaw Sound, Georgia.

0.5 mm with vernier calipers and returned to their respective plots. The surf clam experiment was terminated after 6 months because it was known that the strain involved cannot survive the summer water temperatures in Georgia. The hard clam experiment ran for 15 months.

RESULTS

Surf Clams

The survival of surf clams grown in the various mesh cages is given in Table 1. By May 1986, there were no significant differences (as determined by a Kruskal-Wallis 1-way Analysis of Variance, Table 2) in clam survival among the eight mesh size cages planted at the mean low water mark or those planted at the spring low water mark. Furthermore, there were no significant differences in clam survival between equivalent mesh size cages planted at the mean low water mark versus those at the spring low water mark.

Growth measurements for the surf clams are given in Table 1. By January 1986, there were no significant differences (as determined by 3-way Factorial ANOVA, Table 3) in size attained among cage mesh sizes for clams planted at the spring low water mark or at the mean low water mark. There were also no significant differences in size attained among clams planted in equivalent cage mesh sizes at mean versus spring low water marks. By May 1986, there were significant differences (as determined by ANOVA) among clam size in terms of tidal height and mesh size, but not between replicate cages. One-way ANOVAs for clam growth versus tidal height and mesh size also showed significant differences. The Student-Newman-Keuls (S-N-K) multiple range test shows that surf clam growth was poorest in the 6 mm mesh cages and greatest in the 13 and 19 mm mesh cages.

Hard Clams

By January 1987, hard clam survival was lowest (significant as determined by Kruskal-Wallis 1-way ANOVA, Table 2) in the 19 mm mesh cages at both the mean and spring low water marks (Fig. 3 and Table 4); however, no significant differences in clam survival occurred among other cage mesh sizes between tidal heights or among tidal heights.

By January 1986, there were significant differences (as determined by ANOVA, Table 5) in clam size among tidal height treatments, but not among cage mesh size treatments or in replicate samples (see Table 4). One-way ANOVAs comparing clam size among cage mesh size or tidal height treatments showed the same results. By May 1986, hard clams grown at spring low water were significantly larger (as determined by ANOVA) than those grown at mean low water mark, while cage mesh size was also shown to have a significant effect on size attained. One-way ANOVAs for clam size versus tidal height and cage mesh size showed significant differences. Clams in the 3 mm mesh cages were larger, as determined by S-N-K multiple range test, than those in other

Table 1. Growth and survival of surf clams, *Spisula solidissima*, grown in various cage mesh sizes at the mean and spring low water marks on Cabbage Island, Georgia. Size is given as mean shell length in mm ± one standard error.

	25 Oct. 1985		7 Jan. 1986		8 May 1986		
Mesh Size	Mean Shell Length mm	No. of Clams	Mean Shell Length mm	No. of Clams	Mean Shell Length mm	No. of Clams	% Surv.
Mean Low Water							
3 mm	41.5 ± 0.3	50	45.7 ± 0.6	ND*	54.8 ± 0.5	44	88
3 mm	41.5 ± 0.3	50	45.1 ± 0.6	ND	57.4 ± 0.6	35	70
6 mm	41.5 ± 0.3	50	47.7 ± 0.6	ND	57.3 ± 0.6	39	78
6 mm	41.5 ± 0.3	50	44.2 ± 0.6	ND	56.7 ± 0.5	44	88
13 mm	41.5 ± 0.3	50	45.8 ± 0.5	ND	56.5 ± 0.5	46	92
13 mm	41.5 ± 0.3	50	46.4 ± 0.5	ND	59.3 ± 0.7	37	74
19 mm	41.5 ± 0.3	50	47.4 ± 0.9	ND	58.1 ± 0.6	35	70
19 mm	41.5 ± 0.3	50	47.9 ± 0.7	ND	59.1 ± 0.6	42	86
Spring Low Water							
3 mm	41.5 ± 0.3	50	47.0 ± 0.5	ND	59.0 ± 0.7	37	74
3 mm	41.5 ± 0.3	50	46.4 ± 0.5	ND	59.8 ± 0.7	42	84
6 mm	41.5 ± 0.3	50	46.5 ± 0.4	ND	58.2 ± 0.7	46	92
6 mm	41.5 ± 0.3	50	47.3 ± 0.6	ND	58.6 ± 0.5	47	94
13 mm	41.5 ± 0.3	50	47.0 ± 0.7	ND	57.9 ± 0.8	35	70
13 mm	41.5 ± 0.3	50	46.4 ± 0.6	ND	58.3 ± 0.6	42	84
19 mm	41.5 ± 0.3	50	45.9 ± 0.5	ND	58.9 ± 0.8	25	50
19 mm	41.5 ± 0.3	50	46.6 ± 0.4	ND	59.8 ± 0.8	44	88

* ND = Not Determined.

mesh size cages (see Table 6). By January 1987, significant differences (ANOVA) in clam size versus cage mesh size, tidal height placement, and replicate cages occurred (Table 5). One-way ANOVAs showed that significant differences in clam size between cage mesh size and tidal heights occurred (Table 5).

Table 2. The results of a nonparametric Kruskal-Wallis test on percent survival of surf clams and hard clams.

Surf Clams				
1-Way K-W ANOVA				
May 1986	Cases	Chi-square	Sign. Level	
Tidal Height	16	0.0112	0.9157	NS
Mesh Size	12	2.9751	0.2259	NS
Hard Clams				
Kruskal-Wallis Analysis				
		Test Stat.	Sign. Level	
Jan. 1986		9.1856	0.0269	S
May 1986		8.9104	0.0305	S
Jan. 1987		9.0259	0.0289	S

The S-N-K multiple range test showed that clams grown in the 13 mm mesh cages were smaller than those grown in other cages (Table 6). Since significant differences in cage replication occurred (see below), those cages that were disturbed by storm activities were removed from the data set. These adjusted data show that significant differences in size (ANOVA) in terms of tidal height and cage mesh size occurred, but not in terms of cage replications (Table 5). One-way ANOVAs showed similar results (Table 5). A S-N-K multiple range test showed that clams grown in the 13 mm mesh cages grew the least, with those grown in the 3 mm mesh cages growing the greatest, and no differences in growth between the 6 and 19 mm mesh cages (Table 6).

At the study termination for hard clams, it was found that one frame of cages at the spring low water mark had

Table 3. The results of the Analysis of Variance (ANOVA) tests for surf clam size when planted in different mesh size cages and at different tidal heights.

Factor	DF	F	P
Surf Clams	Jan. 1986		
3-way ANOVA			
Height	1:465	1.626	0.203
Replicate	1:465	1.251	0.264
Mesh	3:465	1.521	0.208
1-way ANOVA			
Height	1:479	1.4260	0.233
1-way ANOVA			
Mesh	3:477	1.4432	0.229
Surf Clams	May 1986		
3-way ANOVA			
Height	1:617	61.639	0.000**
Replicate	1:617	0.002	0.967
Mesh	3:617	15.380	0.000**
1-way ANOVA			
Height	1:631	44.280	0.000**
1-way ANOVA			
Mesh	3:629	10.393	0.000**

** = P<.001

been excavated by the currents. Clams were still contained within the various cages, but with no sediment. As these cages had not been checked since May 1986, they could have been disturbed for up to 8 months. Mean shell lengths of clams from this set of cages were significantly (as determined by both an ANOVA and t-test, alpha = 0.05) smaller than those in the undisturbed frame. Furthermore, clams from the undisturbed set of mesh cages were significantly larger (as determined by both ANOVA and t-tests, alpha = 0.05) than clams in equivalent mesh cages at the mean low water mark.

At termination, both frames positioned at the spring low water mark were heavily fouled with oysters; those at the mean low water mark were also fouled but to a lesser degree. In general, it appeared that the larger the mesh size of the cage, the heavier the fouling.

Table 4. Growth and survival of hard clams, *Mercenaria mercenaria*, grown in various cage mesh sizes at the mean and spring low water marks. Size is given as mean shell length in mm ± one standard error.

	24 Oct. 1985		7 Jan. 1986		8 May 1986		17 Sept. 1986		26 Jan. 1987	
Mesh Size	Mean Shell Length mm	No. of Clams	Mean Shell Length mm	No. of Clams	Mean Shell Length mm	No. of Clams	Mean Shell Length mm	No. of Clams	Mean Shell Length mm	No. of Clams
Mean Low Water										
3 mm	19.5 ± 0.2	100	23.1 ± 0.3	90	31.9 ± 0.5	86	47.3 ± 0.6	ND	51.2 ± 0.5	86
3 mm	19.5 ± 0.2	100	22.9 ± 0.4	92	31.0 ± 0.6	88	45.5 ± 0.5	ND	49.9 ± 0.6	91
6 mm	19.5 ± 0.2	100	23.3 ± 0.4	82	26.5 ± 0.4	79	35.4 ± 0.5	ND	48.0 ± 0.5	86
6 mm	19.5 ± 0.2	100	22.0 ± 0.3	ND*	28.9 ± 0.6	98	34.4 ± 0.5	ND	48.2 ± 0.7	95
13 mm	19.5 ± 0.2	100	21.4 ± 0.4	93	28.8 ± 0.6	81	37.3 ± 0.7	ND	44.6 ± 0.5	92
13 mm	19.5 ± 0.2	100	21.7 ± 0.4	99	29.5 ± 0.4	91	42.9 ± 0.7	ND	45.1 ± 0.5	92
19 mm	19.5 ± 0.2	100	22.2 ± 0.3	32	29.1 ± 0.5	34	39.9 ± 1.3	ND	48.5 ± 0.7	36
19 mm	19.5 ± 0.2	100	22.6 ± 0.4	22	28.8 ± 0.6	23	37.7 ± 0.8	ND	48.4 ± 1.1	23
Spring Low Water										
3 mm	19.5 ± 0.2	100	23.7 ± 0.3	74	33.4 ± 0.4	92	ND**	ND**	59.6 ± 0.7	92
3 mm	19.5 ± 0.2	100	23.4 ± 0.4	81	32.7 ± 0.4	94	ND	ND	49.2 ± 0.4***	94
6 mm	19.5 ± 0.2	100	23.7 ± 0.4	92	31.1 ± 0.3	95	ND	ND	57.4 ± 0.6	92
6 mm	19.5 ± 0.2	100	24.1 ± 0.3	ND	31.7 ± 0.4	99	ND	ND	49.1 ± 0.4***	97
13 mm	19.5 ± 0.2	100	24.5 ± 0.4	88	33.2 ± 0.4	86	ND	ND	58.6 ± 0.7	86
13 mm	19.5 ± 0.2	100	23.1 ± 0.4	90	30.0 ± 0.4	102	ND	ND	44.5 ± 0.4***	99
19 mm	19.5 ± 0.2	100	24.3 ± 0.3	27	31.1 ± 0.6	23	ND	ND	55.1 ± 0.9	33
19 mm	19.5 ± 0.2	100	22.6 ± 0.8	32	31.8 ± 0.4	27	ND	ND	49.2 ± 0.8***	21

* ND = Not Determined.
** ND = Not Determined due to winds keeping the tide in and cages not becoming exposed at low tide.
*** Cages in which sediment was washed out by currents and tide.

Table 5. The results of the Analysis of Variance (ANOVA) tests for hard clam size when planted in different mesh size cages and at different tidal heights.

Factor	DF	F	P
Hard Clams	Jan. 1986		
3-way ANOVA			
Height	1:446	39.293	0.000**
Mesh	3:446	2.034	0.108
Replicate	1:446	0.347	0.556
1-way ANOVA			
Height	1:460	38.134	0.000**
1-way ANOVA			
Mesh	3:458	1.943	0.122
Hard Clams	May 1986		
3-way ANOVA			
Height	1:574	114.137	0.000**
Mesh	3:574	22.437	0.000**
Replicate	1:574	1.360	0.244
1-way ANOVA			
Height	1:588	102.193	0.000**
1-way ANOVA			
Mesh	3:586	19.336	0.000**
Hard Clams	Jan. 1987		
3-way ANOVA			
Height	1:1076	203.925	0.000**
Mesh	3:1076	71.541	0.000**
Replicate	1:1076	228.194	0.000**
1-way ANOVA			
Height	1:1090	88.578	0.000**
1-way ANOVA			
Mesh	3:1088	45.407	0.000**
Hard Clams	Jan. 1987 (Adjusted data)		
3-way ANOVA			
Height	1:775	484.166	0.000**
Mesh	3:775	43.586	0.000**
Replicate	1:775	0.761	0.383
1-way ANOVA			
Height	1:779	510.142	0.000**
1-way ANOVA			
Mesh	3:777	28.119	0.000**

** = P<.001

DISCUSSION

This research has shown conclusively that cage mesh size had no effect upon the survival of either clam species, as long as the initial size of the seed animals were greater than the mesh size of the cage. Significant losses were observed for hard clams (seeding size $\bar{x}$ = 19.5 mm) placed within 19 mm mesh cages. The smaller clams were probably washed out of cages with the tides and currents. Evidence in support of this hypothesis can be obtained from the mortality pattern of these clams with major losses being suffered following initial planting; whereas after 3 months of clam growth, losses had dropped off sharply. Surviving clams in the 19 mm mesh cage had presumably grown to a sufficient size to prevent further wash out. Furthermore, no dead clams were found within the 19 mm mesh cages during sampling and many seed clams were recorded in the immediate vicinity of the 19 mm mesh cages. Tidal or current washout of clams is extremely important when one deals with smaller size seed animals. Hard clams used in this experiment were large for seed animals. A clam farmer generally utilizes smaller and less expensive seed sizes, *e.g.*, <10 mm in shell length.

If this experiment was undertaken using smaller (*e.g.* 6 mm) seed hard clams, there is little doubt, in the opinion of the authors, that there would have been low clam survival (due to tidal wash out) within the 13 mm and 19 mm mesh, cages, limited survival in the 6 mm mesh cages and good survival within the 3 mm mesh cages. Good clam survival of 6 mm seed planted in 3 mm mesh cages (Walker, 1984) and of 10 mm seed planted in 6 mm mesh cages (Walker and Humphrey, 1984) have been obtained in Georgia, whereas poor survival has been obtained when using 6 mm seed within 6 mm mesh cages (unpublished data). Thus wash out of clams (regardless of species) due to tidal flow or currents is an extremely important factor for clam growers to accommodate, especially in areas of relatively high tidal flux, *e.g.*, Georgia (2.4 to 3.0 meter tides).

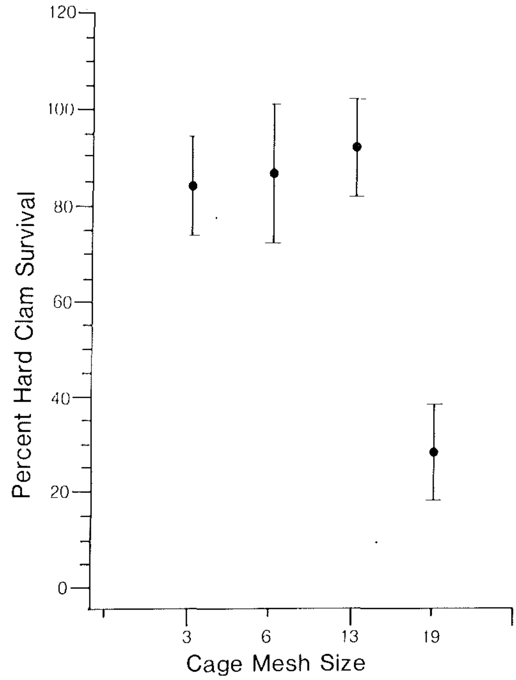

Figure 3. Combined mean percent survival with 95% confidence intervals for hard clams grown in different mesh size cages (January 1989).

Tidal height planting has been shown to have pronounced effects on the growth rates of both clam species in this study. Significant differences in surf and hard clam growth occurred with greater growth at the spring low water mark. This is in agreement with an earlier study (Walker and Heffernan, in press), where surf clams and hard clams of the same stocks used in this experiment were planted at approximately the same site, but in a different type of cage (13 mm mesh vinyl-coated wire). Significant differences in growth rates were observed between individuals planted at spring low water (greatest growth), mean low water (intermediate) and one hour above mean low water (lowest growth). No surf clams survived at the two hours above mean low water mark; whereas, there were no significant differences in survival for hard clams up to the three hours above mean low water mark (Walker and Heffernan, in press). Hard clam growth decreased with increases in tidal exposure (Walker and Heffernan, in press).

Interpretation of the effects of cage mesh size on surf and hard clam growth is more difficult than that of tidal height planting, and is compounded by the heavy oyster fouling on cages in the final months of the experiment. Surf clams grew best in the larger mesh size cages. Hard clams in the 3 mm mesh size cages were significantly larger in shell length after 7 months than those grown in other mesh size cages. If one discards data from disturbed cages, after 15 months, clams in the 3 mm mesh size cages were still larger than clams grown in other mesh size cages with clams from the 13 mm mesh cages growing the least. Only in January, 1987, were clams grown in 13 mm mesh cages found to be significantly different than clams grown in 6 mm or 19 mm mesh cages. By January, all cages were heavily fouled with oysters. In general, larger mesh size cages were more heavily fouled with decreasing levels of relative fouling with decreases in cage mesh size. Further-

Table 6. The results of a Student-Newman-Keuls multiple range test (alpha = 0.05) for surf clam or hard clam size versus cage mesh size.

Surf Clams — May 1986				
$\bar{x}$ shell length in mm	56.1	57.5	57.9	59.0
Cage mesh size in mm	6	3	13	19
Hard Clams — May 1986				
$\bar{x}$ shell length in mm	30.1	30.1	30.5	32.5
Cage mesh size in mm	19	6	13	3
Hard Clams — Jan. 1987				
$\bar{x}$ shell length in mm	46.6	49.9	50.6	51.8
Cage mesh size in mm	13	6	19	3
Hard Clams — Jan. 1987 — Adjusted Data				
$\bar{x}$ shell length in mm	47.5	50.3	50.8	52.9
Cage mesh size in mm	13	6	19	3

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more, cages at the spring low water mark were more heavily fouled than cages at the mean low water mark. The 19 mm and 13 mm cages at the spring low water mark were so heavily fouled with oysters covering the mesh of the cage at termination of the experiment that clams had to be removed through the cage bottom. By the end of the experiment, the actual cage mesh size of the 19 mm and 13 mm mesh cages was probably smaller than that of the 3 mm mesh size cages due to oyster fouling. Based on the overall data, it can be concluded that optimum hard clam growth occurred in the smallest mesh size cage; whereas optimum surf clam growth occurred in the largest mesh cage.

An unplanned result of this experiment was that hard clams were shown to grow better when maintained within the sediment rather than when they are free within cages and exposed to tidal action and currents washing them about the cage (see Table 4, May 1986). In all cases in this experiment where hard clams occurred in cages with sediment washed out, clams were found to be significantly smaller in shell length than those in replicate cages. This can be seen in the final sampling of hard clams at the spring low water mark. One set (or frame) of cages was completely without sediment for possibly up to 8 months (*i.e.*, May 1986 to January 1987, see Table 4). Clams in the disturbed cages averaged 6 to 14 mm less in mean shell length than those clams in their replicate cages.

Hard clam survival did not significantly differ between disturbed and nondisturbed cages. Fortunately, the exposure time of clams (*i.e.*, out of sediment) at the mean low water mark did not occur during the summer months, when clams exposed to direct sunlight and air temperatures up to 40°C die rapidly. Clams exposed for possibly up to 8 months (*i.e.*, May 1986 to January 1987) at the spring low water mark were only exposed on the lowest of tides, 4 to 6 days per month and only then for short periods of time before the tide returned. Furthermore, the cages themselves, especially the 3 mm and 6 mm cages, shaded the animals to some degree and the 13 mm and 19 mm cages at this time period were heavily covered with oyster spat and juveniles. Thus these animals were also well shaded, reducing the danger from tidal exposure.

The observed decrease in clam growth with increase in intertidal planting height is probably due to the decrease in submergence time, which presumably affects the feeding time of the clams. For clams in this study, clam growth decreased with increases in intertidal planting height. Newcombe (1935) and Belding (1910) observed that the rate of growth of the soft-shell clam, *Mya arenaria* (L.), decreased with increases in intertidal exposure time. Kerswill (1941), working in Canada, states "In the intertidal zone, the growth rate depends upon the extent of exposure at low tide; quahaugs will live but grow slowly near half-tide level, and the growth rate increases toward the lower levels, reaching a maximum just below low water level, provided there is no eel-grass or other obstruction to water circulation."

Greater hard clam growth was shown to be correlated with greater current speeds (Kerswill, 1949). He showed that in subtidally stacked series of clam trays, clams nearest the surface (area of greatest current) grew at a greater rate than those below it, with slowest growth occurring at the bottom trays (area of slowest currents). Furthermore, he showed that hard clams growing in eelgrass beds, which impede the current, grew less than those occurring on the sandflats. Clams from less dense areas of the eelgrass bed grew at intermediate values. Fiske *et al.* (1968) observed that hard clams grew poorly in eelgrass beds which presumably interfered with water circulation and food supply; however, they offered no data to support this observation. In North Carolina, hard clams grew at a greater rate inside eelgrass beds than those occurring out on the sandflats (Peterson *et al.*, 1984). Beal (1983) working in North Carolina, found that hard clams grew faster in seagrass areas than in unvegetated bottoms in one locality, slower in a second locality and at an equivalent rate in another area. Thus, clam growth was dependent upon site selection and the environmental parameters (food concentration, food type, current speed, etc.) of that location. In the absence of water, no feeding occurs and the longer the exposure time within the intertidal zone, the less the opportunity for feeding.

In this experiment, optimum hard clam and surf clam growth occurred in the 3 mm and 19 mm mesh cages, respectively, and at the spring low water mark. It is reasonable to assume the impediment to water currents is greater in the small (3 mm) mesh cages than in the larger ones (19 mm). Two possible explanations for the observed mesh size induced differences in hard clam growth, acting separately or in concert, are proposed. First, increased food availability; the elevated sedimentation rates in the smaller mesh cages bring more food particles from the water column within reach of clam siphons. Second, reduced disturbance; with lowered water currents, clams may have fewer interuptions to their feeding regime due to water turbidity. The latter hypothesis is supported by the reduced growth of hard clams grown in cages which had sediment removed (see above). Surf clams generally occur in high energy habitats (nearshore to offshore areas). Thus the higher current flow through the larger mesh cages is probably more natural to them. Based on the overall growth data, it can be concluded that optimum hard or surf clam growth is dependent upon cage mesh size, but that tidal cage planting height is more important.

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