OPTIMUM SEED PLANTING SIZE AND MESH SIZE OF BOTTOMLESS MESH ENCLOSURES FOR CULTURING THE NORTHERN

QUAHOG

MERCENARIA MERCENARIA (LINNAEUS, 1758), IN COASTAL GEORGIA

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ABSTRACT

Georgia quahog farmers presently grow 8- to 10-mm seed clams in protective mesh bags until they reach a size of approximately 25 mm. At this point, they are removed from the bags and placed beneath bottomless mesh enclosures for rearing to market size. Quahog farmers want to know if they can utilize smaller sized seed clams under finer mesh enclosures. A 4 X 5 factorial experiment with 5 replicate plots per factor was performed to determine the optimum combination of seed size (1 mm, 5 mm, 11 mm, and 14 mm mean sizes) and protective mesh size of bottomless mesh enclosures (1.5 mm, 3 mm, 6 mm, 12 mm, and 18 mm) for the culturing of northern quahogs, *Mercenaria mercenaria* (Linnaeus, 1758), in coastal Georgia. One-meter- square test plots (N=100) were randomly established and seeded at 750 quahogs per plot on an intertidal sandy-mud flat on Four Mile Island in May 1998. Plots were terminated in November 1998. No 1-mm and few 5-mm (3.1 ± 7.7%) seed survived regardless of the size of the protective mesh enclosure. Likewise, essentially no quahogs, regardless of planting size, survived under the 18-mm mesh enclosures (0.48 ± 0.48% for 14 mm seed). The results of this study show that seed quahogs as small as 14 mm can be cultured successfully under bottomless mesh enclosures of 3-mm (54.9% survival) and 6-mm (65.9% survival) mesh sizes. In general, quahog seed grew faster under 6-mm bottomless mesh regardless of the initial size of the planting seed. By utilizing smaller seed under bottomless mesh enclosures, the farmer can reduce by one-third the time and effort it takes to grow seed to a 25-mm size in mesh bags. In order to increase overall survival of seed to harvesting size, it is recommended that farmers grow the seed to a shell length of at least 20 mm within the mesh-bag-line system prior to placement under bottomless mesh enclosures.

Georgia has the greatest tidal amplitude (2.4 to 3.0 m) along the southeastern United States coastline. Due to the large flow of water in and out of our salt-marsh estuaries, techniques developed for rearing northern quahogs, *Mercenaria mercenaria* (Linnaeus, 1758), in other United States coastal areas do not work well in Georgia.

The University of Georgia Marine Extension Service has developed a simple and inexpensive method for culturing the northern quahog in soft-bottom mud and sandy-mud areas which predominate in coastal Georgia. Large-size quahog seed (12-mm in shell length) purchased from a commercial hatchery are placed in a mesh-bag-line culture system (Walker and Hurley 1995; Walker et al. 1997; Walker 1997). Seed (N = 7,500 per bag) are grown in ADPI mesh bags (originally designed to culture oysters). A line is attached to the bags, which are placed on the river bottom for approximately 4 to 6 months. To ensure high rates of seed survival, bags with quahogs must be shaken monthly to remove accumulated silt and sediment. This is a very labor intensive procedure. As the seed grow, quahog density per bag is reduced by half on a bimonthly basis. During this thinning process, the original bags are replaced by one's with a larger mesh size. Additional mesh bags are deployed to house the remaining quahogs. Once seed reach a shell length of approximately 25 mm, 7,000 to 9,000 clams are placed directly on the intertidal river bottom and covered with a bottomless mesh enclosure (Hurley and Walker 2000). Enclosures are constructed of either 6-mm or 12-mm plastic mesh screen attached to a 2.4 by 3.7 m (8.9 m^2) frame made of 12-mm diameter reinforcement rods. Sides of the plots are protected by 12.7-cm wide strips of vinyl house siding. The siding is pushed down until it is flush with the top of the sediment. This prevents predators from burrowing under the enclosures from the sides and also keeps quahogs from migrating out of the plot. Quahogs grow for approximately 8 to12 months under the enclosures until they reach market size. The combination of mesh bags and bottomless mesh enclosures produces a market size quahog in 15 to 18 months with high survival rates (Hurley and Walker 2000).

The use of mesh bags greatly increases survival rates of small seed when compared to tray or bottom cage culture methods (Walker and Hurley, 1995). However, the use of mesh bags is very labor intensive. Once quahogs are placed under the bottomless mesh enclosures, they must be checked on a monthly basis. If sedimentation begins to bury the enclosures, the tops are lifted by one end, shaken and laid back down. It requires one person approximately two minutes to clean each enclosure.

Although this method for growing quahogs is successful, farmers want to know if even smaller quahogs can be planted under bottomless mesh enclosures, thus reducing effort and time to maintain them. We chose 25 mm as the best size for planting in the bottomless mesh enclosures, since by then quahogs are relatively safe from most macro-predators such as mud crabs, *Panopeus herbstii* (Whetstone and Eversole 1981) and blue crabs, *Callinectes sapidus* (Gibson and Blogoslawski 1989; Menzel 1989). In addition to determining optimum mesh size for the enclosures, this study also attempts to ascertain the optimum planting size for quahog seed obtained from commercial clam hatcheries.

A 4 X 5 factorial experiment with 5 replicates per factor was designed to determine both the optimum size for quahog planting seed and the optimum plastic mesh size for the bottomless mesh enclosures. Seed sizes of $\bar{x}$ =1.4 ± 0.02 (SE) mm (range 0.8 to 1.8 mm), $\bar{x}$ = 5.2± 0.03 mm (range 4.4 to 5.9 mm), $\bar{x}$ = 11.3± 0.10 mm (range 7.3 to 14.0 mm), and $\bar{x}$ = 14.2 ± 0.10 mm (range 11.2 to 18.2 mm) were purchased from SeaPerfect, Inc. in South Carolina. One hundred quahogs in the two smaller sizes and two hundred each in the larger two sizes were measured with Vernier calipers to determine initial mean shell length (longest possible measurement, i.e., anterior-posterior) to the nearest 0.5 mm. Each size class of quahogs was divided into 25 groups of 750 quahogs. Counts were performed manually. Bottomless mesh enclosures were made of 1.5-mm, 3-mm, 6-mm, 12-mm, and 18-mm diameter vexar plastic mesh. Plastic meshes were attached to one-meter-square frames made of 12-mm diameter reinforcement rod. One hundred experimental plots, each 1 square meter, were established. Five rows of 20 plots each were established on a sandy-mud intertidal flat on Four Mile Island. Each row had one replicate of the combination of quahog seed size and mesh enclosure size. Test plots were assigned randomly by a random numbers table. The first row started at the spring low-water mark. Thereafter, each row was spaced approximately one meter apart farther up into the gently sloping intertidal zone. It takes approximately 30 minutes for all plots to be covered or uncovered by the tide. Vinyl house siding was cut into 12.7-cm-wide strips, 4-meters long. The siding was bent at right angles at 1-m intervals to form a square. Then it was pushed down into the sandy, mud substrate until it was flush with the sediment surface forming a submerged barrier around the plot. Each plot was seeded with 750 quahogs of the appropriate size. A bottomless mesh enclosure of appropriate mesh size was then placed over the top of the plot. Plots were set up on May 15-17, 1998 and seeded on May 22, 1998.

An experimental plot identification tag indicating the initial seed stocking size and diameter of the bottomless mesh enclosure was placed into a plastic bag. The plastic bag was rolled up and inserted into a 6-cm-long piece of 18-mm diameter schedule 80 PVC pipe. The pipe and tag were buried in the plot along with the quahogs.

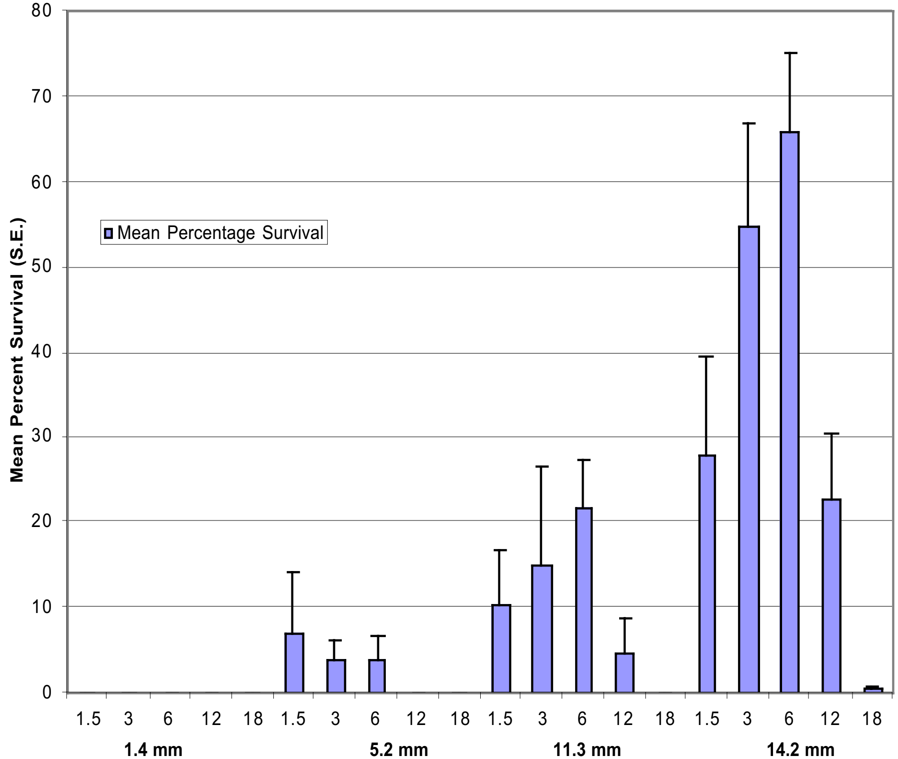
Plots were harvested on November 3, 4, 17, and 18, 1998. All quahogs, tags, and surface sediments were placed into plastic sacks in the field. Back at the laboratory, sediment, tag, and quahogs were emptied onto a 2 X 2 mm mesh screen and washed to remove the sediment. When possible, 30 quahogs per plot were randomly selected and measured for shell length. Then, total count of surviving quahogs per plot was determined.

Survival and quahog shell length data were analyzed by one-way Analysis of Variance (ANOVA) ($\alpha = 0.05$) and Tukey's Studentized Range test (SRT) ($\alpha = 0.05$). Each size group of quahogs was analyzed by ANOVA to determine if significant differences in quahog size occurred among the various mesh sizes of the enclosure. Percent survival data was arcsine transformed prior to analysis. One-way ANOVA and Tukey's SRT were performed on survival data for each size class of quahogs.

Survival of quahogs per size class and per bottomless mesh enclosure size are given in Figure 1. Overall, quahog survival per size class regardless of bottomless mesh enclosure size was 0%, 3.0±1.5%, 10.4±3.1%, and 34.4±6.1% for 1-mm, 5-mm, 11-m and 14-mm quahogs, respectively. Quahog survival per mesh enclosure size regardless of initial quahog stocking size was 11.4±4.2%, 18.4±6.3%, 23.0±6.5%, 5.9±2.9%, and 0.2±0.13% for the 1.5-mm, 3-mm, 6-mm, 12-mm, and 18-mm mesh enclosures, respectively. No 1-mm size quahogs survived regardless of mesh enclosure size. Virtually, no quahogs (0.2%), regardless of initial stocking size, survived under 18-mm mesh enclosures. For 5-mm quahogs, ANOVA revealed no significant differences ($p = 0.4383$) in survival among quahogs planted under the various sizes of mesh enclosures. Survival ranged from 0% for 5-mm quahogs from the 12-mm and 18-mm mesh enclosures to 7.1±7.1% under the 1.5-mm mesh enclosures. Survival under the 3-mm and 6-mm mesh enclosures was 3.9±2.4 and 4.1±2.6%, respectively. For the 11-mm quahogs, ANOVA showed no significant differences ($p = 0.0726$) in survival among quahogs planted under the various mesh treatments. Survival of quahogs planted under various mesh enclosures ranged from 0% under 18-mm mesh enclosures to 21.8±5.5% under the 6-mm mesh enclosures. Quahog survival under the 1.5-mm, 3-mm, and 12-mm mesh enclosures was 10.5±6.4%, 14.9±11.6%, and 4.7±4.2%, respectively. Survival of 14-mm quahogs ranged from 0.48±0.48% for quahogs under 18-mm mesh enclosures to 65.9±9.1% for those under 6-mm mesh enclosures. Quahog survival under the 1.5-mm, 3-mm, and 12-mm mesh enclosures was 27.9±11.7%, 54.9±12.0% and 22.7±7.8%, respectively. ANOVA showed that significant differences ($p < 0.0001$) in survival of 14-mm quahogs did occur with survival of clams in the 18-mm mesh enclosures being statistically lower than

FIGURE 1

The mean percent survival ± S.E. of northern quahog, *Mercenaria mercenaria,* seed of different sizes planted under various mesh sizes of bottomless-mesh enclosures in coastal Georgia.



those in the 1.5-mm, 3-mm, and 6-mm mesh enclosures. Quahog survival under the 12-mm mesh enclosures was significantly different from that for the 6-mm mesh enclosures, but not of that of other mesh sizes.

In general, quahog growth was significantly higher when seed were reared under 6-mm or 3-mm mesh enclosures for all initial planting seed sizes, with the exception of the 1.4-mm seed where there were no survivors (Fig. 2). One-way ANOVA and Tukey's STR comparing growth of 5-mm seed showed that quahogs were significantly ($p < 0.0001$) larger when cultured under 6-mm mesh plots ($\bar{x} = 24.6 \pm 0.41$ mm). Five-mm seed were statistically equal in size when grown under 3-mm mesh ($\bar{x} = 21.9 \pm 0.32$ mm) and under 1.5-mm mesh enclosures ($\bar{x} = 20.2 \pm 0.27$ mm). No 5-mm seed survived in 12-mm or 18-mm mesh plots. ANOVA revealed significant differences ($p < 0.0001$) in size for 11-mm seed grown under the mesh enclosures. Tukey's SRT showed that quahogs from the 6-mm mesh enclosures ($\bar{x} = 28.7 \pm 0.30$ mm) were not statistically different in size from those under the 12-mm mesh enclosures ($\bar{x} = 26.1 \pm 0.40$ mm). They were, however, larger than quahogs from other treatments. Quahogs were not significantly larger under 12-mm mesh treatment than those under 3-mm mesh enclosures ($\bar{x} = 25.0 \pm 0.41$ mm). Quahogs were smaller than other treatments when grown under the 1.5-mm mesh enclosure ($\bar{x} = 20.7 \pm 0.29$ mm), and no clams survived under the 18-mm mesh treatments. In the 14-mm quahog group, clams were statistically ($p < 0.0001$) the same size under 6-mm ($\bar{x} = 31.8 \pm 0.20$ mm) and 3-mm mesh enclosures ($\bar{x} = 30.8 \pm 0.19$ mm). Both were larger than quahogs reared under the 12-mm mesh enclosure ($\bar{x} = 28.8 \pm 0.23$ mm). Quahogs under the 1.5-mm mesh treatment ($\bar{x} = 25.5 \pm 0.28$ mm) were the same size as those under the 18-mm mesh enclosures ($\bar{x} = 24.2 \pm 0.77$ mm), but were significantly smaller than quahogs in the other treatments.

DISCUSSION

Quahog farmers in Georgia want to utilize smaller sized seed for culturing clams under bottomless mesh enclosures. The mesh bag stage is the most labor intensive phase of culturing quahogs in Georgia. So it stands to reason that the longer they stay in the mesh bags, the more time and effort it takes to clean and maintain the bags. Presently, 10- to 12-mm seed clams are purchased from commercial hatcheries and placed into a mesh-bag-line culture system for up to 6 months for rearing up to a 25-mm size. Once they have attained 25 mm in shell length in the bags, clams are placed under bottomless mesh enclosures for rearing to harvest size (44.5 mm in shell length). The bottomless mesh enclosure phase lasts for approximately 8 to 12 months, and it requires little effort to maintain the plots. This combination of growing methods allows quahogs to grow to market size in 15 to 18 months with fairly high survival rates, i.e., > 74% survival (Hurley and Walker 2000).

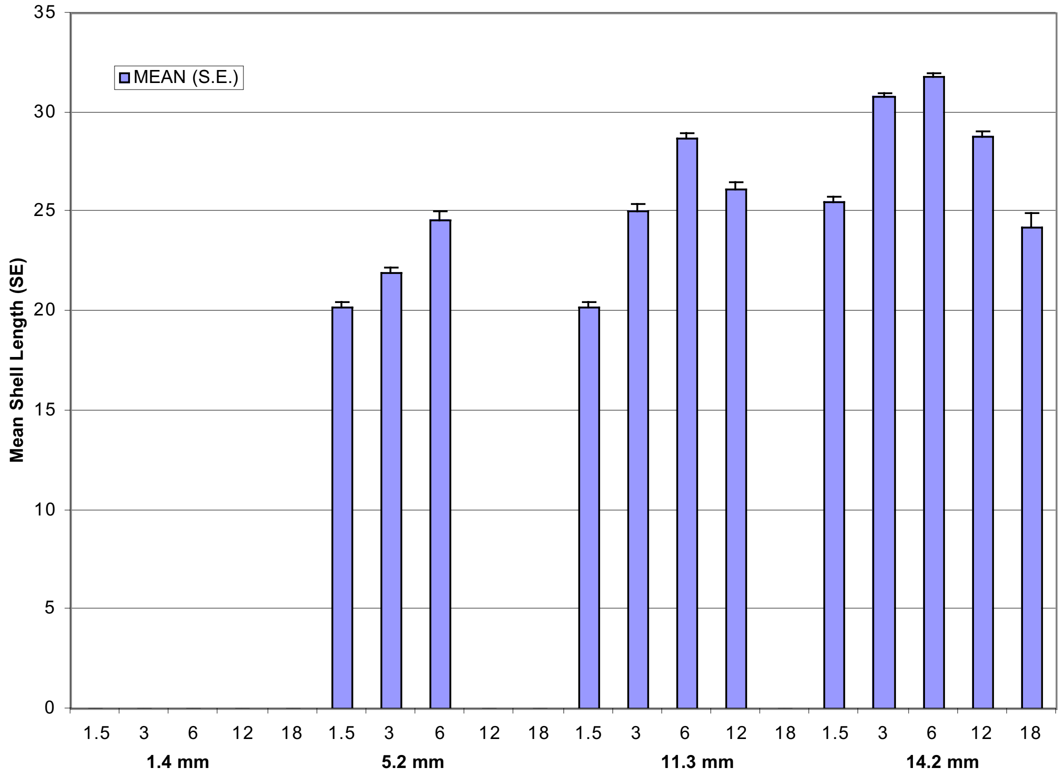
To successfully culture quahogs to a marketable size, a farmer must have survival rates of at least 50%. In this experiment, acceptable quahog survival occurred only when 14-mm seed were used in conjunction with 3-mm or 6-mm bottomless mesh enclosures. The use of 1-mm and 5-mm seed under bottomless mesh enclosures resulted in almost 100% mortality. The use of 11-mm seed under enclosures also resulted in unacceptable losses. Likewise, and regardless of the initial seed size used, the use of 1.5-mm, 12-mm, and 18-mm mesh enclosures also failed to protect quahog seed adequately.

Mortality of seed quahogs in the larger mesh sizes was probably the result of exposure and opportunity. As silt accumulated on the enclosures, quahogs migrated up through the enclosure, whereupon they either were washed away by currents or were easily accessible to predators. Only a few individual quahogs (some ranged to 18 mm) from the initial 14-mm size group would have been large enough to be retained by the 18-mm mesh enclosures. It is presumed that the few 14-mm seed (0.48%) survivors that were planted under the 18-mm mesh were probably larger than the mesh diameter at the start of the experiment. Likewise, the 11- mm seed had relatively low survival under the 12-mm mesh enclosures compared to the smaller diameter mesh enclosures. The 11-mm seed had 100% mortality under the 18-mm diameter mesh. Several rough oyster drills, *Eupleura caudata*, were found in the washed samples from the larger mesh enclosure plots. Due to the small size of this snail, it could easily pass through the mesh openings of the12-mm and 18-mm mesh enclosures, but it could not have entered the smaller mesh enclosures. Quahog shells with drill holes were observed, but no quantitative observations on this predation pressure were recorded.

In general, quahog seed grew faster under 6-mm bottomless mesh enclosures regardless of initial seed planting size (Fig. 2). The largest rate of quahog growth (a mean shell length increase of 19.4 mm or 373% increase) occurred with the 5-mm seed planted under 6-mm mesh enclosures; however, survival was only 4.1%. Quahog seed with initial sizes of 11.3 mm and 14.2 mm reared under 6-mm mesh enclosures had 154% and 124% increase in size, respectively. In a previous experiment using 26.6-mm seed quahogs under mesh enclosures, clams grew significantly larger in 12- and 19-mm mesh enclosures than they did in 6-mm mesh enclosures (Hurley and Walker 2000). In cage culture, 20-mm seed quahogs grew significantly faster in 3-mm mesh cages than in 6-mm, 13-mm, or 19-mm mesh cages (Walker and Heffernan 1990). In cages, the small mesh protruding into the current presumably baffles the current and allows food particles to settle out. This makes the food

FIGURE 2

The mean shell length ± S.E. of northern quahog, *Mercenaria mercenaria*, seed of different sizes planted under various mesh sizes of bottomless mesh enclosures in coastal Georgia.



more easily accessible to the quahogs. The enclosure mesh lies on the bottom substrate and on top of the clams. The smaller mesh sizes may interfere with feeding efficiency, especially as the bags accumulate silt. As a result, quahogs are forced to draw water and food particles through both the mesh and the layer of silt. Our results indicate that the 6-mm mesh is the optimum mesh size for the enclosure and provides the best growth and survival rates (Figures 1 and 2).

Based upon the results of this experiment, quahog farmers in Georgia should continue to grow small seed clams in mesh bags. The 14-mm seed planted under the 6-mm mesh enclosures had survival rates of 60%. This compares unfavorably with the 90% survival rates when 26-mm seed are used (Hurley and Walker 2000). However, since most commercial hatcheries do not sell seed above 14-mm size, farmers need to plant seed in mesh bags and grow them to a larger size before transplanting them to bottomless mesh enclosures. The critical question is what is the optimum size clams should attain before they are transplanted to the mesh enclosures. Further experimentation similar to this study but using larger size seed, 14 to 25 mm, would define the optimum planting size of seed under the bottomless mesh enclosures. A conservative approach to shorten the labor intensive mesh-bag phase while still achieving a high survival rate would be to grow the seed at least until they reach 18 to 20 mm before deploying them under the bottomless mesh enclosures. Once quahogs reach 20 mm, they appear to grow better when cultured within the substrate (Flimlin 2000). This agrees with the observations of Walker (1997). Northern quahog 3- to 9-mm seed grew faster in Florida when allowed to bury in a substrate (Vaughan and Creswell 1990).

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