COMPARISON OF FIELD CULTURE METHODS FOR THE NORTHERN QUAHOG IN THE COASTAL WATERS OF GEORGIA

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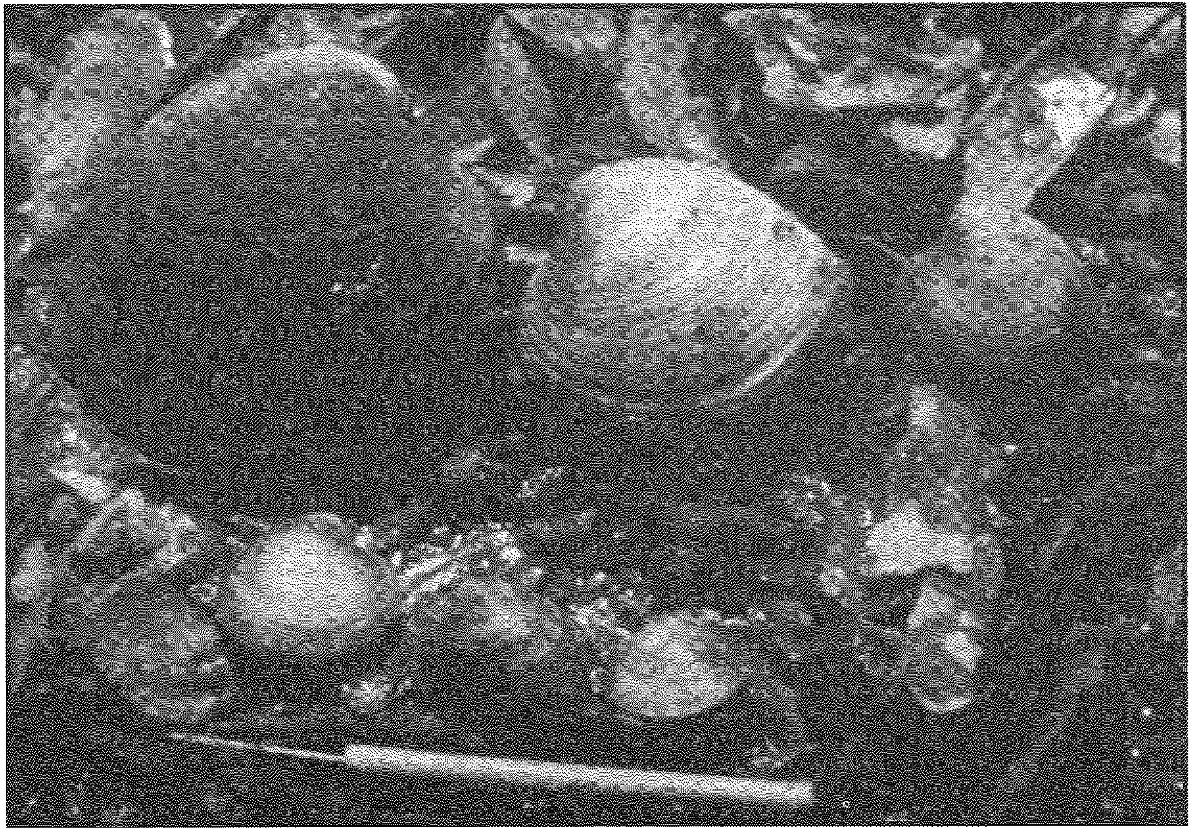
ABSTRACT

This study compared growth and survival of the northern quahog, *Mercenaria mercenaria* (L.), cultured in bottom mesh-bag-line systems, bottom wire-mesh cages, and off-bottom wooden trays. The results show that quahogs grew significantly slower in the mesh-bag-line system than in either off-bottom tray or bottom mesh-cage systems. Although growth was slower for quahogs cultured in mesh bags, survival was consistently higher in the bags than the other methods of culturing clams.

Keywords:
aquaculture, bag, cage, culture, growth, mollusc, survival, tray



Northern Quahog
Mercenaria mercenaria

Mud bottoms predominate throughout salt-marsh areas within the coastal waters of Georgia, South Carolina, and northeastern Florida. Traditional culture methods for northern quahogs, *Mercenaria mercenaria*, require firm bottoms (sand and shell) either to support the weight of off-bottom wooden trays filled with gravel or for the partial burial of bottom wire-mesh cages. Bottom cages work well on the intertidal flats of the open sound; whereas, off-bottom trays work better back in the creek systems of the marsh. A mesh-bag-line system for culturing quahogs based on a similar system used for culturing oysters and clams in Florida (Vaughan et al. 1988) was developed for the Satilla Sea Farms, Inc. in Georgia (Walker and Hurley 1995). The modified mesh-bag-line system was designed to function in soft-bottom areas, since the Satilla Sea Farm's lease area consisted of predominantly mud bottoms. Normally two years of growing time are required for quahogs to attain market size (Walker 1984, 1987; Walker and Humphrey 1984), although it was noted that clams deployed in mesh bags at the Satilla Sea Farm site had not reached market size after two- and one-half years. Consequently, concerns arose that the mesh-bag-line system, although excellent for culturing small clams (Walker and Hurley 1995), might not be efficient for raising them to market size compared to other methods. This study was conducted to compare the growth and survival rates of quahogs raised in mesh bags, off-bottom wooden trays, and bottom cages in the coastal waters of Georgia.

MATERIALS AND METHODS

On June 5, 1994, 14.6±0.2 SE mm quahogs were stocked at 500 clams per bag in eight mesh bags and at 1,000 clams per cage in four cages. Mesh bags were 9.5 mm mesh oyster culture bags, four of which were attached to each of two long lines. Bags were 1.0 X 0.5 m in size (0.5 m^2) and were positioned on a long line as described by Walker and Hurley (1995). Bottom cages (N=4) were 1.0 X 1.0 X 0.3 m in size (1.0 m^2) and constructed of 8.5 mm mesh vinyl-coated wire. Bottom cages were partially buried (0.15 m) in a sandy/mud substrate at the spring low-water mark on an intertidal flat exposed to Wassaw Sound at the mouth of House Creek, Little Tybee Island, Georgia (Figure 1). One line of four mesh bags was deployed on a sandy substrate adjacent to the cages and parallel to the river. The remaining line was established on a mud substrate at the spring low-water mark on the inside of the intertidal flat along House Creek.

On February 28, 1995, it was noted that one cage and one mesh bag from the sand flat had suffered propeller damage. The mesh bag was exchanged for a new one and the cage hole was sealed. All quahogs were harvested and the experiment terminated on May 13, 1995, when 100 clams per cage or bag were measured for shell length (anterior-posterior) to the nearest 0.5 mm with Vernier calipers and a total count was taken to determine survival.

In a second experiment on May 25, 1994, two groups of quahogs were harvested from off-bottom trays in House Creek. Quahogs from Group 1 were 19.0±0.3 mm long, while those in Group 2 two averaged 13.0±0.2 mm long. Quahogs from each of the two groups were stocked at densities of 1,000 clams m^2 in either mesh bags (N=5 bags per stock at 500 clams per bag) or in off-bottom trays (N=4 trays per stock at 1,450 clams per tray) at the

House Creek site. An additional four trays and five mesh bags stocked with 19.0 mm seed clams were established at Groves Creek (Figure 1). Off-bottom trays (1.44 m^2) were constructed with plywood bottom (1.2 X 1.2 m) and wooden sides (5.1 X 10.2 cm) and their tops were constructed of 12.7 mm mesh vinyl-coated wire. Trays were positioned off-bottom on four cinder blocks and were filled with Carolina Bay gravel. The top of the box was approximately 30 cm above the mean low-water mark. Mesh-bag-line systems (N=5 bags per line) stocked with 500 quahogs per bag were positioned in a mud substrate at the spring low-water mark. One line of five bags was planted at House Creek, while one line of Group 1 clams was set up at Groves Creek. Trays and bags at House Creek were terminated as above, on May 12, 1995; while bags at Groves Creek were terminated as above, on May 13, 1995. Trays at Groves Creek were sampled for growth by measuring 100 individuals per tray, but no estimate of survival was obtained.

Differences in growth and survival were analyzed by Analysis of Variance (α=0.05) and Tukey's Studentized Range Test (SRT) (α=0.05) using SAS for PC computer (SAS Institute Inc. 1989). All percentage data were arcsine transformed prior to statistical analysis.

RESULTS

Quahog growth and survival data for comparison of bottom cages and mesh bags in either sand or mud substrates are given in Table 1. Analysis of Variance and Tukey's SRT showed that significant differences ($p<0.0001$) in growth occurred. Clams grew larger in bottom cages ($\overline{X}$=38.9 mm) than those from bags planted in sand ($\overline{X}$=31.2 mm), which in turn were significantly larger than clams grown in mud ($\overline{X}$=30.0 mm). No significant difference in quahog survival occurred between the cages and bags in sand or mud treatments when all replicates were used ($p=0.5582$) or when the cages and bags severely damaged by a propeller were eliminated from the data set ($p=0.5266$). Survival in the overall data set ranged from 45.9% in cages to 84.5% in mesh bags on the sand flat, with adjusted survival (eliminating damaged cage and bags) ranging from 58.8% in cages to 92% in bags on the sand substrate. Low survival (7%) in one cage almost certainly was attributable to propeller damage whereby predators were allowed access to the cage or clams may have been washed out of the cage. Low survival in another cage (10.1%) was due to crab predation. Numerous shells exhibited signs of crab predation, but aside from a large non-predatory spider crab, no crabs were found. One of the bags adjacent to the cages on the sand flat was damaged by a propeller resulting in high mortality (38%). In one bag on the mud substrate, heavy mortality (80%) occurred, also because of apparent propeller damage. In addition at harvest, an egg case of a predatory whelk, *Busycon carica*, was found in the torn bag. Heavy mortality in a second bag (45%) apparently resulted from the first bag being pulled up by the propeller and partially repositioned on top of the second bag, suffocating some of the clams in the latter.

Quahog growth rates in trays and bags at the Groves and House Creek sites are listed in Table 2.

At both sites, Group 1 clams (initial mean size of 19 mm) grew significantly larger (both sites $p<0.0001$) in trays than in bags. Clams in bags were significantly larger at Groves Creek ($p<0.0001$) than at House Creek. In the trays, clams were significantly larger at House Creek than at Groves Creek. For Group 2 (initial mean size of 13 mm), clams grew significantly larger ($p<0.0001$) in trays than in bags at House Creek.

Survival data for quahogs in trays and bags at the Groves and House Creek sites are given in Table 3. For clams grown in trays and bags at House Creek, significant differences in survival ($p=0.0054$) occurred between treatments. Tukey's SRT revealed that no difference in survival occurred between Group 1 animals in bags (95.6%), Group 2 animals in bags (81.9%), and Group 2 animals in trays (69.3%). Nor was there a difference between Group 2 animals in bags, Group 2 animals in trays, and Group 1 clams in trays (60.5%). Thus survival was different only between Group 1 animals in trays versus Group 1 clams in bags. No significant difference in survival ($p=0.1038$) occurred for Group 1 animals planted in bags at House and Groves Creek sites.

DISCUSSION

Raising quahogs to commercial size takes longer in mesh bags than in bottom cages or off-bottom trays. The exact reasons for the reduction in growth rate of clams in mesh bags is unknown; however, restricted water flow within the bags is one possible explanation. The small mesh size of the bag combined with its position on the bottom may well have prevented adequate water flow through the bag or prevented the clam's siphon from functioning properly in drawing water. Smaller mesh sizes of bottom cages were found to increase significantly the growth rate of quahogs (Walker and Heffernan 1990a). This presumably was due to the baffling effect of the mesh sides extending into the water column, which allowed food particles to settle near clams. However, in the bag system, water does not necessarily move through the bag as it would a cage, since bags are lying on the bottom and do not project into the water column. In addition, clams were observed to bunch at either one end or at the center of the bags, which exacerbated the negative effects of density upon growth. Furthermore, since quahog survival was greater in bags than in bottom cages or off-bottom trays, higher clam densities within bags possibly could account for the lower growth observed. Increased stocking densities have been shown to retard growth of quahogs in trays and cages, (Eldridge et al. 1979; Walker 1984) as well as in the mesh-bag-line system (Walker and Hurley 1995).

Greatest growth occurred in the trays where quahogs increased 213% and 192% in size compared to 166% in bottom cages; however, direct comparisons between clam growth in trays and cages are not feasible because different size seed were used for each method. Further, trays were positioned higher in the intertidal zone than cages, and trays were positioned farther back in the creek system. Thus water temperature, phytoplankton abundance and species composition could be different for animals in trays compared to animals in cages. Previous studies on both northern quahogs and Atlantic surfclams, *Spisula solidissima*, showed that increased intertidal exposure resulted in slower growth of clams (Walker and Heffernan 1990b). Thus one would expect greater growth to occur for quahogs planted in the cages positioned at the spring low-water mark than for clams in trays positioned above the mean low-water mark. However, in this experiment, greater growth appears to have occurred within trays positioned above the mean low-water mark.

One possible explanation for the greater growth of quahogs in trays rather than bottom cages, which were lower in the intertidal zone, may be due to genetic selection factors. The clams used in this experiment were obtained from a previous genetic selection experiment (Crenshaw et al. 1993). These clams represent a third generation stock selected for rapid growth under tray culture conditions. It is well known that response to selection must be obtained from cohorts that are cultured under conditions similar to those under which their parents grew out, and that stress of any sort tends to affect selected lines more profoundly than unselected, control lines (Falconer 1981; Crenshaw et al. 1996). Clams grown in the trays have been selected for environmental conditions associated with that rearing method (i.e., increased intertidal exposure and gravel substrate). Clams transplanted to the cage and mesh-bag-line culture methods, however, may have experienced new stresses associated with those systems, such as restricted siphon movement in bags, muddier or more sandy substrates, or stress produced by increased wave action for clams in bottom cages.

In seasonal seed clam growth studies in Florida, small seed (3-9 mm grown to 10-15 mm) consistently grew better in trays filled with sand and covered with a 2-mm mesh top than did seed planted in bags with a 2-mm lining. These in turn produced better growth than seed cultured in 1-mm mesh cages (Vaughan and Creswell 1989). Direct comparisons between the Florida tests and the growth test in Georgia are difficult. The Florida rearing test used small seed and small mesh size culture units, while the Georgia study used larger clams and larger mesh units. Trays filled with sand are a common rearing method used in the Indian River, Florida area, where a 0.6- meter tide occurs; whereas, gravel must be used in trays in Georgia where a 2.4-to-3-meter tide produces currents which wash away sand in trays. The tray method does appear to produce clams with a good rate of growth and an adequate survival rate (>50%).

Overall, quahog survival was 46% in cages and 65% in trays compared to 83% for the bag method. Greatest variability in survival occurred in bottom cages, while the least variability occurred within the bags. Propeller damage to one cage accounted for its higher mortality rate, and large macropredators obviously were able to enter another cage since a spider crab was present in it at the termination of the experiment. Although there were no statistical differences in clam survival between grow-out methods, survival rates of clams in bags were consistently higher in all tests than survival rates in either cages or trays.

Although growth was found to be slower, the bag method still has several advantages over the cage and tray methods. First, animals grown in mesh bags show increased percent survival. Second, the cost of constructing the mesh-bag-line system is considerably less than the other methods (Walker and Hurley 1995). Third, the mesh-line-bag system lasts longer, at least five to six years, compared to cages and trays which last approximately two years. In addition, it is easier and quicker to check the bags for predators than it is to check either cages or trays. Finally, it is easier to deploy and harvest quahogs in the mesh-bag-line system than it is in either of the other two methods.

It is recommended that quahog farmers in Georgia use the mesh-bag-line system for culturing small seed clams until they are 30 to 35 mm long. At that point, they should be transplanted into bottom cages for final growth to market size. At 30 to 35 mm, quahogs are safe from most predators, i.e., mud crabs, starfish, oyster drills, and snapping shrimp; however, they are still vulnerable to blue crab, whelk, and stingray predation. Thus they need to be protected in cages which have a mesh size that is sufficient to hold the clams while preventing the entry of large predators. Quahog stocking densities should be between 500 to 1,000 clams per m^2 in the bottom cages (Eldridge et al. 1979; Walker 1984). The cages should allow ample water flow which helps provide adequate food for growing the clams to market size faster than they can be grown in the mesh bags. The use of trays for final rearing of quahogs to market size is not recommended, because, unlike the small quahogs, large ones are unable to bury themselves into the gravel.

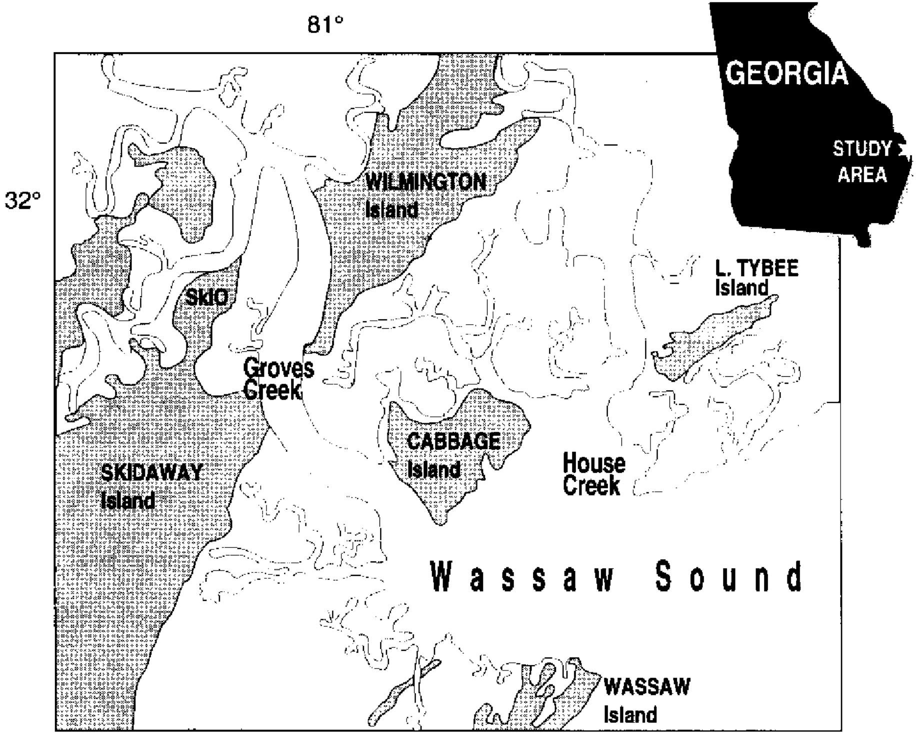


Figure 1. Location of House Creek and Groves Creek culture sites for northern quahogs, *Mercenaria mercenaria,* in Wassaw Sound, Georgia

Table 1. Growth and survival data for northern quahogs cultured in bottom cages, mesh bags placed in a sandy substrate and mesh bags placed in muddy substrate on an intertidal flat at the mouth of House Creek, Little Tybee Island, Georgia. The asterisks indicate bags or cages which suffered propeller damage.

GROWTH

	Cages $\bar{x}$ size in mm ± SE	Bags in Sand $\bar{x}$ size in mm ± SE	Bags in Mud $\bar{x}$ size in mm ± SE
1	37.2±0.60	31.4±0.32	32.0±0.42
2	37.5±0.56	29.8±0.35	31.1±0.50
3	42.1±0.54	31.7±0.34	32.8±0.44
4	39.8±0.49	32.1±0.34	24.2±0.40
Mean ± SE	38.9±0.29	31.2±0.17	30.0±0.28
Per cent Increase	166	114	106

Table 1 continued.....

SURVIVAL

	Per Cent Survival	Per Cent Survival	Per Cent Survival
1	66.4	90.2	100.0
2	100.0	97.0	100.0
3	7.1*	62.2*	55.2
4	10.1	88.6	20.2*
Mean ± SE	45.9±22.6	84.5±7.7	68.9±19.4
Adjusted Mean ± SE	58.8±26.2	91.9±2.6	85.1±14.9

Table 2. Growth of two groups of northern quahogs planted in either wooden trays filled with gravel or in mesh bags at two sites in Wassaw Sound, Georgia. Initial size of Group 1 and Group 2 clams were 19.0±0.3 mm and 13.0±0.2 mm, respectively.

	GROUP 1 $\bar{x}$ size in mm ± SE		GROUP 2 $\bar{x}$ size in mm ± SE	
HOUSE CREEK				
	TRAYS	MESH BAGS	TRAYS	MESH BAGS
1	41.2±0.61	27.3±0.89	37.0±0.44	22.6±0.58
2	42.6±0.60	27.3±0.97	37.2±0.58	20.6±0.67
3	39.5±0.62	23.3±0.60	40.1±0.53	23.2±0.61
4	39.7±0.60	27.5±0.79	37.5±0.54	20.7±0.50
5		27.1±0.64		21.6±0.60
Mean ± SE	40.7±0.31	26.5±0.38	38.0±0.27	21.8±0.27
Per cent Increase	213	104	192	68

Table 2 continued.....

	GROUP 1 $\bar{x}$ size in mm ± SE	
GROVES CREEK		
	TRAYS	MESH BAGS
1	36.5±0.48	30.5±0.47
2	35.5±0.44	26.4±0.51
3	35.3±0.48	27.2±0.51
4	35.3±0.43	30.3±0.51
5		32.2±0.47
Mean ± SE	35.7±0.23	29.3±0.24
Per cent Increase	88	54

Table 3. Survival of two groups of northern quahogs planted in either wooden trays filled with gravel or in mesh bags at two sites within Wassaw Sound, Georgia. ND = not determined. The results of the Tukey's Studentized Range Test are provided for the per cent survival data, where means with the same letter indicates no significant difference.

	GROUP 1 Per Cent Survival		GROUP 2 Per Cent Survival	
HOUSE CREEK				
	TRAYS	MESH BAGS	TRAYS	MESH BAGS
1	46.3	97.6	76.7	54.7
2	34.0	93.3	62.4	90.9
3	87.7	98.9	80.5	79.7
4	74.0	93.3	57.4	93.3
5		94.9		90.7
Mean ± SE	60.5±12.3 a	95.6±1.1 b	69.3±5.6 a,b	81.9±7.2 a,b

Table 3 continued.....

	GROUP 1 Per Cent Survival	
GROVES CREEK		
	TRAYS	MESH BAGS
1	ND	94.9
2	ND	92.5
3	ND	94.7
4	ND	89.3
5		73.3
Mean ± SE		88.9±4.0

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