WILD EASTERN OYSTER, *Crassostrea virginica,* SPAT COLLECTION FOR COMMERCIAL GROW-OUT IN GEORGIA

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Abstract

In Georgia, an extended reproductive season (late March – early October) with periods of intense oyster recruitment (204,700 spat/m^2/month) presents a unique opportunity to establish an oyster aquaculture industry based on wild eastern oyster, *Crassostrea virginica* (Gmelin, 1791), spat collection and grow-out. Our research focused on determining the optimal method for collecting wild spat. We employed the following techniques: commercial oyster spat sticks, PVC sticks coated in cement slurry, and bamboo stakes all arranged in an array of 36 sticks per ~0.5 meter square. Additional treatments were plastic window screening coated in cement slurry and house shingles that were attached to individual ~0.5 meter square frames with 36 panels per replicate. Three replicates per treatment type were randomly distributed intertidally and adjacent to each other at the same site during April 2006 in Sapelo Sound, Georgia. Treatments were retrieved during August 2006 and evaluated for oyster density/2.54 cm^2. The percentage of single oysters that was damaged during removal was assessed, and the mean shell height (mm) of live oysters was also determined for each treatment. Treatments using PVC sticks coated with a cement slurry recorded the greatest oyster density [mean 5.64 ± 0.34 (S.E.) oysters/2.54 cm^2] and the least number of oysters that were fatally damaged during collection (mean 16.39 ± 3.04 %). Both treatments incorporating the cement slurry, screen and PVC pipes, yielded the greatest growth with mean oyster height being 31.20 ± 1.40 mm and 28.70 ± 2.18 mm, respectively. Bamboo had the lowest oyster density (mean 0.66 ± 0.23 oysters/2.54 cm^2) and commercial spat sticks had the highest percentage of oysters that were fatally damaged during collection and lowest mean shell height (mean 99.26 ± 41 % damaged shells; mean 15.60 ± 1.68 mm). Results of this research indicate that wild oyster spat collection is a viable option in the initiation of an oyster industry in Georgia and that growers should use cost-effective PVC pipes coated with thin cement slurry.

Introduction

Georgia once led the nation in eastern oyster, *Crassostrea virginica* (Gmelin, 1791), harvesting mainly for the cannery trade, with over 8 million pounds of oyster meats being harvested in 1908 (Harris 1980). In 2007, the oyster industry harvested only 14,480 pounds of meats. Although the natural harvest of oysters is low today, there is considerable interest among commercial fishermen and hard clam, *Mercenaria mercenaria* (Linnaeus, 1758), farmers in developing an oyster aquaculture industry in Georgia.

Georgia has an extensive oyster population (Harris 1980), but does not produce many half-shell oysters for national or international markets. Georgia has an overabundance of natural recruitment each year. Oysters spawn from March/April to October (Heffernen *et al*. 1989). Oyster recruits called spat that settle in April/May grow rapidly and become sexually mature within two months and spawn throughout the remainder of the summer into fall (O'Beirn *et al*. 1996a). As a result massive settlement occurs on existing oyster reefs. Oyster recruitment rates are high in Georgia (O'Beirn *et al*. 1995, 1996a, b, 1997), with record rates as high as 204,700 spat per meter square settling in a month (Thoresen *et al*. 2005). The result of this high settlement is that intense competition for space and food produces long, thin and narrow oysters that are mainly consumed locally during the winter oyster roast season.

A majority of research investigating the probability of oyster culture in Georgia has focused on increasing the marketability of adult oysters by reducing spat fouling associated with the oyster reproductive season (Heffernan and Walker 1988; Adams *et al*. 1991; Moroney and Walker 1999). Though oyster spat fouling is a serious problem facing the oyster industry, rewards from high oyster recruitment rates may someday offset the costs through provision of cheap oyster seed. Most oyster spat for commercial grow-out in the continental United States is produced in hatcheries that provide some level of consistency for oyster growers operating in areas where oyster recruitment is low and often sporadic. Areas of the world that have more reliable periods of oyster recruitment have continually and successfully utilized methods of wild spat collection. Traditional oyster industries in some regions of Italy, France, China, and Japan still rely to some degree on wild oyster spat collected on materials such as modified PVC pipe (commercial spat collectors), lime-covered tiles, bamboo sticks, and strings of oyster and scallop shells (ren) (Matthiessen 2001). Several operations in Australia and New Zealand collect wild oyster spat primarily through the use of PVC pipes covered in cement slurry. Along Georgia's coast it is feasible to investigate the efficacy of a variety of methods used in oyster industries worldwide, as well as new alternative methods for collecting large quantities of wild oyster spat that stem from consistently high oyster recruitment rates. The purpose of our research was to evaluate five techniques for single wild oyster spat collection using oyster density, mortality, growth, and spat with damaged shell after extraction as metrics to assess success.

Materials and Methods

To determine a fast, efficient and inexpensive means of collecting natural oyster spat for possible oyster culture in Georgia, various spat-collecting methods were deployed on 7 April 2007 within the intertidal zone at the two-hour-above mean low water mark in alignment with natural oyster reefs at Ridge River Mouth, Creighton Island in the Sapelo Sound, Georgia. All plots were terminated on 1 August 2007.

Five treatments were tested to determine which produced optimal seed oysters for eventual grow-out to a marketable size of 76 mm. One-meter-long, approximately 5-cm diameter, bamboo stakes (no cement); 2.0-cm diameter commercial spat collectors made of PVC longitudinally grooved pipe with chips of calcium carbonate embedded within it; and 2.0-cm diameter PVC schedule 40 pipe covered in a cement slurry, were deployed in densities of 36 pipes (6 x 6) per ~0.5 m^2. Cement slurry was made in a wheelbarrow using 36.2 kg of Portland cement, 36.2 kg sand, and 36.2 kg garden lime and mixed until all constituents were evenly distributed. Water was added until the mixture had a consistency similar to that of honey. PVC sticks and house-screen units were coated in a layer of cement slurry approximately 5-mm thick. Three replicate plots per treatment were deployed. Sticks were driven into the mud substrate along the creek bank so that 0.61 m of the stick was above the substrate surface. Additional treatments were thirty-six 17.8 cm^2 square window house-screen units dipped in cement slurry and thirty-six 17.8 cm^2 square, plain house shingling (no cement). Shingles and screen were suspended at all four corners by cable ties from a PVC frame built of 2.0-cm schedule 40 PVC pipe where individual screens or shingles were spaced approximately 2.54-cm apart and approximately 20-cm off the mud bottom. Frames resembled hollow boxes with 1 m x 25-cm wide runners above and below screen and shingle units. Each frame stood on four legs that were 0.61-m long. These legs were used to stabilize the units in the mud substrate. Individual sample units for screen and shingle treatments were concentrated in the center of each unit to allow for adequate water flow. Three replicate plots per treatment type were deployed.

On 1 August 2007 all treatments were terminated. Information on oyster shell morphology, oyster mortality, and the percentage of oysters with fatally damaged shells resulting from removal was collected from one 2.54 cm^2 sample area for each of 32 randomly selected sample units (i.e., a single commercial spat stick, bamboo stake, PVC stick with cement slurry, house-screen panel with cement slurry, or house-shingle panel) for each of three replicates per treatment type. Data was collected within the area of a standardized 2.54 cm^2 grid to assure consistency of surface area for information collection between treatment types. Oysters (N=40) were randomly selected from each replicate for each treatment type and measured for shell height (from hinge to lip), length and width (across two valves) to the nearest 0.1 mm with Vernier calipers. Density was determined by counting the number of spat per 2.54 cm^2. Natural mortality was determined by manually counting the number of dead versus live oysters per sample area. Oysters were manually removed from each sample area for each sample unit, and the percentage of resulting fatally damaged shells due to removal was determined.

One-way Analysis of Variance (ANOVA) and Tukey's Studentized Range Test (α =0.05) using SAS for PC (SAS Institute Inc., 1989) were carried out. All proportional data were arcsine transformed prior to statistical analysis (Sokal and Rohlf 1981).

Results

The results of oyster spat settlement, growth and natural mortality are given in Fig. 1. Oyster recruitment was significantly ($P<0.0001$) higher on the spat sticks [mean 5.46 ± 0.40 (S.E.) per 2.54 cm^2], PVC pipes (mean 5.64 ± 0.34 per 2.54 cm^2), and screen (mean 4.97 ± 0.34 per 2.54 cm^2) coated with cement than on the shingles (mean 0.75 ± 0.26 per 2.54 cm^2) and bamboo sticks (mean 0.66 ± 0.23 per 2.54 cm^2). Spat shell heights were significantly ($P<0.0001$) higher from the screen (mean 31.2 ± 1.4 mm) and PVC cement-coated sticks (mean 28.7 ± 2.19 mm) than those on bamboo (mean 18.6 ± 1.51 mm), shingles (mean 15.6 ± 1.68 mm) and spat sticks (mean 15.5 ± 1.23 mm). Natural mortality of oysters while deployed was significantly higher ($P<0.0001$) on the spat sticks (mean 14.7 ± 3.66%) than on the remaining treatments: PVC sticks (mean 5.54 ± 2.10%), bamboo (mean 5.34 ± 3.81%), screen (mean 1.85 ± 1.07%) and shingles (mean 0.93 ± 0.93%).

The ratio of oyster shell height to shell length per treatment is given in Fig. 2. Ratios were significantly ($P<0.0001$) higher for oysters from screen (mean 1.52 ± 0.05) and PVC sticks (mean 1.46 ± 0.05) which were greater than oysters from spat sticks (mean 1.29 ± 0.05), which were larger than those from shingles (mean 1.14 ± 0.05) and bamboo (mean 1.11 ± 0.035).

The resulting percent damage to oysters once removed from the spat collectors is given (Fig. 3). There were significant ($P<0.0001$) differences in the amount of damage to oysters: spat sticks (mean 99.3 ± 0.42%) > bamboo (mean 75.0 ± 5.46%) > screen (mean 42.6 ± 5.17%) = shingles (mean 32.4 ± 14.9%) and PVC sticks with cement slurry (mean 16.4 ± 3.04%).

Figure 1: Oyster spat density (No. oysters/2.54 cm^2 ± S.E.), mortality rate (percent/2.54 cm^2 ± S.E.) and shell height (mm ± S.E.) for oysters collected from house screen with cement slurry, house shingle, PVC sticks with cement slurry, commercial spat sticks, and bamboo treatments.

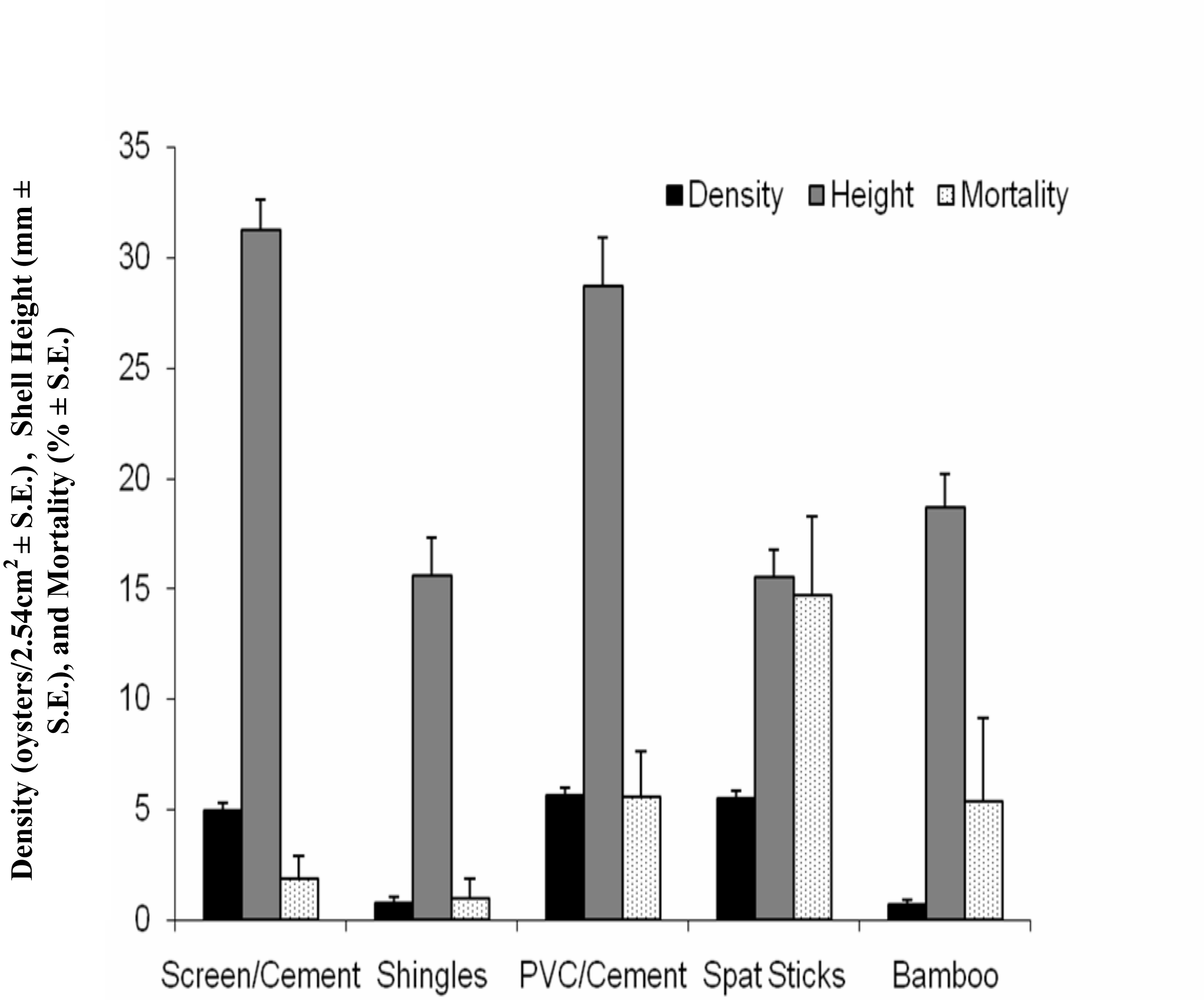


Figure 2: Oyster shell height to shell length ratio (± S.E.) for oysters collected from house screen with cement slurry, house shingle, PVC sticks with cement slurry, commercial spats sticks, and bamboo treatments.

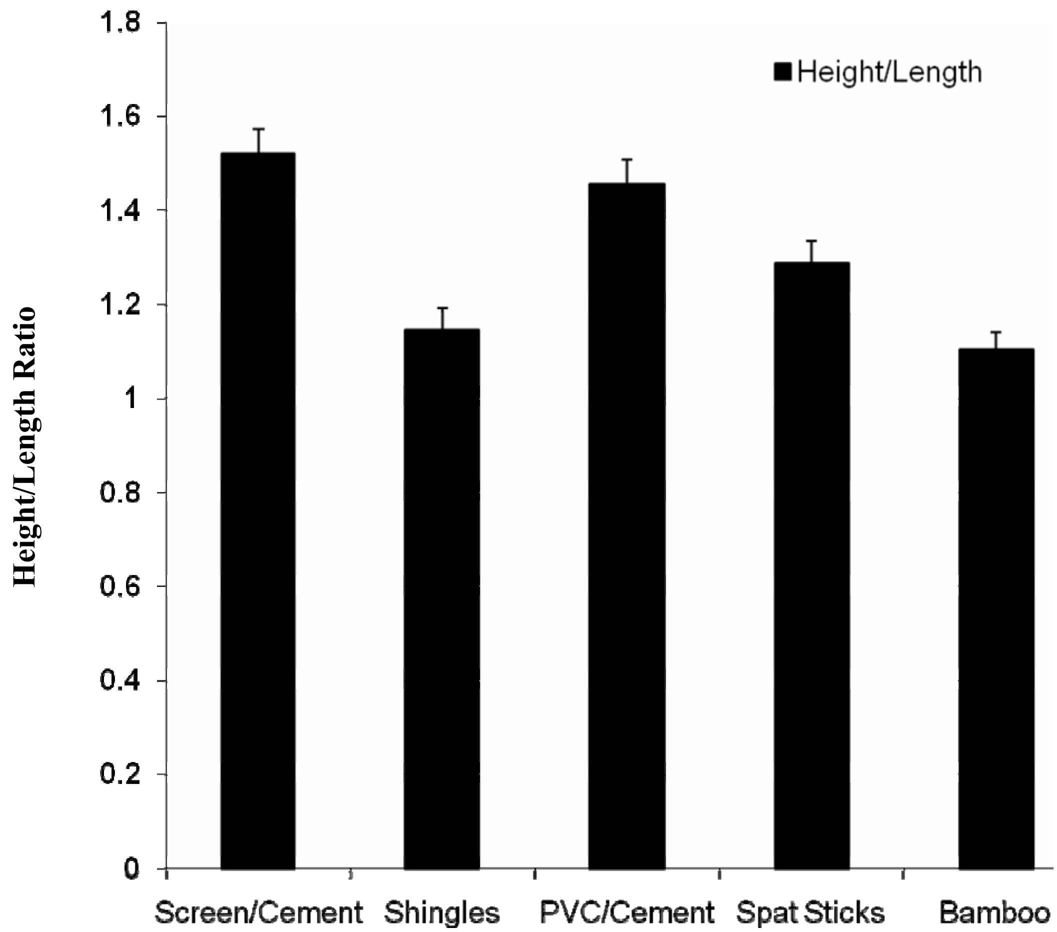
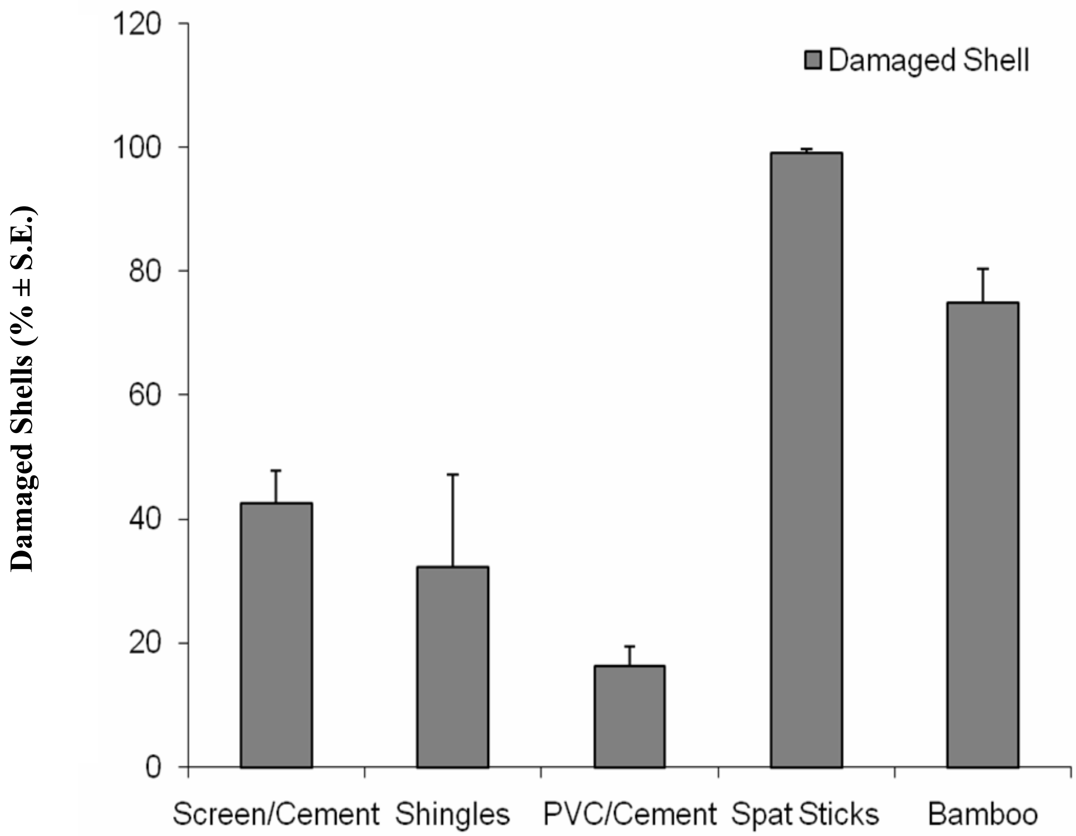


Figure 3: Percentage of oysters with fatally damaged shells (± S.E.) for oysters collected from house screen with cement slurry, house shingle, PVC sticks with cement slurry, commercial spat sticks, and bamboo treatments.



Discussion

Commercial spat sticks performed poorly when used to collect single oyster spat for eventual grow-out in racks and mesh bags. It was nearly impossible to remove small-sized oysters from this treatment type without substantial shell damage. The high natural oyster mortality rate on spat sticks was likely a function of the high numbers of smaller oysters that were more susceptible to predation due to thinner shells and easier accessibility by predators. Oyster mortality rate on bamboo sticks was intermediate, and settlement of oysters on this treatment type was low. Low oyster mortality on bamboo likely resulted from the presence of fewer oysters and the smooth, disk-shaped oyster growth on this particular treatment type that likely confounded predator ability to manipulate and consume young oyster prey. Like spat stick treatments, there was a greater percentage of oyster spat with fatally damaged shells during removal on bamboo sticks due to firm attachment of smaller oysters to these treatments. PVC sticks with cement slurry were superior with respect to the extraction of oyster spat as expressed by a low percentage of oysters with fatally damaged shells on this treatment type. Oysters were larger on PVC sticks with cement indicating that oysters may have settled earlier on this treatment than aforementioned treatment types, which could have contributed to less shell damage associated with thicker oyster shells. The thin cement slurry covering PVC sticks was brittle and cracked easily between adjacent oysters, which minimized damage to spat near the shell attachment area. This suggests that this collection technique may, to some degree, protect oysters from sustaining shell damage. Increased structural complexity associated with greater oyster growth and density could have contributed to lower mortality on PVC sticks with cement than on spat stick treatments due to protection from predation. House-screen covered with cement slurry had the lowest oyster mortality rate of all treatments due to the way this treatment type was constructed (screen units were vertically oriented and stacked 2.54 cm apart). This would have hindered predator access to prey. Greater oyster growth and density (oyster shell height was greatest on this treatment type) on house screen with cement enhanced physical complexity on these treatments, which may have complicated the feeding strategies of predators. Soniat *et al.* (2004) found that vertically oriented structures that provided protective cover to oysters reduced oyster mortality due to siltation and predation. The proportion of oysters with fatally damaged shells during extraction from house screen with cement was higher than expected when compared to PVC with cement and house-shingle treatments. Oysters on screen with cement sustained greater damage during removal than PVC with cement and house shingles due to incorporation of the screen material directly into the oysters shell as a result of growth creating a non-pliable structural unit. House shingling yielded low oyster density, growth, and the lowest oyster mortality rate of all treatment types. As observed on screen treatments low mortality rate was likely due to vertical orientation and protection provided via the way shingle units were arranged. The proportion of spat with fatally damaged shell during extraction from house shingling was intermediate and low when compared to all treatment types except PVC sticks with cement. Deterioration of shingle material may have slightly enhanced extraction of oysters allowing for the easy peeling of oysters away from shingling material.

Oyster spat recruitment was five times higher on screen panels coated with cement slurry, PVC sticks with cement slurry, and the commercial spat sticks than on the shingles or bamboo treatments. Higher recruitment on these substrates was likely due to the presence of calcium carbonate in the cement or embedded in the spat sticks. Calcium carbonate is the main ingredient needed for building oyster shell. Significantly higher growth of spat occurred with the PVC sticks and screen cement slurry-coated treatments with spat being approximately twice the size of those on other treatments. The disparity in oyster height between oysters on treatments with and without calcium carbonate could have occurred as a result of early oyster settlement onto calcium-carbonate-enriched structures.

Density did not affect shell height, but it did affect the height-to-length ratio. Both the screen and PVC cement-coated material had high recruitment rates and produced the greatest oyster growth in terms of shell height. These two treatments produced oysters with higher shell height/shell length ratios (Fig. 3). Thus, growth rates for these oysters were similar to those oysters found on natural reefs where the competition for space results in oysters that are long, narrow and thin. The two treatments with the lowest recruitment, shingles and bamboo, produced a higher proportion of circular-shaped oysters where the ratio was closer to one. It is important to note that oyster spat collected from PVC sticks and screen with cement slurry appeared to exhibit a greater degree of cupping than oysters extracted from other treatments.

Both the screen and PVC sticks coated with cement slurry (Figure 4) and the shingle treatments (Figure 5) have the potential for commercial application. Commercial spat collectors were not optimal at extracting young spat for grow-out in racks or bags; however commercial spat collectors have worked well in the past at collecting and growing large oysters (Manley 2007). It was a previous oyster reef restoration study that used spat sticks to form an artificial reef that led us to this experiment and the belief that an aquaculture industry for oysters could be developed in Georgia (Manley 2007). Spat sticks deployed in April attracted oyster spat by May, and oysters grew to a mean market size (76 cm) by the following March. The experiment was performed in an area of moderate spat recruitment, thus oysters were not overcrowded and grew well due to low competition for space. Oysters grown to a marketable size on commercial spat sticks have thicker shells and some can be easily removed without damage. If a farmer uses spat sticks to grow oysters to market size, he or she will need to implement a grading system for separating oysters (those used for roasts as opposed to oysters for the half shell market). Usually young oysters of uniform size, such as hatchery reared spat or small wild-collected spat that are graded regularly and mechanically stimulated by waves or scheduled cleaning and rotation, grow to be adults of desired shape for the raw half shell trade. Manley (2007) arranged commercial spat sticks in densities of 81 sticks per one-meter-square plot which after two years yielded approximately 155 kg (341 lbs) of live oyster shellstock valued at ~$230.00 based on the present value of a bushel (52-60 lb) of roast oysters in Georgia ($35.00). The cost of 81 one-meter- long commercial spat sticks is ~$280.00. Therefore it is not presently economically viable to use commercial spat sticks for a market based on roast oysters in Georgia. However at ~$85.00 (material and labor cost) per 81 PVC sticks covered in cement slurry, it would be economical to produce roast oysters using the aforementioned treatment type. Thus PVC with perhaps a thicker coat of cement slurry is a viable option for a grow-out market that focuses on roast oysters, as well as a spat -collection operation to support an oyster half-shell industry in Georgia. Collecting spat on PVC with cement slurry causes less damage to very young, delicate oysters. Another advantage is that these oysters can be collected at much smaller sizes, and they maintain an appealing and uniform shape. Collecting spat with commercial spat sticks for producing single oysters for further culture to market size has no commercial application, since 100% of the young oysters sustained damage as they were removed from the sticks. Likewise heavy oyster damage occurred while removing them from bamboo. Shingles could be used in areas where spat fouling renders an area unfavorable for spat collection due to extreme overset as observed the mouth of the Duplin River, Sapelo Island (Thoresen *et al.* 2005.)

Capital cost and labor, as well as return on investment are critical to the start-up and growth of a commercially viable half-shell oyster industry in Georgia. The materials and techniques used in this research varied greatly in price and to a lesser extent labor of construction per unit (i.e., a single screen panel coated in cement slurry, shingle panel, PVC stick coated in cement slurry, commercial spat stick, and bamboo stake). PVC with cement slurry provides a far greater value in terms of cost and labor based on return than any other treatment type with a total yield of an estimated 711 oyster spat successfully collected from each stick (Table 1). Screen with cement slurry was the least expensive treatment to construct at $0.004 per single unit (price of frame included) and was the second most efficient treatment with an efficiency rate of 2.85 undamaged spat per 2.54 cm^2 (Table 1). With labor estimated at $7.00 per hour, it would cost $8.79 to secure an equal volume of undamaged spat for plant-out by using screen with cement slurry. The cost for using PVC stick coated in cement slurry was estimated to be $1.06 per unit (including labor at $7.00/hr) (Table 1). It would be highly uneconomical to use the other treatment types evaluated during this research solely for spat collection. Spat sticks, bamboo and shingles could cost up to $419.58, $47.14, and $37.14, respectively, to get the same number of spat collected on a single PVC stick covered in cement slurry (Table 1). However it is important to note that bamboo is fairly easy to cultivate, and if one wanted to use bamboo the cost could be dramatically reduced by independent cultivation.

In conclusion, the harvest of large quantities of single oyster spat using PVC sticks coated with cement for commercial grow-out is a viable option for the Georgia oyster industry. Oyster settlement on treatments with cement slurry was generally higher than it was on other materials. Flexible PVC sticks with cement provided greater quantities of undamaged single oysters than other treatments and may potentially be a method for culturing clusters of oysters for the roast market. PVC coated with cement slurry was the most cost effective material providing an estimated 711 viable spat per unit at a cost of ~$0.50 per unit. It is also important to note that only 61 cm of a 92-cm stick was exposed, since a portion of each stick was anchored in the mud substrate leaving a surface area of approximately 383.2 cm^2 available for oyster settlement. The use of PVC further reduces costs since it is resistant to deterioration associated with the marine environment and can be reused. Thus, this study is the first step in developing a successful method for culturing a quality single oyster in Georgia. The next step is to develop the optimal method for culturing the spat to a marketable size by winter for sale in the winter raw oyster half shell and roast market. By marketing oysters prior to spring, growers can avoid oyster-fouling problems starting with the next oyster-spawning season, as well as, oyster disease mortalities due to *Perkinsus marinus* which would occur over summer and into the fall (O'Beirn *et al.* 1996b).

Future suggestions for spat collection include reducing the thickness of the cement slurry coating on the PVC sticks. It was observed during this research that in areas where the cement coating was slightly thinner, fewer oyster shells were damaged during extraction. Future research could focus on varying the thickness of the cement coating on the PVC and other spat collection materials, as well as, trying different concentrations of lime in the cement slurry.

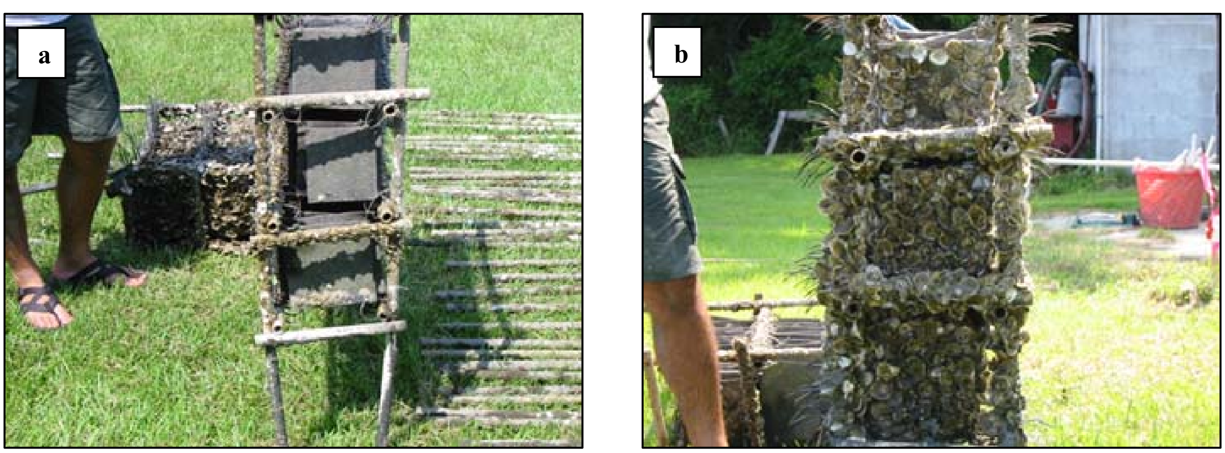
Table 1. Comparison of the commercial applicability of each treatment type by unit based on cost, labor investment, efficiency, unit surface area, and estimated harvest.

Treatment Type	Unit[a] Cost[b] ($/unit)	Labor Investment[c] (hrs/unit)	Efficiency[d] (Un.Sp./2.54 cm^2)	Surface[e] Area (cm^2)	Est. Harvest[f] (no. spat/unit)
Screen/Cement	0.004	0.07	2.85	35.60	39.90
Shingles	0.14	0.05	0.51	35.60	7.10
PVC/Cement	0.50	0.08	4.71	383.20	710.70
Spat Sticks	3.50	0.009	0.04	383.20	6.03
Bamboo	3.00[g]	0.05	0.17	958.10	64.10

[a] Unit represents a single component of each treatment type (i.e., a single screen panel coated in cement slurry, shingle panel, PVC stick coated in cement slurry, commercial spat stick, and bamboo stake).
[b] United States dollars per individual unit ($/unit)
[c] Labor investment in hours per individual unit (hrs/unit). Labor is estimated to be $7.00/hour.
[d] Undamaged spat during extraction per 2.54 cm^2 sample area (Un.Sp./2.54cm^2) for each treatment type.
[e] Surface area exposed and available for settlement per unit (cm^2)
[f] Estimated harvest of undamaged spat per unit (no. spat/unit).
[g] Bamboo value was based on commercial estimates. Bamboo used during this research was donated by the University of Georgia Bamboo Farm and Coastal Garden free of charge.

Figure 4: Oyster spat settlement on (a) commercial spat sticks, (b) PVC coated with cement, and (c) bamboo stakes.

Figure 5: Oyster spat settlement on (a) shingles and (b) house screen coated with cement.



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