EVALUATION OF EASTERN OYSTERS, *Crassostrea virginica* (GMELIN, 1791), SPAT COLLECTORS FOR WHITEHOUSE SEAFOOD

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The University of Georgia: A Land and Sea Grant Institution

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Abstract

The University of Georgia Marine Extension Service is developing an oyster aquaculture industry for the State of Georgia. This project examines various forms of Quonset hut devices designed and constructed by Whitehouse Seafood to collect oyster spat. All designs and material were sprayed with cement slurry intended to aid in the attraction of spat and in easing the removal of oysters from collectors. Designs were all based on 4 foot x 5 foot sections of 1/8 inch gauge steel wire spot welded in a 6 inch grid pattern formed into a semi-circle of 15 inches height or of PVC pipe. Experiment one examined the use of burlap coated in cement deployed on huts for spat collection. Huts with burlap sheets coated in cement met with failure, as they were unable to withstand the currents, tides and wave action over summer. Experiment two investigated six treatments: huts with 6-inch wire grid; huts with 3-inch wire grid; huts with 6-inch wire grid and mussel rope; huts with 6-inch wire grid and 3-inch strips of burlap; huts with 6-inch wire grid and sisal rope; and huts with PVC ¾ inch bars. Huts were deployed on May 2 and sampled on September 19, 2011. PVC huts had the second highest density of oyster spat, but were not statistically lower than the highest treatment with the 3 inch wire. In terms of growth, oysters from the PVC huts were consistently larger than oysters grown on other treatments, but were not significantly larger than those grown on sisal rope or 3-inch wire huts. The PVC Quonset huts performed the best. Each PVC huts produced by February 2012 4.5 bushels of legal sized oysters of which approximately half were singles and others were doublets or triplet oysters. A half bushel of undersized oysters were also gathered and replanted per PVC hut. Oysters on PVC huts grew too fast which resulted in thin shells. Oysters should be replanted on the bottom to thicken shells prior to shipping and marketing. The experiment showed that marketable single oysters can be produced within a year when grown in coastal Georgia.

Introduction

The University of Georgia Marine Extension Service is working to develop an oyster (*Crassostrea virginica* Gmelin, 1791) aquaculture industry for the State of Georgia. Georgia once led the nation in marketing wild oysters in 1908 when over 8 million pounds of oysters were harvested (Harris 1980). Due to overharvesting and mismanagement of the wild stock of oysters, the industry began to collapse and by the 1930's the industry was in major decline (Ofiara and Stevens 1987; Harris 1980). From 1957 to 1966, most oysters were sold in state as a shucked product with lesser amounts sold as live oysters (Carley and Frisbie 1968). The shucking industry has died out primarily from the inability to keep a work force (Ofiara and Stevens 1987). Presently, no oyster shucking houses are in operation in Georgia. Today, oysters are harvested primarily in fall and winter for the sack trade, where live oysters are sold locally for oyster roasts. The oyster industry has remained with a ten year (2000-2010) average harvest of oyster meat of only 11,541 pounds per year valued at $43,943. It is envisioned that utilizing aquaculture techniques that a viable and sustainable oyster industry can once again become a major fishery for the State of Georgia.

Today there is considerable interest in the Georgia hard clam (*Mercenaria mercenaria* Linnaeus, 1758) aquaculture industry to diversify. Oysters are seen as a potential resource for increasing shellfish sales in Georgia. The price for high-quality raw-bar-grade oysters continues to rise nationally as a result of a decreasing supply and growth in the consumer market base (Brake *et al*. 2003; Jacobsen 2007). Specifically, the increased consumer demand for smaller-sized "boutique" oysters (2 inch) could have a major impact upon the developing Georgia oyster aquaculture industry and launch Georgia into a major oyster supplier. During the spring 2012 Georgia legislative session, the 3-inch legal size limit for harvesting oysters was reduced to 2 inches.

This project examines various devices designed and constructed by Whitehouse Seafood to collect oyster spat. All designs and material were sprayed with cement slurry intended to aid in the attraction of spat and in easing the removal of oysters from collectors. The overall methodology is to be able to collect natural spat and grow the spat to market size on the collectors either at the same site of collection or by moving the devices after the recruitment period (April to October; Manley *et al.* 2008, 2009) to various areas about the commercial shellfish growing lease for final growth to market size. This report examines different designs for gathering spat oysters during the recruitment period in Georgia's coastal waters.

Materials and Methods

The study site is located just north of Cumberland Sound, Camden County at 30.83002 X -81.494167 (Figure 1). The site is a small inlet in a salt marsh island just north of Crab Island which is north of Kings Bay Naval Submarine Base and is north and across the river of Stafford Island and south and across the river from Flood Island. Crooked River is just north of the experimental site. The site is just off the Intra-Coastal Waterway. The area is surrounded by salt marsh with native intertidal oyster reefs occurring along the fringes of the marsh. The center of the inlet is a large intertidal sand/mud flat.

Water temperature, salinity, dissolved oxygen and pH data were obtained from the Georgia Department of Natural Resources regular water monitoring program from station 6218. Station 6218 is located at 30.823 X -81.498 between Crab Island and just south of the oyster experimental test site.

Whitehouse Seafood wished to investigate various methods for gathering oyster spat. Criteria for making Quonset type huts for oyster spat attachment were: material that complies with existing state cultch regulations, stackable, light weight, easily transportable both before and after deployment, stable in waves and tides, will not sink into mud substrate, does not disturb the existing estuary bottom, and is economical to manufacture. In addition huts in stacks of five needed to keep a low vertical profile of two feet or less in accordance to State of Georgia regulations; be convenient for two people to handle; and be made of standard lengths of building material with minimal waste of material.

Three basic types of huts were built with various variables attached in order to recruit oyster spat. Huts consisting of burlap were 4 x 5 ft sections of 1/8 inch gauge steel wire spot welded in a 6-inch grid pattern formed into a semi-circle of 4 x 5 x 15 inches and covered with cement coated burlap (Figure 2 and 3). A PVC huts was constructed with three 1½ diameter PVC conduit and 16 ¾ inch diameter PVC conduit pipes. Sixteen 1 1/8 inch holes were drilled at 3 inch spacing along the three 1 ½ diameter pipes. The ¾ inch pipes were inserted through the holes in the 1½ diameter pipes after being bent with a 2 inch long PVC pipe bending box heater so that a semi-circle with a 15 inch height was formed. One 1½ diameter pipe formed the top and the other two formed the bottom support. The remaining huts consisted of one 1½ diameter PVC pipes with three ¾ pipes placed as above: one on each end and one in the middle. This structure was used as a support mechanism for other material attachment (Figure 5).

Cement coating consisted of 40% by volume Portland cement, 30% sand, 15% pelletized lime and 15% pulverized lime. Cement was applied by spraying with a Popcorn Paint Spray Gun or by dipping burlap in the cement mixture contained in a wheelbarrow.

Figure 1. Map location of the experimental site just south of the Crooked River in Cumberland Sound, GA

Experiment one

Burlap huts (Figure 2): 1/8 inch gauge steel wire spot welded in a 6-inch grid pattern was cut into a 4 ft X 5 ft section and bent into a semi-circle so that the middle was 15 inches off bottom. A 4 x 5 ft sheet of burlap was dipped into a wheelbarrow of cement and then placed on the wire frame. Once cement dried the sheet was attached to the frame. Only six single huts were deployed. Cost of material $7.15 per unit.

Burlap huts with holes: Same as above except a knife was used to cut an X in the burlap into each 6-inch square grid after the cement had cured (Figure 3). The resulting 4 triangles are pushed down into the holes. Only three single huts were deployed. Same cost as above, but more labor was required to cut holes.

Figure 2. Wire huts covered in a sheet of burlap coated in cement; three covered with burlap perpendicular, three covered with burlap parallel to creek bank and three with holes parallel to creek bank

Experiment two

Hut with 6 inch grid: a PVC frame for support was covered with a single layer of 1/8 inch gauge steel wire spot welded in a 6-inch grid pattern. Unit was then sprayed with cement. A total of 27 units deployed as three single units, three stacks of three units and three stacks of five units. Material cost $8.25 per unit. Low labor involved in construction.

Hut with 3 inch grid: a PVC frame was covered in two layers of 1/8 inch gauge steel wire spot welded in a 6-inch grid pattern so that the two layers formed 3 inch spacing. Unit was then sprayed with cement. A total of 27 units deployed as three single units, three stacks of three units and three stacks of 5 units. Material cost $12.50 per unit. Low labor involved in construction.

Hut with 6 inch grid and mussel rope: a PVC frame for support was covered with a single layer of 1/8 inch gauge steel wire spot welded in a 6-inch grid pattern. Non-biodegradable Mussel rope is laid across on 4 inch center and attached to frame with 8 inch cable ties. Unit was then sprayed with cement. A total of 27 units deployed as three single units, three stacks of three units and three stacks of 5 units. Material cost $16.25 per unit. Mussel rope cost was $8.00 per unit but is re-usable. Low labor required to construct.

Hut with 6 inch grid and 3-inch strips of burlap (Figure 5): a PCV frame for support with 1/8 inch gauge steel wire spot welded in a 6-inch grid pattern was covered with 3-inch strips of burlap placed approximately 3 inches apart. Unit was then sprayed with cement. A total of 27 units deployed as three single units, three stacks of three units and three stacks of 5 units. Material cost $9.75 per unit. Very time consuming in terms of labor to make.

Hut with 6 inch grid and sisal rope (Figure 5): a PVC frame for support was covered with a single layer of 1/8 inch gauge steel wire spot welded in a 6 inch grid pattern. Biodegradable sisal rope (3/8 inch diameter) was intertwined among the grid work and attached to frame with 8 inch cable ties. Unit was then sprayed with cement. A total of 27 units deployed as three single units, three stacks of three units and three stacks of 5 units. Material cost $8.25 per unit with low labor to construct.

Hut with PVC bars (Figure 4): a PVC frame made from 1.5-inch diameter PVC pipe was used to support ¾-inch diameter PVC conduit pipes. Pipes (16 ribs) were spaced approximately 4 inches apart along the frame. A total of 27 units deployed as three single units, three stacks of three units and three stacks of 5 units. Material cost $15.70 per unit. Very low labor required to construct.

All huts were deployed on May 2, 2011. Oyster spawning season in Georgia is from April to October (Heffernan *et al.* 1989). Sampling of spat density and spat size was performed on September 19, 2011.

Figure 3. Wire huts covered with a solid sheet of burlap dipped in cement and huts with cut squares

Experiment one

Huts constructed of wire mesh and burlap were positioned as follows: along a creek bank three huts with a burlap cover were placed parallel to the bank, three huts were placed perpendicular to the bank, and three huts with burlap cover with holes were placed parallel to the creek bank at the low water mark. Placement of huts were solid hut parallel to creek bank alternating with huts with holes parallel to creek bank and then three solid huts perpendicular to bank (Figure 2 and 3). The huts along the creek bank were adjacent to native intertidal oyster reefs.

Figure 4. PVC huts in stacks of 1, 3, and 5 deployed randomly along an oyster reef

Figure 5. Huts with sisal rope (left) and huts with 3-inch burlap strips (right)

Experiment two

Six different treatments were used to determine which treatment provided the optimum spat collector mechanism. Treatments were huts with 6-inch wire spacing, huts with 3-inch wire spacing, huts with 6-inch wire spacing with three inch strips of burlap, huts with 6-inch spacing with intertwined sisal rope, huts with 6-inch wire spacing with mussel rope, and PVC huts. In addition to the treatments, huts were deployed as either a single hut per treatment, stack of three huts per treatment, or a stack of five huts per treatment. There were three replicates of each stack per treatment. No pattern was used in placement of huts other than all nine stacks per treatment were in a random row along the bank. Huts were deployed along the intertidal creek bank in the following pattern: PVC huts, huts with mussel rope, huts with burlap strips, huts with Sisal rope, huts with 3-inch wire spacing, and huts with 6 inch spacing. Huts were placed below the oyster reefs in the intertidal zone and parallel to the creek bank. Native oysters occurred all along the creek bank.

On September 19, 2011, all huts were sampled for spat density and random oysters measured for shell length with a Vernier caliper to the nearest 0.1 mm. The area of a grid to determine density was 10.8 cm^2. To determine if differences in spat recruitment occurred on the top side versus the underside of huts, density estimates were made and the data combined between treatments. To determine if differences in recruitment occurred between different areas of the huts, density estimates from the underside were compared from the top of the underside of the hut, the side nearest the *Spartina* marsh and the side near the open water. To determine if the number of huts in a stack affected recruitment combined underside density data from all single huts were compared against those in combined stacks of three and five. Analysis of Variance was performed on all data and Tukey-Kramer Multiple-Comparison test (alpha = 0.05) was used to separate means.

Results

Water temperature, dissolved oxygen and pH values ranged from 10.3°C in January to 30.1°C in August, 9 mg/l in January to 4.6 mg/l in August, and 7.3 July to 7.8 in November/December, respectively (Figure 6). These values are representative of normal cycles in the coastal waters of Georgia. Water salinities remained high throughout the year of drought ranging from 26.8 ppt in March to 37.8 ppt in September.

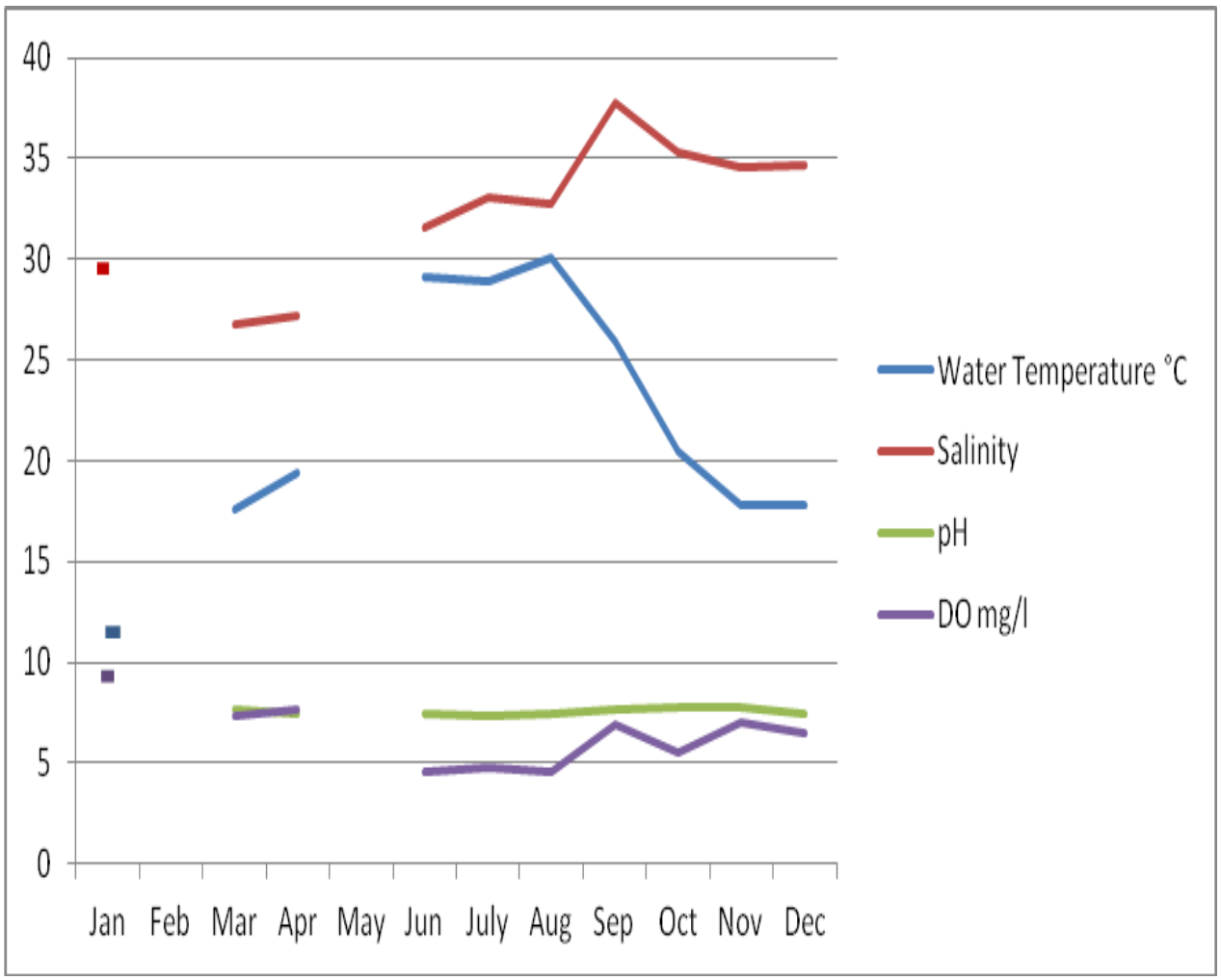

Figure 6. Water temperature (°C), salinity (ppt), pH and dissolved oxygen (DO mg/l) values for the experimental site located in Cumberland Sound for January to December 2011. Data from the Georgia Department of Natural Resources

Spat Recruitment

Experiment one

Attempts at collecting spat on the huts with burlap covers orientated parallel or perpendicular to the creek bank and those cut to form holes met with failure. The huts did collect spat especially on the underside, but the huts in general did not survive the exposure to tides, current, waves and storm activities. Only small pieces of burlap were found still attached to wire for huts along the creek bank (Figure 7). Mean number of spat found on the underside of burlap pieces with holes were 19.5 ± 4.91 (S.E.) per 10.8 cm^2, which were not significantly different (P = 0.7572) from that on solid burlap (parallel and perpendicular combined), 16.9 ± 4.21 per 10.8 cm^2. Mean sizes of spat were 32.0 ± 3.70 mm on huts with holes, which were not significantly (P = 0.5213) larger than oyster that were 27.4 ± 3.52 mm on solid sheets of burlap.

Figure 7. The remains of a hut originally covered in burlap with holes silt in squares

Experiment two

Clear patterns in spat recruitment were observed in the experiment at the Whitehouse Seafood commercial lease in Camden County, Georgia (Table 1). The combined spat recruitment data across all treatments showed that significantly ($P < 0.001$) more spat attached to the underside of huts (mean = 18.67 ± 0.49 per 10.8 cm^2) than on the outside (8.57 ± 0.32) of huts. Likewise, significantly ($P < 0.001$) more spat attached on the water side of huts (17.29 ± 0.61) which was significantly higher than those on the *Spartina* side (13.28 ± 0.59) which in turn was significantly higher than those from the tops of the huts (9.91 ± 0.47) (Figure 8). Less clear was the spat recruitment according to the number of huts in stacks. The number of spat on a single hut (17.21 ± 1.43) was not significantly different than that for combined huts in stacks of three or five. Mean density of spat on stacks of five huts (20.14 ± 0.68) were significantly greater ($P = 0.011$) than huts in stacks of three (17.20 ± 0.80 per 10.8 cm^2).

Figure 8. A hut with 3-inch burlap strips coated with cement where most oysters are on the side facing the river (right), with few oysters on top or on the side facing the salt marsh (left)

Table 1. Number of spat counts, mean density (per 10.8 cm^2), standard error, and results of the Tukey-Kramer Multiple-Comparison test on hut position where similar letters indicate no significant difference between means.

Combined data across treatments ($P < 0.001$; $F = 293.98$)

Hut Position	Count	Mean No.	S.E.	Tukey's
Under side	486	18.67	0.49	a
Outside	486	8.57	0.32	b

Combined data across treatments ($P < 0.001$; $F = 43.99$)

Position on hut	Count	Mean No.	S.E.	Tukey's
Water	317	17.29	0.61	a
Spartina	317	13.28	0.59	b
Top	317	9.91	0.47	c

Table 1 continued

Combined data across treatments (P <0.001; F = 4.53)

No. of huts	Count	Mean No.	S.E.	Tukey's
Stack of 3	180	17.20	0.80	a
Single	57	17.21	1.43	a,b
Stack of 5	252	20.14	0.68	b

For the six different hut treatments all combined data from stacks of one, three and five (Table 2), there was a significant (P <0.0001) difference in spat recruitment on the underside of huts. Significantly fewer spat attached to the wire huts with mussel ropes (8.3 ± 0.68 per 10.8 cm^2). Spat attachment on sisal rope (16.64 ± 0.75) was not significantly different than that on burlap strips (18.84 ± 1.24). No significant difference occurred between huts with burlap strips, 6 inch wire (22.05 ± 1.29) or PVC (22.14 ± 0.98) huts. No significant differences occurred between the 6 inch wire, PVC and 3-inch wire huts (23.58 ± 1.21).

Table 2. Mean density of spat (per 10.8 cm^2), standard error, and results of the Tukey-Kramer Multiple-Comparison test on hut treatments where similar letters indicate no significant difference between means

Hut type	Count	Mean No.	S.E.	Tukey's
(P<0.0001; F = 28.70)				
Mussel Rope	81	8.31	0.68	a
Sisal Rope	78	16.64	0.75	b
Burlap strips	81	18.84	1.24	b,c
6 inch wire	81	22.05	1.29	c,d
PVC	78	22.14	0.98	c,d
3 inch wire	81	23.58	1.21	d

Spat recruitment on single huts

There was no significant differences (P = 0.6947) in density of spat on the various treatments (Figure 9). Densities ranged from 9.5 on PVC huts to 21.3 spat per 10.8 cm^2 on 3-inch wire huts.

Figure 9. Spat on a 6-inch wire hut from a single stack

Spat recruitment within stacks of huts

In general greater numbers of spat recruited to the hut on top in the stacks of three; however it was only significantly higher for the huts with 3-inch wire spacing. For huts with 3 inch spacing of wire coated in cement, significantly (P= 0.004) more spat attached to the top layer (32.0 ± 3.43 per 10.8 cm^2) than the bottom ground layer (23.56 ± 2.04), while the middle layer (21.78 ± 2.05) was not significantly different than the top or bottom hut. There was no significant difference (P= 0.1372) in the mean oyster spat density for the wire huts with 6 wire spacing with means ranging from 16.89 (± 2.54) for the bottom layer to 27.11 (± 3.61) for the middle layer. There was no significant difference between layers for the PVC huts (P= 0.6036) with means ranging from 21.89 (± 1.29) for the bottom layer to 24.67 (± 1.62) for the top layer (Figure 10). There was no significant difference (P= 0.6443) in huts with wire and Sisal rope intertwined among grid with means ranging from 16.1 (± 2.30) from the middle to 19.11 (± 1.41) from the top layer. There was no significant different in burlap strip huts (P = 0.0574) with means ranging from 9 (± 3.69) for the top layer to 21.4 (± 1.80) on the bottom layer. Likewise no significant differences occurred for the hut with mussel rope which ranged from 16.11 (± 2.30) in the middle to 19.11 (± 1.11) on the top.

Figure 10. Oyster spat on PVC huts in a stack of three

In general there was no pattern for recruitment among huts stacked in five. For PVC huts there was a significant difference detected (P= 0.0099) with the ground layer having the lowest number (14.2 ± 2.44 per 10.8 cm^2) which was not significantly different than the middle layer (23.2 ± 1.70). The middle layer was not significantly different than the other layers which ranged from 25.11 (± 2.88) for the mid-top to 26.2 (± 2.73) at the top. For huts with 3-inch burlap strips, significantly (P= 0.0012) lower numbers recruited to the top (10.0 ± 4.15) than the other four layers which were not different and ranged from 23.4 (± 2.69) for the ground layer to 25.6 (± 2.80) for the mid-bottom layer. No significant difference (P= 0.3340) occurred among layers for the huts with 6-inch grid spacing with means ranging from 18.2 (± 3.12) at the ground layer to 29.1 (± 3.16) at the mid-bottom layer. No significant differences occurred (P= 0.9488) among layers for the wire hut with 3 inch spacing. Means ranged from 22.4 (± 3.19) on the ground to 26.89 (± 4.82) from the mid-bottom layer. Huts with mussel rope on the ground (11.2 ± 1.97) were significantly different (P = 0.0098) than those from the top hut (21.33 ± 2.08), with no difference in other layers. No significant difference (P = 0.0913) occurred between huts with mussel rope. Means ranged from 3.5 (± 1.12) in the hut second to bottom to 10.83 (± 2.37) from the top hut.

Oyster size

Experiment two

For the combined oyster size data across all treatments (Table 3), there were no significant differences in oyster size for oysters from the outside or underside of treatments (P= 0.44) or from their location on the huts: top, water or *Spartina* side (P= 0.42).

There was significant differences (P = 0.002, F = 6.07) in the size of oysters collected from the combine stacks of three huts (26.25 ± 0.31mm) which were smaller than those from the stacks of one (27.75 ± 0.54) or five (27.57 ± 0.26) which were not different in size (Table 4).

Table 3. Mean oyster shell length in mm, standard error, and results of the Tukey-Kramer Multiple Comparison tests where similar letters indicate no significant difference between means.

Combined data across treatments (P = 0.44, F = 0.59)				
Hut Position	Count	Mean Size	S.E.	Tukey's
Under side	489	26.35	0.36	a
Outside	489	26.75	0.37	a
Combined data across treatments (P = 0.42; F = 0.87).				
Hut Position	Count	Mean Size	S.E.	Tukey's
Water	316	27.01	0.448	a
Spartina	316	26.36	0.454	a
Top	316	26.22	0.452	a

Table 4. Mean size in mm of oysters collected from combined data across all treatments and results of the Tukey-Kramer Multiple-Comparison test where similar letters indicate no significant difference between means

Combined data across treatments (P = 0.002; F = 6.07)				
No. of huts	Count	Mean Size	S.E.	Tukey's
Single	314	27.75	0.54	a
Stack of 5	994	27.57	0.26	b
Stack of 3	718	26.25	0.31	b

For all spat size combined (stacks of 1, 3 and 5) per treatment data, significant differences ($P < 0.0001$) in mean size did occur between treatments (Table 5). Mean oyster size on mussel ropes (23.98 ± 0.37 mm) was lower than other treatments except on 6 inch wire (24.63 ± 0.36) which were statistically the same. Mean sizes of oysters on the 6 in wire and huts with burlap strips (25.95 ± 0.57) were the same. Oysters on the burlap strips, 3 inch wire (27.37 ± 0.43) and sisal rope (29.82 ± 0.45) were statistically the same size. Oysters from the PVC huts (30.94 ± 0.42) were statistically the largest sized oyster, only being equal in size to those grown on the sisal rope.

Table 5. Mean size in mm of spat from all huts, standard error and results of the Tukey-Kramer Multiple-Comparison test where similar letters indicate no significant difference between means

Hut type	Count	Mean Size	S.E.	Tukey's
($P < 0.0001$; $F = 6.12$)				
Mussel Rope	323	23.98	0.37	a
6 inch wire	324	24.63	0.36	a,b
Wire with burlap strips	324	25.95	0.57	b,c
3 inch wire	312	27.37	0.43	c
Sisal Rope	312	29.82	0.45	c,d
PVC	312	30.94	0.42	d

Spat size on single huts

Significant differences ($P < 0.0001$) in oyster size did occur between treatments of single stack huts (Table 6). Mean oyster size on 6 inch wire (21.61 ± 0.87 mm) were not different from 3-inch wire huts (25.92 ± 0.82) but were lower in density than all other treatments. Spat size on 3-inch wire huts were not statistically different from that on burlap strips (29.03 ± 1.18), mussel rope (29.21 ± 1.69), or PVC (29.71 ± 1.43) huts. Mean spat size on burlap strips, mussel and PVC were not different than that on sisal rope (31.64 ± 1.41) huts.

Table 6. Mean size in mm of spat from single huts, standard error and results of the Tukey-Kramer Multiple-Comparison test where similar letters indicate no significant difference between means

Hut type	Count	Mean Size	S.E.	Tukey's
(P <0.0001; F = 9.73)				
6 inch wire	38	21.61	0.87	a
3 inch wire	37	25.92	0.82	a,b,c
Burlap strips	36	29.03	1.18	b,c,d
Mussel	24	29.21	1.69	b,c,d
PVC	24	29.71	1.43	b,c,d
Sisal Rope	36	31.64	1.41	c,d

Spat size within stacks of huts

Mean spat size for oysters grown in stacks of three huts, oysters grown on huts with mussel rope, strips of burlap and 6 inch wire were equal in size but significantly (P<0.0001) smaller than those from 3 inch wire, sisal rope or PVC huts (Table 7). There was no significant difference between oyster size for those on 3-inch and 6-inch wire huts.

Spat size in the treatments of stacks of five was significantly different (P<0.0001) between treatments. Spat size on mussel rope, 6 inch wire and burlap were not statistically different from each other, but were smaller than those from the other treatments, except between the burlap and 3-inch wire treatments (Table 8). Spat on PVC and sisal rope were significantly larger than the other treatments.

Table 7. Mean size in mm of spat from huts stacked in three, standard error and results of the Tukey-Kramer Multiple-Comparison test where similar letters indicate no significant difference between means

Hut type	Count	Mean Size	S.E.	Tukey's
(P <0.0001; F = 19.69)				
Mussel	179	23.09	0.44	a
Burlap	108	24.07	1.01	a
6 inch wire	107	24.93	0.67	a,b
3 inch wire	108	27.26	0.80	b,c
Sisal Rope	108	29.57	0.75	c
PVC	108	30.65	0.71	c

Table 8. Mean size in mm of spat from huts stacked in five, standard error and results of the Tukey-Kramer Multiple-Comparison test where similar letters indicate no significant difference between means

Hut type	Count	Mean Size	S.E.	Tukey's
(P <0.0001; F = 18.25)				
Mussel	120	24.27	0.62	a
6 inch wire	179	25.10	0.47	a
Burlap	180	26.47	0.78	a,b
3 inch wire	167	27.77	0.59	b,c
Sisal Rope	168	29.61	0.60	c,d
PVC	189	31.27	0.58	c,d

Discussion

With the exception of the huts constructed with a solid sheet of burlap coated in cement and those with holes cut into the burlap sheets, all other types of huts were successful in collecting oyster spat. The sheets of burlap coated with cement were unable to withstand the physical actions of waves, tides and currents and were for the most part torn off the wire frame (Figure 7). For commercial purposes the huts constructed of PVC were considered optimal for collecting and growing oyster spat. For all data combined (Table 2), PVC huts had the second highest density of oyster spat, but were not statistically lower than the highest treatment with the 3 inch wire. In terms of growth, oysters from the PVC huts were consistently larger than oysters grown on other treatments, but were not significantly larger than those grown on sisal rope or 3 inch wire. Huts with sisal rope produced approximately 30% less spat than those on PVC or 3 inch wire huts (Table 2).

The cost of the PVC huts was $15.70 per unit which was more than all others except huts constructed with mussel rope which was $16.25 per unit. The increase cost was due to the cost of the mussel rope itself. The mussel rope treatments caught fewer oyster spat (65% fewer than those on 3-inch-wire huts Table 2) and they grew slower than oysters from other treatments (Table 5). Thus, use of the mussel rope huts is not preferred. The PVC pipe probably provided greater surface area for spat attachment than other treatments which would account for the higher densities of spat. Other hut treatments were more cost effective, but produced in general fewer oyster spats. Huts with the 3 inch burlap strips were inexpensive at $9.75 per unit but were the most labor intensive to construct. Field observations showed that the strips worked better within the stacks with the top hut in the stacks having lost parts of the striping.

All huts worked well in terms of deployment. They were easily stackable and transferrable by truck or boat (Figure 11). A single individual could deploy each hut type. None of the huts sank into the mud; however, all huts were planted at the lower edge of an oyster reef in an area that had shell mixed into mud bottoms. Results may have been different if planted on more muddy bottoms which dominate the coastal intertidal areas of Georgia. All huts with the exception of the huts covered with burlap coated in cement withstood field deployment and met the initial criteria for deployment. Two individuals could easily reposition huts after spat collection and for final grow out.

No measurements were determined for oysters for the final grow out phase. After sampling all treatments in September 2011 for spat density and size, stacks were broken up with the huts per stack spread one or two huts upwards into the intertidal zone and one or two huts spread downwards into the intertidal to subtidal zone (Figure 12). Oysters were allowed to grow until February at which time they were harvested by Whitehouse Seafood.

At harvest in February 2012, 4.5 bushels of legal size (3 inch) oysters were obtained from each PVC huts (Figure 13). Of which half were singles and the remainder either doublets or triplets. Approximately, one half bushel of sublegal oysters was obtained per PVC hut. Growth was not considered optimal from a commercial standpoint, because the oysters were growing too fast. The shells were thin and were believed that they would be unable to withstand shipping and handling efforts which would have resulted in substantial shell breakage.

Figure 11. Six inch wire and PVC huts stacked in boats and one individual deploying a wire hut with mussel ropes

Figure 12. PVC huts in stacks at sampling in September and huts redeployed after sampling

Whitehouse Seafood took less productive huts treatments and transported them to areas of the commercial lease that needed resource refurbishing (Figure 14).

From an observational stand point, it was believed by Whitehouse Seafood that oysters growing adjacent to the bottom had thicker shells than oysters growing farther off the bottom. No data was taken to determine if the observations in the field were accurate, but this should be investigated. It may be possible that near the end of the growing season, oysters should be removed from the huts and planted on bottom to thicken the shells prior to marketing and shipping and reduce shipping breakage. A new type of PVC cement coated structure is being designed so that the structure can be set up in a teepee structure for spat collection deployment and then be laid directly on bottom for the oyster's growth to market size (Figure 15).

Figure 13. A PVC and a 3-inch wire hut ready for harvest in February, 9 months after deployment

Figure 14. A 6-inch wire frame hut ready for harvest in February, 9 months after deployment

Figure 15. A new test teepee design to be tested in 2012

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