Commercial Farm Production of the Southern Bay Scallop (*Argopecten irradians concentricus*), an Alternative Aquaculture Species

Final Report

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Submitted to
Mr. Kal Knickerbocker
DIVISION OF AQUACULTURE
DEPARTMENT OF AGRICULTURE AND CONSUMER SERVICES

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Objectives
The main objective of this project was to provide critical grow-out data for the production of the southern bay scallop. This project is a response to the imminent need for crop diversification within the Florida bivalve aquaculture industry. Exploration of the aquaculture potential of other mollusk species is ongoing at various research institutions within Florida. In addition to the current species under investigation we believe the Florida bay scallop (*Argopecten irradians*) is an excellent candidate to diversify the industry. This species has great potential for commercial success due to its rapid growth and high market value. To date researchers have focused on many aspects of hatchery, nursery, grow-out and marketing of bay scallops. Specifically, a study by Blake, Adams, Degner and Sweat in 1999 investigated the production, marketing and economics of the bay scallop off of Crystal River, Florida. These researchers concluded that refinement of grow-out systems and a better site location were needed to reduce fouling, increase growth and maximize survival.

The current research was designed to determine: 1. Are existing clam leases adequate for bay scallop production? 2. Are locations near the Blake et. al., 1999 study site (located away from fouling sources) better for scallop production? 3. What are the best containment systems, under existing regulations, for the production of bay scallops on these sites?

Present State of Knowledge
Early research focused on the culture of the bay scallop (*Argopecten irradians*). Researchers developed methods for maturing, spawning and rearing spat (Loosanoff & Davis, 1963). Basic rearing techniques for the bay scallop were then introduced in 1971 by Castagna. Grow-out techniques were further refined in 1975 by Castagna, while Castana and Duggan (1971) demonstrated that market size scallops could be raised in large cages within five to seven months. In the early 1980's Rhodes and Widman used Japanese pearl nets and lantern nets to increase stocking density and exert better control of grow-out densities and growth. Others attempted to produce scallops in closed re-circulating systems, but were met with mixed results (Mann and Taylor, 1981). However, grow-out in the natural environment continued to be the most successful and economical method of production. At the same time, intensive bay scallop production was underway in Martha's Vineyard (Karney, 1991) which influenced the development of basic culture technology for the bay scallop. The success of this research in the United States led to the development of the Chinese bay scallop aquaculture industry (Zhang, 1995). Today, China is the largest producer of bay scallops in the world.

Bay scallop aquaculture in Florida began with the work of Norm Blake, who reared bay scallops in Tampa Bay in 1996 (Lu and Blake, 1996). This work detailed the production, marketing and economics of bay scallops produced on the west coast of Florida (Blake, et al., 1999). Blake et al. (1999) used a floating barge (8 m x 8 m) to suspend aluminum cages (13 mm mesh) one meter below the surface. The barge system was placed over a two acre educational lease awarded by the Department of Environmental Protection in Citrus County, Florida. Each cage was stocked with 300 scallops; the barge had a capacity of 60,000 scallops. Both growth and mortality were high and depended on the type of cage material, degree of fouling and the density of scallops. This study concluded that modifying the cages and changing the grow-out location, away from sources of fouling organisms, would vastly improve grow-out production (Blake, et al., 1999). The work of Blake et al. (1999) serves as the starting point for the current study.

Additionally, these authors investigated the market potential for locally produced bay scallops and concluded that a market could be readily developed if adequate supplies of reasonably-sized whole scallops were available. They also suggested that a small single owner operation would only yield a marginal net return. They did conclude, however, that gains from economy of scale, production system refinements and labor reduction could increase production and generate greater net returns.

Rationale/Justification/Applicability

There is a critical need for diversification of the Florida marine bivalve aquaculture industry. The hard clam (*Mercenaria mercenaria*) has been a successful commercial aquaculture species for Florida growers, but it is the only shellfish species currently being commercially produced. The single species culture (*M. mercenaria*) on the west coast of Florida is the problem which creates the opportunity of developing a new candidate for culture. The bay scallop is fast growing, reaches market size in just one year, and has a high market value (Blake, et al., 1999). In the Pacific Northwest, culture methodologies and markets have been developed for multiple bivalve species (i.e., clam, oyster and mussels). In Washington State, for example, there are at least seven species of bivalves that are commonly cultured (Toba, 2005).

State and federal programs have been attempting to diversify the Florida bivalve industry. A 2005 USDA study investigated the market potential of two species of Ark clam for culture, (*Anadara ovalis*) the Blood Ark and *(Noetia ponderosa*) the Ponderous Ark. Based on the studies findings, the 'consensus' was that there was limited appeal of these species in the commodity market and they were not good candidates for production due to their largely relative obscurity (Degner et al., 2005). The sunray clam (*Macrocallista nimbosa*) is another bivalve currently being considered for culture in Florida. However, this species has similar difficulties to overcome as Ark clams particularly its undefined market potential. The bivalve industry in the southeastern US is concurrently conducting research on genetic manipulation techniques to help the clam industry in Florida. The USDA Agricultural Research Service, in conjunction with Florida Sea Grant and Harbor Branch Oceanographic Institute, investigated the use of triploid *M. mercenaria* as a means to increase growth rate and enhance stress resistance under culture conditions. This research resulted in successful triploid induction in the hard clam, *M. mercenaria*. However, the triploids that were produced were smaller, not larger, than their diploid counterparts. Results on stress resistance are incomplete. This industry needs to continue to seek a new candidate of marine bivalve.

The hatchery production experience of BSC in producing the bay scallop combined with the previous research of a Florida Sea Grant study by Blake et al., 1999 that investigated the aquaculture potential and marketing of the bay scallop was the foundation for this project. An established market already exists to absorb a significant amount of product (Blake, per comm.). Blake et al. indicated further investigation was necessary to determine cost effective and adequate commercial grow-out containment systems for this species. The current study furthers the Sea Grant work by specifically investigating grow-out containment systems.

Methods and Procedures

Two sites (referred to as northern and southern) were selected along the west coast of Florida in areas of known scallop habitat (i.e. coastal inshore and near shore waters with associated sea grass beds). The southern site was selected to test the potential for grow-out of bay scallops on an existing clam lease. This site was located in two meters water depth on the BSC lease in southwestern Tampa Bay (27^o 35.854' N; 082^o 35.493' W). The northern site (N 28^o 38.217' N; 82^o 45.777' W) was selected to be close to the previous scallop aquaculture study location (Blake, et al. 1999). However, the northern site was intentionally placed in deeper water (3.5 meters water depth) and further from sources of fouling organisms (i.e. oyster bars, estuaries and low salinity water) that proved problematic in the Blake study.

This project also had to comply with existing state regulations for bivalve leases. A water column lease for grow-out operations was not feasible under existing regulations; consequently, the use of common culture equipment, such as lantern nets, Japanese pearl nets and floating cages, was not possible. The maximum height of grow-out cages was limited to 0.30 m off the bottom for this project. Four treatments, consisting of different bag/cage designs, were used to test scallop grow-out potential. The treatments were: flat clam bags, tented clam bags, ground level plastic cages and elevated plastic cages (Table 1).

Table 1. Growout Treatments and Number of Replicates at Each Restoration Site

Treatment	**Northern Site Replicates**	**Southern Site Replicates**
Flat Clam Bag	5	5
Tented Clam Bag	5	5
Elevated Cage	5	5
Bottom Cage	5	5

Standard 8.0 mm mesh clam bags (M&R Seafood, Cedar Key, FL) (1.27 m x 1.11 m) were used. The tented clam bag treatments consisted of standard clam bags that were “tented open” with five pieces of ½” PVC pipe cut to 0.15 m length and secured on the inside top and bottom of the bag. All clam bag treatments were attached to the bottom with ½” PVC stakes (0.30 m in length). Cages were constructed from 7.0 mm square plastic mesh screening (Aquatic Ecosystems # N1170) folded to form a rectangle of 1.27 m x 1.07m x 0.15m. Cage seams were sealed with cable ties. Cage volume was maintained by five ½” PVC pipes (0.15 m length) that were attached to the top and bottom of the cages with cable ties. Bottom cage treatments were staked directly to the bottom with ½” PVC stakes (0.30 m in length). Elevated cages were attached 15 cm off the bottom with ½” PVC stakes (0.46 m in length). To prevent the bottom from sagging, a 1” PVC pipe (33 cm diameter; 1.5 m in length) was attached from corner stake to corner stake on the diagonal for support. In summary, there were two sites, four treatments per site, and five replicates per treatment (Table 1).

In December of 2008, all replicates were stocked with 300 scallops (average shell height (hinge to lip measurement) >15 mm). Treatments were checked bi-monthly for seven months to examine scallops and clean the cages. Scallop growth rate was determined monthly from one replicate per treatment per site. The study was terminated at the northern location one week before the opening of the recreational scallop season (end of June 2009) and the first week of July 2009 (southern location). Data analysis included growth rate, survival, fouling, and overall scallop appearance.

Results

Monthly site visits were performed to collect data on temperature, cage condition and scallop growth. The lowest observed temperature (9.0^0 C) was recorded on the northern site in January 2009 (Figure 1). The southern site also revealed a lowest temperature during January (17.0^0 C) which was 8.0^0C higher than the northern site. The study period encompassed the winter through early summer during which the temperature increased at both locations from the January lows to highs of 28.5^0 C and 29.0^0 C at the northern and southern sites, respectively.

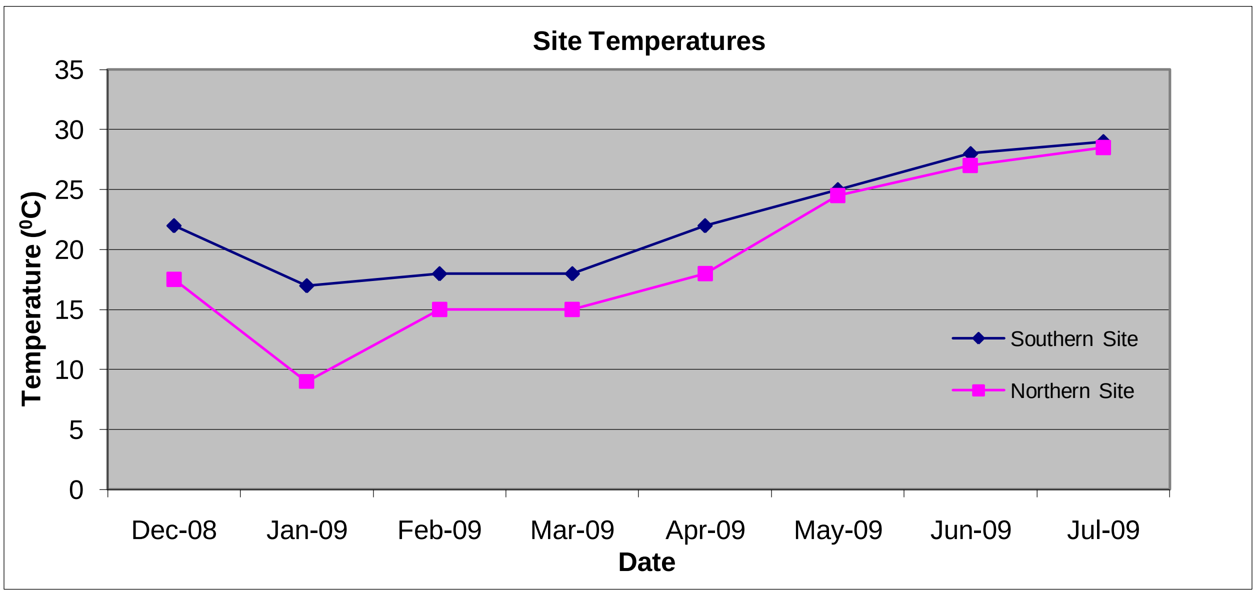

Figure. Water temperature at each sampling location from December, 2008 through July, 2009.

Southern Site

Mean size for scallops stocked at the southern site was 17.3 ± 2.8 mm scallops. Increase in shell height, which is an indirect measure of growth rate, during the 200 day grow-out period is shown in Figure 2. Scallops in all treatments at the southern location grew throughout the study. The elevated cage treatments attained the largest shell height (49.8 ± 0.9 mm); bottom cages attained 47.7 ± 0.9 mm, tented clam bags reached 42.9 ± 2.4 mm and the flat clam bags had the smallest shell height (42.7 ± 2.7 mm).

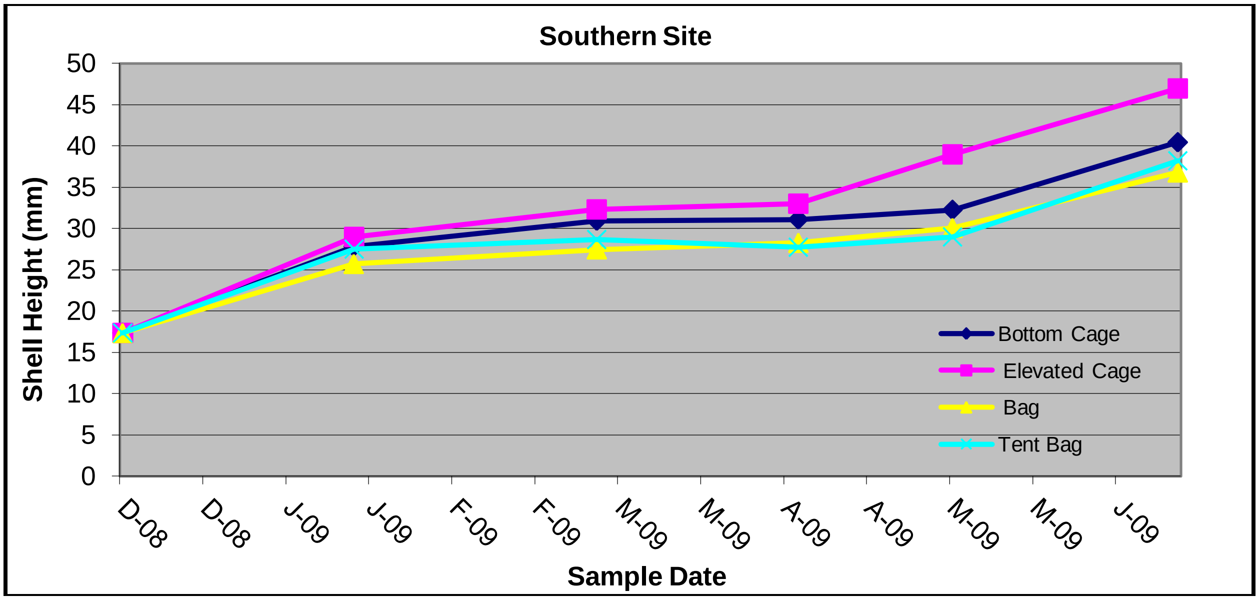

Figure 2. Mean shell height of bay scallops within each treatment at the southern site.

Differences in shell height among treatments were compared using ANOVA and Tukey's HSD post hoc test of comparison (Figure 3). No significant difference in shell height was observed between scallops held in the elevated cages and bottom cages ($P>0.05$). No significant difference in shell height was observed between tented clam bags and the flat clam bags ($P> 0.05$). Significant differences in shell height were found between cage treatments and bag treatments ($P< 0.05$).

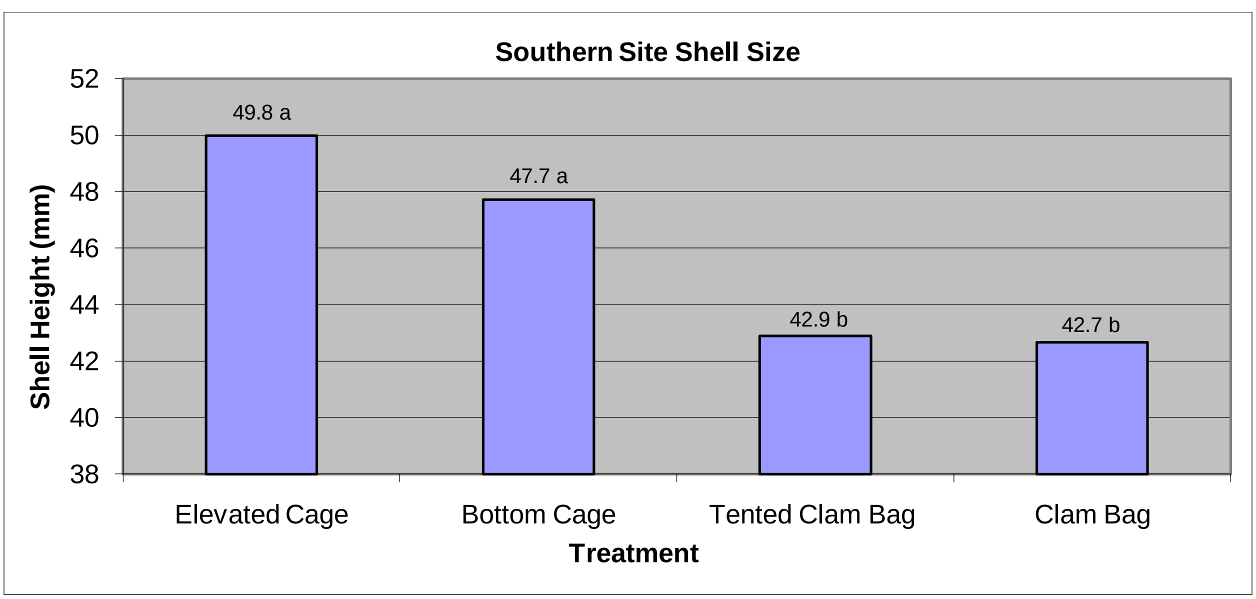

Figure 3. Comparison of shell height among the various treatments at the southern site. Values with a common superscript were not significantly different. Tukey's HSD; $\alpha = 0.05$.

Survival rate for the southern site was calculated at the termination of the study (Figure 4). The highest percent survival was in the bottom cages (91.2 ± 4.5) followed by elevated cages (64.6 ± 10.9) and tented clam bags (37.1 ± 17.9). The lowest survival was in the flat clam bag (15.1 ± 10.6). Comparisons of percent survival revealed differences among all treatments (P<0.05).

Figure 4. Comparison of survival among the various treatments at the southern site. Values with a common superscript were not significantly different. Tukey's HSD; $\alpha = 0.05$.

Northern Site

Mean size of scallops at the time of stocking at the northern site was 17.3 ± 2.8 mm. Scallops in all treatments grew steadily throughout the study (Figure 5). The elevated cage treatments attained the largest shell height (42.1 ± 1.2 mm), followed by bottom cages (38.1 ± 0.9 mm) and tented clam bags (35.2 ± 2.9 mm). Flat clam bags had the smallest shell height (32.7 ± 2.3 mm).

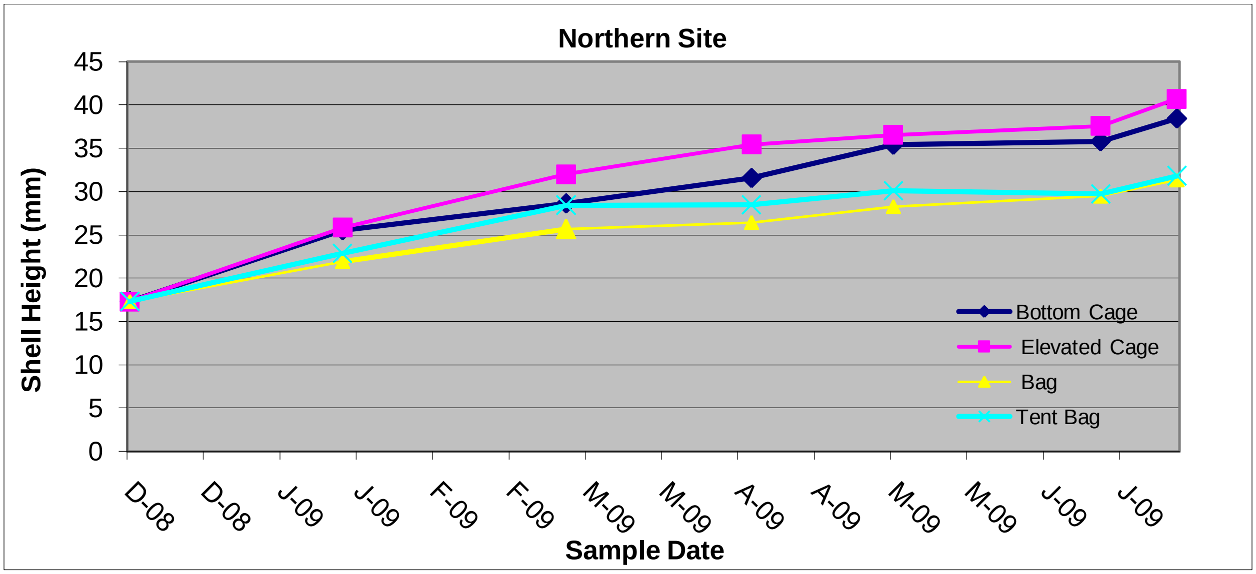

Figure 5. Mean shell height of bay scallops within each treatment at the northern site.

No significant differences in scallop size were found between elevated cages and bottom cages (P>0.05) or between tented clam bags and flat clam bags (P>0.05) (Figure 6). Significant differences in shell height were found between cage treatments and bag treatments (P<0.05).

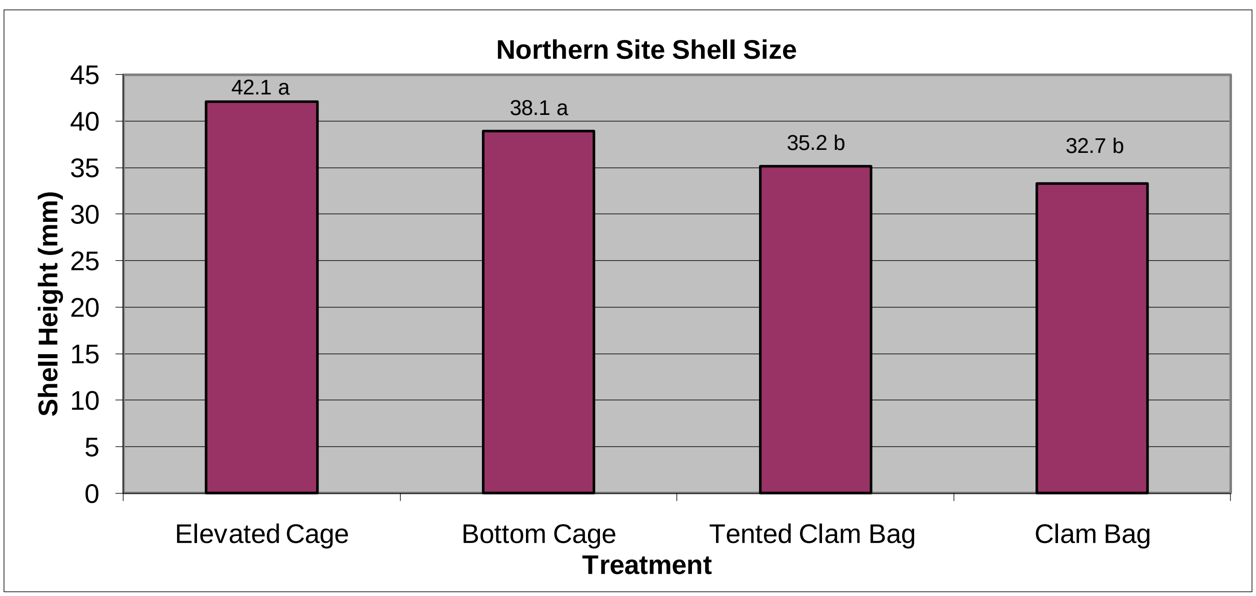

Figure 6. Comparison of shell height among the various treatments at the northern site. Values with a common superscript were not significantly different. Tukey's HSD; $\alpha = 0.05$.

Percent survival was calculated at the termination of the study (Figure 7). The highest percent survival occurred in the elevated cages (93.4 ± 2.7), followed by bottom cages attained (81.9 ± 2.8) and tented clam bags (49.1 ± 20.9). The lowest percent survival occurred in the flat clam bag (56.1 ± 19.3%). Significant differences in percent survival were found between the elevated cage and the bottom cage ($P<0.05$). No significant differences in percent survival were found between tented clam bags and flat clam bags ($P>0.05$) (Figure 7).

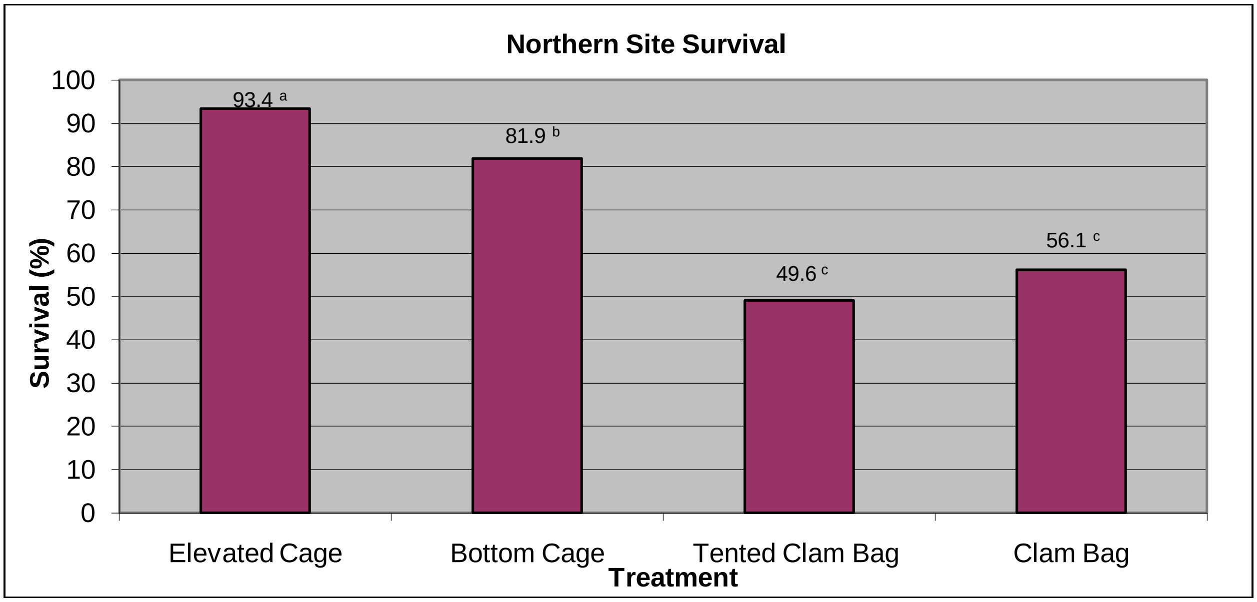

Figure 7. Comparison of percent survival among the various treatments at the northern site. Values with a common superscript were not significantly different. Tukey's HSD; α = 0.05.

Northern and Southern Site Comparison

Comparisons in growth from similar treatments between the two study sites are shown in Figure 8. Treatments at the southern site were significantly larger than their northern counterparts (P<0.05).

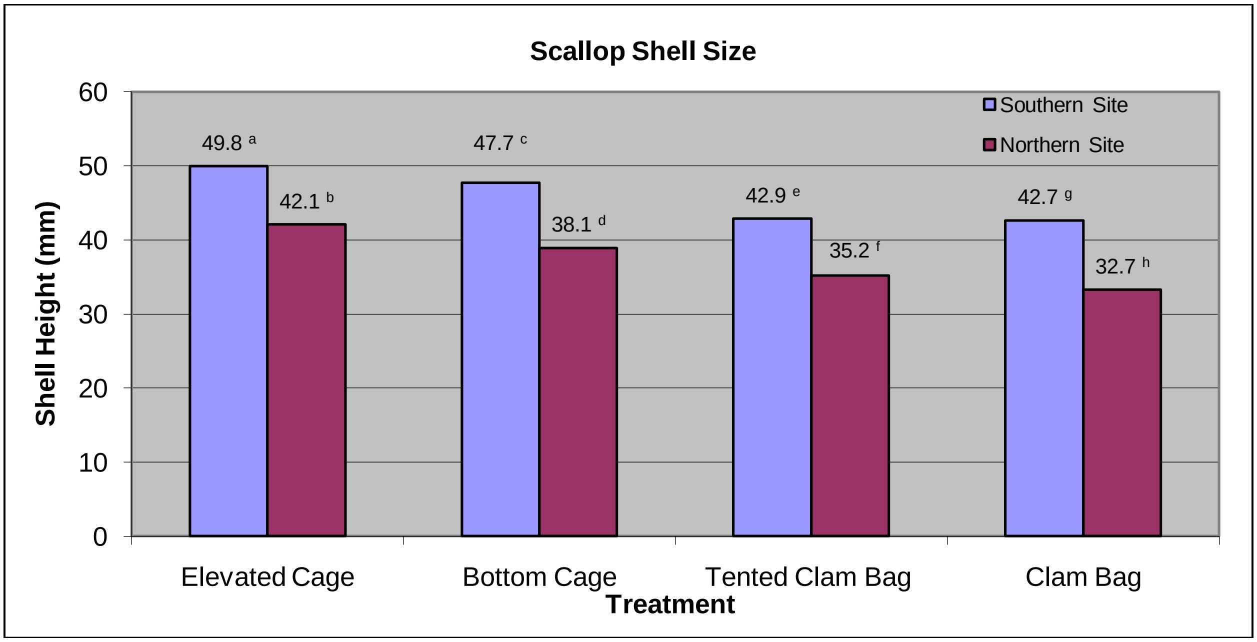

Figure 8. Comparisons in shell height among the four treatments between the two sites. Values with a common superscript were not significantly different. Tukey's HSD; $\alpha = 0.05$.

Comparisons in percent survival from similar treatments between the two study sites are shown in Figure 9. The survival rate were significantly higher at the northern site than the southern site for the elevated cage, tented bag and flat clam bag treatments ($P<0.05$). Survival rates of the elevated cage were significantly greater at the southern site than the northern site ($P<0.05$).

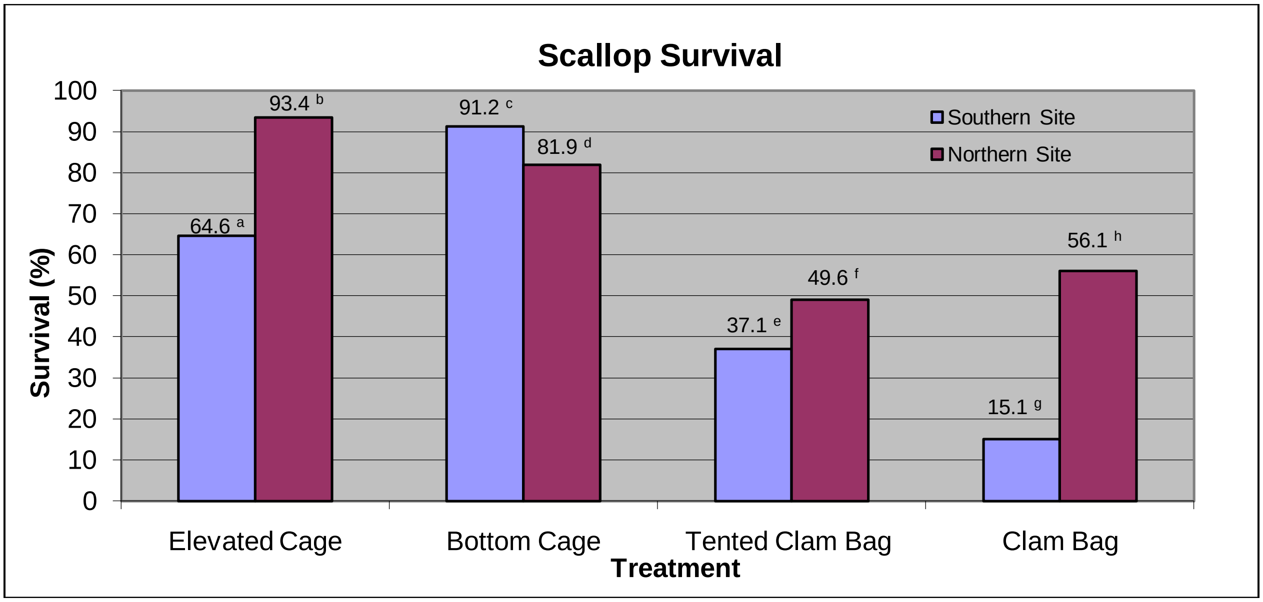

Figure 9. Comparison in percent survival among the four treatments between the two sites. Values with a common superscript were not significantly different. Tukey's HSD; α = 0.05.

Discussion

One objective of this study was to determine if an existing clam aquaculture lease would be suitable for the successful culture of bay scallops. During the investigation, important differences in water quality and habitat were found between the two locations. The southern site, adjacent to the existing BSC clam lease in Tampa Bay, was in two meters of water and surrounded by seagrass meadows. Scallops placed on this site were found to grow faster than the northern location, regardless of treatment. The higher growth rates at the southern site could be explained by the slightly higher temperatures and the availability of higher phytoplankton biomass. From April through July, water clarity at the southern site was often less than 18 inches. In contrast, water clarity at the northern site over the same period was generally greater than 10 feet. Although the southern site had the highest growth rates, survival was significantly lower in three of the four treatments when compared to the northern location.

During the final collection at the southern site, many shells in the elevated cages were severely fouled with oysters (Appendix 1). Elevated cages also contained "fresh dead" scallops with decomposing tissue and scallops with hinge disease. Most of the empty shells within the elevated cages were in a narrow size range, indicating mortality probably occurred within a narrow time window. The recent mortality in elevated cages was caused by excessive fouling on both sides of the shell resulting in difficulty opening and closing the valves.

At the southern site, shell height in elevated cages was not significantly different that in bottom cages, although bottom cages had the highest overall survival. Scallops in bottom cages did not experience complete fouling on both shell valves, as the bottom valve generally rested on the sediment surface. This precluded fouling on one valve and mitigated the effect of severe fouling on scallop health. It was noted, however, that many scallops in this treatment were beginning to have difficulty fully closing the valves.

Survival in bag treatments at the southern site was significantly lower compared to cage treatments. In both bag treatments we found many small broken shell remnants, crab holes chewed into the bags and a few stone and mud crabs residing in the bags. These findings indicate that clam bags are not suitable containment devices for scallop culture and containment devices such as cages and elevated cages are necessary.

Fouling at the southern site was first noticed in March and increased in intensity through the termination of this project in July. This degree of fouling reduced the aesthetics of the scallop thus preventing a farmer from marketing them as a whole product. Additionally, the labor required to maintain the cages at the southern site was high. These cages had to be cleaned bi-monthly and the elevated and bottom cages had to be changed out frequently due to heavy fouling in the spring. The fouling at this location is heavy and frequent enough to prevent a farm operator from achieving suitable quantities of clean, un-fouled, marketable scallops. These findings support the conclusions of Blake et. al. (1999) that leases in estuarine waters are not suitable for scallop production.

The findings from the northern site, which was sufficiently removed from estuarine influences, proved to be more favorable for scallop production. This site was selected so as to approximate the environmental conditions from the Blake, et al. (1999) study. In our study, however, the site was intentionally placed in deeper waters far removed from potential fouling environments (i.e. oyster bars, estuaries and low salinity water) that proved problematic in the previous study. Scallops at this site grew more slowly than at the southern site regardless of treatment. The scallops in the elevated cages reached a minimum market size- 40 mm- 192 days after stocking. This growth rate is adequate for commercial production. The lower growth rates at this location appeared to be influenced by the lower temperatures and the absence of dense algal blooms. Routine site visits from April through July found the water to be clear to the bottom all year and the lateral clarity was generally greater that ten feet.

Scallops were largest in elevated cages, although growth in this treatment was not statistically different than in bottom cages. Scallop size in both bag treatments was significantly smaller than both cage treatments. Tented bags supported larger sized scallops than flat bags, but this difference was not statistically significant.

Although the northern site had lower growth rates than the southern site, survival at the northern site was significantly higher in three of the four treatments. The survival rates of the elevated cage treatments was the highest on the site (93.4 ± 2.7%) followed by the bottom cage (81.9 ± 2.8%) (Table 8). The bag treatments differed significantly from the cage treatments in survival rate at this site. The tented clam bag treatment appeared to have the highest survival rate of the bag treatments (49.1 ± 20.9%) although it was found to be statistically similar to the flat clam bag treatment (56.1 ± 19.3%).

During examination of the shell remaining in the clam bag treatments these researchers found evidence of predation similar to the southern site where there were many small broken shell remnants, crab holes chewed into the bags and stone, mud and calico crabs residing in the flat clam bags (Appendix 2). These findings indicate that clam bags are not sufficient containment devices for scallop culture and containment devices such as cages and elevated cages are necessary. During routine maintenance the researchers found that the rolling macro-algae, common in this area, settled easily on the clam bags potentially causing water flow restriction to the scallops. The rolling macro-algae were not found to cover the cages and passed under the elevated cages and only surrounded the edges of the bottom cages but did not cover the top of the cage. Fouling on the cages and bags on the northern site was minimal (Appendix 3). Cage maintenance was minimal. Cages were easily brushed clean of settled solids and no hard fouling was observed during routine visits.

Shell fouling in all treatments at this site was virtually nonexistent (Appendix 2). The scallop shells in all containment systems at this site were free of fouling that would degrade their appearance for marketing. The absence of significant fouling would allow a farmer to marketing these scallops as a high quality whole product. Additionally, the labor required to maintain the cages at the northern site was insignificant and there was no need to change out the cages during the project. We suggest sites similar to the northern location are adequate for the production of high quality scallops using elevated cages.

Conclusions

This research showed that existing clam leases located near highly productive estuarine systems provide the best growth. The drawbacks for bay scallop production on these leases come from the heavy fouling that occurs in these highly productive ecosystems. Fouling causes high labor costs, low product appearance and catastrophic losses due to heavy fouling with oysters and barnacles. Therefore, these lease sites are not suited for the culture or production of bay scallops. In contrast, offshore areas in the vicinity of the northern study site were adequate for bay scallop production. The high survival rates and moderate growth combined with low to no fouling would allow a potential farmer to consistently produce a high quality sustainable product with minimal labor.

Under the current regulations pertaining to bottom leases and the "single level" elevated cages used in this study; this type of operation would not produce the biomass necessary to justify commercial production. However, if water column leases were issued by the state of Florida, farmers could utilize commercially available lantern net systems to increase the productivity of a lease. Lantern nets would allow for use of multi level/vertical containment systems to maximize biomass production per acre. The use of a water column lease would significantly increase the profitability of such an operation. However, further research is necessary to determine if this is an economically feasible method of production in Florida waters.

III. Relevant Literature

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Appendix 1 Southern Site Shell Fouling

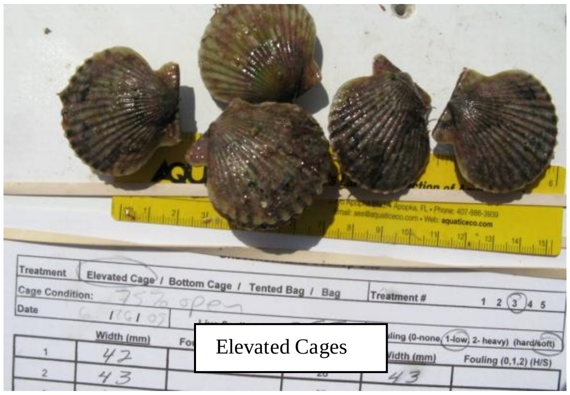

Elevated Cages

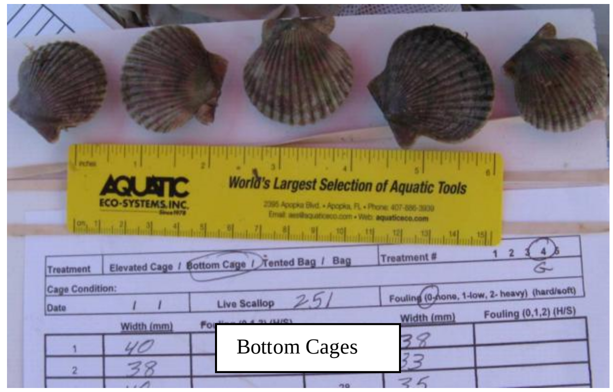

Bottom Cages


Tented Clam Bag


Flat Clam Bag

Appendix 2 Northern Site Shell Fouling


Elevated Cages



Bottom Cages

Tented Clam Bag

Flat Clam Bag

Appendix 3 Northern Site Cage Fouling

Elevated Cage

Bottom Cage

Tented Clam Bag

Flat Clam Bag