Final Report

Eliminating Barriers to Commercial Production of Sunray Venus Clams in Florida: Enhanced Hatchery Production, Growout Site Selection, and Definition of Wholesale Market Product Attributes

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BY

Leslie N. Sturmer
University of Florida IFAS
Shellfish Aquaculture Extension Program
Cedar Key, FL

John Scarpa
Harbor Branch Oceanographic Institute at Florida Atlantic University
Aquaculture and Stock Enhancement Program
Fort Pierce, FL

Charles M. Adams
University of Florida IFAS
Food Resources and Economics
Gainesville, FL

Steve Otwell
University of Florida IFAS
Food Science and Human Nutrition
Gainesville, FL

Todd Osborne and L. Rex Ellis
University of Florida IFAS
Soil and Water Sciences
Gainesville, FL

R. LeRoy Creswell
University of Florida IFAS
Florida Sea Grant Extension
Ft. Pierce, FL

Sea Grant
Florida

PROJECT SUMMARY:

The growth of the Florida clam culture industry is a dramatic success story. However, the industry is built on a single clam species *Mercenaria mercenaria*. An industry based exclusively on one species can suffer economic instability due to market fluctuations or losses from disease. Diversifying the shellfish culture industry by developing farming technology and markets for other bivalve species and products may mitigate production and market risk, thereby enhancing economic stability and growth of the industry. The goal of this project was to successfully demonstrate to the various sectors of the Florida shellfish aquaculture industry the potential of the sunray venus clam, *Macrocallista nimbosa*, as a new species to diversify and expand the industry. In our previous research, we successfully spawned sunray venus clams, cultured the larvae, produced seed and reared them through growout using techniques similar to those for commercial hard clam culture, which was our hypothesis. The existence of a latent market was demonstrated via restaurant/consumer acceptance studies. However, Florida hatchery operators may be reluctant to move forward developing sunray venus clam broodstock or producing seed until they are confident that the growers have a marketable product for wholesale distribution. This "chicken and egg" scenario may be overcome by assisting the industry as was done to head start the hard clam industry in Florida. By developing simultaneously the technology with industry alongside, information gaps and potential barriers to commercialization of this species were targeted.

In this study, we hypothesized that enhanced hatchery production through broodstock development, growout site selection, and determination of wholesale market-related product attributes may 1) eliminate barriers to commercialization of this new aquaculture species, 2) facilitate technology transfer to the Florida hard clam industry, and 3) promulgate market development. Therefore, the objectives of this proposal were to: 1) Create initial founder broodstock lines for Florida hatcheries; 2) Demonstrate to hatchery operators the proper development broodstock for seed production; 3) Determine production performance of sunray venus clams for field-based nursery and growout culture at multiple existing commercial high-density lease areas; 4) Establish a relationship between soil (substrate) and sunray venus clam productivity at multiple lease areas using a soils-based approach; 5) Define a) salinity and b) soil preferences for selection of future lease sites for sunray venus clam culture; 6) Determine the sensory, microbial, and nutritional profiles of cultured sunray venus clams; and 7) Examine product attributes of sunray venus clams with respect to wholesale market and product distribution standards for molluscan shellfish.

Objectives 1 and 2 were accomplished by creating separate lines of broodstock sunray venus clams using multiple parents in a factorial mating scheme to capture genetic diversity for future selection by commercial hatcheries. Commercial hatchery personnel assisted in initial creation of lines and/or attended workshops to learn about animal breeding schemes. Objective 3 was accomplished by providing seed clams produced in the first objective to multiple commercial land-based nursery and field growout operators and sampling periodically to measure production parameters. Objective 4 was accomplished by correlating soil characteristics (e.g., grain type, H_2S concentration) from multiple soil cores at different growout sites with sunray venus production parameters. Objective 5a was accomplished by performing a standard lab-based experiment of replicated salinity treatments to determine optimal salinity. Objective 5b was accomplished by comparing production parameters of sunray venus cultured in replicated containers of known soil types at one lease area. Objective 6 was accomplished by utilizing standard sensory and microbial tests to evaluate groups of sunray venus held at different storage temperatures and using standard methods to determine the nutrients required by the Nutrition Labeling and Education Act. Objective 7 was accomplished using a facilitated mail survey of primary wholesalers and their downstream buyers by providing them with samples of market-size sunray venus clams; as well as a survey of buyers at the Boston Seafood Show. Outreach was accomplished as hatchery operators, land-based nursery operators, growers and wholesalers were engaged in this research, thereby allowing for technology transfer to each of these industry sectors during the project.

The project yielded data and materials to fill voids of our previous Florida Sea Grant-supported sunray venus clam projects, thus lowering or eliminating barriers to commercialization of this species by Florida shellfish culturists and serving as a complement to the $19 million Florida hard clam culture industry. Broodstock production and education will aid commercial hatchery operators in their initial production of seed for the industry. Characterization of soil types and chemistry will aid in determining compatibility of existing shellfish culture leases or in siting future leases for this species. Determining product attributes in the wholesale distribution system will help guide the development of local, regional and national markets. Economic benefits to the industry include the potential to diversify revenue streams and increase net return to the grower while ensuring the ability of hard clam farmers to sustain their shellfish aquaculture-based economy.

INTRODUCTION AND RATIONALE:

Federally funded (over $10 million) job retraining programs during the 1990s provided an infrastructure to introduce shellfish aquaculture as an alternative employment opportunity to many rural communities along Florida’s west coast (Colson and Sturmer 2000). Fishermen were suffering economic hardships due to the demise of capture fisheries from state regulations and fishery closures. Since then, Florida has seen a dramatic increase in aquacultured shellfish production. The clam industry grew from $1.2 million (41 farmers) in 1991 to $19 million (393 farmers) in 2007 (Adams et al. 2009a). The economic activities associated with this new industry were also assessed: total economic impact included nearly $49.5 million in output of clam sales, $30.1 million in value added revenue, $25.1 million in labor income, $3.7 million in property income, $1.3 million of indirect business taxes, and 563 jobs (Adams et al. 2009a).

The growth of the Florida clam culture industry is a dramatic success story. However, the industry is built on a single clam species *Mercenaria mercenaria*, which can lead to market problems. The industry value fell to just under $13 million in 2003 (FASS 2004) and to $10.7 million in 2005 (FASS 2006) as dock-side prices plummeted from 13¢ to 9¢ per clam during the 2001-2004 economic downturn, which was not observed for other bivalve species, such as oysters (R. Rheault, ECSGA pers comm). Unfortunately, an industry based exclusively on one species can suffer economic instability due to market fluctuations or losses from disease (e.g., QPX in Northeast, U.S.; Smolowitz et al. 1998, Ford et al. 2002). Diversifying the shellfish culture industry by developing farming technology and markets for other bivalve species and products will mitigate production and market risk, thereby enhancing economic stability and growth of the industry.

Figure 1. Cultured Sunray Venus Clams, *Macrocallista nimbosa.*

There has been considerable investment in researching the potential of other bivalve species, including angel wings (Gustafson et al. 1991), bay scallops (Moss et al. 2000), and blood arks (Degner et al. 2005a), for diversification of the hard clam industry in Florida and the southeastern U.S. Unfortunately, none of these species are being cultured commercially today because of either culture or market limitations. However, successful diversification and expansion of bivalve aquaculture is occurring in Washington state, which started with oysters, then added manila clams, followed by geoducks (Beattie and Blake 1999). This diverse Pacific Northwest shellfish industry has evolved as a result of grower ingenuity and strong industry representation coupled with public assistance from various West Coast academic institutions.

The sunray venus *Macrocallista nimbosa* is an attractive venerid clam distributed from South Carolina to Florida and the Gulf states. Commercial fishermen targeted the sunray venus clam in the late 1960s in several shallow water areas off the northwest Florida coast. Even though the large 4-7 inch clams were shucked and processed for the minced meat and chowder markets (Stokes et al. 1968, Jolley 1972), commercial harvesting was halted due to the limited size of the fishing grounds. However, growth experiments using marked individuals suggested that these popular clams attain a length of three inches (40 g whole) within 12 months (Stokes et al. 1968); similar in time to hard clams in Florida.

The existence of a latent market and the potential growth rate of the sunray venus clam, along with it being a native species, make it a logical choice as a new species to diversify and expand the Florida hard clam industry. In previous Florida Sea Grant supported projects, we successfully spawned and cultured larvae to produce seed (Scarpa et al. 2008). These seed (12 mm shell length) were reared using the Florida bottom bag method to a potential market-size of 60-65 mm shell length and 22-25 mm shell width (Fig. 1) in 15 months at an experimental lease site (Sturmer et al. 2009). However, sunray venus clams planted at two commercial lease sites resulted in lower survival (38-55% vs 76%), lower growth rate (1.9 mm/month vs 3.3 mm/month), and a large portion (20-55%) with shell deformities (Fig 2.).

We suspect these various responses were related to differences in soil substrate (i.e., sand, mud) among the sites. In general, hard clams tend to grow better in sandy sediments relative to muddy sediments (Grizzle et al. 2001). Pratt and Campbell (1956) found a negative relationship between silt and clay fractions with clam growth. Sunray venus clams are typically found in quartz-type soils (NOAA, no date); as was the case for the broodstock used in our previous studies. Grizzle et al. (2001) suggest that although sediment affects growth, its signature may not always be strong, as effects of soil characteristics can be confounded by other environmental variables, such as wave currents. Soil organic matter is an important soil characteristic as it provides an energy source for many of the biogeochemical transformations that occur in estuarine environments. Organic matter decomposition byproducts can include hydrogen sulfide (H_2S), which affects survival and growth of bivalve species (Bergquist et al. 2004). Soil mapping efforts at a high-density clam lease area (Dog Island) near Cedar Key, FL indicate considerable spatial variability of these factors within the lease area, which provides a spatial context for understanding variability in individual lease parcel performance (Ellis et al. 2009).

Figure 2. Example of shell deformity in cultured Sunray Venus Clam.

Although sunray clams on the commercial sites took longer to reach “marketable” size as compared to the experimental site, we were able to use a portion of the cultured sunray venus clams for consumer acceptance studies in 2008 (Adams et al. 2009b). Product was placed in several restaurants within the region. Customers ordering sunray venus clams were asked to complete a brief table-side questionnaire that solicited information on product attributes and acceptance. The survey data indicated an overwhelmingly positive rating by consumers and participating chefs (Adams et al. 2009b). Seventy percent of the respondents (n=239) found sunray venus clams to be “Excellent” and 20% “Very Good”. Clams were rated highly on the basis of several specific attributes, such as appearance, taste, texture, tenderness, and value. In addition, 94% of the survey respondents indicated that they would order the product again at the price charged and 97% indicated they would recommend the product to others. These responses were robust across gender, age, and other demographic characteristics. Thus, the initial market assessment and consumer evaluation studies found a very high degree of product acceptance within the north central Florida study region. However, information is needed regarding the product attributes of sunray venus clams with respect to the wholesale and distribution sectors of the market, not just the final consumer.

The technical and consumer acceptance results of our previous projects noted above generated interest from Florida clam culturists. However, Florida hatchery operators were reluctant to move forward developing sunray venus clam broodstock or producing seed until they were confident that the growers have a marketable product for wholesale distribution. This “chicken and egg” scenario may be overcome by assisting the industry as was done to head start the hard clam industry in Florida (Colson and Sturmer 2000). By developing simultaneously the technology with industry alongside, we targeted information gaps and potential barriers to commercialization of this species, thereby reducing the potential for failure as occurred with the angle wing clam (brittle shell), scallops (leases, culture methods), and ark clams (hatchery methods, limited markets). Therefore, in order to obtain full adoption of this species by industry, this work focused on identifying and eliminating potential production and distribution/marketing barriers that may serve as constraints to establishing sunray venus clams as a feasible complement to hard clams. Hatchery operators, land-based nursery operators, growers and wholesalers were engaged in this research, thereby allowing for technology transfer to each of these industry sectors.

GOAL AND OBJECTIVES:

The goal of this project was to successfully demonstrate to the various sectors of the Florida shellfish aquaculture industry the potential of the sunray venus clam *Macrocallista nimbosa* as a new species to diversify and expand the industry. In previous research, we have successfully spawned sunray venus clams, cultured the larvae, produced seed and reared them through growout (Scarpa et al. 2008, Sturmer et al. 2009) using techniques similar to those for commercial hard clam culture, which was our original hypothesis. The existence of a latent market was demonstrated via restaurant/consumer acceptance studies (Adams et al. 2009b). Economics of seed production was determined in the prior project and costs fall within the range for hard clam seed in Florida. We hypothesized that enhanced hatchery production through broodstock development, growout site selection, and determination of wholesale market-related product attributes may 1) eliminate barriers to commercialization of this new aquaculture species, 2) facilitate technology transfer to the Florida hard clam industry, and 3) promulgate market development.

Therefore, the objectives of this project were:

1) To create initial founder broodstock lines for Florida hatcheries;
2) To demonstrate to hatchery operators the proper development and maintenance of broodstock for seed production;
3) To determine production performance of sunray venus clams for field-based nursery and growout culture at multiple existing commercial high-density lease areas;
4) To establish a relationship between soil (substrate) and sunray venus clam productivity at multiple lease areas using a soils-based approach;
5) To define a) salinity and b) soil preferences for selection of future lease sites for sunray venus clam culture;
6) To determine the sensory, microbial, and nutritional profiles of cultured sunray venus clams; and,
7) To examine product attributes of sunray venus clams with respect to wholesale market and product distribution standards for molluscan shellfish.

METHODS AND RESULTS:

Objective 1. Create initial founder broodstock lines for Florida hatcheries.

Our field trials conducted in previous projects (2010-12) utilized single- or double-parent crosses to produce replicate families for experimental culture of this species. However, commercialization requires multi-parent crosses to produce founder broodstock that retain as much genetic diversity as possible from wild local populations for future selection efforts. To ensure that Florida clam hatchery operators do not initiate genetic bottlenecks, which may result in inbreeding depression, or limit genetic diversity in their product and future lines for selective breeding, separate lines were made available.

Adult sunray venus clams (n=50-100) were collected in 2011 and, again, in 2012 from natural assemblages in three locations along the west coast of Florida and delivered to the HBOI-FAU hatchery. The objective was to produce individual brood populations each derived from 10 females fertilized by 10 males to give an effective parental number of 20. Conditioned broodstock (Scarpa et al. 2008) were spawned using a standard thermal shock of 10ºC (Hadley et al. 1996). Females were isolated in small bowls to collect eggs; eggs were aliquoted into beakers for insemination by different males. After insemination, all fertilized eggs were pooled and placed into culture vessels. Larvae and post-set families were fed microalgae (*Isochrysis* spp. and *Cheatoceros* spp.) and cultured separately using standard hard clam protocols (Hadley et al. 1996).

In February 2012, using sunray venus clams cultured at Alligator Harbor, a cross of 11 females by 10 males was accomplished. Eggs from the females were pooled and then divided into separate containers to ensure sperm from each individual male was able to fertilize eggs without competition from sperm of other males, thus ensuring genetic diversity. In April 2012, two spawns were conducted one day apart using Seahorse Key natural sunray venus clam stock. One brood population was created from five females fertilized by three males and the second brood population was created from one female fertilized by four males. In July 2012, a single spawn was conducted using Anna Maria Island natural sunray venus clam stock. A single brood population was created using eight females fertilized by six males. Natural stock has traditionally been more difficult to spawn as compared to cultured organisms due the variability of conditioning. Even with conditioning at the hatchery, natural stock was typically large (>5 inches) and more difficult to condition.

Over 225,000 seed from Seahorse Key (SHK) stocks and an additional 225,000 seed from Anna Maria Island (AM) stocks were nursed at the UF shore-based facility in Cedar Key. From these, 100,000 SHK juveniles and 84,000 AM juveniles were planted at the UF experimental lease for further rearing. After growout was completed, sunray venus clams served as founder broodstock for hatcheries in Florida. Florida operators were provided with sunray venus clams from each "line" to initiate their programs. Harvesting and dissemination of these stocks to commercial seed suppliers began in 2013. In addition, over 1,000 adult sunray venus clams (F1 generation) harvested from prior field trials and held at the UF experimental lease were provided to five hard clam hatchery operators in the state.

Objective 2. Demonstrate to hatchery operators the proper development and maintenance of broodstock for seed production.

The proper development of sunray venus clam broodstock for seed production was demonstrated to Florida clam hatchery operators to ensure they do not initiate genetic bottlenecks or limit genetic diversity in their product and future lines for selective breeding. During production of replicate families, Florida hatchery operators were invited to HBOI-FAU to watch and participate in hatchery operations. Hatchery operators were shown how to maximize genetic diversity by using factorial pair-wise matings to theoretically capture maximum genetic diversity. The operators were educated on the need for the use of Florida broodstock for developing founder broodstock. As all hatchery operators were not able to attend the actual spawnings at HBOI-FAU, workshops were held on the east coast (HBOI-FAU) in December 2011 and on the west coast (Cedar Key) in January 2012 to introduce and review the concept of effective parental number (Ne), methods for maximizing Ne, and review state BMPs/regulations (Bronson 2007) regarding genetics of cultured species.

Objective 3. Determine production performance of sunray venus clams for growout culture at multiple existing commercial high-density lease areas on the west coast of Florida.

Growout at Commercial Lease Sites, 2010-11

About 154,000 growout-size seed (average shell size: 26 mm, length; 9 mm, width) were distributed to 13 growers located at six commercial lease areas in three counties on the west coast of Florida. These areas included the Alligator Harbor Aquaculture Use Area (AUA) in Franklin County; Pelican Reef High-Density Lease Area (HDLA), Gulf Jackson HDLA, and Dog Island HDLA near Cedar Key, Levy County; and South and North Pine Island HDLAs in Lee County. The lease locations represented about 50% of the existing shellfish aquaculture lease areas on the west coast of Florida. However, over 80% of the hard clams produced in the state are attributed to these areas (Adams et al., 2009a). Participation of interested growers was solicited through a newsletter article in the April 2010 issue of *The Bivalve Bulletin*. Grower selection was based on ensuring that we had representation at each lease location and a willingness to participate in this project.

Prior to receiving seed, each grower was provided with an informational package containing a summary of results from the previous funded projects and culture guidelines (i.e., gear, stocking densities, handling protocols). Each grower received from 8,000 to 14,000 final plant seed during July to September and agreed to plant a minimum of 2,500 juveniles in three polyester mesh (9mm) bottom bags at a density ($50/ft^2$) found acceptable in the 2007-09 growout trials. This allowed for comparison of harvest results among the various growing areas. The bag culture method is typically used by the hard clam industry in Florida for rearing seed to harvest size (Fernandez et al. 1999). The remaining juveniles were used by growers to experiment on their own and evaluate other stocking densities, growout bag modifications, or growout methods (e.g., bottom cages, bottom plants). Each grower was provided with a HOBO® temperature data loggers, which was placed inside a growout bag. In addition, continuous water quality data (salinity, dissolved oxygen) at the growout locations in Franklin and Levy Counties were available. Growers in Lee County were provided with refractometers so salinity could be measured periodically at those lease sites. Growers were also instructed and provided with data sheets to record their results and observations, such as presence of predators and fouling organisms.

The growout rearing trials were terminated after 12 months, which was the culture time required for sunray venus to reach a size of ~50 mm shell length (SL) in previous rearing trials at the UF experimental lease at Dog Island HDLA near Cedar Key (Sturmer et al. 2009). At harvest, three replicate bottom bags were sampled and live clams counted to estimate survival. Fifty sunray venus clams from each bag, if available, were measured for shell length (SL), shell width (SW), and total weight (TW), and determination of shell deformities. Also, 12 sunray venus clams from each bag were selected for dry meat weight and condition index analyses, which was calculated using the ratio of dry meat:dry shell x 100. Meats and shells were dried in an oven at 65°C for 48 hours (Fernandez et al. 1999). Harvest data for growout culture trials initiated by industry project partners in 2010 were compiled. These production data were analyzed using appropriate statistical tests after testing for underlying assumptions (Sokal and Rholf 1995). Statistical differences were considered significant if $p<0.05$.

Survival of sunray venus clams harvested from the three lease sites at the Alligator Harbor AUA was excellent (average per lease ranging from 55-71 %), and shell deformities (4-9 %) were low. We have been conducting field trials with industry partners in Franklin County since 2007. These results were the most promising that we have seen over that time period. Production results obtained from leases in Levy County were variable. Survival of sunray venus clams harvested from the three leases at the Pelican Reef HDLA was the lowest obtained in this study, ranging from 4 to 35%. The presence of oyster spat, drills, and moon snails in the bags may help to explain the high mortality and also indicated that the bags did not completely bury. Although survival obtained at the two leases within the Gulf Jackson HDLA was higher (25-48%), these results would not be considered commercially acceptable. Significant differences occurred between the two leases at the Dog Island HDLA, with 62% survival obtained at one site and 11% at another. Bags planted at two leases within the South Pine Island HDLA were disturbed after planting, resulting in 100% mortality of the sunray venus clams, while bags sampled from the third lease resulted in low survival (34%) and high shell deformities (31%).

Sunray venus clams harvested from the leases at Alligator Harbor AUA had significantly lower growth (average of leases = 42.6 mm SL, 17.0 mm SW, 12.5 g TW) than those harvested from leases in Levy County. Differences in environmental conditions (higher salinities and observed lower primary productivity levels), as well as varying harvest densities, may have been contributing factors. A longer growout period may be warranted. Sunray venus clams harvested from the five leases within the Pelican Reef and Gulf Jackson HDLAs in Levy County exhibited similar growth (47.4-52.7 mm SL, 19.3-21.0 mm SW, 17.2-21.9 g TW). Significant differences in growth of sunray venus clams (47.8 versus 54.2 mm SL, 17.7 versus 21.3 mm SW, 13.9 versus 23.0 g TW) cultured at the two leases in the Dog Island HDLA were determined. This most likely can be attributed to differences in subaqueous soils properties at these two leases (see Objective 4), as environmental parameters and growers' experience were the same. Sunray venus clams harvested from one lease located in the Pine Island HDLA were comparable to those in Levy County (50.8 mm SL, 20.3 mm SW, 20.2 g TW).

Water temperature and salinity were recorded at three of the commercial lease areas during this study. Alligator Harbor AUA had a mean water temperature of 72.1°F (± 13.3°F), ranging from 40.7-95.4°F. Salinity averaged 33.8 ppt (± 3.6 ppt) and ranged from 24.0-41.1 ppt. Water temperature at the Dog Island HDLA averaged 73.8°F (± 13.2°F), varying from 36.8-95.1°F. Average salinity was lower at the Dog Island HDLA (25.0 ppt ± 3.2) than the Alligator Harbor AUA. Water temperature at the Gulf Jackson HDLA was similar to the other lease areas, averaging 72.0°F (± 12.5°F) and ranging from 40.7-93.1°F. Mean salinity values (24.1 ppt ± 3.6) were similar to those of Dog Island HDLA.

Growout at Commercial Lease Sites, 2011-12

A follow-up to the 2010-11 growers project was begun in the fall of 2011 during which we provided 33,000 growout-sized seed to an additional eight growers to evaluate another 11 commercial leases in four counties (Franklin, Lee, Levy, Saint Johns). Leases included three located within the Alligator Harbor AUA, two within the Pelican Reef HDLA, two within the Dog Island HDLA, and three within the Pine Island HDLAs. In addition, one lease was located in St. Johns County nearby the Matanzas Inlet on the Florida east coast. Of the 11 leases planted with sunray venus clams in 2011, five were identified because of acceptable production obtained in the previous study. Six new leases were selected based on their subaqueous soil properties and the potential for acceptable production. Culture guidelines based on results from previously-funded projects were provided to growers. Participants planted a minimum of three bottom bags at densities found acceptable in prior growout trials, allowing for comparison of results among the various trials, growing areas, and years. After a growout period of 11-13 months, which was the culture time required for sunray venus to reach a size of ~50 mm shell length (SL) in previous rearing trials, the bottom bags were harvested at each of the participating growers' leases during August through December (2012). Sunray venus were counted to estimate survival and samples (minimum 50 from each bag) measured for shell length (SL), shell width (SW), total wet weight (TW), and determination of shell deformities.

Survival of sunray venus clams from lease sites located in the Alligator Harbor AUA ranged from 10.3 to 54.1%. These values were lower than the previous year and may be attributed to predation by cownose rays at two of the leases. Production values for the Levy County sites were variable. Mean survival at the two lease sites from Dog Island HDLA were similar (49.0 and 52.3%), while survival at leases located at Pelican Reef HDLA was lower and not commercially acceptable (24.8 and 36.8%). Leases located within the North and South Pine Island HDLAs produced commercially viable results with survivals ranging from 50.8-60.5%. Production values were not obtained from the Matanzas Inlet site, as the grower reported that the bags had disappeared. Sunray venus clams harvested from the Alligator Harbor AUA had slower growth (42.7 SL, 16.1 mm SW, 11.3 g TW) than those harvested from the other lease areas. Differences in environmental conditions (higher salinities) as well as predation pressures may have been contributing factors. Planting in dipped bags and a longer growout period may be warranted. Sunray venus harvested from the Pelican Reef HDLA (48.9-54.4 mm SL, 19.0-20.0 mm SW, 17.5-21.8 g TW), Dog Island HDLA (50.6-57.8 mm SL, 18.6-20.1 mm SW, 18.5-25.5 g TW), and the two Pine Island HDLAs (48.0-57.0 mm SL, 18.5- 21.0 SW, 16.0-24.0 g TW) exhibited similar growth. The lease site located in the North Pine Island HDLA produced the largest clams (21.0 mm SW, 24.0 g TW) and had the highest survival (60.5%) of leases examined this year. Shell deformities for all sites ranged from 0-4.7%.

Water temperatures and salinities at commercial lease areas, with the exception of the leases located in Pine Island Sound, were measured using YSI model 6600 data sondes. Data for the Alligator Harbor AUA were available from September 2011 through August 2012. Water temperatures during that time period averaged 73.4 ± 9.9°F and ranged from 48.3 to 90.8°F. Salinities averaged 31.7 ± 2.7 ppt and ranged from 19.6 to 36.3 ppt. Water quality for the Pelican Reef HDLA was reported from December 2011 to October 2012. Water temperatures averaged 74.3 ± 9.8°F and ranged from 44.7 to 93.5°F. Salinities averaged 25.6 ± 4.1 ppt and ranged from

9.9 to 36.4 ppt. The lower salinities were the result of coastal flooding associated with two tropical storms during the summer. Water temperatures within the Dog Island HDLA from December 2011 to October 2012 averaged 75.5 ± 9.8°F and ranged from 44.8 to 91.7°F. Salinities averaged 26.6 ¡À 2.3 ppt and ranged from 16.7 to 33.8 ppt.

To provide sunray venus clams for possible additional studies, such as the alternative culture and harvest method study which was funding by FDACS in 2013, and to obtain additional seasonal and annual culture data, 400,000 seed were obtained from the HBOI hatchery and land-based and field nursed at UF facilities in Cedar Key. This also allowed for evaluation of several types of nursery bags (dipped versus undipped) and a technique used by east coast clam growers in which nursery bags are partially buried at plant by using a pump. In addition, 268,000 seed from this spawn were provided to four nursery operators to evaluate under commercial conditions at two different locations (Indian River and Lee Counties).

Land-based and Field Nursery Trials

To continue to determine optimal stocking densities for juvenile sunray venus, approximately 300,000 1.2 mm-sieved seed (average number per milliliter, 234/ml; average shell length, 3.2 mm) were produced under Objective 1 at the Molluscan Hatchery of HBOI-FAU and shipped to the UF land-based nursery in Cedar Key for rearing during the summer of 2011. Seed were stocked into quadruplicate 5.55 ft^2 trays at densities of 2500, 3000, 3500, and 4000/ft^2. One tray of each stocking density was placed inside a 200-gallon tank. Unfiltered saltwater was distributed to each tank by laminar flow via a distributor pipe at one end of the tank, resulting in a flow rate of 50-65 liters per minute. Seed were rinsed every 1-2 days with freshwater to remove accumulated silt, sediment, and feces. This was easily accomplished by pulling the standpipe and allowing the water to drain prior to rinsing the seed. After cleaning, the trays were rotated within the tank to minimize differences of tray location. In addition, the trays were switched amongst the tanks every two weeks. Water temperature was recorded hourly with a Tidbit® temperature data logger; salinity was measured daily using a refractometer. After 55 days, the stocking density trial was terminated. Typically, it takes about 8 weeks for hard clam seed (>1.2 mm sieve) to reach a size in which the majority can be retained on a 3.3 mm mesh sieve (the smallest sieve size used in grading seed for the field nursery). During this time period, water temperatures and salinities averaged 85.8±3.3ºF and 26±2 ppt, respectively. Seed from each stocking density were separately sieved on 3.3 and 4.0 mm screens. Volumes for each sieve size (>4.0, >3.3, and <3.3 mm) were determined and two subsamples (5-50 milliliters) were counted to estimate numbers and survival. Prior to sieving, 30 animals from each tray were measured for shell length.

Mean survival, shell length, and number of seed retained on a 3.3 mm sieve were statistically analyzed at the end of the land-based nursery phase using the PROC GLM procedure in SAS version 9.2 software. Percentage data were arc-sine-square-root transformed prior to analysis. All statistical tests were considered significant when $p \leq 0.05$. No statistical differences were detected among the stocking densities for survival, shell length, or >3.3 mm sieved seed. These results are commercially acceptable as the average survival for each density over the 8-week nursery period ranged from 92 to 95%, average shell length ranged from 8.4 to 8.9 mm, and average percent of seed greater than a 3.3 mm sieve size ranged from 80-85%. Further, these results indicated that densities typically used in nursing hard clam seed can be used for sunray venus clam seed.

Approximately 220,000 sunray venus seed (average shell length, 9.1 mm) were transferred to the field nursery at the UF experimental lease located within the Dog Island HDLA in late July. Seed were planted in 16 ft^2 bottom bags (4 mm mesh) at varying densities (500, 625, and 750/ft^2). Field nursery bags were harvested 4 months later. High mortalities occurred across all stocking densities with overall survival averaging 14%. Shells in the bags were the same size as those at planting, indicating that mortalities occurred early in the nursery period. Water temperatures measured inside one of the nursery bags with a HOBO® data logger averaged 88.3°F ($\pm$2°F) during the first week after planting with a maximum value recorded at 93.9°F. Heat stress could have been a contributing factor, resulting in animals not burying. It must be noted that growers also reported hard clam losses at leases in Levy County during August as a result of high water temperatures. No analyses could be conducted on effects of nursery bag stocking densities on sunray venus growth and survival.

Future Lease Site Selection

We continued to work with staff from the Florida Department of Agriculture and Consumer Services (FDACS), Division of Aquaculture in examining alternative lease areas for the potential of sunray venus culture in Levy County. Four sites (south of Dog Island, east of Atsena Otie, west of Pelican Reef HDLA, and north of North Key) were examined in the fall of 2011. Two to eight growout bags each stocked with 800 sunray venus seed were planted at each site. Harvesting occurred a year later (fall 2012). Four test plots (two inshore and two offshore) were located within the south Dog Island site. Growth (54.7-55.7 mm SL, 18.8 mm SW, 20.9-21.2 g TW) and survival (48.8-56.9%) for both inshore plants were similar. The offshore plants exhibited lower survival (33.7%), but similar growth (57.7 mm SL, 18.4 SW, 21.0 g TW). Sunray venus clams harvested from the test site west of Pelican Reef HDLA had lower survival (38.7%) but similar growth (52.1 mm SL, 19.7 mm SL, 20.7 g TW) as the Dog Island test plants. Commercially acceptable survival (52.3%) was obtained for sunray venus clams reared at the Atsena Otie test site; however, growth (47.9 mm SL, 15.9 SW, 13.7 g TW) was lower than all other test sites. The culture bags planted at the North Key test site could not be located.

Two soil cores were collected prior to planting in 2011 at each test sites in Levy County for use in correlating initial subaqueous soil properties to production values. Although organic matter (OM) (0.4-0.9%), silt (2.5-6.0%), and clay (2.1-4.7%) content varied by 125 to 140% among sites, sand content (89.9-95.4%) and bulk density (BD) (1.4-1.6 g/cm3) were similar. Sites with >50% survival had slightly lower OM (0.5%), silt (3.3%), and clay (2.6%) content, and higher sand content (94.1%) and BD (1.6 g/cm3) than leases with <50% survival (respective values: 0.7%, 3.7%, 3.7%, 92.6%, and 1.5 g/cm3). A correlation analysis was performed to relate sunray venus survival to soil properties. Sand content (r=0.84, p=0.07) and BD (r=0.70, p=0.18) were positively correlated with sunray venus survival, while silt (r=-0.61, p=0.28), clay (r=-0.78, p=0.12), and OM (r=-0.64, p=0.24) content were negatively linked to survival. None of the soil properties were statistically significant (p<0.05); however, sand content (p=0.07) exhibited a strong association with sunray venus clam survival.

OBJECTIVE 4. Establish a relationship between soil (substrate) and sunray venus clam productivity at multiple lease areas using a soils-based approach.

We chose the term "soil" rather than sediment or substrate for two specific reasons: 1) as with any rooted plant or benthic/soil organism, infaunal clams are closely associated with the soil in which they live, and as such, are likely influenced by soil properties to some degree, although little research has been conducted on sediment/clam relationships (Fegley 2001) and 2) there is a new effort by the USDA Natural Resource Conservation Service (NRCS) to extend their extensive and detailed soil survey into shallow coastal waters (Demas and Rabenhorst 1999; Bradley and Stolt 2003; Ellis 2006). Regarding point 1, the sediment research thus far has focused on hydrogen sulfide, but relating productivity to other soil properties such as organic matter content and particle size has not occurred, especially not in an experimental setting. Regarding point 2, some coastal areas already have extensive subaqueous soil maps completed such as MapCoast in Rhode Island (http://www.ci.uri.edu/projects/mapcoast/) where partners such as Sea Grant and NRCS cooperate to inventory the estuarine resources. This has great potential in Florida, but all mapping efforts are hindered by a lack of interpretations for soil map units. Aquaculture productivity for different soil types is an important interpretation and pilot research for such information is needed (Ellis and Osborne 2008).

<u>Growout at Commercial Lease Sites, 2010-11</u>

To understand differences in soil properties among existing shellfish aquaculture leases and account for spatial variability within individual leases where sunray venus clams were evaluated, the soils at each growing site were sampled and characterized. The soils at each commercial lease (see Objective 3) were sampled at the time participating growers planted seed in 2010 and at harvest 12 months latter to examine the relationships between subaqueous soil properties and sunray venus clam production under commercial conditions. At each of the sites, the soils were cored in triplicate. The core tube was pushed into the soil by hand, capped with a stopper, and retrieved by hand. This method was suitable for retrieving soil cores where disturbance to nearby areas was to be avoided. Soil cores were transported back to the UF soils laboratory for extrusion and analysis. Soil cores were extruded and sectioned into 0-10, 10-20, and 20-30 cm samples. These samples were oven dried at 100^{o}C then weighed to determine bulk density. Organic matter (OM) content and particle size distribution (PSD) was determined on the oven-dried samples. The OM content was estimated by weight loss after ignition (Donkin 1991), while the PSD was determined by settling via the pipette method (Soil Survey Staff 1996). As hydrogen sulfide (H_2S) toxicity may be an issue in clam aquaculture, soil samples were analyzed for H^2S productivity in the field, using a direct measure probe (Fisher Scientific Accumet AP125 Portable pH/Ion/mV temperature Meter). To further determine differences in soil properties, soils were also sampled at two locations where broodstock were collected in previous projects (St. Teresa Beach, Franklin County and Seahorse Reef, Levy County). At harvest (July-September 2011), sediment cores and grab samples for hydrogen sulfide (H_2S) analyses were taken. Soil properties measured included % content of organic matter (OM), silt, clay, and sand. To highlight trends, we defined leases with >50% survival as commercially acceptable. Only four leases (three at the Alligator Harbor AUA and one at the Dog Island HDLA) met this criterion with survival ranging from 55 to 71%. These sites contained higher mean sand content (>87%) and lower mean silt content (<2.5%) at planting than the other nine leases. Hydrogen sulfide content was too variable and correlations were negligible. Correlation analysis was performed on survival and growth data, after appropriate transformations, with soil characteristic data (Sokal and Rholf, 1995) from the multiple sites.

Detailed analyses of soil cores taken at plant follow for each lease area. Two of the three leases sampled at the Alligator Harbor AUA displayed similar soil properties, with mean OM equal (0.47%), silt ranging from 0.4-1.0%, clay from 2.7-3.1%, and sand from 96-97%. For the third lease, OM, silt, and clay content were higher (0.82%, 8.5%, and 4.5%, respectively), while sand content was lower (87.0%). For the three leases located within the Pelican Reef HDLA, soil properties varied greatly reflecting the dynamic nature of this area. OM ranged from 1.3-2.2%, silt from 1.7-6.7%, clay from 3.6-6.8%, and sand from 89.7-93.3%. Survival of sunray venus clams was also low and varied (4-35 %), as were shell deformities (1-6 %), at this HDLA. Soils collected from two leases located within the Gulf Jackson HDLA had similar values for OM (2.1 and 2.0%) and clay (5.2 and 5.1%); however, silt (5.5 and 12.0%) and sand (89.4 and 82.7%) differed. The lease, which exhibited lower silt and greater sand content, had higher sunray venus clam survival (48%), as compared to the second lease (25% survival). Shell deformities were negligible at both sites (1%). Soil properties also differed for the two leases located at the Dog Island HDLA. OM and silt content were almost doubled from one site to the other (1.5 versus 3.1 % and 2.3 versus 4.4%, respectively), while clay and sand were relatively similar (5.4 versus 6.6 % and 92.7 versus 89.0 %, respectively). The lease with lower OM and silt content supported acceptable survival (62%), but also had greater shell deformities (5%), whereas survival at the second lease was low (11%). No growth data were obtained at the two leases within the South Pine Island HDLA, while survival was low and deformities were high at the third lease site. However, data from soil cores taken at plant indicated that sediments at these leases contain properties (OM, sand, etc.) that potentially could yield acceptable sunray venus clam production.

Relationships between soil properties and sunray venus survival were examined using Pearson's correlation with the PROC CORR function in SAS software (version 9.2). Bulk density (BD) (r=0.51, p=0.003) and sand (r=0.32, p=0.08) content were positively correlated to survival, while organic matter (OM) (r =-0.39, p=0.03), clay (r=-0.32, p=0.08), and silt (r=-0.25, p=0.18) content exhibited negative correlations. Of the soil properties measured, only BD and OM content were significantly linked ($p<0.05$) to survival. The inverse relationship between the two is self-explanatory. Bulk density measures the mass of soil per unit volume, and is dependent on mineral composition (sand, silt and clay), OM content, and porosity. High bulk density values are indicative of soils that are compacted with low porosity. Sandy soils (1.4-1.6 g/cm^3) have higher bulk densities due to less total pore spaces than silt (1.1-1.39g/cm^3) or clay soils (<1.1 g/cm^3). BD for samples ranged from 1.0-1.7 g/cm^3 and averaged 1.5 g/cm^3 (± 0.17) across all leases, indicative of silty and sandy textures. OM content varied by sample from 0.39-5.7% and averaged 1.2% (± 1.1) across all leases. Mean OM, silt, and clay (0.8%, 3.1% and 3.9%, respectively) content were lower at leases where survival was >50% than leases with <50% survival (2.0%, 5.8%, and 5.4%, respectively). Conversely, BD and sand content were higher at sites with >50% survival (1.55 g/cm^3 and 93.2%) than sites with <50% survival (1.43 g/cm^3 and 89%). Given these relationships, sunray venus survival was greater at sites that contained lower soil organic matter content (as well as silt and clay) and had bulk densities indicating definite sandy consistency. Further research is needed to fine-tune ranges of subaqueous soil parameters that lead to better sunray venus production. Although bulk density measures soil compaction indirectly, direct quantification, via a penetrometer, could yield a more thorough understanding of soil dynamics in relation to sunray venus production.

Growout at Commercial Lease Sites, 2011-2012

The soils at each commercial lease (11 total, see Objective 3) were sampled at the time participating growers planted seed in 2011 to examine the relationships between subaqueous soil properties and sunray venus clam production under commercial conditions. Soil properties measured included bulk density (BD), organic matter (OM), silt, clay, and sand content. To highlight trends, we defined leases with approximately 50% or greater survival as commercially acceptable. Six leases (one at Alligator Harbor AUA, two at Dog Island HDLA, and three at the Pine Island HDLAs) met this criterion with survival ranging from 49 to 60%. Unlike the results from the prior year, sand and silt content were similar for leases with >50% survival (93.2-97.7% sand content, 0.1-2.0% silt content) and those leases with <50% survival (92.8-97.5% sand content, 0.2-1.6% silt content).

Detailed analyses of soil cores taken at plant for each lease area follow. The three leases at Alligator Harbor AUA exhibited similar soil properties with mean OM nearly equal (0.24-0.26%), silt content ranging from 0.2-0.7%, clay content from 1.7-2.7%, and sand content from 97.2-97.7%. Average survival ranged from 10.3-54.1% and shell deformities ranged from 0.7-4.0%, with the highest value for both parameters occurring at the lease with the highest sand (97.7%) and lowest clay (1.7%) contents. The two leases at Dog Island HDLA had similar OM (0.4-0.7%), silt (1.6-2.0%), and sand (95.2-93.2%) contents, but clay content varied from 3.2 to 5.3 %. Mean survival for these two leases was 49.0 and 52.3%. Shell deformities averaged 6 and 28%. The two leases at Pelican Reef HDLA had similar OM (1.5-2.2%), silt (1.6-1.3%), clay (5.7-5.8%), and sand (92.8-93.0%) contents. Survival for sunray venus from both leases was <50% (24.8 and 36.8%). Shell deformities averaged 9.2 and 52.0%. The three leases at Pine Island HDLA exhibited similar OM (0.3-0.5%) and sand (97.1-97.5%) contents, but silt (0.1-2.0%) and clay (1.0-3.4%) contents varied. Average survival was >50% at all three leases ranging from 50.8-60.5%. Shells deformities remained low, ranging from 0-4.7%. The lowest mean survival (50.8%) and highest presence of shell openings (4.7%) occurred at the same lease. This lease had the lowest silt content (0.05%) and highest clay content (3.4%) of the three leases.

Relationships between soil properties and sunray venus production (survival) during 2011-12 field trials were statistically examined using Pearson's correlation with the PROC CORR function in SAS software (version 9.2,). Sand (r=0.22, p=0.53) and silt (r=0.17, p=0.63) content were positively correlated to survival, while organic matter (OM) (r=-0.31, p=0.38), clay content (r=-0.32, p=0.36), and bulk density (BD) (r=-0.12, p=0.75) exhibited negative correlations. Unlike the previous year, soil properties were not correlated to sunray venus survival (p>0.05). This is somewhat expected, as ranges of soil properties were narrow. Mean sand content for leases with >50% survival was 96.5% and 95.1% for those with <50% survival. Silt content was 1.2% for leases with >50% survival and 1.1% for leases with <50% survival. Clay content varied the most, 2.6% (>50% survival) to 4.0% (<50% survival), while bulk density (1.56 and 1.58 g/cm3) varied the least. Organic matter (OM) varied from 0.4% (>50% survival) to 0.9% (<50% survival). Another factor to consider was that predation resulted in higher mortalities at the Alligator Harbor leases. Sunray venus seed were planted in undipped bags, as opposed to stiff dipped bags used in the previous year, and were more vulnerable to predators, such as the cownose ray. After removing data from the leases most affected by possible predation at Alligator Harbor AUA, another correlation analysis was performed. Silt (r=-0.17, p=0.69), clay (r=-0.76, p=0.03) and OM (r=-0.90, p=0.002) content were negatively correlated with survival, while sand content (r=0.76, p=0.03) and BD (r=0.71, p=0.05) were positively linked to survival. Trends were more apparent after the two affected leases were removed as sand, clam and OM content and BD were significantly correlated to sunray venus clam survival.

After examining the relationships from the second year (2011-12), we included data from the previous year's study (2010-11) in the correlation analysis. Sand content (r=0.31, p =0.18) and BD (r=0.45, p=0.04) were positively correlated with survival, while OM (r=-0.61, p=0.003), silt (r=-0.08, p=0.74) and clay (r=-0.50, p=0.02) content were negatively associated with survival. Of the soil properties analyzed, organic matter content, clay content, and bulk density were significantly linked to survival. Once again, we removed the Alligator Harbor AUA leases that were harvested in 2012 and possibly affected by predation and analyzed correlations between sunray venus survival and soil properties. Sand content (r=0.46, p=0.04) and BD (r=0.74, p=0.0003) were positively correlated with survival. Silt (r=-0.17, p=0.49), clay (r=-0.64, p=0.003), and OM (r=-0.79, p<0.0001) content were negatively associated with sunray venus survival. The difference between the latter analysis and the one prior, which included the Alligator AUA sites in which predation affected survival, was that sand content was determined to have a greater and significant positive correlation to sunray venus clam survival.

OBJECTIVE 5. Define a) salinity and b) soil preferences for selection of future lease sites for sunray venus clam culture.

Salinity Preference Studies

Salinity preference of juvenile (sub-adult) sunray venus clams was examined in controlled laboratory experiments. Previous research with nursery seed (avg length = 4.7 mm, avg wt = 19 mg) indicated that 10 psu (ppt) was lethal in 7 days and 20 psu had reduced survival, but not growth (Scarpa et al. 2009a). Sunray venus clams (~6 month growout culture) were collected from a field culture site for use in this experiment. Ten juvenile clams with a mean shell length of 35.8 ± 0.22 mm, which is about 2/3 market size, and mean live weight of 6.6 ± 0.5 g were each placed in triplicate tanks containing 15L of 16, 24, 32, and 40 ppt saltwater. Treatment salinities were made by adding a marine salt mixture or fresh water to 1-µm filtered saltwater (~30 ppt salinity). Sunray venus clams had been at 24 ppt in the field before being shipped to the lab, held at 24 ppt in the lab, and then placed in treatment tanks. Sunray venus clams in tanks were fed two times per day with the microalgae *Isochrysis aff. galbana* at a density of 100,000 cells/ml. Water was changed every other day. Dissolved oxygen, salinity, pH and temperature were recorded daily. Sunray venus clams were observed for mortality daily over 28 days. Salinity treatments were close to target values for most of the experiment. Environmental parameters were similar among all salinity treatments. Average mortality was greatest in the 40 ppt treatment (30%), least in the 16 and 24 ppt treatments (0%) and minimal in the 32 ppt treatment (7%), which occurred near the end of the experiment. Sunray venus clams in the 32 ppt treatment exhibited gaping in 2-4 clams per replicate tank, whereas this was not noticed or as prevalent in the other salinity treatments. As sunray venus clams typically grow in sand, and these clams were taken from a culture site, the gaping behavior may be from a lack of sediment surrounding the animal and the water being near an optimal salinity. Sunray venus clams tolerated an 8 ppt step change in salinity with minimal or no mortality and fared well with a 16 ppt step change in salinity, which is a good characteristic for culturing in areas that may experience sudden or drastic salinity changes from storms or droughts.

Salinity tolerance of sunray venus clams has been examined using step-change challenges and found to range from 16-40 ppt, but prior salinity acclimation was not taken into account. A second study examined the effect of prior salinity acclimation on salinity tolerance. Sunray venus clams (n=34, ~36 mm length) acclimated to salinities of 16, 24, 32 and 40 ppt from the prior experiment were subjected for 18 days to different salinity treatments in duplicate as follows: 16 to 12, 14 and 16 ppt; 24 to 12, 24 and 40 ppt; 32 to 12,16 and 32 ppt; and 40 to 16 and 24 ppt. SRV clams acclimated to 16 ppt were found to survive rather well (83 and 88%) when exposed to lower salinities (12 and 14 ppt). In general, sunray venus clams experiencing a salinity change of ≥12 ppt had no survival regardless of initial salinity acclimation. Hemolymph osmolality of surviving clams followed water osmolality ($R^2 = 0.99$). Large juvenile sunray venus clams in growout may be more resilient to lower salinities (12-16 ppt) when acclimated to lower salinities and if the change is gradual versus abrupt.

Soil Mesocosm Study, 2010-11

Similar to the determination of optimal salinity conditions, the edaphic characteristics favored by this species was also determined. To determine specific subaqueous soil preferences by the sunray venus clam during growout culture, a mesocosm study was initiated on October 26, 2010 in which common but distinct sediment types were tested. Soils were bulk collected and homogenized manually (each soil independently) from three areas in Cedar Key: 1) sand with low organic matter and silt fraction from a sandbar south of Seahorse Reef, where adult sunray venus clams have been collected for broodstock; 2) sand with high organic matter and silt fraction at Seahorse Key; and 3) sand with intermediate organic matter and silt fraction from the Dog Island High-density Lease Area where sunray venus have been reared in previous field trials. Each soil type was characterized by particle size distribution (PSD) which includes percent sand, silt and clay. Soil bulk density and organic matter content as a percent of total mass (% OM) were determined on each soil type. The sandbar soil (soil A), collected off of Seahorse Key was found to be 97% sand, 3% silt, and 0% clay with an organic matter content of 1%. The Dog Island lease soil (Soil B) was determined to have similar OM content (1%) but had slightly finer soil texture. Soil B textures were 94% sand, 5% silt, and 1% clay. Finally, the Seahorse Key dock soil (soil C), which was collected in a low energy embayment on the leeward side of the island, showed marked differences in fine particle content. Soil C texture was determined to be 82% sand, 10% silt, 4% clay, and 4% organic matter.

Soil types (treatments) were dispensed into three-gallon plastic buckets to an approximate natural bulk density. Forty (40) juvenile sunray venus clams (average length, 29.9 mm; average width, 10.7 mm; and average weight, 3.8 grams) were added to each bucket at a commercial stocking rate of $60/ft^2$. Buckets were partially buried (with surface protection similar to growout bags—clam bag mesh material secured over each bucket) at the UF experimental lease within the Dog Island HDLA. Each soil treatment was experimentally replicated six times for a total of 18 buckets; buckets were placed on the lease in a random block design and buried to within 10 cm of the top rim of the bucket. Buckets were retrieved in May 2011 at which time the number of sunray venus clams per bucket were counted to estimate percent survival and a minimum of 50 clams per bucket were measured for growth metrics (length, width, height, and total weight) and number of shell deformities (%). Deformity and survival percentages were transformed using the arcsine square root transformation prior to analysis in SAS. If considerable predation pressure was evident (evidence of crab activity or individuals present in mesocosms), then information from the affected buckets was not used. Treatment means of dependent variables were subjected to a one-way analysis of variance according to the General Linear Model procedure of SAS 9.2. A Tukey's honestly significant difference test was used to compare treatment means when the analysis was significant ($p \leq 0.05$).

Soil A, the soil with the highest sand content, had significantly higher sunray venus clam survivorship (corrected) than Soil B and C. Sunray venus clams grew larger on average (11.0 g) and had fewer deformities (2.2%) in sandier soils (>94% content - soil A and B) than clams (9.6 g, 18.7% deformities) in soil C that contained more silt / clay (>6%). Shell length and width were also significantly higher in Soil A and B than in Soil C. By far, the most dramatic result observed was the much higher percentage of growth deformities in the Soil C treatment (18.7%) versus the Soil A and B treatments (2.2% and 2.0% respectively). While it is unclear if this metric directly affects clam health and survivorship, it can have a negative impact on marketability of this species to commercial buyers and consumers and possible affect shelf life in refrigerated storage.

A plausible reason for differences in growth metrics and survivorship between the soils may be due to gas diffusion into soils from the overlying water column. Coarser textured soils (higher sand and lower silt/clay content) tend to have greater macropores that facilitate gas exchange between the soil–water interface. The finer texture soils, like soil C, which has greater silt and clay content, may retard diffusion of oxygen into the soil profile and likewise reduce the rate of H_2S diffusion out of the soil. Further investigation in the relationships between the redox status and sulfide concentrations of mesocosm soils at harvest and sunray venus growth and survival metrics is warranted.

Soil Mesocosm Study, 2011-12

A second mesocosm experiment (soil bucket study) was initiated in November 2011 to examine correlations between subaqueous soils and sunray venus clam productivity at much finer resolution of soil textures than the prior mesocosm study. Production and soils data obtained from the 2010-2011 growers trials and results from the 2010-2011 bucket study were used to design the second phase. To further define soil property tolerances of the sunray venus clam, seven soil treatments (4 experimental replicates each for a total of 28 bucket mesocosms) that spanned a range of 85-100% sand (quartz beach sand) in 3% increments of increase were utilized. The fine particle material (salt marsh mud) made up the difference and also increased organic matter as % sand decreased. These materials were collected in bulk and characterized in the same manner as the previous soil studies (particle size distribution, organic matter). Forty (40) juvenile sunray venus clams (average length, 16.3 mm; average width, 5.9 mm; and average weight, 0.7 grams) were added to each bucket at a commercial stocking rate of $60/ft^2$. Buckets were partially buried in the same manner as they were in the first study at the UF experimental lease within the Dog Island HDLA. Upon completion in May (2012), buckets were harvested and clams enumerated and evaluated in the same manner as previously (length, width, height, weight, deformities). Substrate selectivity was determined by correlation analyses between growth metrics and subaqueous soil characteristics.

Results from a second six-month in-situ mesocosm study indicated there were no significant differences ($p>0.05$) among the soil treatments in sunray venus shell length (mean range 34.8-36.8 mm), shell width (mean range 11.7-12.4mm), or total weight (mean range 5.2-6.3 g). Similarly, there was no statistical difference between the survival among soil types (mean range 82-95%), nor the rate of shell deformity observed (0-2.7%). These findings suggest that the range of soils tested is conducive to sunray venus clam production. An interesting observation was that the highest shell width (12.4 mm), shell length (36.8 mm), total weight (6.3 g), and survival (95%) were found in the 91% sand treatment, while the lowest survival (82%) and highest rate of shell deformity (2.7%) were found in the 85% sand treatment. However, due to variability in the measurements, there were no statistically relevant differences in clam survival or characteristics due to soil treatments. Results from both soil mesocosm studies suggest that soils with greater sand content are suitable for sunray venus clam production.

OBJECTIVE 6. Determine the sensory, microbial, and nutritional profiles of cultured sunray venus clams.

<u>Sensory Profile</u>

A formal, science-based sensory profile was developed to characterize sunray venus clams produced through aquaculture relative to seasons (summer and winter) as has been done for hard clams and oysters (Garrido et al. 2007, 2009). Samples of cultured sunray venus clams (cohorts from the completion of the 2009 field trials in Cedar Key) were provided for use in developing the lexicons and standards that were necessary to support the sensory profiling for this clam. The sensory profile was developed by the established and trained shellfish sensory panel maintained in the UF Food Science and Human Nutrition Department. This panel was previously developed through prior support from the Cedar Key Aquaculture Association and a FSG-funded project for hard clams and raw oysters (Garrido et al. 2007, 2009).

Following development of the specific sunray venus profile questionnaire, the trained panel evaluated several sunray venus clam samples during two times of the year to account for seasonal differences (water temperature and potentially salinity) that can influence product composition, flavors, appearance and taste. About 900 clams (average size: shell width, 20 mm; shell length, 49 mm; whole-weight, 18 grams) were delivered on June 22, 2010; an additional 275 clams (average size: shell width, 23 mm; shell length, 62 mm; whole-weight, 33 grams) were delivered on January 20, 2011. Product was characterized by appearance (color, volume of meat), aroma, basic tastes, flavor, aftertaste, texture and mouth-feel and compared to hard clam profiles (Garrido et al. 2009).

The sensory profile of the sunray venus clam is summarized. An extremely attractive external feature is the peach to orange color tones and radiating pattern of the glossy-smooth shell. The grayish-brownish tones of the uncooked shell turn these colors when heated. The cooked shell should be very appealing to consumers and can be used in attractive plate presentations or displays. The edible meat is lighter in color, varying from white, cream to light yellow. The attractive meat colors could also be used in marketing efforts to embellish the product. The plumpness and volume (i.e., an almost full half-shell) of the meat can be used to distinguish the sunray venus clam since the ratings were very high for these two attributes. In terms of taste, ratings for “salty” were a very distinguishing attribute. This result is not unexpected since clams are filter-feeders and this clam is cultured in high salinity waters. The salty flavor would not necessarily distinguish clams from a region, but could reflect seasons and local weather conditions. Also, there is an interesting range in the ratings for umami basic taste, which has not been previously described for hard clams. Umami is a term borrowed from the Japanese, meaning "good flavor" or "good taste". Scientists describe this fifth basic taste as brothy, meaty, or savory. This could be another attractive term used in marketing to describe the sunray venus clam. In addition, the sunray venus clam has a distinguishable seaweed and metallic-like flavor, similar to chicken liver, and the light meat texture is very firm. Presence of sand or grittiness in any clam is an unpleasant and negative mouth-feel. During this study, there was no detection of “grit” in samples of sunray venus clams tested.

Shelf Life Studies

Samples of sunray venus clams collected during the summer (June 2010) and winter (January 2011) for the sensory profile were also used in evaluating shelf life parameters under refrigerated storage by assessing survival (not-gaping), total microbial loads, and changes in sensory character. In this study, harvested sunray venus clams were tempered at 72°F for 6-10 hours prior to being placed in refrigerated storage, which was maintained at a constant 45°F. Visual judgments were used to assess survival of sunray venus clams on a daily basis. Gaped clams were considered dead when they did not respond by closing their shells to specified agitation, or tapping, after the clams were held for a short time at room temperature. Dead clams were counted and removed from the sample bags. Sensory measures were based on observations and development of off-flavors and other changes in attributes.

The shelf life of sunray venus clams harvested in the summer was eight days (after harvest) with a survival of 86-92%; whereas the shelf life of clams harvested in the winter was 21days and survivals ranging from 90-98%. During the summer shelf life assessment, sensory ratings were also determined for raw meats of the sunray venus clam. The sensory assessment involved a team of three seafood experts experienced in sensory judgments for raw and cooked seafood. The sensory judgments were based on daily evaluations of the clams using a 9-point hedonic scale that equates to ‘Preferred’ quality (1-3), ‘Acceptable’ quality (4-6), and ‘Unacceptable’ (7-9). ‘Unacceptable’ quality denoted the end of shelf life, while ‘Acceptable’ denoted the transition from ‘Preferred’ product quality. Like other clams, the sunray venus clam has a mild sea breeze odor and a briny, metallic flavor during the ‘Preferred’ stage. The end of shelf life is characterized by a disappearance of the ocean-like odors, and development of the typical odors and flavors that denote spoilage, such as strong fishy, wet dog, and bitterness. Microbial measures showed that end of the shelf life was mainly due to presence of off flavors and off-odors (wet dog, bitter, putrid) rather than of high bacterial counts.

An unanticipated and unique observation of the sunray venus clam is the tendency of this mollusk to remain closed when approaching mortality. This is in contrast to other clam species and even the sunray venus clam during the first week in refrigerated storage. Clams typically gape or open when they become weak or die during storage. Therefore, it is recommended that retailers conduct a daily sensory evaluation of sunray venus clams nearing the shelf life expiration date (7 days after harvest in the summer and 19 days after harvest in the winter) to ensure product is suitable for consumption.

Additional shelf life evaluations were conducted in 2011 to better define seasonal survival of sunray venus clams in refrigerated storage. Sunray venus clams were harvested from the UF experimental lease nearby Cedar Key in February (winter; average size=23 mm shell length, 62 mm shell width, 33 grams total weight) and June (summer; average size=21 mm shell length, 51 mm shell width, 20 grams total weight). In this study, the summer-harvested sunray venus clams (water temperature at harvest, 85°F) were tempered at 72°F for 6-10 hours prior to being placed in refrigerated storage, which was maintained at a constant 45ºF. Product harvested in the winter (water temperature at harvest, 58°F) did not need to be tempered. The shelf life of clams harvested in the winter was 20 days with a survival rate of 97%. These results were very similar to the first study in which sunray venus clams were reported to have a shelf life of 21 days with a survival rate of 86%. The shelf life of sunray venus clams harvested in the summer was 8 days (after harvest) with a survival of 82%. Again, this was very similar to the first study results, in which sunray venus clams were reported to have a shelf life of 8 days with a survival rate of 86%. The winter-harvested sunray venus clams had 19 days of preferred quality, while the summer-harvested sunray venus clams had 6 days of preferred quality and one day of acceptable quality. The end of shelf life was characterized by a disappearance of the ocean-like odors and development of the typical odors and flavors that denoted spoilage, such as strong liver taste, bitterness, and putridness.

Nutritional Profile

A complete nutritional profile for cultured sunray venus clams was determined by analyzing triplicate pooled groups of clams for the required nutrients by the Nutrition Labeling and Education Act (i.e., calories, calories from fat, total, fat, saturated fat, trans, fat, cholesterol, sodium, total carbohydrate, dietary fiber, sugars, protein, vitamin A, vitamin C, calcium and iron; Food Labeling Guide 2008), as well as other nutrients (e.g., copper, vitamin B12, zinc) that may be present but are not required by the U.S. Food and Drug Administration (FDA) as presence of these nutrients may help in marketing of sunray venus clams. Nutrients were determined using appropriate AOAC (2000) methods.

Sunray venus clams are a low fat source of protein. A single 3-ounce (85 g) serving of sunray venus clams (18 to 20 cooked clams) provides approximately 9 g of protein. The low fat content (<1%) was composed primarily of polyunsaturated fat (68%, with 50% omega-3 fatty acids) and the remainder (32%) as saturated fat. The level of cholesterol in sunray venus clams was about 25 mg per 85 g serving. This level is low when compared to fish, shellfish, and other foods, such as pork, eggs, chicken, and cheese. The most important nutritional feature of the sunray venus clam is that a single 3-ounce (85 g) serving provides a good complement of minerals and vitamins. A 3-ounce serving size of cooked sunray venus clams also provides the following vitamin and mineral daily requirements: 45% of vitamin B12, 10% of vitamin A, 4% of vitamin C, 40% of iron, 4% of zinc, 6% of copper, and 10% of calcium. Interestingly, iron is known as the 'hard to get' mineral, since only 6 mg of iron is absorbed per 1000 calories consumed. With sunray venus clams, consumers receive a high percentage of iron without having to consume a lot of calories. Sunray venus clams have an average sodium content of 360 mg per 100 grams. A nutritional facts panel for a 3-ounce serving was developed.

OBJECTIVE 7. Examine product attributes of sunray venus clams with respect to wholesale market and product distribution standards for molluscan shellfish.

<u>Survey of Wholesaler Dealers</u>

The potential market demand for cultured sunray venus clams was assessed to determine constraints in developing a commercial market for this new candidate species. Assessing wholesale dealers' attribute demand was accomplished by a facilitated mail survey, which asked respondents to rate a variety of sunray venus clam product attributes. Five certified shellfish wholesale dealer firms located in Cedar Key participated as the facilitators and identified their own "downstream" dealer, broker, or shipper clients to receive samples of cultured sunray venus clams for evaluation. Understanding the product attribute assessment by, and requirements of, these firms and their "downstream" buyers is vital to initiating acceptance of cultured sunray venus clams within the existing market channels.

Shipments of sunray venus clams and surveys were sent during late 2010 and early 2011 to a sample of certified molluscan shellfish dealers across the United States. Shipments were made to 21 firms, ranging in location from Florida, New York, to California. Additional shipments of sunray venus clam samples to "secondary" wholesale dealers were sent in the fall of 2011 using product harvested by participating growers. Also, during mid-2011, an additional nine shipments (with surveys) of sunray venus clams were sent to wholesale/distributors who visited the *Fresh from Florida* booth at the Boston Seafood Show. Each firm received 150-180 sunray venus clams (average size: width, 23 mm length; length, 60 mm; whole-weight, 31 grams). Initially, two potential size grades were to be shipped; however, a large enough size variation in cohorts harvested from field trials that would be needed to provide the two size classes was not available. The shell stock clams were shipped in polystyrene boxes with chilled gel packs via overnight courier to the respective client. The sunray venus clams were properly tagged by the primary dealer prior to distribution to the downstream dealers. Harvesting, processing, and shipping of the sunray venus clams complied with federal and state regulatory requirements for molluscan shellfish (FDA 2005, FDACS 2002). In addition, each firm received a "survey kit" which contained a product attribute survey instrument and a series of five fact sheets with information on the aquaculture potential, consumer acceptance, sensory profile, shelf life assessment, and nutritional profile of the sunray venus clam. The survey recipients were asked to try the clams either cooked or raw, and rate/comment across a wide range of product attributes and market-related issues.

Results obtained from a survey of wholesale dealers (n=35) conducted in 2010-11 are summarized. The information was analyzed and salient respondent recommendations determined by type of business, region of the country, business revenue category, product line diversity, and other demographic factors. A total of 29 dealers responded to the survey; a summary of their responses follow. The majority of survey respondents were distributors, located in the southeast U.S., had total annual seafood sales exceeding $10 million, reported molluscan shellfish sales as being the greatest percentage of annual sales, carried a diversified product line of molluscan shellfish, and considered oysters and clams as the most important products offered. Dealers were asked to rate the shellstock sunray venus clams provided across several attributes, using an 8-point Likert Scale, with 1 being a lower rating and 8 a higher rating. Most attributes (shell appearance, meat color, cooked meat taste) received relatively high ratings (6.6-7.3), the lowest being given for the taste of raw product (5.4) and texture (5.1). Survey recipients were asked to assess other product attributes, such as presence of grit, shell color, meat yield, shell thickness, and shelf life. Half of the survey respondents were not able to detect any grit in the product, while 46.7% detected 'some grit,' and 3.3% detected 'excessive grit'. Meat yield was suggested to be 'about as expected' or 'more than expected' by 56% and 44% of respondents, respectively. Approximately 70% of respondents indicated that shell thickness was 'just right,' while 90% found shelf life to be 'acceptable.' Most respondents indicated that the clam size received was acceptable.

Survey recipients were asked to provide perceptions on the potential demand for sunray venus clams. Approximately half the respondents (46%) indicated they ‘Could sell some’, while 42% suggested a ‘High market demand’ will exist. Respondents also suggested that of the key product attributes for sunray venus clams, the most attractive marketable attributes would be taste, shell appearance, and meat yield. Information provided by respondents regarding the likely peak season of demand, the quantity of clams that could be sold during this peak season, and the likely per unit price was too variable to provide clear findings; however, the responses suggested that the market may likely exist year-round, with potentially significant volume of sales being possible. The average price that respondents would be willing to pay was $0.183, though there was a considerable range in responses.

The overall assessment of sunray venus clams by dealer and client respondents was extremely favorable. In addition, respondents provided useful information on suggested shipping and handling methods, possible seasonal characteristics of the market, potential wholesale price levels, and other related information. This information provides guidance to the existing industry as attempts are made to properly "place" sunray venus clams in the current market for molluscan shellfish in Florida and the US. The findings from this dealer survey corroborates the findings from previous consumer acceptance surveys conducted in 2008 and 2010, in that sunray venus clams are highly rated as a potential new candidate aquaculture species. These findings suggest that a latent market exists for sunray venus clams.

Survey of Seafood Buyers

In addition to the wholesale dealer survey, an additional survey was conducted at the 2011International Boston Seafood Show. This premier seafood tradeshow, held annually at the Boston Convention Center, represents a unique opportunity to exhibit new seafood products to a wide range of buyers and seafood trade associations, including wholesalers, processors, distributors, restaurants, retail grocers, etc. Cultured sunray venus clams were featured at a booth within the *Fresh from Florida* Pavilion, in cooperation with the Florida Department of

Agriculture and Consumer Services (FDACS), Bureau of Seafood and Aquaculture Marketing. Visitors to the booth were provided with cultured sunray venus clams to sample. The clams were cooked by a professional chef utilizing a recipe that featured the unique taste and texture attributes of the cultured sunray venus clam. Approximately 2,000 clams were served to approximately 800 individuals who visited the booth. A brief on-site survey was administered to those who sampled the clams. The survey was intended to collect additional information about consumer acceptance of the various attributes of cultured sunray venus clams and asses the willingness to purchase the product in the market. There were 239 surveys completed at the Boston Seafood Show booth revealing an overwhelming, positive assessment of the product across a range of attributes and factors. For example, 86% of the respondents rated the sunray venus favorably and 80% said they would purchase them. In responding to standout attributes of the sunray venus, 75% stated taste, 55% stated texture, 33% state shell appearance, and 15% stated meat color. The information from these surveys further help to describe the consumer acceptance of sunray venus clams, though the information from these completed surveys was not as detailed as that obtained from the wholesale/distributor shipments. However, the Boston Seafood Show surveys help to further identify those characteristics and attributes of the sunray venus clam that are most preferred by potential buyers.

At the 2012 International Boston Seafood Show (IBSS), cultured sunray venus clams obtained from field trials were provided to the FDACS celebrity chef to cook and serve at their *Fresh from Florida* Pavilion. A brochure developed for the 2011 IBSS, in which the project team introduced the sunray venus clam and surveyed interested buyers, was revised and provided. Visitors and buyers were introduced to a new seafood product. Those who sampled sunray venus clams agreed with results obtained by the project team at the 2011 IBSS,

OUTCOMES AND IMPACTS:

To obtain full adoption of this species by industry, this project focused on identifying and eliminating potential production and marketing barriers that may serve as constraints to establishing sunray venus clams as a feasible complement to existing hard clam culture and markets. Previous research has shown that sunray venus clams were able to be grown on an experimental basis and have been found acceptable by consumers. Previous efforts to diversify species in the Florida clam culture industry have failed for various reasons (e.g., shell breakage, gear differences). Therefore, it was anticipated that this project would yield data and materials to fill in voids of our previous sunray venus clam projects, thus lowering or eliminating barriers to initiate full commercialization of this species by Florida shellfish culturists. If these last information voids were not resolved, it may be possible that the sunray venus clam would not be adopted by Florida clam farmers as the risk would be too great for an industry whose product sells for pennies at the farm.

By working with each industry sector throughout this and former projects, the barriers may be lowered or eliminated thus allowing the industry to have a forward momentum and head start towards production as was done with the initial hard clam training projects conducted in Florida during the 1990s. Five percent (5%) of the Florida clam growers and 30% of the wholesalers in Cedar Key were engaged in this applied research, thereby allowing for technology transfer to each of these industry sectors. During this project, results of the various components were disseminated to the aquaculture industry in the form of several deliverables, with over 600 people informed of the results of this integrated project. Findings provided science-based information necessary for commercial clam culturists and entrepreneurs to make an informed decision regarding sunray venus clam culture.

Specific outcomes from this project include:

Broodstock production and education aided commercial hatchery operators in their initial production of seed for the industry.

Seed was provided to 13 commercial growers in four counties, which allowed transfer of our findings directly to stakeholders during the project. Field nursery and growout culture methods for sunray venus clams are not prohibitive, but do exhibit some differences from hard clam methods.

Earlier problems with shell deformities found in field trials conducted in 2007-9, which appeared to be gear and substrate-related, have been resolved. Efforts in 2010-12 incorporated a planting technique used by growers on the east coast and field sites were limited to those with soil properties, which were more suitable for this species. These modifications resulted in shell deformities being reduced to less than 5% in field trials with clam growers.

This study yielded information that will aid in the characterization of soil types and chemistry for determining compatibility of existing shellfish culture leases and siting future leases for this promising aquaculture species.

Sensory, microbial, and nutritional profiles of cultured sunray venus clams were completed, which allows wholesale distributors and consumers to make informed decisions on distribution and consumption.

Understanding the product attribute assessment by, and requirements of, certified shellfish wholesalers and their own "downstream" dealers, is vital to initiating acceptance of cultured sunray venus clams within the existing market channels. Product attribute and wholesale market studies yielded key information that can be used to establish wholesale market and product distribution standards, and will help industry better understand its market development potential.

Our knowledge of the market for sunray venus clams is extended beyond the previously described restaurant sector and help guide the development of viable local and regional markets for cultured sunray venus clams. This further facilitates the commercial acceptance of cultured sunray venus clams by all sectors of the molluscan shellfish market.

Fact sheets on the following topics were written and published through Florida Sea Grant: 1) aquaculture production potential, 2) consumer acceptance, 3) sensory profile, 4) shelf life assessment, and 5) nutritional analysis.

The debut of the cultured sunray venus clam at selected restaurants and retail markets in south Florida in 2012 marks yet another milestone in the commercialization of this promising aquaculture species. Four certified shellfish wholesalers have begun distributing sunray venus clams cultured in Pine Island Sound (Lee County). An internet search using "sunray venus clams" will retrieve information derived from our project on the Chef's Resources website, as well as sites of these commercial growers/wholesalers.

A recent (2012) newspaper article in the Ft. Myers News-Press featured a Pine Island clam grower, who is now culturing sunray venus clams. "I think this could be really big for Southwest Florida," the grower was quoted as saying. "I think it could eventually become like the next stone crab … a delicious product that people come here just to eat, that's where I think this is going."

PROBLEMS ENCOUNTERED:

The creation of initial sunray venus clam founder broodstock lines for Florida hatchery operators was delayed as the Experimental Molluscan Hatchery at HBOI-FAU was razed and completely renovated during 2010, which took longer than planned (through December 2010). This renovation occurred as the building was damaged during the hurricane seasons of 2004 and 2005 and support for the renovation was finally approved. Therefore, objectives 1 (creation) and 2 (demonstration to hatchery operators) had been delayed to 2011.

Sunray venus clams have the tendency to gape, just like hard clams, in the first few days of refrigerated storage (objective 6). An unanticipated and unique observation of the sunray venus clam is the tendency of this mollusk to remain closed when approaching mortality. This is in contrast to other clam species and even the sunray venus clam during the first week in storage. Clams typically gape or open when they become weak or die during storage. Therefore, it is recommended that retailers conduct a daily sensory evaluation of sunray venus clams nearing the shelf life expiration date (7 days after harvest in the summer and 19 days after harvest in the winter) to ensure product is suitable for consumption. Also, shellfish wholesalers/dealers might consider having a “best by date” on the tags of sunray venus product sold, just like eggs, fresh produce, and others foods sold in the United States.

Presence of sand or grittiness in any clam is an unpleasant and negative mouth-feel. During this study, there was no detection of “grit” in the summer samples of sunray venus clams that had been purged after harvest. However, grit was detected in the winter sample. These sunray venus clams were harvested from a bottom plant using clam rakes. If sunray venus clams are going to be harvested from bottom plants and/or any scenario that would result in the presence of grit, it is highly recommended that the product is purged (either by wet storage by the wholesaler or on the lease after harvesting by the grower) to reduce and/or eliminate the presence of sand, or “grit”.

The low survival obtained in the field nursery trials resulted in low numbers of sunray venus seed available for grower trials in 2011. Regardless, we were able to plant a small number of growout seed at 11 commercial lease sites, as well as at four sites being evaluated as potential new lease areas.

NEW RESEARCH DIRECTIONS:

Our ongoing research indicates that a strong relationship exists between soil type preference and this infaunal mollusk. Field trials conducted using the bottom bag method have revealed variability in production characteristics; as such, this method may not be reliable for sunray venus culture. Bottom culture (planting under cover nets), a method used in other states for the culture of hard clams, may be more suitable. Small plots of bottom-planted sunray venus clams were tested to determine if this method can increase survival and reduce shell deformities. A new study to be initiated in 2013 with funding from the FDACS Florida Aquaculture Program will compare alternative methods for growout (bottom net) and harvesting (pump-driven harvester) to current practices (bottom bag) by examining their effects on production characteristics, product quality, subaqueous soils, and water quality.

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