Final Report

Sunray Venus Clam:
A New Species to Diversify the Florida Aquaculture Hard Clam Industry

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ABSTRACT

Hard clam, *Mercenaria mercenaria*, farming has developed into a major industry in Florida. Diversification from a single species product may help stabilize and expand the industry. The native sunray venus clam, *Macrocallista nimbosa*, grows quickly and was harvested and marketed in Florida, thereby making it a logical choice as a new candidate species for culture. Early experimental culture indicated that methods for the sunray venus clam should be very similar to current hard clam culture methods. Therefore, we tested the hypotheses that: 1) sunray venus clam seed could be produced in a hatchery, 2) sunray venus clams could be reared to a harvestable size by shellfish growers using culture methods similar to those employed by the Florida hard clam industry, and 3) market perception for cultured sunray venus clams would be favorable.

INTRODUCTION

Over the past two decades, Florida has seen a dramatic increase in aquacultured shellfish production. The hard clam industry grew from $0.4 million in farmgate sales (13 farmers) in 1987 to $18 million (336 farmers) in 2001. In addition to the increase in farming operations, many ancillary businesses, such as hatcheries, culture equipment manufacturers, and shellfish wholesalers, have developed over the same time span. The total economic impact of the clam industry on Florida was calculated in 1999 to be $33.9 million in output and $9.0 million in labor income (Philippakos et al. 2001). However, the industry is built on a single clam species and the value fell to just under $13 million in 2003 as dockside prices plummeted from 13¢ to 9¢ per clam during the 2001-2004 economic downturn (FASS 2004), which was not reflected in some other bivalve species, such as oysters (R. Rheault, President, East Coast Shellfish Growers Assoc., pers. comm).

Although clam farming has developed into a major industry in Florida, diversification from a single species product may help stabilize and expand the molluscan shellfish aquaculture industry. The rapid recruitment of fishermen into shellfish aquaculture, along with the exceptional growth rates associated with the productive, subtropical waters of Florida, has encouraged producers to seek information on other bivalve species that would provide crop diversification and augment profit potential. Species diversification may be one alternative to mediate losses associated with a monoculture-based industry and to spread production risks. Native molluscan species that could be cultured and marketed along with clams are logical options. However, small clam farmers do not have the time, experience, or resources to develop new product lines or investigate the feasibility of developing new aquaculture species

Many shellfish aquaculturists and seed suppliers in Florida became aware of the need to diversify their businesses by participating in the New Molluscs for Aquaculture Workshop in November 1999. Conducted in cooperation with the Florida Department of Agriculture and Consumer Services, Florida Sea Grant and the UF Cooperative Extension Service, the workshop allowed audience members and a selected panel of researchers, biologists, marketers, economists, regulators and resource managers to characterize the culture and market potential of alternative molluscan species. It was concluded that efforts should be undertaken to further determine the production feasibility and market demand of the angel wing, bay scallop, blood ark and sunray venus clam (Fig. 1).

The angel wing has been studied (Gustafson et al. 1991), but its thin shell and need for sand substrate during metamorphosis has delayed its use in an industry built on hard clam methods. Bay scallops can be successfully cultured in Florida (Blake et al. 2000), but new rulemaking may be needed for raft culture, which requires water column usage in Florida waters. The blood ark is in its early research stages (Power et al., 2005), but is not as familiar to most American consumers. The sunray venus clam, of the four species identified as candidates, is most similar to a hard clam and was previously the target of a commercial fishery in Florida.

Figure 1. Sunray Venus Clam, *Macrocallista nimbosa*

The sunray venus clam, *Macrocallista nimbosa* (Lightfoot 1786), is an attractive venerid clam distributed from South Carolina to Florida and the Gulf states (Abbott 1974). Interest for commercialization of this species was noted by Akin and Humm (1960) when they found unusually dense populations at Alligator Harbor. From 1967 to 1972, two million pounds of clams were landed near Bell Shoal, St. Joseph Bay with a value estimated at $0.25 million (Godcharles and Jaap 1973). Several processing plants were established in the area where clam meats were shucked and further processed into strips, minced or chopped pieces, or packaged whole (Stokes et al. 1968). During the same time period, processors engaged in an education program to communicate to consumers features of their high quality clam meats (NOAA no date). Attributes promoted included grit-free meat as a result of clams being harvested from sandy bottoms, as well as a sweeter and more tender-tasting product than most other clams. Because of the potential economic value of the sunray venus fishery and the relatively small size of the productive area, the Florida Department of Natural Resources conducted surveys in the early 1970s to locate new clam beds of possible commercial significance along Florida's northwest coast (Jolley 1972). Although beds were located between Panama City and Cedar Key, these areas yielded smaller catches than those at Bell Shoal. Total landings of clam meat (289,000 pounds) from 1986 to 1992 were valued at $183,031. However, insufficient natural stocks of clams, as well as the small size of fishing grounds, limited the development of the fishery (Stokes et al. 1968, Ritchie 1977).

Limited information pertaining to the life history of sunray venus clams exists (e.g., Futch 1967, Cake 1970). Haines (1975, 1976) performed the most comprehensive study for culture. In summary, sunray venus clams were found to be ripe year around, but peak spawning occurred in the fall (Haines 1976). Haines (1975) found that spawning this clam in the laboratory was difficult and attempts at inducing spawning by temperature shock, gonadal extracts, mechanical and chemical stimulations were all unsuccessful. Viable larvae were produced by "strip" spawning the clams, but strip spawning was only successful with animals collected in October and November (i.e., during natural spawning). Larvae were best cultured in 2-4L flasks and not in larger vessels, which may indicate culture method problems, such as using *Nannochloris oculata* as a primary food source. Some larvae were cultured through metamorphosis when using *Monochrysis* sp. and *Isochrysis* sp. in addition to *Nannochloris* sp., but no quantitative feed study was performed. Larvae developed in

typical bivalve fashion from 90-120 μm D-stage larvae at 24-48 hr to 160 μm pediveligers and then metamophosed at 180-200 μm after 14 days (8-14 day range). These successful cultures occurred at 25-31 ppt and 23-25^{o}C. Preliminary salinity tolerance studies on embryos and larvae indicated optimal salinities of 25-35 ppt at 24^{o}C for both stages, which was similar to the originating waters of the broodstock. Unfortunately, algae concentrations were not quantified in any experiment reported, except to note volumes added, which probably influenced growth as much as the algae species combination used.

Growth experiments using marked individuals in the wild 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 (Sturmer et al. 1995; Fernandez et al. 1999). This rapid growth rate, along with documentation on the high quality of its meats, could result in these clams being sold in the lucrative raw or steamer clam markets. Observations made by Stokes et al. (1968) on handling and processing of the sunray venus clam indicated that once refrigerated, clams maintained good closure and could be kept for a week. Shelf life is an important attribute when considering the marketing and distribution of molluscan shellfish as live shellstock. Although market and pricing information was obtained through the fishery for processed clam meats, there is a dearth of information about the potential of sunray venus as shellstock. A mollusc survey was conducted by the Florida Department of Agriculture and Consumer Service, Division of Seafood and Aquaculture Marketing staff at the 2000 International Boston Seafood Show (DACS 2000). Samples of sunray venus clams and other marine molluscs were collected from Florida waters by University of Florida extension agents and provided for inspection by seafood wholesale buyers. The appearance of the sunray venus clams received the most interest by buyers with the product form preference for whole shellstock. According to survey results, wholesale prices suggested ranged from $.20 to $.25 each and $1.50 to $2.50 per pound. Comments included that market preference would be regional, but interest included Asian and export. This small convenience sample of potential buyers revealed considerable interest in this clam for domestic and export markets.

Successful diversification and expansion of bivalve aquaculture is occurring in Washington State; starting with oysters, then adding manila clams and, more recently, 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 prior fishery, market and potential growth rate of the sunray venus clam, along with being a native species, makes it a logical choice as a new candidate species (Mann 1984) to diversify and expand the modern Florida hard clam industry. Early experimental culture work by Haines (1975) indicates that culture methods for the sunray venus clam should be very similar to current hard clam culture methods, although to our knowledge no attempts have been made to commercialize on Haines' early data. Therefore, we tested the hypotheses that sunray venus clam seed could be produced in a hatchery and reared to a harvestable size by shellfish growers using culture methods similar to those employed by the Florida hard clam industry and that market perception for cultured sunray venus clams would be favorable.

METHODS and RESULTS

Objective 1) Identify methods for sunray venus broodstock handling and spawning.

Broodstock Collection: A Special Activity License was obtained through the Florida Fish and Wildlife Conservation Commission allowing project investigators and industry partners to collect sunray venus clam broodstock. Collecting adult sunray venus clams for broodstock was initiated in May 2006 in Cedar Key (Levy County) by searching the adjacent sandbars off of Seahorse and North Keys. The initial searches in Cedar Key were done by raking the sand substrate at low tides. A total of three trips in May yielded 21 sunray venus clams at an effort of over 25 man-hours. Broodstock collection trips in Franklin County began in July and ran through November 2006. Collecting was focused around St. Teresa Beach, but surrounding beaches and islands were also explored. Five trips were conducted and a total of 222 sunray venus clams were collected. The industry partner in Franklin County shared an observation that by finding keyhole-shaped siphon holes or V-shaped spray marks leading from the hole, we were more likely to locate the clams. Digging in the vicinity of the "keyhole", or the point of the V-shape, to a depth of roughly 6" would often reveal the target species. Two more searches in Cedar Key waters during October and November, where we adopted this new strategy of identifying spray marks at low tides, yielded 69 sunray venus clams.

Shipping Trials: Prior to shipping sunray venus clams, mock shipping trials were performed, using hard clams, to determine a shipping method. The type of insulated boxes, number of gel packs, amount of oxygen injected, and volume of salt water were determined through these mock trials. Three shipping trials (shipping dates were not done on collection dates) with sunray venus clams were conducted to ascertain whether adults should be transported in “wet” versus “dry” conditions. On 11 July, double polyethylene bags placed in three large insulated boxes (ID 39.4 x 39.4 x 19 cm, 1.9 cm wall or 15.5" x 15.5" x 7.5", ¾" wall) were each filled with 6 L of salt water (wet treatment). Thirteen sunray venus clams were placed in the water-filled bags and the air space was injected with oxygen. Six frozen gel packs wrapped in newspaper were placed in the box and the box sealed. Three medium insulated boxes (ID 26.7 x 20.3 x 15.2 cm, 3.8 cm wall or 10.5" x 8" x 6", 1½" wall) were each stocked with 13 sunray venus wrapped lightly in moist newspaper and 3 frozen gel packs wrapped in newspaper (dry treatment). A max-min thermometer was placed in one box of each treatment. Shipping containers were shipped priority overnight via a commercial courier and arrived at HBOI the next morning. Two additional shipping trials were conducted to further evaluate the shipping methods: 9 August (eight sunray venus clams were stocked in each shipping box) and 7 September (six sunray venus clams were stocked in each shipping box).

Clams that were shipped “experimentally” on 11 July, 9 August and 7 September arrived in very good to excellent condition the following day. The 11 July shipment had one cracked clam in five of the six shipping boxes and experienced eight mortalities (~11%) in culture over the next five days. There was no noticeable difference in mortalities from wet or dry shipping treatments. The 9 August shipment had only one clam cracked in the entire shipment (wet treatment) and experienced four mortalities (~8%) in the next six days; again no difference between shipping treatment was noted. The 7 September shipment had no clams cracked from shipment and had

only one mortality (~3%) in the next 10 days of culture. The data above indicate that sunray venus clam broodstock can be handled similarly to hard clam broodstock (i.e., dry shipping in a cool environment).

Reproductive Assessment/Spawning Trials: After ascertaining mortality from shipment, induced spawning of sunray venus clams was attempted using thermal stimulation (i.e., periodic 5-10 C increase in water temperature). No spawning occurred on the day of shipping arrival for any clams from the experimental shipments. All sunray venus clams were placed in their own conditioning tanks. Mortality and substrate preference was observed as the clams were held in the conditioning system (20-22 C). Clam mortality occurred from high temperature in the system (~30C, chiller not working) or from being out of the supplied substrate (aragonite sand, 0.5-1.0mm diameter). For example it was noted that the 11 July and 9 August shipments experienced high temperatures (30-31^{o}C) and heavy mortality in the conditioning system as the chiller unit failed, whereas the 7 September shipment was exposed to lower temperatures (21-24^{o}C) and exhibited lower mortality.

Histological analysis was performed on tissue samples taken immediately upon receipt of the sunray venus clams or after various intervals after receipt of clams from the following shipments: 11 July, 9 August, 26 October, 9 November and 21 November shipments. Six clams were sampled immediately upon receipt, except in August in which seven clams were sampled over a one week period. Additional sampling of clams from the 11 July shipment was performed monthly from date of receipt through November and from the August shipment throughout the month of August. Overall, 66 clams were sampled, which indicated 38 males and 28 females or a slightly skewed ratio of 1.4 males:1.0 female.

Samples (3 from wet and 3 from dry shipment) taken on day 0 from the July shipment consisted of 4 males and 2 females. They were in various stages of development ranging from stage 1 (undifferentiated) through stage 4 (spawning), but the majority (83%) were in pre-spawning (1-3) stages. Samples taken during the first week from the August shipment consisted of 5 females and 2 males and again exhibited a range of development; 28.5% in pre-spawning, 28.5% in spawning and 43% in spent stage. The percentage of clams noted in the spawning stage increased in samples collected in the fall. Of the clams sampled from the 26 October shipment, four were male and two were female; 17% in pre-spawning stage, 50% spawning and 33% spent. The 9 November samples consisted of 3 males and 3 females, which exhibited the same development as the October shipment. Spawning stage decreased towards the end of November. Clams sampled from the 21 November shipment consisted of 5 males and 1 female; 33% were in spawning stage and 66% were in pre-spawning stages. Clams from the July shipment showed an increase in percentage of those in spawning stage over time, likely due to conditioning (e.g. food availability and steady temperature). The majority of clams collected in the summer were in pre-spawning or spent stages, while those collected in the early fall were predominately in spawning stages. By late fall, clams that were spent from early fall spawning were now in early developmental stages.

The first ever successful induced spawning of both male and female sunray venus clams was accomplished on 13 October 2006 from 30 clams shipped on 7 September 2006, indicating that

the conditioning environment (temperature, salinity and feed) was conducive to clam health and reproduction. Induction was by thermal shock and dissected sperm addition. Approximately 500,000 eggs were obtained from one female and fertilized by sperm from one male. The second successful induced spawning occurred on 10 November utilizing 27 clams from the 9 July 2006 shipment and 21 clams from the 25 Oct 2006 shipment. During this attempt at spawning, six animals were also injected with 0.4 mL of 2mM serotonin. Clams that were injected did initiate spawning, but the five females released immature eggs that did not develop. The male that spawned was utilized for fertilizing the one female that spawned from thermal shock and addition of dissected sperm.

In year two (2007), sunray venus clam broodstock were maintained in plastic trays (42 x 32 cm) filled with aragonite (0.5-1.0mm) and placed in four separate conditioning systems (20-25^{o}C), which were fed microalgae daily. Low levels of mortality occurred and one tank was completely lost. The cause of the complete mortality was not able to be determined, but this system had the highest number of clams, therefore a water quality or bacterial issue may have disrupted the system. Spawning induction was attempted with two groups in August 2007 by thermal shock, stripped sperm addition, and serotonin injection. Thermal shock and stripped sperm addition had no effect, but serotonin injection caused 8 of 11 clams to spawn (all males) from one group and 4 of 9 clams to spawn (2 males and 2 females) in the second group. The eggs production was minimal, but sperm was added to the egg suspension. Approximately 35,000 D-stage larvae were noted the following day and utilized for documentation of larval development (see next objective).

After holding sunray clam broodstock for a total of 14-17 months, they were induced to spawn in January 2008 by thermal stimulation. A total of four females and six males spawned on the second thermal cycle from a group of 26 animals. Again, this indicates that sunray venus clam broodstock may be maintained in captivity for long periods for breeding purposes.

Broodstock sunray venus clams seem to do better in a substrate, unlike broodstock hard clams that do not need substrate. The substrate may be problematic as it can go anaerobic, leading to toxic hydrogen sulfide production or it may be a site for pathogenic bacteria to bloom. Therefore, sunray venus clam broodstock conditioning is similar to hard clams, but modifications for holding sunray clams (i.e., substrate or other methods) need to be examined.

Objectivr 2) Establish hatchery protocols for rearing sunray venus embryos through larval metamorphosis.

Approximately 500,000 eggs were obtained from the 13 October 2006 spawn. Eggs were placed in a 500L tank at a salinity of 30-31 ppt and temperature of 26-28^{o}C. After 24 hr, D-stage larvae were abundant and feeding on supplied microalgae (*Isochrysis* sp., strain T-Iso). Larvae grew appropriately, but there was high mortality (Table 2). The second spawn on 10 November 2006 yielded approximately 1,100,000 D-stage larvae after 24 hrs of culture. This culture had negligible mortality (~12%) during larvae culture. Larvae from both spawns grew similarly at HBOI and the larvae grown at two different institutions grew similarly with pediveligers noted at

day 7 and then being placed in "setting" systems on day 8, which is similar in time for hard clam larvae.

Jose Nuñez of the UF-Whitney Laboratory followed development of the second sunray venus clam spawn (10 November 2006) at HBOI and then transferred 24 hr old larvae to the Whitney Lab for further culture (22.5^{o}C and 35 ppt salinity). Video documentation of the 10 November 2006 spawn for development from fertilization to pre-pediveliger was done during a seven day period. The microscope was equipped with eye-pieced micrometer and a Javelin "Cromaship V" CCTV video camera. Video footage of the larvae development was recorded by an attached Canon Optura 500 digital video camera. Unfortunately, after moving the larvae from the hatchery to an indoor location because of an incoming cold front all the larvae died overnight (day 7). Survival from day 2 to day 7 was 85.1%, which was similar to that at HBOI. Early developmental stages were similar to the hard clam. The 8 August 2007 spawn was transferred to Jose Nuñez on culture day 5 to continue documentation of late larval development, metamorphosis and early juvenile growth.

Metamorphosis from planktonic pediveliger to benthic juvenile occurred during the few days after being placed in the setting systems. The 13 October and 10 November 2006 spawns were tested for substrate preference. Larvae were placed in downwellers (120 µm mesh bottom and 0.143 m^2 area) with substrate (sand at <500 µm or aragonite at 500-1000 µm diameter) to a depth of 5-10 mm or without substrate. Overall, larvae metamorphosed successfully in all treatments.

The 13 Oct. spawn of sunray venus clams was divided among three downwellers for setting (no substrate, sand, and aragonite). After 3 months of culture it was noted that the sand substrate had the highest return (100%), followed by aragonite (71%) and then no substrate (49%) of clam number. We are dubious of the 100% return in the sand substrate for this preliminary experiment, which may have occurred from a miscalculation of the original number of clams added. It was noted that the aragonite sand developed fouling organisms, but the animals were not fouled. Therefore, the 10 November spawn of clams was utilized to test the preference of larvae for setting survival in sand versus no substrate (triplicate downwellers for each treatment). After two months of culture the sand substrate again yielded the highest return (58%) as compared to no substrate (35%). Sunray venus clam larvae metamorphosis/settlement and early growth without substrate is consistent with hard clam culture methods. Substrate can be problematic during settlement and early growth as noted for the following of aragonite substrate, therefore, even though survival may be diminished without substrate, the ease of culture and efficiency for cleaning systems and observing growth for 2-3 months without substrate may be offset.

Objective 3) Grow a group of sunray venus clams from post-set to commercial size using standard hard clam methods.

The sunray venus clam juveniles produced from the 13 October and 10 November 2006 spawns were cultured using standard hard clam protocols for land-based nursery. Clams were fed microalgae cultures of a flagellate (*Isochrysis* sp.) and diatom (*Chaetoceros* sp. or *Thallasiosira weissflogii*) and cleaned every other day. As clams grew they were size sorted by sieving and

enumerated using standard volumetric procedures. Sunray venus clams are more elongated as compared to a hard clam, which is virtually round. Therefore, sieve sizes and length relationships will need to be redone for hard clam farmers; height (dorsal-ventral) is more important in size sieving as compared to length. The first spawn yielded ~32,000 juveniles three months after setting (63% return) and the second spawn yielded ~454,000 juveniles two months after setting (46% return).

In January 2007, about 1/3 of the nursery seed clams from the 13 October spawn (approximately 37 clams/mL, i.e., >2.0mm but <3.8 mm sieve size) were transported "dry" from HBOI to a commercial seed supplier (Nursery Operator 1) for further nursery culture. Clams were placed in either two upwellers with no substrate or two plastic trays (42 x 32 cm) with about 4cm of sand substrate (<500 um diameter) at a density of 17200 clams/sq meter (1600/sq ft). Clams (n=30) were sampled in May 2007 and measured for length (anterior-posterior) and weight. Clams in sand were larger in shell length (SL) than those in the upweller: 20.4 ± 2.1mm (1.1 ± 0.27g) vs. 12.0 ± 1.3mm (0.3 ± 0.08 g). Nursery clams from the 10 November spawn were cultured at HBOI until project partners were identified in the Spring (March 2007) when water temperature increased.

Approximately 53,000 sunray venus clam seed, ranging in size from 9.3-18.5 mm SL, were placed in commercial field plots in Alligator Harbor on 29 May 2007 for field nursing. Soft bags and hard cages were stocked at different densities (100-500/ft^2) with different seed sizes (sieve sizes of 5.0, 6.7 and 9.0 mm). Seed were harvested monthly afterwards through September and stocked into growout systems. Survival ranged from 31.6% for soft bags to 94.3% for cages with an average survival of 62.8%. Growth rates in terms of shell length ranged from 0.115-0.252 mm/day (3.45-7.56 mm/month). A total of 30,000 sunray venus clams were planted into growout systems (soft bags, bags with internal PVC frames or hard cages) at densities of 20-70/ ft^2. Portions of these clams were utilized for Objective 5.

Growout – Alligator Harbor

Growout of sunray venus was conducted in cooperation with a clam farmer whose lease was located within the Alligator Harbor Aquaculture Use Area east of Carrabelle in Franklin County. The lease is located about a mile east of St. Teresa beach where adult sunray venus were collected for brood stock. The substrate at this lease area is characterized by hard-packed sand. A YSI 6600 data sonde was deployed at a piling marking the perimeter of the lease area in August 2007. Measurements, every 30 minutes, were recorded at six inches above the bottom. Monthly averages and standard deviations for water temperature and salinity values from August 2007 through November 2008 were calculated. Water temperatures ranged from a low of 55.0^oF in January 2008 to a high of 86.3^oF in July 2008. Salinities were consistently high, ranging from 27.4 ppt in April 2008 to 35.9 ppt in June 2007.

Alligator Harbor lease area were planted into growout systems between June 28 and August 16, 2007. The juveniles ranged in size from 21.9 to 33.2 mm in shell length (SL). The systems utilized included polyester mesh (9 mm) bottom bags (dimensions: 3' by 4', or 12 ft^2), which are typically used for culturing hard clams in Florida, and bottom cages. Bottom cages (dimensions:

3’ by 3’ by 6”, or 9 ft^2) were constructed from 1” mesh vinyl coated wire and lined with polyester mesh (9 mm) material. The cages were sunk into the substrate so that only 1-2” of the cage remained above the bottom. Tops constructed from the same materials were used to cover the cages. This system allowed the clams to readily burrow into the bottom sediments without the hindrance of a bottom layer of material. Stocking densities varied from 21 to 51 per square foot. These rates were determined by the number of juveniles available; however, some fell within the range of those typically used in hard clam growout (50-75/ft^2).

On May 4, 2008, a total of five bags (three from the June 28, 2007 plant and two from the August 16, 2007 plant) were harvested. Survival after 8.6 and 10.2 months was 74.5 and 80.4%, respectively. Growth was similar between the two plants and ranged from 1.61-1.77 mm/month. Although survival rates would be considered commercially acceptable for hard clam growout, growth rates were lower than those documented for hard clams. Shell deformities or irregularities were observed in many of the sunray venus harvested. The deformities were limited to the ventral margin (shell lip) with one valve (shell) usually having excessive curvature resulting in a depression (or indentation) of the shell. This caused the shell lips not to meet in some of the clams, thus leaving a visible opening. Of the live sunray venus clams harvested from bags, the percentage of those that were deformed ranged from 15 to 22.5% per bag. All of the sunray venus were transported back to Cedar Key and replanted in cages to be utilized for Objective 5 (see below).

During October through November 2008, sunray venus that had been planted on July 11 and August 15, 2007 were harvested and delivered to an area restaurant participating in the market evaluation. Survival of sunray venus in these two plants and two culture systems ranged from 24.2 to 46.3%. Predation was the cause of mortality with holes and crushed shell found in all the bags, and stone crabs observed in all of the cages. After 15-16 months, sunray venus in the bags and cages averaged 45.6 and 64.7 mm in SL, respectively. Higher growth was obtained in the cages (2.4 mm/month) versus the bags (1.2 mm/month). The number of shell deformities was also quantified. Of the live sunray venus harvested from bags, 16.7% were deformed; whereas, deformities were lower (<5%) in sunray venus harvested from cages.

Land-based Nursery, Field Nursery, and Growout - Cedar Key

On June 20, 2007, about 86,000 seed (sieved on a >2.0 mm screen, 48 per milliliter) from the November 10, 2006 spawn were shipped from the Experimental Molluscan Hatchery of HBOI to a commercial land-based nursery facility located in Cedar Key. The sunray venus seed were placed in shallow trays within raceways and nursed under similar conditions as hard clams, which were also being reared in the system. On August 6, a total of 62,850 seed sieved up on 4.0 and 6.0 mm screens, resulting in 73% survival over the 47-day nursery period.

The field nursery and growout culture stages were conducted on a UF research lease located within a commercial shellfish aquaculture high-density lease area (known as Dog Island) in the Gulf of Mexico, east of Cedar Key in Levy County. The site is basically a submerged sand spit with the substrate characterized by a mixture of sand and some mud. Water quality conditions at the Dog Island lease area from August 2007 through November 2008 were monitored using a

YSI 6600 data sonde which was deployed at a piling less than 100' from the site where the sunray venus were reared. Measurements, every 30 minutes, were recorded at six inches above the bottom. Monthly averages and standard deviations for water temperature and salinity were calculated. Water temperatures ranged from a low of 61.0°F in November 2008 to a high of 88.1°F in August 2007. Salinities showed less of an annual pattern ranging from 22.1 ppt in April 2008 to 31.0 ppt in October 2007 and July 2008. These salinity values were lower than those measured at the Alligator Harbor growing site.

On the same day (August 6, 2007), about 9,000 of the larger sunray venus seed (sieved on a >6.0 mm screen, 4.3 per milliliter) were stocked into six hard cages (3' by 1.5' by 6", or 4.5 ft^2), constructed from 1" mesh vinyl coated wire and lined with polyester mesh (4 mm) material. The seed averaged 11.7 $\pm$ 0.7 mm in SL, 4.3 $\pm$ 0.3 mm in SW, and 7.5 $\pm$ 0.4 mm in SH. The stocking density used was 328/ft^2, about 50% of that typically used in field nursing hard clam juveniles (625/ft^2). On November 20, the nursery cages were pulled. After 106 days, the sunray venus juveniles averaged 26.2 $\pm$ 2.1 mm in SL, 9.3 $\pm$ 0.8 mm in SW, and 15.9 $\pm$ 1.3 mm in SH, resulting in a growth rate of 4.1 mm in SL per month. Although stone crabs were present in all cages, 7,255 juveniles were recovered, resulting in 81.8% survival over the 3 ½-month field nursery culture period. Growth and survival rates of sunray venus documented in both the land-based and field nursery exceeded those considered commercially acceptable for hard clams.

A portion of the nursed juveniles were transferred to hard cages, similar to those used in the field nursery but 3' by 3' by 6" deep (9 ft^2) in size and lined with 9 mm mesh polyester material, for continued growout at the same location. Three cages were stocked at a rate of 383/cage (42.5/ft^2), and another two cages were stocked at a rate of 500/cage (55.5/ft^2). Maintenance on the cages during the growout period included periodic inspections and removal of fouling organisms from the cage tops by cleaning with a brush. Sunray venus adults were harvested during October 2008 and delivered to restaurants participating in the market evaluation. Harvest data obtained from the five growout cages may be summarized as follows. Survival averaged 76.7% from the three cages stocked at the lower rate, and 59.9% from the two cages stocked at the higher rate. Predation was the cause of mortality with stone crabs observed in all cages and a large amount of crushed shell noted in several of the cages. Average growth during the 11.1 to11.25-month growout period for sunray venus stocked at the lower and higher densities was 4.18 and 3.07 mm per month, respectively. Growth and survival of sunray venus were comparable to those documented for hard clams.

To ensure there was adequate product for restaurant evaluations in the Cedar Key/Gainesville scheduled for the fall of 2008, it was decided to transfer some of the larger sunray venus at the Alligator Harbor lease area in Franklin County to the growout site in Levy County. On May 5, 2008 six cages of a similar design as that previously described (exceptions included an increased depth of 10" and a different top design to minimize stone crab entry) were stocked each with 379 sunray venus (average size: 39.9 $\pm$ 2.0 mm in SL, 16.3 $\pm$ 1.0 mm in SW, 22.4 $\pm$ 1.1 mm in SH), resulting in a density of 42/ft^2. During November 2008, sunray venus adults were harvested and delivered to restaurants in the area participating in the market evaluation. Table 5 summarizes the harvest data obtained from the six cages. Survival averaged 77.6% from the three cages harvested on November 3, and 62.4% from the three cages harvested a week latter. Again,

predation was the cause of mortality with stone crabs observed in all cages and a large amount of crushed shell noted in several of the cages. Average growth over the 5.98 to 6.25-month growout period was 3.52 to 4.14 mm per month, respectively. Growth and survival rates of sunray venus were comparable to those obtained from cages harvested the prior month. Interestingly, a large majority of the sunray venus that had been stocked in the cages with deformities had "grown out" of the shell irregularities. A wide growth increment (band) without any irregularities was prevalent in most of the sunray venus; depressions or openings in the ventral shell margin were no longer present.

Objective 4) Characterize financial considerations of hatchery production of the sunray venus clam.

The original objective for this effort was to characterize financial considerations of hatchery production for the sunary venus clam. We found that no current information existed on the financial characteristics of a "typical" hard clam hatchery in Florida for comparison. As a result, this objective could not be completed as originally proposed. In lieu of fully characterizing financial considerations for a sunray venus clam hatchery, the differences in hatchery processes were noted.

The hatchery process employed for sunray venus clam, *Macrocallista nimbos*a, seed production was similar to the process utilized for hard clam, *Mercenaria mercenaria*, seed production. Similar costs may be expected to incurred with respect to broodstock acquisition, energy to move and heat water, labor, algae, various supplies, capital cost of space for broodstock maintenance and spawning, and other expenses. However, there are some differences that may need to be utilized in the production of sunray venus clam larvae and seed.

Sunray venus clam broodstock clam seem to prefer being buried in a substrate, which limits the number of clams that can be placed in a system. Therefore, there would be an added expense of obtaining substrate (e.g., construction sand), containers (e.g., plastic dish pans) for the substrate, and a larger area for broodstock maintenance. The other difference noted was that production of post-set was greater (50-66%) in settlement systems with substrate (sand or aragonite) versus no substrate. This substrate effect was also noted in nursery seed growout. However, the need for substrate for larval metamorphosis and growth was not an absolute necessity. A hard clam hatchery operator noted that substrate improves hard clam settlement numbers, too, but the problems associated with substrate (e.g., anoxic pockets, cleaning problems that lead to fouling) in a hatchery and early nursery are more trouble that the reduced survival and growth.

Although substrate in probably a necessity for broodstock maintenance, all other aspects of sunray venus clam hatchery procedures and expenses may be similar or only marginally different as compared to hard clam hatchery procedures and expenses.

Objective 5) Test market perception of sunray venus clams at wholesalers and restaurants.

Introduction

The primary purpose of this objective was to demonstrate the market potential of sunray venus clams. This was accomplished by formally assessing consumer acceptance of sunray venus

clams within a variety of commercial restaurant settings. In addition, the opinions of chefs were informally solicited regarding the use of sunray venus clams. The goal was not to determine the overall size of the market for sunray venus clams, but rather to determine if a latent market for the product exists. If a latent market is identified, then additional study would be required to identify the size of the market, barriers to development, product placement strategies and other critical variables required for successfully establishing a viable market for this new, non-traditional cultured product. The first step, however, is to provide insight into the market potential for sunray venus clams, particularly within the market regions proximate to the trial production locations. This methodology will allow for a more informed approach to eventual market expansion if deemed necessary and feasible by industry representatives.

Methods

The overall methodology chosen was to survey individuals who have just consumed sunray venus clams in a restaurant setting. To access a sample of such individuals, four restaurants were asked to participate as survey hosts. The basic approach was to locate a small number of restaurants willing to participate in the study and agree to provide the manager/chef with a no-cost supply of properly tagged shellstock on an agreed upon schedule. The managers/chefs could serve the clams in any manner they wanted and charge any price they deemed appropriate. In return, the restaurant staff would ensure that patrons who consumed sunray venus clams would be asked to complete a very brief survey prior to leaving the restaurant. Those completed surveys would be archived on site and periodically provided to the research team to allow the assessment of consumer acceptance.

Restaurant Participation

Four restaurants were contacted regarding participation in the survey. The basic approach was to contact each manager/chef and explain the purpose of the research, as well as the conditions associated with participation. All accepted the offer to participate. Three of the four restaurants were located in north central Florida (NCF), while the fourth was located in Apalachicola. The three NCF restaurants included The Island Room (Cedar Key), Campbell's (Bronson), and Ballyhoo Grill (Gainesville). The Island Room is a "white table cloth" restaurant located in the Cedar Cove Marina, while Ballyhoo Grill (located near the University of Florida campus) strives for a casual/sports bar atmosphere. Campbell's is a casual, affordable seafood restaurant located in the rural area between Gainesville and Cedar Key. The other participating restaurant was Avenue Sea, a white table cloth restaurant located within the historic Gibson Inn in downtown Apalachicola.

The managers and/or chefs of all four restaurants were contacted and the goals of the study were discussed in detail. All agreed to participate, as long as the clams were properly tagged as coming from approved waters and handled by a state approved wholesale shellfish dealer. The chefs also requested we adhere to a delivery schedule that ensured product to be available during the weekend rush. The product was provided to the restaurants free of charge, and the managers were to prepare the clams in any manner they wished and charge the price they felt appropriate. The clams were boxed and tagged, then delivered to each restaurant on the agreed upon date/time, typically a Thursday morning. The clams were bagged in standard nylon mesh clam bags, placed in a standard waxed shipment box with cool packs, and then delivered directly to the

restaurant within the following two-hour period. The clams were checked by the restaurant staff for proper tagging, then were transferred immediately to a refrigerated storage room. The clams were then ready for access by the chef for preparation over the next few days.

The managers, chefs, and waitstaff were provided basic biological information on the species being cultured, the culture process, and other related information. This was intended to provide the knowledge necessary for the waitstaff, in particular, to respond to questions by inquisitive customers wishing to order the sunray venus clams. An informational primer was produced for discussion with and distribution to waitstaff. Restaurant managers were asked to ensure that their waitstaff read and studied the primer. One restaurant held a brief training session for the waitstaff immediately prior to the arrival of the first shipment. The other restaurants ensured the project team that the primers would be provided to the waitstaff.
As mentioned earlier, the managers and chefs were encouraged to prepare the clams in any manner they wished, even raw. Serving proportions were also at their discretion. They were told to promote them in any manner as well, either on the main menu, as a chalk board special, menu insert, etc. One restaurant requested promotional table "tents" to help increase consumer awareness of the sunray venus clams. There was no attempt to measure the effectiveness of alternative methods of promotion.

Questionnaire Development and Implementation
The primary method of assessing consumer acceptance was via a brief "table-side" questionnaire. The questionnaire was given to patrons who had consumed sunray venus clams while dining at the restaurant. The brief survey instrument was to be handed to the patrons by the waitstaff as they received their bill and encouraged to read and complete the questionnaire prior to getting up from the table. The waitstaff were asked to become familiar with the questionnaire and address any questions or concerns the patrons might have. The completed questionnaires were then gathered by the waitstaff and archived in a folder within the manager's office. A supply of questionnaires was provided to the each of the participating restaurants. An additional printing was required to keep pace with the demand. The completed questionnaires were then retrieved by a project team member during the next scheduled sunray venus clam delivery.
The questionnaire developed for the study was very similar to that utilized in an earlier study by Moss, Degner, and Adams (2000). The questionnaire solicited information on the manner in which the clams were prepared/served, the price paid, ranking of key product attributes, detection of grittiness, hesitancy to consume sunray venus clams, willingess to order the product again or recommend the product, and various demographic variables. The questionnaire was designed to require less than 5 minutes to complete. A survey protocol was developed and submitted to the University of Florida Institutional Review Board (IRB) for approval, as required. The IRB protocol approval (#2008-U-908) was obtained on 7 October 2008.

Product Delivery
Sunray venus clams were delivered to the restaurants at the time and day of the week determined by the manager/chef. Typically, this was on a Thursday morning. The product was delivered as live, shellstock as previously described. Each restaurant received the number of clams they could reasonably expect to sell during the next 3-4 days. The numbers delivered to each restaurant changed over time as the local demand was more clearly determined (**Table 1**). The clams were

delivered over an approximate two-month period, with 10 deliveries being made. The first delivery was made on 23 October 2008 and the last delivery was made 18 December 2008. The average size of the clams delivered to all restaurants was consistent, with the exception of the clams delivered on 12 December 2008, which were somewhat smaller than those delivered on other dates. A total of 5,922 clams were delivered to the participating restaurants over the duration of the project.

Table 1. Numbers and average size of clams delivered.

Date	Number Delivered	Number per Restaurant	Ave. SL	Ave. SW	Ave. SH	Ave. T wt
10.23.08	750	250	64.5	22.9	37.2	33.9
10.24.08	200	200	-	-	-	-
10.30.08	750	250	62.9	22.3	36.4	32.4
10.31.08	236	236	64.7	24.2	36.9	36.7
11.06.08	1125	250-500	61.0	24.2	35.0	32.9
11.07.08	236	236	64.7	24.2	36.9	36.7
11.12.08	1250	250-500	65.8	25.6	37.3	39.6
11.17.08	250	250	-	-	-	-
12.12.08	500	500	53.5	21.2	30.4	23.5
12.18.08	625	625	62.9	22.7	34.8	32.6

Note: SL - shell length; SW - shell width; SH - shell height; T wt - total weight. SL, SW, and SH are in millimeters, while T wt is I grams. Size data are not available for the deliveries made on 24 October 2008 and 17 November 2008.

Findings

A total of 239 completed questionnaires were obtained from the four participating restaurants. Of that total, 41% were completed by patrons from Ballyhoo Grill restaurant. Of the remaining completed surveys, 21% came from Campbell's, while 20% and 18% came from The Island Room and Avenue Sea, respectively. All of the completed questionnaires were completed by the patrons while at the respective restaurants, with the exception of one that was mailed in. There is no way of determining if the questionnaires were completed by unique respondents. The possibility does exist that some of the questionnaires were completed by the same individual. However, the waitstaff at Ballyhoo Grill and Campbell's indicated some patrons were repeat sunray venus clam "customers", but only completed a questionnaire on the first restaurant visit. In addition, there was no attempt to measure the bias associated with non-respondents, i.e., those individuals who refused to complete a questionnaire. A "completed" questionnaire may have some missing information, as the respondent chose not to answer a particular question. Thus, there may not be 239 responses for each question. However, the information provided for each question is utilized in the discussions and summaries provided below.

Of the 239 restaurant patrons who completed at least some portion of the questionnaire, 51.9% and 48.1% were male and female, respectively (**Table 2**). Regarding age distribution of respondents, 21.3% were under the age of 30, while 39.1% were between the ages of 50 and 64.

The majority of the respondents (80.7%) had resided in the southeast US for the longest portion of their lives. In addition, 92.8% of the respondents currently resided in Florida (based on the zip code of their current residence). Finally, 87.4% of the respondents were Caucasian.

Table 2. Demographic characteristics of the respondent sample.

	Survey Respondents	
Characteristic	**Number**	**Percent**
Gender		
Male	120	51.9
Female	111	48.1
Years of Age		
< 30	50	21.3
30-35	20	8.5
36-49	52	22.1
50-64	92	39.1
65 and above	21	8.9
US Region of Longest Residence		
West	10	4.6
Midwest	17	7.8
NE	15	6.9
SE	176	80.7
Current Florida Resident		
Yes	218	92.8
No	17	7.2
Race / Cultural Heritage		
Caucasian	208	87.4
Afro-American	2	0.8
Asian	7	2.9
Hispanic	9	3.8
Other	12	5.0

Note: The percentages for each major characteristic may not add to 100 due to rounding.

The following discussion addresses the average responses for each question across all the restaurants combined. The responses for each restaurant are not provided due to confidentiality reasons. However, these responses may be available from the project team upon approval of the restaurant management.

"How were the Sunray Venus Clams prepared"

Respondents were asked how the clams that they ordered were prepared. Recall that the chefs were encouraged to prepare the clams in a manner they felt appropriate. Of those that responded to this question, 47.3% indicated that the clams were steamed, while 26.3% indicated the clams were broiled/baked and 5.4% indicated the clams were prepared in a soup/stew, respectively. Also, 1.8% of the respondents indicated the clams were either fried or served raw. In addition,

17.4% of the respondents indicated the clams were prepared in some other manner.

"Were the Sunray Venus clams served as an Entrée or Appetizer"
The majority of the clams were served as an appetizer. Of those responding to this question, 78% indicated that the clams were served as an appetizer, while the remaining respondents (22%) indicated that the clams were served as an Entrée.

"Please indicate the price you paid for the Entrée or Appetizer"
The price requested of the respondent by the questionnaire was the price paid for the clam entrée or appetizer. Thus, the restaurant setting price indicated is not analogous to a per unit price paid in a retail seafood shop setting. The price the restaurant buyer would be willing to pay for the individual clam was not requested via the questionnaire. However, debriefings with the chefs and managers suggested that all would be willing to pay a higher price than they are currently paying for commercially available hard clams. The price solicited by the questionnaire was the price paid by the patron, which includes the cost of the clams, cost of other ingredients, restaurant overhead costs, restaurant mark-up, etc. The individual retail price per clam cannot be derived from the questionnaire price. The number of clams per serving would vary whether the clams were served as an entrée or appetizer type, as well as by preparation method. Unfortunately, this information was not solicited. However, the prices can provide restaurant managers with a proxy of what a patron would pay for a "typical" serving across a variety of preparation methods. In addition, the prices charged by the participating restaurants were conceived within a short-term, promotional context. The eventual price charged for a sustained menu item may vary from that indicated in this survey.

Of the respondents who answered this question, 41% indicated the price paid for an entrée was greater than $5.00, but less than $10.00, while 33% paid over $10.00 (**Table 3**). The average price paid for an entrée across all preparation methods was $9.65. Over two-thirds of the respondents paid between more than $5, but less than $10, for an appetizer. The average price paid for an appetizer was $7.80.

Table 3. Percentage Distribution of Prices Paid by Respondents.

		Price Range Paid by Respondent		
	≤ $5	**$5.01 - $10**	**> $10**	**Average**
Entree	26%	41%	33%	$9.65
Appetizer	24%	67%	9%	$7.80

Note: The "Average" price is that reported across all preparation methods.

"How would you rate the Sunray Venus clams?"
Respondents were asked to rate the clams they consumed over a range of product attributes (**Table 4**). These attributes included appearance, taste, texture, tenderness and value. Finally, the respondent was asked to provide an "overall" rating of the clams consumed. The rankings are provided across all preparation methods for clams served both as an entrée or an appetizer. Note that the majority of respondents indicated that the product was with "Excellent" or "Very Good". For example, 84% of the respondents indicated that the appearance was "Excellent", whereas 13% indicated that the product was "Very Good" and a total of 3% indicated that the

product appearance was “Good” to “Poor”. A similar ordinal pattern is seen for the other attributes, with the majority of respondents indicating that “Taste”, “Texture”, and “Tenderness” were either excellent or very good. In addition, 61% of the respondents indicated the clams were a good “Value”, which was intended to provide some insight into the patrons’ perception of whether or not they were “getting their money’s worth”. Initial measurements suggested that the meat yield for sunray venus clams was very high, which may explain the favorable rankings in terms of “value”. Finally, 90% of the respondents rated the product as either “Excellent” or “Very Good”. In summary, the majority of the respondents who provided the rankings suggested that sunray venus clams, prepared in the manner and served in the volume in which the participating chefs felt appropriate, were highly rated. Only 3% and 14% of the respondents rated appearance and value as good to poor, respectively.

Table 4. Product Attribute Ratings.

	Excellent	Very Good	Good	Fair	Poor
	. . . . . % of all respondents selecting each attribute				
Appearance	84	13	2	1	0
Taste	72	18	8	2	0
Texture	63	25	9	2	1
Tenderness	58	25	9	4	2
Value	61	24	10	4	1
Overall	70	20	8	2	0

Note: The rankings are across all preparation methods.

The product attribute ratings across demographic characteristics provide some insight into how the ratings were associated with gender and age. The number of individuals (Nq) responding to a specific question is given in the Appendix Table as the value corresponding to a given product attribute. Note that for some attributes, less than 239 respondents (totaled across all demographic characteristics and product attributes) are indicated. This is due to some of the respondents not providing either an attribute rating or the demographic information requested (i.e., gender or age). The N for each attribute:demographic characteristic combination is the number of respondents that provided both. The percentage value provided for a specific combination is the number of respondents replying to that specific question divided by the total number of respondents for the overall demographic category (i.e., gender or age), rather than the percentage of a specific gender or age. For example, in Appendix 1, a total of 105 male respondents indicated that the “Appearance” of the sunray venus clams was “Excellent”, while 96 female respondents provided the same rating. There were 239 respondents (male and female *combined*) that rated the Appearance of the sunray venus clams. Thus, 43.9 % of the male respondents (105/239) rate the Appearance as Excellent, while 40.2% of the female respondents did the same. The percentages were computed across the total number of respondents regardless of gender to provide greater insight into importance of that rating category across the total set of potential consumers, regardless of gender or age. There do not appear to be any strong pattern of attribute ratings by gender or age. The sunray venus clams were rated highly by all age groups and genders.

“Did you detect any grittiness in the Sunray Venus clams?”

The sunray venus clam possesses a grit pocket, which is located on the siphon end of the animal. The grit pocket is a normal feature of the sunray venus clam, and is quite noticeable in the wild animals initially taken for preliminary attribute assessment by the project team. Thus, the presence of a noticeable grit pocket was anticipated in the cultured animals. Prior to the cultured animals being utilized in the restaurant consumer acceptance trials, the project team noticed the absence of a noticeable grit pocket in the cultured sunray venus clams. At present, this unexpected finding cannot be explained. And the project team was unsure of the prevalence of the absence of a noticeable grit pocket in the cultured clams. Thus, a question was included in the questionnaire that would allow the respondent to indicate the grittiness if the condition occurred. Only 11% of the respondents indicated the presence of "grittiness" in the clams. It is unknown to what degree this grittiness existed, the source of the grittiness, or if the grittiness varied by restaurant, preparation method or cohort of cultured clams. The latter issues may be addressed through further analysis of the survey data, however initial scrutiny finds that the few respondents indicating the presence of grittiness were not characterized by a clear pattern for restaurant they patronized, the week in which the clams were delivered, or preparation method.

"Please indicate your initial reaction to the thought of eating Sunray Venus clams."
Patrons were asked about their initial thoughts concerning the consumption of sunray venus clams. This question was of interest given there are no current commercial sources. Thus, the greater likelihood existed that most respondents would have never consumed sunray venus clams. Respondents were asked to indicate their hesitancy toward eating sunray venus clams on a 9-point Likert scale (Babbie, 2005), ranging from 1 ("Not Hesitant At All") to 9 ("Extremely Hesitant"). The average Hesitancy Index (HI) value selected by the patrons who responded to this question was 2.21, which suggests the average respondent was not very hesitant to the thought of consuming sunray venus clams, which is a new, non-traditional seafood item. Only 30 respondents out of the 239 who responded to this question indicated a hesitancy level of 5 or higher.

No strong pattern appears to exist between gender and age with respect to the measure of hesitancy. For example, the overall HI for males was 2.30, while the HI for females was slightly lower at 2.16. In addition, the overall HI for individuals in the "<30" age group was 2.83, while the HI for individuals in the "30-35", 36-49", "50-64", and "65+" groups were 1.52, 1.94, 2.17, and 1.97, respectively. Note that the least hesitant age group was the "30-35" group, while the most hesitant was the youngest age group.

"Would you order this product again at the same price?" and "Would you recommend this product?"
An overwhelming majority (94%) of the respondents indicated that they would order this product again at the price they paid for it. In addition, 97% of the respondents indicated they would recommend this product to others.

Summary
The survey findings suggest that restaurant patrons found sunray venus clams to be a very acceptable product. Patrons were offered the clams prepared a variety of different ways. The pricing was quite variable across entrees, appetizers, and preparation methods. The majority of

patrons rated sunray venus clams as Excellent to Very Good, and would order the product again at the price paid, as well as recommend the product to others. In addition, an *a priori* concern regarding the sunray venus clam was the potential for grittiness, due to the "grit pocket" which is naturally occurring in wild sunray venus clams. Approximately 90% of the survey respondents did not detect any grittiness from the cultured clams. Additional cross tabulations may be done to assess the impact of respondent residence location and race or cultural heritage on the acceptance of sunray venus clams. However, given the strong overall acceptance levels, the findings are likely to be very similar to that found for gender and age of respondent.

REFERENCES

Abbott, R.T. 1974. American Seashells, second edition. Van Nostrand Reinhold Co., New York. 663 pp.

Akin, R.M. and H.J. Humm. 1960. *Macrocallista nimbosa* at Alligator Harbor. Quart. J. Fla. Acad. Sci., 22(4): 226-228.

Babbie, E. R. 2005. *The Basics of Social Research*. Thomson Wadsworth Publishers. Belmont, CA.

Beattie, H. and B. Blake. 1999. Development of culture methods for the geoduck clam in the USA (Washington state) and Canada (British Columbia). World Aquaculture, 30(3): 50-53.

Blake, N.J., C. Adams, R. Degner and D. Sweat. 2000. Aquaculture and Marketing of the Florida Bay Scallop in Crystal River, Florida. Florida Sea Grant TP-106, Gainesville, FL, 48 pp.

Cake, Jr., E.W. 1970. Some aspects of the ecology, biology and fishery of the sunray venus clam. Proc. Natl. Shellfish. Assoc., 60: 1 (abstract).

DACS. 2000. Mollusc survey: A survey of interested buyers at the International Boston Seafood Show, Florida Department of Agriculture and Consumer Services, Division of Seafood and Aquaculture Marketing, Tallahassee, FL, 4 pp.

FASS. 2004. Florida Agriculture Statistics Service – Aquaculture. (www.nass.usda.gov/fl)

Fernandez, E.M., J. Lin and J. Scarpa. 1999. Culture of *Mercenaria mercenaria* (Linnaeus): effects of density, predator exclusion device and bag inversion. J. Shellfish Res., 18: 77-83.

Futch, C.R. 1967. Potentially commercial clams of the genus *Macrocallista*. July Suppl. to Salt Water Fisheries Leaflet 3, FL Brd. Conserv. Mar. Lab., St. Petersburg, FL, 2 pp.

Godcharles, M.F. and W.C. Jaap. 1973. Exploratory clam survey of Florida nearshore and estuarine waters with commercial hydraulic dredging gear. Professional Papers Series No. 21, Florida Department of Natural Resources, St. Petersburg, Florida. 77 pp.

Gustafson, R.G., R.L. Creswell, T.R. Jacobsen and D.E. Vaughan. 1991. Larval biology and mariculture of the angelwing clam, *Cyrtopleura costata*. Aquaculture, 95: 257-279.

Haines, M.L. 1975. The reproductive cycle, larval development, culture, and tolerances of the sunray venus clam *Macrocallista nimbosa* (Lightfoot 1786). Ph.D. dissertation, Florida State University, Tallahassee, FL. 165pp.

Haines, M.L. 1976. The reproductive cycle of the sunray venus clam *Macrocallista nimbosa* (Lightfoot 1786). Proc. Natl. Shellfisheries Assoc., 66: 6-12.

Jolley Jr., J.W. 1972. Exploratory fishing for the sunray venus clam, *Macrocallista nimbosa*, in northwest Florida. Tech. Ser. No.67, 42pp, FL Dept. Nat. Res., Mar. Res. Lab., St. Petersburg, FL.

Moss, S., R. Degner and C. Adams. 2000. Marketing Analysis of Florida Bay Scallop Aquaculture in Crystal River, Florida. In: Aquaculture and Marketing of the Florida Bay Scallop in Crystal River Florida. Florida Sea Grant TP-106, Gainesville, FL, 48 pp.

NOAA. no date. The sunray venus clam. National Oceanographic and Atmospheric Administration Food Fish Facts No. 49, National Consumer Educational Services Office, National Marine Fisheries Service, Chicago, Illinois. 1 p.

Philippakos, E., C. Adams, A. Hodges, D. Mulkey, D. Comer, and L. Sturmer. 2001. Economic Impact of the Florida Cultured Hard Clam Industry. Florida Sea Grant College Program SGR-123, University of Florida, Gainesville, FL, 23 pp.

Power, A.J., L. Sturmer, C. Lucas, R.L. Walker and J. Manley. 2005. Gametogenic cycle of the Ponderous ark, *Noetia ponderosa* (Say, 1822) from Cedar Key, Florida. J. Shellfish Res., 24: 69-73.

Ritchie, T.P. 1977. A comprehensive review of the commercial clam industries in the United States. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Washington, D.C.

Stokes, R.J., E.A. Joyce Jr. R.M. Ingle. 1968. Initial observations on a new fishery for the sunray venus clam, *Macrocallista nimbosa* (Solander). Tech. Ser. No.56, 27pp. FL Brd. Conservation Mar. Res. Lab., St. Petersburg, FL.

Sturmer, L.N., E. Quesenberry, J.Scarpa, and D.E. Vaughan. 1995. Development of a shellfish aquaculture industry on the west coast of Florida. World Aquaculture Society ’95, Book of Abstracts, San Diego, California, p.279.

Florida Sea Grant Project Synopsis

2. Date: 30 January 2008

3. Project Title: Sunray Venus Clam: A New Species to Diversify the Florida Aquaculture Hard Clam Industry

4. Project Number: R/LR-A-44

7. Dates Covered: 1 February 2006 – 30 January 2008

8. Results and Discussion:

8.A. Attainment of Technical Objectives:

The goal of this research project is to evaluate, demonstrate, and develop aquaculture of the sunray venus clam, *Macrocallista nimbosa*, as a new species to diversify and expand the bivalve culture industry in Florida. The overall hypothesis is that sunray venus clam seed can be obtained from a hatchery and reared to a harvestable size by shellfish growers using culture methods similar to those employed by the hard clam, *Mercenaria mercenaria*, industry.

8.B. Advancement of the Field:

The basic premise that hard clam culture methods are suitable for the sunray venus clam, *Macrocallista nimbosa*, is holding up to testing. If the clam performs as expected in grow out and is accepted by consumers the potential for this clam to help diversify and expand the Florida clam culture industry is great. The different aspects of culture tested to date (i.e., broodstock conditioning, spawning, larvae culture and nursery culture) indicate very little difference between methods used for hard clams and those needed for this species. The only difference noted is that broodstock require substrate. The higher production of seed found when using sand substrate does not need to be adapted, unless the economic analysis indicates otherwise.

This represents the first documentation of hatchery-produced sunray venus grown under culture conditions in open-water environments. Although the number of sunray venus clams produced was low, one group each from commercial shellfish aquaculture lease areas in two counties were cultured through potential market size. At the Cedar Key site, “market size” sunray venus (63 mm, shell length; 22 mm, shell width) were produced from post-set seed (>2.0 mm sieved seed, ~5 mm shell length) in 16.3 months; whereas, hard clams require about 17 to 20 months to reach “littleneck” size (50 mm SL, 25 mm SW). These results provide guidelines for future efforts of researchers and shellfish growers.

8. C. Problems Encountered:

During the initial broodstock shipments to HBOI, the chiller unit on the conditioning system failed repeatedly before a replacement was found. This caused some excessive mortality in those

clam groups and limited conditioning. The broodstock that were first obtained were numbered with a marking pen that normally holds up to water. However, it was found that the glossy periostracum of the sunray clam allowed for the mark to slowly vanish. This was corrected by using cyanoacrylate glue to attach small numbered plastic tabs (~7mm) so as to follow broodstock in the conditioning system.

Shell deformities were first observed during sampling at the Alligator Harbor lease area on January 24, 2008. Afterwards we began documenting deformities at each growing location during inspection and harvesting. Our observations suggest that this was a substrate-related problem. The bottom substrate at Alligator Harbor was characterized by hard-packed sand, while sediments at the Dog Island site were sandy but softer. The highest number of deformities occurred in sunray venus that were cultured in bottom bags at the former site. In spite of the sunray venus having a large protruding foot, the bottom layer of polyester material on the bag may have restricted the clams in burying. Interestingly, sunray venus harvested from bags at Alligator Harbor with a high percentage of deformities (up to 22%) and replanted in bottom cages at Cedar Key, "grew out" of their deformities over a 6-month period. We do not know if that was in response to the different location (ie. substrate), culture system, or both.

8.D. New Research Directions: The determination of a maximum feed density was undertaken. Triplicate 4-L beakers each containing 24 clams (42±3 mg) were fed 0, 50, 100, or 200 K cells/mL of *Isochrysis* sp. twice/day over a four week period. Growth (as measured by many parameters: weekly wet weight change (abs or %), total wet weight change (abs or %), absolute final wet or dry weight) did not increase above the 100K cells/mL treatment. Filtration rates, as determined from algae clearance over a 4-hr period, decreased with increasing cell density: ~50mL/hr at 50K cells/mL, ~30mL/hr at 100K cells/mL, ~10mL/hr at 200K cells/mL.

10.B. Tools, Technologies and Information for Improved Ecosystem Management: The methods being evaluated will be directly transferred to current and future bivalve farmers of Florida. This technology transfer will occur through extension workshops and publications. The project partners assisting currently would have the first opportunity.

10.D. IMPACTS (Activities that have significant scientific, economic or social benefits): The basic premise that hard clam culture methods are suitable for the sunray venus clam, *Macrocallista nimbosa*, is holding up to testing. If the clam performs as expected in grow out and is accepted by consumers the potential for this clam to help diversify and expand the Florida clam culture industry is great.