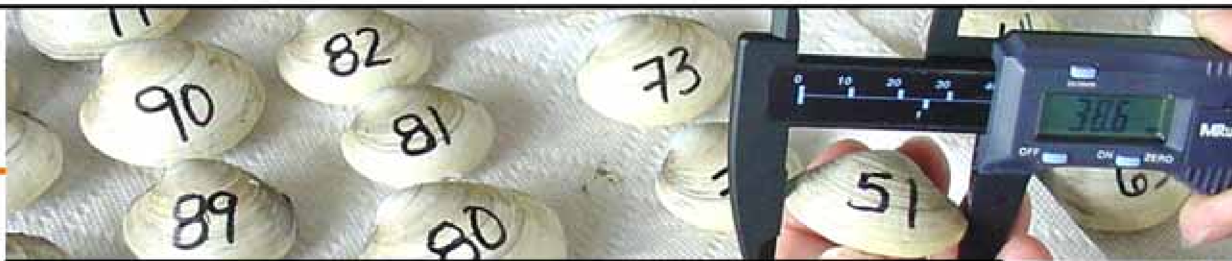







Wednesday, February 2, 2011
Community Center, Cedar Key

Clam Culture Industry Workshop

AGENDA

1:00–5:00 PM

Welcome and Introductions
Sue Colson, City of Cedar Key Commissioner
Karl Havens, Florida Sea Grant College Program
Tim White, UF School of Forest Resources and Conservation

Focus on the Potential of Sunray Venus Culture and Marketability

Seed production and broodstock development
John Scarpa, Harbor Branch Oceanographic Institute at FAU
Nursery and growout field trial results and evaluation of leases
Leslie Sturmer, UF IFAS Cooperative Extension Service
Consumer acceptance results and wholesale market attributes
Chuck Adams, UF IFAS Food and Resource Economics
Sensory, nutritional, and shelf life profiles
Laura Garrido and Steve Otwell, UF Aquatic Food Products Lab
A discussion of what we know and do not know from seed to table

Project Updates

Clam stock improvement through hybridization and backcrossing
John Scarpa, Harbor Branch Oceanographic Institute at FAU
Selection for heat tolerance in clams using biomarkers
Shirley Baker, UF SFRC Fisheries and Aquatic Sciences
Soil properties on clam leases under varying efforts and harvesting
Rex Ellis and Todd Osborne, UF IFAS Soil and Water Science
Decision support tools for clam farmers
Leslie Sturmer, UF IFAS Cooperative Extension Service
Growout evaluation of the bay scallop
Curt Hemmel, Bay Shellfish Company
Industry feedback and discussion

5:00 PM Social Hour

Hosted by the Cedar Key Aquaculture Association


SUNRAY VENUS CLAM SEED PRODUCTION AND BROODSTOCK DEVELOPMENT FOR FLORIDA CULTURISTS

John Scarpa, Harbor Branch Oceanographic Institute at Florida Atlantic University
Jose Nuñez, University of Florida, The Whitney Laboratory for Marine Bioscience
Leslie Sturmer, University of Florida IFAS, Cooperative Extension Service
LeRoy Creswell, University of Florida IFAS, Florida Sea Grant
Susan Laramore, Harbor Branch Oceanographic Institute at Florida Atlantic University

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 during the late 1960-70s in several shallow water areas off the northwest Florida coast. Although natural growth rates were estimated to be high its patchy distribution limited commercial exploitation. The existence of a latent market and the potential growth rate of the sunray venus clam, along with it being a native species, made it a logical choice to evaluate as a potential new aquaculture species to diversify and expand the Florida hard clam culture industry.

Seed Production

Adult sunray venus clams were collected from the wild and placed in trays with aragonite sand in temperature-controlled tanks (68-77^{o}F, 30-32 ppt) and fed microalgae daily for conditioning. Histological analysis of gonad tissue indicated an approximate 1:1 female to male ratio. Spawning has been induced using thermal-cycling (10-18^{o}F increase), sperm-addition, or 2 mM serotonin injection. Standard hard clam hatchery techniques were utilized to produce larvae and seed; that is, small amounts of sperm were added to egg mixtures that resulted in D-stage larvae the following day. Larvae were fed microalgae daily and water (30-31 ppt, 78-82^{o}F) changed daily. Larval development was similar to hard clams; pediveligers (~220 µm) were noted at day seven at which time they were placed in downwellers. Metamorphosis occurred over several days. Settled clams were fed mixtures of microalgage species and water was changed approximately every other day. This information has been compiled into a video (DVD) for hatchery operators and culturists. Nursery seed were distributed to project partners for further culture using both upwellers and trays, which resulted in the production of growout seed.

Optimal Hatchery Conditions

Basic physical and biological parameters for optimum culture environments also need to be determined. Salinity tolerance and growth of nursery seed was examined by exposing sunray venus clam nursery seed (live wt = 19mg, length = 4.7mm) to salinities of 10, 20, 30 or 40 ppt for three weeks. All clams in the 10 ppt treatment died by the end of week 1. After three weeks, survival (81%) and growth (270%) were best at 30 ppt. A feed density trial was initiated with sunray venus clam juveniles (live wt. = 42mg) to determine maximum cell density for growth. Clams were exposed to 0, 50, 100, or 200 K cells/mL of *Isochrysis* sp. twice/day over a four-week period. Growth did not increase above the 100K cells/mL treatment. Sunray venus clam culture methods to date are exhibiting little difference from hard clam methods for spawning, larvae culture, and early nursery culture.

Broodstock Development

Our next goal is to assist Florida shellfish hatchery operators as there may be a reluctance to move forward developing sunray venus clam broodstock or producing seed until they are confident that 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. Our previous projects utilized single- or double-parent crosses to produce replicate families for *scientific* culture of the species. However, commercialization requires multi-parent crosses to produce founder broodstock (G_0) that retain as much genetic diversity as possible from wild local populations for future selection efforts. Therefore, we will create initial founder broodstock lines for Florida hatcheries, as well as our research. We will also demonstrate to the industry the proper development of sunray venus clam broodstock for seed production (e.g., concept of effective parental number (Ne) and factorial pair-wise matings) to ensure that Florida clam hatchery operators do not initiate genetic bottlenecks or limit genetic diversity in their product and future lines for selective breeding.

This research is supported by Florida Sea Grant College Program (Projects R/LR-A-44, 45, 46).

EVALUATION OF THE SUNRAY VENUS CLAM: RESULTS OF LAND-BASED NURSERY, FIELD NURSERY AND GROWOUT TRIALS

Leslie N. Sturmer, University of Florida IFAS, Cooperative Extension Service
John Scarpa, Harbor Branch Oceanographic Institute at Florida Atlantic University

The overall goal of this project has been to evaluate, demonstrate, and develop aquaculture of the sunray venus clam, *Macrocallista nimbosa*, as a new species to diversify the bivalve culture industry in Florida. The objectives of field trials conducted during 2007-10 were to utilize hard clam culture methods as a starting point to 1) establish methods for land-based culture, 2) compare field culture methods for nursery and grow-out, and 3) document survival and growth of sunray venus clams in these culture phases.

Land-based Nursery Seed produced in the first spawning trial in 2007 were distributed to land-based nursery operators to rear in commercial settings. Juveniles (>2.0 mm sieve; 37/ml; 6 mm shell length, SL) were reared in upwellers at a density of 1,600/ft^2 for 4-5 months. Average size of nursed juveniles was 12 mm SL from wellers and 20 mm SL from wellers in which substrate (10 inches of sand) was added. Although addition of substrate was advantageous for growth, it could be problematic if allowed to go anaerobic. Replicated nursery trials were conducted in 2008 at the UF Shellfish Facility in Cedar Key using downwellers. In both trials (July and October), stocking densities of 1,000 to 4,000/ft^2 of bottom area were evaluated. High mortalities were noted in the first trial after several weeks. Survival in the second trial ranged from 66 to 69%, but growth (5-15% sieved on a 4.0 mm screen) was minimal after nine weeks. In September 2009, seed (>1.2 mm sieve, 294/ml, 3.5 mm SL) were stocked at densities from 1,000 to 2,500 per ft^2 in trays placed inside tanks in which water was distributed via laminar flow. After 7-8 weeks, no differences were found among the densities. Survival (87-91%) and growth (70-79% sieved on a 4.0 mm screen, 8-9 mm SL) were commercially acceptable.

Field Nursery and Growout Production performance of sunray venus clams under field nursery and growout conditions was examined during 2007-10 at two commercial clam lease areas (Alligator Harbor near Carrabelle and Dog Island near Cedar Key) in the Gulf of Mexico. Sunray venus seed (118,000, 9-18 mm SL) were field-planted in nursery systems (hard cages and soft bags) at densities of 100-550/ft^2. After 42-119 days, survival ranged from 32 to 94% and daily growth rate was 0.12-0.25 mm SL. During 2008-9, four nursery trials were conducted with bottom bags at the Cedar Key site. Seed, ranging in size from 7 to 14 mm SL and planted at densities of 310 to 575/ft^2, were nursed for 78 to 113 days. Results were variable. In one trial, high mortalities were noted as rain from Tropical Storm Fay dropped salinities below 20 ppt following planting. In the other trials, survival ranged from 17 to 66% and final seed size from 20 to 24 mm SL.

Sunray venus juveniles (27 mm SL; 10 mm shell width, SW) were further cultured in hard cages at densities of 42-55/ft^2. After 11 months, sunray venus (61-67 mm SL, 22-23 mm SW, 30-37 grams weight) were harvested for market perception tests. Survival ranged from 50-82%. Production performance of sunray venus juveniles (26 mm SL) grown in soft bottom bags and bags modified with internal PVC frames (1” and 1 ½”) at densities of 44/ft^2 was also documented.

After 12 months, no significant differences were found among bag types for survival, which ranged from 65-76%, or growth (56-59 mm SL, 22 mm SW, 27-29 grams weight). However, 19-22% of the sunray venus harvested from bottom bags were deformed; whereas only 1-4% of those harvested from bags with frames were deformed. The shell irregularities were limited to the ventral margin with one valve having excessive curvature resulting in a depression. Stocking densities of 38-70/ft^2 in bottom bags were evaluated at both sites with juveniles ranging in size from 24 to 27 mm SL. At one location, sunray venus reached 46-56 mm SL with survivals of 24-58% after 13-16 months. At the other location, sunray venus reached 50-55 mm SL with survivals of 67-75% after 12 months. Bottom plants, in which seed are broadcasted directly onto the substrate and covered with protective netting, are currently being evaluated. Preliminary results indicate faster growth (63 mm SL in 12 months) and less shell deformities when compared to other culture methods, but survivals have been marginal (38-53%).

Summary To date, land-based nursery, field nursery, and growout culture methods for sunray venus clams are not prohibitive. Sunray venus clams were cultured using methods similar to those used for hard clams; however, production results were site-specific. At one site commercially acceptable survival and growth rates were obtained. Although current trial production efforts appear successful, problems with shell deformities, which may be gear and substrate-related, must be resolved. Further, sunray venus did not consistently perform well in bottom bags. Where the bag worked, aqueous soils were sandy but not hard-packed. Results of field trials suggest that sunray venus may do better at lower densities than those used for hard clams; but this will require additional field testing.

Following is a summary of our observations after working with this molluscan species for four years. The sunray venus is a very active clam with a large muscular foot and long siphons. It is oblong in shape as opposed to the round shape of a hard clam. Thus, seed must be longer to be retained in sieves used by industry for hard clams. For example, the shell length of a sunray venus held on a 4.0 mm screen is about 9 mm; whereas the length of a hard clam is 6 mm. Harvest sizes of the sunray venus may also differ from those typical for the hard clam. For example, a sunray venus with a shell width (SW) of 1 inch has a shell length of about 2.7 inches and a weight of 42 grams (11/lb). For a similar-sized hard clam (1” SW or littleneck), average length and weight are about 1.9-2.0 inches and 34 grams (13/lb), respectively. What is most interesting is the meat (wet weight) of the sunray venus weighs almost 2.5 times more than the meat of a hard clam. The shell of the sunray venus is not as thick or as heavy as a hard clam; but, it is not brittle. Sunray venus have handled well during sieving, stocking, planting, and harvesting activities. Shell breakage must still be evaluated during processing.

What’s next? During 2010-11, the project team is working with industry partners to eliminate barriers to commercialization of this new aquaculture species. Objectives of our current studies are to 1) determine production performance for field nursery and growout culture at multiple existing commercial lease areas, 2) establish a relationship between soils (bottom substrate) and productivity at lease areas using a soils-based approach, and 3) define salinity and soil preferences for selection of future lease areas.

This research is supported by Florida Sea Grant College Program (Projects R/LR-A-44, 45, 46).

MARKETABILITY OF THE SUNRAY VENUS CLAM: RESULTS OF CONSUMER ACCEPTANCE STUDIES AND EXAMINATION OF WHOLESALE MARKET PRODUCT ATTRIBUTES

Chuck Adams, University of Florida IFAS, Food and Resource Economics
Leslie Sturmer, University of Florida IFAS, Cooperative Extension Service

Sunray venus clams *Macrocallista nimbosa* represent an interesting addition to the complement of molluscan shellfish available through commercial culturists and wild harvesters in Florida. Recent studies have evaluated the consumer acceptance of both cooked and raw sunray venus clams in local Florida markets. The studies provide an assessment of consumers' opinion of sunray venus clams with respect to a number of product attributes. Overall, the studies found that consumers rate sunray venus clams very highly as a food product, with a strong willingness to both order the product again and recommend the product to others.

Cooked Product Assessment

Sunray venus clams were served in a typical restaurant setting, either as an appetizer or an entrée. Most clams were served steamed, baked or broiled.

- A total of 5,900 cultured sunray venus were delivered to four restaurants in north Florida.
- Average shell length per clam was 53-65 mm (2.1-2.6") and average total weight per clam was 23-37 grams (12-20/lb).
- Within participating restaurants, 239 patrons tried sunray venus and completed surveys.
- Most respondents were only slightly hesitant to try cooked sunray venus clams.
- Only 11% of the respondents detected any grittiness in the clams.
- For all respondents, 94% were willing to order the product again and 97% were willing to recommend the product.

Product Attribute Ratings of Cooked Sunray Venus Clams for the Respondents

	Excellent	Very Good	Good, Fair, or Poor
	. . . . . % of all respondents for each attribute		
Appearance	84	13	3
Taste	72	18	10
Texture	63	25	12
Tenderness	58	25	17
Value	61	24	15
Overall	70	20	10

Raw Product Assessment

Sunray venus clams were served in sushi restaurant settings, either as an appetizer or an entrée. Most clams were served raw in the traditional sushi or sashimi manner, but other preparation styles included seviche, on the half-shell, etc.

- A total of 1,200 cultured sunray venus were delivered to four sushi restaurants in north FL.

- Average shell length per clam was 66-68 mm (2.6”) and average total weight per clam was 40-44 grams (10-11/lb).
- Within participating restaurants, 101 patrons tried sunray venus and completed surveys.
- Most respondents were only slightly hesitant to try raw sunray venus clams.
- Only 19% of the respondents detected any grittiness in the clams
- For all respondents, 83% were willing to order the product again and 91% were willing to recommend the product. The acceptance rate was lower in traditional Asian sushi restaurants; 63% willing to order again and 64% willing to recommend.

Product Attribute Ratings of Raw Sunray Venus Clams for the Respondents

	Excellent	**Very Good**	**Good, Fair, or Poor**
	. . . . . % of all respondents for each attribute		
Appearance	60	24	16
Taste	44	31	25
Texture	45	25	30
Tenderness	43	32	25
Value	53	20	27
Size	40	29	31
Color	56	24	20
Overall	43	33	24
Non-Asian consumers	*51*	*30*	*19*
Asian consumers	*32*	*27*	*32*

Summary

The overall assessment of sunray venus clams by survey respondents was extremely favorable, for both cooked and raw product. Cooked product was rated very highly on the basis of appearance, taste, and texture, with 90% of the respondents indicating a rating of Excellent or Very Good. The overall rating was slightly lower for raw product, with 76% of the respondents indicating a rating of Excellent or Very Good. For the raw product, a lower percentage of the Asian consumers rated the product as either Excellent or Very Good (59%). Only 11% of the respondents detected any grittiness in the cooked product, while 19% of the respondents found grittiness with the raw product. Overall, a strong willingness to order cooked or raw sunray venus clams again was found, though Asian respondents were less inclined.

What’s Next?

Information is also 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. Currently, the project team is examining these attributes by working with local clam wholesalers using a facilitated mail survey of the primary wholesalers and their downstream buyers, who will handle samples of market-size sunray venus clams. Determining product attributes in the wholesale distribution system will help guide the development of local, regional, and national markets.

This research is supported by Florida Sea Grant College Program (Projects R/LR-A-44, 45, 46).

SENSORY, NUTRITIONAL, AND SHELF LIFE PROFILES OF THE SUNRAY VENUS CLAM

Laura R. Garrido and W. Steven Otwell
University of Florida IFAS, Food Science and Human Nutrition, Aquatic Food Products Lab

Sensory Profile

The trained seafood sensory panelists at the UF Aquatic Food Products Lab conducted a sensory evaluation of the sunray venus clam *Macrocallista nimbosa* to describe, or profile, the characteristics of this new aquacultured clam. 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 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. 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. The sensory profile for sunray venus clams follows.

Appearance	Very plump, fully covered clams, predominantly light color meat
Aroma	Moderate briny and metallic aroma
Basic Flavors	Salty, with moderate umami
Flavors and Aftertastes	Seaweed was the predominant flavor accompanied by strong metallic
Textures	Firm texture

Nutritional Profile

Sunray venus clams are a low fat source of protein. A single 3-ounce (85 g) serving (18 to 20 cooked clams) provides approximately 9 grams (g) of protein. The low fat content ($\leq$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:

- 45% of the daily requirement of Vitamin B12.
- 10% of the daily requirement of Vitamin A and 4% of the daily requirement of Vitamin C.
- 40% of the daily requirement of Iron. With clams, consumers receive a high percentage of iron without having to consume a lot of calories.
- 4% of the daily requirement of Zinc and 6% of the daily requirement of Copper.
- 10% of the daily requirement of Calcium.

The sodium content of mollusks, such as clams and oysters, can range from undetectable to as high as 600 mg/100 g. The level depends on the salinity of the water within the growing areas. Sunray venus clams have an average sodium content of 360 mg per 100 grams.

Shelf Life Assessment

Molluscan shellfish (clams, oysters) are typically shipped as live shellstock and adequate shelf life is an important product attribute. For mollusks, shelf life is the time from when the clams are harvested from the water until they are no longer fit to eat. The shelf life of the sunray venus clam was documented during the summer and winter to account for the influence of water temperatures at harvest. 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. Results of the shelf life assessment are tabulated in the following table.

Harvest Conditions	Avg. Storage Temperature	Shelf Life (days after harvest)	% Survival (range)
Summer (water temp >85°F)	45°F	8 days	86 - 92%
Winter (water temp <75°F)	45°F	14 days	90 - 94%

During the summer shelf life assessment, sensory ratings were also determined for raw meats of the sunray venus. 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 scale that equates to 'Preferred' quality, 'Acceptable' quality, and 'Unacceptable'. 'Unacceptable' quality denoted the end of shelf life, while 'Acceptable' denoted the transition from 'Preferred' product quality. Like other clams, the sunray venus 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.

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 12 days after harvest in the winter) to ensure product is suitable for consumption.

This research is supported by Florida Sea Grant College Program (Project R/LR-A-46).

HARD CLAM STOCK IMPROVEMENT THROUGH HYBRIDIZATION AND BACKCROSSING

John Scarpa, Harbor Branch Oceanographic Institute at Florida Atlantic University
Leslie N. Sturmer, University of Florida IFAS, Cooperative Extension Service
Shirley M. Baker, University of Florida IFAS, Fisheries and Aquatic Sciences Program
Eric Cassiano, University of Florida IFAS, Tropical Aquaculture Laboratory
Susan E. Laramore, Harbor Branch Oceanographic Institute at Florida Atlantic University

The Florida hard clam culture industry is based primarily on the "notata" variety of the northern hard clam *Mecenaria mercenaria*, which may not be suited for some Florida environments. The local warm-water southern hard clam *Mercenaria campechiensis* may have suitable production characteristics for Florida environments and readily hybridizes with *M. mercenaria*, but is known to gape during refrigerated storage. Therefore, an examination of production characteristics of these species and their hybrids was undertaken.

Hybridization is the "crossing" of dissimilar parents. There are three predominant hybridizations: intra-specific (same species), inter-specific (different species), and intra-generic (different genera). When attempting to produce inter-specific hybrid clams, it is imperative to determine that the parental clams are pure, as hybrid hard clams exist naturally where the two species co-exist. We utilized cultured *M. mercenaria notata* (M) and wild *M. campechiensis* (C) as broodstock to produce five families that each contained the pure (♀x♂: MxM, CxC) and hybrid (MxC, CxM) groups. Parental clams were spawned in individual containers to prevent unwanted fertilization. Protein allozyme analysis of progeny indicated that at least one parental clam was already a hybrid in two of the five families. This genetic analysis reflects the difficulty of using visual characteristics to differentiate between species that naturally hybridize.

Three families, which each contained the two pure and two hybrid groups, were reared under commercial conditions during 2008-9. Differences at early culture stages were not evident. Growout seed were planted in the fall of 2008 for comparison. One year later at harvest, parental and hybrid groups were evaluated for survival, growth (shell length, shell width, total weight, dry meat weight), reproductive status, and shelf life in refrigerated storage. The pure CxC group performed the worst overall. Hybrid groups (MxC, CxM), depending on family, outperformed the pure MxM group in growth and total production (lbs/bag). However, both hybrid groups exhibited reduced shelf life and increased gapping during storage compared to pure MxM, although the MxC hybrid resisted gapping longer than the CxM hybrid. This may indicate a maternal effect, but only three groups were tested.

Hybrid clams are as functional reproductively as the pure stocks. Therefore, we are attempting to reduce gapping and increase shelf life during storage while maintaining production characteristics by using backcross breeding. Backcrossing is the crossing of a hybrid with one of its parental species in order to achieve offspring with a genetic identity that is closer to its parent, but with the addition of the characteristic of interest. Preliminary data of field-nursery backcross hard clams cultured at Cedar Key and the Indian River Lagoon will be presented.

Support for this research comes from USDA-CSREES and Florida Aquaculture Specialty License Plate.

SELECTION FOR HEAT TOLERANCE IN CLAMS USING BIOMARKERS

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John Scarpa, Harbor Branch Oceanographic Institute at Florida Atlantic University
Leslie N. Sturmer, University of Florida IFAS, Cooperative Extension Service

In 2007, sales of Florida cultured hard clams *Mercenaria mercenaria* were estimated to have an impact of $53 million to the state's economy and creation of over 600 jobs. Florida represents the southernmost limit of the northern hard clam, where subtropical temperatures allow for a long growing season. However, growers across the state of Florida have experienced chronic losses of market-size clams when summer water temperatures exceed 90^{o}F. Climate change will certainly have an effect on worldwide agriculture; crops that are currently near climate thresholds, such as clams, are likely to suffer. Clearly there is a need for a heat-tolerant clam strain if the Florida industry is to reduce current summer mortalities and adapt to future climate change.

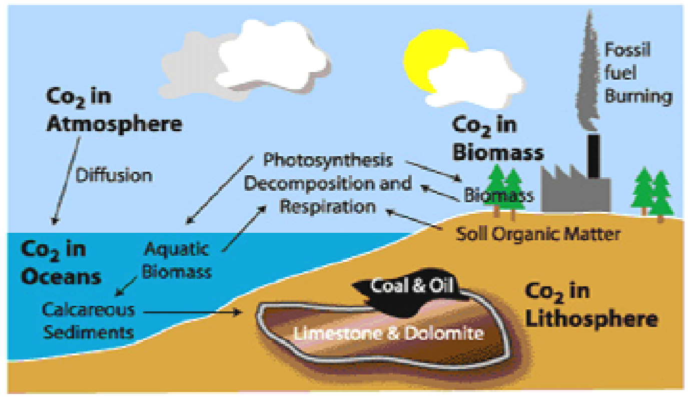
For the past several years we have been examining the utility of two basic breeding techniques, triploidy and hybridization, for increasing survival and production in Florida waters. Growth and survival of triploid clams in the field and laboratory produced mixed results, with no major advantage of triploid clams for Florida culturists. We are currently examining the utility of interspecific hybridization (*Mercenaria mercenaria* x *M. campechiensis*) and backcrossing of F1 hybrids to the hard clam. These studies demonstrated that thermal tolerance in clams is under genetic control. In both projects we produced families from single-parent crosses, with parents selected at random from available broodstock. Some families consistently performed better than others.

Our work suggests that heat shock proteins may be the mechanism whereby different strains of clams tolerate high temperatures. Heat-shock proteins (Hsp) are involved in formation, transportation, and degradation of proteins. Some Hsp increase when cells are exposed to elevated temperatures, or other stressors that damage proteins, and are referred to as inducible. Other forms of Hsp are synthesized under non-stressful conditions for cellular housekeeping and are referred to as cognates. In a previous project, we found that a hard clam family having approximately twice as much cognate Hsp compared to two other families, also had significantly greater survival (93% compared to 28% and 39%) after heat challenge. In addition, other studies indicate that changes in metabolic rate in response to thermal stress may play a role in survival and could also be heritable. Together, these data suggest that using biomarkers of thermo-tolerances, such as Hsp, we can target particular genetically distinct groups for selective breeding, thus reducing the time and resources needed for strain development.

Our NOAA-funded research to be conducted during 2010-12 will provide the necessary data to assess if biomarkers, or indicators, can successfully be used in selective breeding programs for thermal tolerance in cultured hard clams. Development of more robust clam strains would represent an important gain over the present reliance on unselected stocks and would have a positive impact on production of cultured clams in Florida, improving production and cash-flow for clam farmers and ancillary businesses.

LONG-TERM CARBON SEQUESTRATION BY MOLLUSCAN AQUACULTURE

Patrick Baker, University of Florida IFAS, Fisheries and Aquatic Sciences Program
Shirley Baker, University of Florida IFAS, Fisheries and Aquatic Sciences Program



(source: EUROPA, European Union)

All forms of agriculture have ecological impacts and shellfish aquaculture is no exception. However, mollusks sequester climate-changing greenhouse gases in a mineralized form and shells of cultured bivalves represent a long-term carbon sink, offsetting carbon released from burning of fossil fuels. Mollusks convert carbon into calcium carbonate ($CaCO_3$) shell, which is 12% carbon by weight (or 44% carbon dioxide). The carbonate used by mollusks derives, ultimately, from atmospheric carbon dioxide, and carbon stored this way can persist on geological timescales as limestone.

We estimated the amount of carbon sequestered by hard clam farming in Florida. Two areas were sampled for this study: Dog Island, to the east of Cedar Key (27 samples), and Gulf Jackson/Pelican Reef to the west of Cedar Key (9 samples). Samples were from October 2009-July 2010, during regular harvests. Samples (mesh bags) were selected haphazardly by the clam growers themselves from the bags they had retrieved on that date. Each was processed by the clam growers using their standard methods, and then the discarded shells and bag were given to the researchers. Live clams were counted and a random subsample of 20 clams was measured to estimate shell weight of the sample. Shell mass per clam bag was estimated by adding the estimated weight of the market clams, the estimated weight of the oysters on the bags, and other shell that was saved and cleaned. Of this weight, 96% was calcium carbonate which is 12% carbon by weight. Average production was 22.5 kg $CaCO_3$ per bag per year or 10,030 kg per hectare per year (8121 kg per lease), or an estimated 24.43 g of $CaCO_3$, or 2.93 g carbon in total shell material, for each clam sold.

It is important to note that the above results were obtained using existing clam farming methods; nothing needs to be changed to produce this long-term carbon storage. We anticipate that this information will be of use to clam growers at least one and possibly two ways. First, given public concerns regarding the sustainability of seafood (including aquaculture), clam growers can add green house gas storage to the list of ways in which clams are "green." Second, if carbon credits ever become a commodity, clam growers have a value-added byproduct already at hand, for which we now have a quantitative estimate.

Eat a clam and save the earth. Every clam that is eaten represents about 3 grams of carbon removed from the atmosphere!

This research was supported through the Florida Sea Grant College Program.

EXAMINING RELATIONSHIPS BETWEEN HARD CLAM FARMING ACTIVITIES AND AQUEOUS SOIL PROPERTIES

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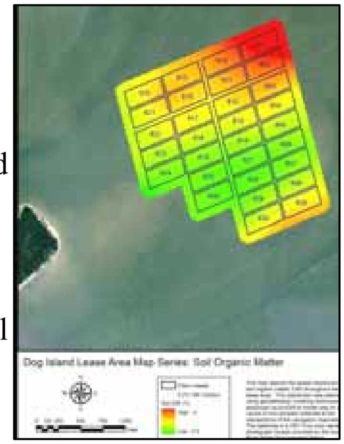

Sediment characteristics, such as sediment type, particle size distribution, and soil permeability, seem important for hard clam growth; however, characterization of sediment is a short coming in many studies. This project to be initiated this year will complement the recently completed USDA-funded project in which we conducted a spatial survey of surface soil properties at the Dog Island High-density Lease Area (HDLA) near Cedar Key to determine spatial patterns within the lease area.

Introduction Florida's inshore coastal waters have limited intertidal areas, thus the majority of hard clam cultivation is subtidal. Given that clams spend a majority of their life buried in aquatic soil, it is expected that soil properties affect clam productivity. While determining what soil properties may be best for clam growth was a focus of prior soil-based clam research, there has been no focus on the mechanics of clam aquaculture. Our personal communication with clam farmers reveals differing opinions on the effects of removing a clam bag from the soil. Some observe slight depressions are left after the bags are removed. Opinions differ on whether these areas should be left fallow, and if so, for how long. Other observations suggest that clam burial depth is affected by the particle size of the soil. They explain that in softer soils, clams bury deeper into the soil. After removal of the bag, a depression is left in the soil, which could be filled with either the surrounding soil material or become a trap for suspended soil material. Thus, it is important that the mechanics of this process be investigated, as this could potentially affect clam productivity. Pre- and post-harvesting soil conditions need to be quantified to determine the effect of harvesting. Most farmers believe the soil to be important for clam growth, but all cite a lack of organized knowledge on how it affects growth.

Goal and Objectives The goal of this project will be to assess the differences in soil properties on shellfish aquaculture leases under high and low intensity hard clam cultivation, to determine the influence of clam harvest techniques on subaqueous soils, and to investigate if farming practices can be modified to maximize beneficial characteristics of soils on lease sites. The specific objectives are to: 1) Compare and contrast subaqueous soil properties at two shellfish aquaculture lease areas on both high and low intensity cultivation sites, 2) Compare soils in farmed portions and in adjacent un-farmed portions seasonally to determine reference conditions and any long-term changes to soil properties by clam farming activities, and 3) Analyze soils and landscapes immediately before and after harvesting clam bags and after varying fallow times to determine physical and chemical changes to soils due to harvesting.

Study Sites We are proposing to investigate the soils supporting hard clams and the effect on the soils of harvesting those clams commercially. To do so, we will begin examining farms located within two HDLAs in the Gulf of Mexico nearby Cedar Key this spring. Clam farmers will have a specific role in assisting in site selection and access. The bottoms on which these clams grow are in the middle of many lease parcels, most of which are under the watchful eye of farmers. We have already engaged them in planning meetings for other research to request assistance in choosing areas that have a variety of soil properties and allow access for sampling. The farmers have responded very favorably to soil maps and other results, so we anticipate similar engagement for this project. The results will directly benefit them by giving them direct knowledge of their leases, while this knowledge should also be applicable to other areas.

Experimental and Sampling Design To better understand changes due to intensity of farming activity, leases with high and low farming intensity will be compared with control leases. Control leases will be outside but proximate to the lease area. First, soils will be sampled at both HDLAs at a minimum of three high and three low intensity farmed parcels and adjacent un-farmed areas. Soil properties will be compared based on farming intensity and geography. These sites will be sampled seasonally to determine if seasonality has any effect on lease soil quality. Second, within these sites, soils will be analyzed immediately before and after harvesting to determine the effect of that activity on the soil. The participating farmer will be asked not to replant in that area to allow for sampling at varying fallow periods (e.g., 1 week, 2 weeks, 1 month, 2 months, 4 months, 6 months). Additionally, manual disturbance with an oyster rake will be used to simulate soil disturbance via clam bag harvesting in an un-farmed area.

Soil and Data Analysis Soil physical and chemical data will be analyzed at the UF Environmental Pedology Laboratory. As hydrogen sulfide (H_2S) toxicity is a common issue in clam aquaculture, soil samples will be analyzed for H_2S productivity in the field, using a direct measure probe. Part of this analysis will be the assessment of soil elevation using geostatistics to interpolate spatial observations into a Digital Elevation Model. Spatial data will be interpolated using the Geostatisical Analyst extension of ArcGIS 9.3. Soil data will be compared between and among sites as appropriate to determine whether there are significant differences attributable to farming intensity and geography.

Outcomes Desired outcomes are to: 1) gain knowledge about the integrated effects of clam farming practices on lease soils and their productivity, and 2) determine functional soil-aquaculture relationships that farmers can use to maximize their productivity sustainably. Soil maps created from the analyzed data will be made available to clam farmers. We expect that fallow times will be related to depression size/depth and soil properties. At lower intensities (longer fallow times), the soil should be less disturbed by clamming activity, thus allowing for either settling or erosion to occur. If settling dominates, the depressions should fill in with particles that were previously suspended in the water column (e.g., fine particles). The concentration of fine particles and organic matter in the soil of the depressions should thus increase. If erosion dominates, then the depressions should fill in with neighboring soil material. The resultant soil properties would likely be similar to the natural soil properties. As fallow times decrease, the depressions will have less time to experience erosion or sedimentation; thus, depressions should be better expressed and soil properties should better reflect original soil properties. This research will provide science-based information that can be used by clam farmers in their decision making. For instance, a farmer may choose to rotate farming to different portions of a lease to maintain high soil productivity if it is found that longer fallow times result in soil properties favorable for clam growth. In contrast, a farmer may choose to work an area repeatedly if it is determined that shorter fallow times result in soil properties favorable to clam growth. The findings related to the effect of harvesting on the soils should result in producer behavior changes, provided the results suggest an improvement of techniques.

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DECISION-SUPPORT TOOLS FOR FLORIDA CLAM FARMERS

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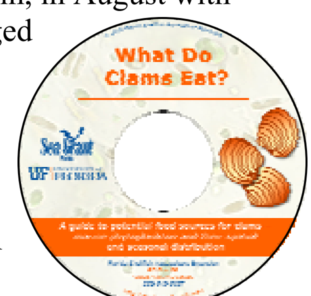
Several applied projects were continued or developed in 2010 to assist Florida clam farmers in making timely and informed management decisions regarding their crops.

Water Quality Monitoring A partnership developed by the Shellfish Aquaculture Extension Program (SAEP) with federal and state agricultural agencies allows for continued operation and maintenance of water quality and weather monitoring stations. Currently, stations are located at five lease areas in four coastal counties (Dixie, Franklin, Indian River, and Levy). These stations provide timely information to clam growers, allowing them to make management decisions based on temperature, salinity, and other measurements. Continuous "real-time" data are made available at the Department of Agriculture and Consumer Services, Division of Aquaculture's website http://www.FloridaAquaculture.com. Archived data are provided in monthly and annual graphic format at the SAEP's website http://shellfish.ifas.ufl.edu.

Water Temperature Monitoring Water temperature plays an important role in biology and directly affects the bodily functions of aquatic organisms necessary for growth and survival. It also influences water quality parameters, such as dissolved oxygen and pH. An ongoing monitoring project is providing detailed and broad coverage of water temperatures by deploying inexpensive data loggers at multiple clam aquaculture leases to adequately describe variability potentially due to water depth, substrate characteristics, currents, or other parameters. The water-proof data loggers used for this project (pictured at right) are small, allowing them to be placed directly inside a clam bag on the lease site. In 2009, 37 data loggers were deployed by Cedar Key growers providing 10% coverage of the Gulf Jackson and Pelican Reef lease areas and 25% coverage of the Dog Island and Corrigans Reef lease areas. Peak water temperatures were recorded in August with maximum values (93.8°F) recorded on August 12. Temperatures ranged from 90.3 to 92.7°F on other leases at that time. During the month of August, temperatures exceeded 90°F on 15 days. These values are important to production as clams cease growth processes at approximately 88°F, and stop filtering around 90°F. In 2010, a similar number of data loggers were deployed. Two water temperature peaks occurred in which >90°F temperatures were recorded. The first occurred in mid-July and then, again, in August with maximum values of 95.8°F reached on August 3, while temperatures ranged from 90.7°to 94.4°F on other leases at that time. Temperatures on the Gulf Jackson leases reached 90°F or higher on 10-12 days during August. Alternately, temperatures on the Corrigans Reef leases reached 90°F or higher for 7-12 days.



What do clams eat? Clam farms are located on submerged land leases in inshore coastal waters. Florida's warm climate supports year-round productivity and good growing conditions for hard clams. Knowledge of what clams eat and when those food items are most available can guide farmers in deciding when to plant seed and harvest clams. In addition, information on patterns of occurrence of harmful algal blooms can help farmers avoid or anticipate losses in clam sales or stocks. A web-based, pictorial guide was developed to assist farmers in identifying potential food sources for clams and their spatial and seasonal distribution. Measures of phytoplankton quantity (chlorophyll *a* patterns) and quality (biomass patterns), as well as species data, from two clam aquaculture regions (Indian River near Sebastian and Suwannee Sound) are presented in this guide. Biographical sketch pages describe over 50 common algal species with information about where and how often the species was found in samples from University of Florida phytoplankton studies, and whether the food is good (nutritious) or bad (noxious or harmful) for clams. The educational tool *What Do Clams Eat?* is accessible at http://shellfish.ifas.ufl.edu and available as a CD-ROM.

Health Monitoring Baseline health monitoring of cultured aquatic stocks has proven to be an important management tool. The UF Fisheries and Aquatic Sciences (FAS) Diagnostic Lab offers basic water quality parameter analysis; bacterial culture of water, algal stocks, and clam larvae; and histologic examination of clam larvae and adults (all for a modest fee). As soon as mortalities are observed, a sample of animals should be collected and submitted for analysis. Any delay makes disease identification more difficult. The FAS lab can provide specimen jars that contain chemical fixatives, and culture media.

COMMERCIAL FARM PRODUCTION OF THE SOUTHERN BAY SCALLOP

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The main objective of this project was to provide critical grow-out data for the production of the southern bay scallop. This project is a response to the imminent need for crop diversification within the Florida bivalve aquaculture industry. Exploration of the aquaculture potential of other mollusk species is ongoing at various research institutions within Florida. In addition to the current species under investigation we believe the Florida bay scallop (*Argopecten irradians*) is an excellent candidate to diversify the industry. This species has great potential for commercial success due to its rapid growth and high market value. To date researchers have focused on many aspects of hatchery, nursery, grow-out and marketing of bay scallops. Specifically, a study by Blake, Adams, Degner and Sweat in 1999 investigated the production, marketing and economics of the bay scallop off of Crystal River, Florida. These researchers concluded that refinement of grow-out systems and a better site location were needed to reduce fouling, increase growth and designed to determine: 1. Are existing clam leases adequate for bay scallop production? 2. Are locations near the Blake et. al., 1999 study site (located away from fouling sources) better for scallop production? 3. What are the best containment systems, under existing regulations, for the production of bay scallops on these sites?

Scallop fouling in elevated cages

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

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

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