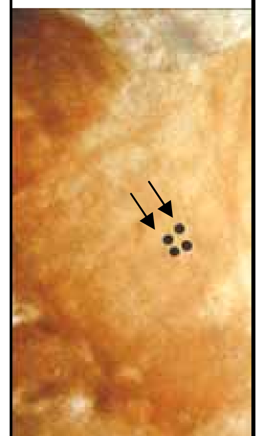


UF/IFAS Fisheries & Aquatic Sciences Department Workshop

Thursday, February 8, 2007
Community Center, Cedar Key

2:00-2:45 PM

Welcome and Introductions
Karl Havens, FAS Department Chair

Genetic Diversity in Florida Commercial Clam Culture
Patrick Baker, UF FAS

Enhancing Clam Production in Florida by Triploidy
Shirley Baker, UF FAS and John Scarpa, HBOI

Clam Stock Improvement through Hybridization
Leslie Sturmer, UF CES

2:45-3:15 PM

Coastal Eutrophication and Clam/Oyster Productivity
Ed Phlips, UF FAS

CLAMMRS: Clam Lease Assessment, Management and Modeling using Remote Sensing Project
Shirley Baker UF FAS and Clay Montaque, UF EE

3:30-4:00 PM

What's in the Clam Bag? *Leslie Sturmer, UF CES*

Sulfide Concentrations in Sediments: Effects on Clams
Derk Bergquist, UF FAS and Derk Bergquist

Clam Health Assessment
Ruth Francis-Floyd and Denise Petty, UF CVM

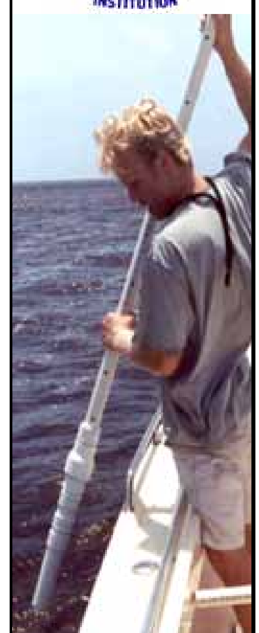
4:00-4:20 PM

Ark Clam and Sunray Venus Culture Potential
Leslie Sturmer, UF CES and John Scarpa, HBOI

4:20-5:00 PM

Industry Feedback Session / Discussion Groups

5:00–6:00 PM Social Hour



Genetic Diversity in Florida Commercial Hard Clams, *Mercenaria mercenaria*.

Investigators: Patrick Baker[1], Brian Bowen[2], Leslie Sturmer[3], Shirley Baker[1], James Austin[1]
[1]*University of Florida - IFAS, Fisheries & Aquatic Sciences*
[2]*University of Hawaii, Department of Zoology*
[3]*University of Florida – Florida Sea Grant Extension*

Selective breeding of crop species usually reduces genetic diversity as a consequence. In some cases, this can lead to inbreeding depression, in which rare but deleterious recessive genes become more common. Inbred lineages may perform well for some traits, and poorly for others. Low genetic diversity also increases vulnerability to environmental change or disease. The measured threat from low genetic diversity is not well studied, however, and information remains scant for commercial bivalves. The unknown risks of low genetic diversity are usually considered acceptable by individual producers, when weighed against the known benefits of selective breeding. Nonetheless, low genetic diversity across an entire industry probably increases the risk of industry-wide impacts.

We collected samples of northern hard clams, *Mercenaria mercenaria*, from commercial hatcheries that supply the Florida cultured clam industry, and from wild hard clam populations. Mitochondrial COI gene fragment sequences were used to estimate genetic diversity within and between hatchery stocks and wild populations. We also obtained data on the frequency of the *notata* shell color phenotype, which has been selected for in hatchery populations. Seven hatchery stocks were then cultured simultaneously, under identical commercial conditions, and performance variables (growth, survival) were calculated. *Researchers intentionally did not know the identities of hatchery stocks.*

Genetic diversity - measured as heterozygosity - of hatchery stocks ranged from 0.43 to 0.9 (mean = 0.72, s.d. = 0.16), compared to 0.76 to 0.91 (mean = 0.84, s.d. = 0.05) for wild populations. The mean values for heterozygosity varied significantly, but there was a wide range of values for hatchery stocks. The lowest heterozygosity value reported was 0.43; generally, any value above 0.5 is considered good genetic diversity in a crop species. *Notata* shell markings could be used as a rough indicator of genetic diversity; as the proportion of wild type (no *notata* markings) increased, so did genetic diversity, although this accounted for only about half of the variability in the data.

Hatchery stock performance varied significantly, but results were nearly masked by within-stock variability. In other words, culture conditions are probably more important than source stock in determining clam performance. Clam growth and survival were not correlated with each other and, furthermore, were not correlated with any of a variety of genetic indices used to estimate genetic diversity or inbreeding. We interpret these results to infer that selective breeding programs for Florida *M. mercenaria* remain in the early stages.

Funded by US Department of Agriculture – Special Grants in Aquaculture

Enhancing Production of Cultured Clams in Florida by Triploidy

Funded by USDA ARS and Florida Sea Grant

Investigators:
John Scarpa, Harbor Branch Oceanographic Institution
Shirley Baker, University of Florida, Department of Fisheries and Aquatic Sciences
Leslie Sturmer, University of Florida, Cooperative Extension Service
Chuck Adams, University of Florida, Department of Food and Resource Economics

Project Summary:

Aquaculture of the northern quahog (=hard clam), *Mercenaria mercenaria*, in Florida is a relatively young industry that has grown very rapidly over the past decade and continues to increase. However, stressors (high temperature, low dissolved oxygen, low phytoplankton productivity, salinity swings, and low body mass due to spawning) may contribute to high summer mortality and unreliable production in the southeast United States and, in particular, southwest Florida. Our hypothesis is that hard clam mortalities from summer stressors can be reduced by creating sterile clams through the basic breeding technique of triploidy. Triploid clams have three sets of chromosomes instead of the usual two. They often grow faster as they do not put energy into reproduction. Induced triploidy has been used successfully in the Pacific Northwest culture of oysters.

Specific objectives in this project were to: 1) Create replicate diploid and triploid families, 2) compare growth and survival of diploid and triploid clams during growout, 3) compare physiological responses of diploid and triploid clams to stress, and 4) compare the economics of triploid production to diploid production.

Triploidy was successfully induced in hard clams using cytochalasin B, but success varied. Typical mass spawning techniques were problematic because eggs were pre-fertilized leading to incorrect timing of application of the chemical and resulting in little triploidy or killing the clam embryos. If triploid clams are found to be advantageous for culture in Florida, a reliable technique for producing triploids must be developed.

Growth and survival of these clams were being followed in the field (SW FL and Cedar Key), however, the hurricane season of 2004 virtually wiped out all planted clams. Only one group was partially salvaged. The triploid clams that survived were significantly smaller than the diploid clams, but had a higher condition index (i.e., ratio of dry meat weight to shell weight) and had no gonads, thus indicating that the clams were sterile. A new set of triploid clams was produced in late 2005 and have been in the field since early 2006. Samples are being taken and analyzed for growth and survival.

Laboratory experiments compared the combined effects of temperature, salinity and low oxygen on diploid and triploid clam survivorship. These challenges were performed to understand what may occur in the field, but under controlled conditions. Two sizes of clams were challenged at 90°F (32°C) at salinities of 10ppt, 25ppt and 40ppt, and normal oxygen levels (normoxia) or low oxygen levels (hypoxia). We found that at salinity extremes (10 and 40 ppt), triploid clams had no advantage over diploid clams. However, at normal salinities (25ppt) there were differences in

the survival of diploid and triploid clams in response to low oxygen. Diploid clams under hypoxia began to die on Day 15 and by Day 22, about 40% were dead. Triploid clams under hypoxia, on the other hand, did not begin to die until Day 18, and at Day 22, only about 10% had died. Therefore, triploidy may increase survival under hypoxic conditions.

Work on this project is continuing. We are setting up experiments to examine the allocations energy in diploid and triploid clams to aid in determining the mechanism (if any) by which triploidy may improve survival. We are also comparing the economics of triploid versus diploid seed production and growout. The result of this analysis will allow the determination of the financial viability of adopting the use of triploid seed clams by an existing hard clam culturist.

Florida Shellfish Aquaculture Development Program

Leslie Sturmer, UF/IFAS Shellfish Extension
Shirley Baker, UF/IFAS Department of Fisheries and Aquatics Sciences
John Scarpa, Harbor Branch Oceanographic Institution
Ed Dunne, Rex Ellis, Todd Osborne, Mark Clark, UF Soil and Water Science Department

With federal funding obtained through the efforts of the Cedar Key Aquaculture Association and Congresswoman Ginny Brown-Waite, a new research program for Florida's clam farming industry is being initiated. The Florida Shellfish Aquaculture Development Program is being administered by the UF/IFAS Shellfish Aquaculture Extension Program and funded through the USDA Cooperative State Research, Education, and Extension Service Special Research Grants. A steering committee made up of clam growers, research and extension faculty, and state agency representatives identified research needs and set priorities for this program. The following applied research projects will begin in 2007.

Clam Stock Improvement through Hybridization

Rationale: The need for a hardier clam strain has become evident over the past few years as clam farmers report below average survival or total losses during the summer months. In Florida, clams normally encounter high water temperatures and reduced phytoplankton levels. Typical water temperatures of 80-90^{o}F are beyond the threshold for many algal species and can reduce clam pumping rates by 50% or more. At the same time, clam metabolism is higher and dissolved oxygen levels are reduced. Together, these stressors may contribute to the increasingly high mortalities seen in Florida. Strain development through basic breeding takes many years and large financial and physical resources to accomplish. A quicker method to capitalize on genetic improvement is through other breeding techniques, such as hybridization. Hybridization is widely used in finfish aquaculture to improve growth, flesh quality, disease resistance or environmental tolerance. There has been limited commercial application of hybridization in shellfish aquaculture.

Background: The hard clam (*Mercenaria mercenaria*), or northern quahog, supports aquaculture operations in Florida and many other states along the east coast of the U.S., as well as fisheries, with a natural range from Canada to the Gulf of Mexico. The southern quahog (*Mercenaria campechiensis*) has supported commercial landings along the Atlantic and Gulf coasts of Florida and is commonly found from North Carolina to the Gulf of Mexico and Caribbean. The two clam species are normally separated by salinity and temperature tolerances. For example, the northern clam is more tolerant of low temperatures than the southern but less tolerant of high temperatures. Another important difference is shelf life. The southern quahog quickly gapes and will die in several days when removed from water. The longer shelf life of the northern clam is one reason it became an aquaculture candidate in the 1950-60s.

Studies have shown that the two clam species hybridize readily in the controlled conditions of a hatchery and off-spring are fertile and viable. During the 1960-70s, a researcher at Florida State University's Marine Lab began to evaluate the potential of clam farming in Florida. Dr. Winston Menzel examined the use of hybrids, with the objective of producing faster growing clams for mariculture. His studies showed that hybrids do have superior commercial traits to either parent species, for example, as good or better growth as the faster growing southern quahog with shelf life as good as the northern parent. Unfortunately, little data was reported on the merit of hybrids for improved survival. Menzel concluded that more effective control of predators must be devised before clam culture could become a profitable venture. A rigorous examination of the use of clam hybridization for increasing survival and production in Florida waters is necessary.

Objectives: Triplicate families of northern hard clams, southern quahog clams, and their reciprocal hybrids will be produced in a hatchery. Spawning, larval and post-set rearing will follow standard protocols used in hard clam culture. Clam seed of each family will be field nursed and grown under commercial conditions. Production characteristics (growth and survival), will be compared between these families at several stocking densities and site locations using both the bag and bottom plant methods. The shelf life of these stocks in refrigerated storage will also be documented. Controlled laboratory experimental challenges will examine the combined effects of temperature and salinity on survivorship of these stocks using natural ranges found in Florida. The physiological mechanism by which hybridization may improve field survival will be determined.

Assessment of Soil Properties in Clam Lease Areas

Rationale: Accounting for variability in soil properties is crucial to understanding the interactions between soils and the plant/animal life supported by them. In aquaculture, clams spend a considerable portion of their life cycle buried in the soil. Soil physical and chemical properties likely have an effect on clam culture and vice versa. Understanding these relationships is crucial to maximizing harvests.

Objectives: As a first attempt at considering soil properties, soils inside and outside a high-use lease area and no-use lease area will be sampled and analyzed. Specifically, an initial land assessment using a soils-based approach will be conducted. In addition, a digital terrain model of the study areas will be created. Since it is likely that soil properties vary considerable within leases, a grid-based sampling approach will be used for obtaining soil cores. Samples for bulk soil characteristics, for example, particle size distribution, bulk density, and organic matter content, will be analyzed to establish relationships between these characteristics and clam productivity.

Coastal Eutrophication and the Productivity of Clams and Oysters

Edward J. Phlips, Shirley Baker, Debra Murie, Erin Bledsoe and Tom Fraser
Department of Fisheries and Aquatic Sciences
Institute of Food and Agricultural Sciences / University of Florida
7922 N.W. 71st Street, Gainesville, Florida 32653
phlips@ufl.edu

The Suwannee River estuary and the surrounding Big Bend region is one of the productive areas in the Gulf of Mexico, and is the site of an emergent clam aquaculture industry. The growth and stability of the clam industry hinges on maintaining a balance between the nutrient imputs which support coastal primary production that feeds clam growth, and avoiding excessive eutrophication that can lead to destructive phenomena, such as harmful algal blooms and periods of anoxia or hypoxia. The Suwannee River drains 28,500 km^2 of southern Georgia and north central Florida. Human development in the Suwannee River watershed over the past century has accelerated the rate of eutrophication. Nitrate levels within the Suwannee River are increasing and concentrations near the mouth and in the upper reaches of the estuary now regularly exceed 1 mg/L. The results of recent tests of groundwater indicate that nitrate levels in regions of the Suwannee River drainage basin near recent agricultural development contain higher levels of nitrogen than anticipated and could lead to even higher nitrogen concentrations in future spring outflows. These observations have precipitated widespread concern about the consequences of these changes on the ecological health of the river and the coastal waters of the Big Bend.

The central goal of this study was to define the impact of coastal eutrophication on the sustainability and productivity of native oyster populations and cultured clams. This goal was pursued within the context of three general hypotheses; a) Changes in the abundance and structure of plankton in coastal environments are related to the nutrient composition and volume of Suwannee River outflow, as well as grazing and predation, b) Up to a certain threshold of nutrient loading, increased abundance of planktonic biomass enhances the resources available for the growth of clams and oysters, and c) Beyond this threshold, excessive levels of phytoplankton biomass and shifts to harmful algal species diminish the productivity and stability of clam and oyster populations.

These hypotheses were tested within the context of four research objectives: 1) To determine the correlation between nutrient loads from the Suwannee River outflow and the abundance and composition of near shore plankton, 2) To determine the impact of planktonic predators and grazers on the abundance and structure of the phytoplankton, 3) To define the link between nitrogen and carbon in the Suwannee River and production of clam and oyster biomass, and 4) To determine the effect of plankton abundance and composition on the growth and survival of oysters and clams.

The results of our study revealed a positive correlation between the loading rate of nitrogen and phosphorus from the Suwannee River and the mean standing crop of phytoplankton in the adjacent nearshore environment. Differences in nutrient load were largely attributable to inter-annual changes in outflows from the river, linked to rainfall amounts. The high rainfall year of 1997/1998 resulted in three-fold higher TN and TP load to the estuary than observed in subsequent low rainfall years. Mean phytoplankton biomasses, in the form of chlorophyll concentrations, were three-fold higher in the high rainfall year than the subsequent low rainfall years, matching the change in nutrient load. Nutrient limitation bioassays for phytoplankton production, performed over the study period, showed a predominance of nitrogen limitation in the nearshore environment. The frequency of nitrogen limitation was greatly enhanced during low rainfall periods, suggesting that the inter-annual differences in nitrogen load were primarily responsible for the observed inter-annual changes in phytoplankton biomass.

Imbedded within the broad relationships between nutrient load and mean nearshore phytoplankton biomass, there were smaller scale spatial and temporal differences in phytoplankton biomass and composition. From a spatial perspective, phytoplankton biomass tended to be higher south of the Suwannee River outflow north of the outflow, reflecting the predominant direction of long-shore water flow, but individual peaks in phytoplankton abundance were observed in various regions within the estuary and not limited to the southern region. Temporally, overall mean phytoplankton standing crops were higher in the warm season than the cold season. However, blooms of certain diatom and dinoflagellate species were also observed in the winter.

Production rate measurements of clam and oyster populations in the nearshore environment revealed important spatial and temporal similarities to those observed for phytoplankton biomass. For example, some clam lease sites north of the Suwannee outflow showed less production over the growth period than leases south of the outflow, supporting the hypothesis that differences in phytoplankton abundance influence the production potential of bivalves. Experiments on the selectivity and rates of grazing of cultured clams showed that certain species of phytoplankton were selectively consumed or grazed at higher rates. These observations indicate that shifts in species composition of the plankton community could alter the efficiency of food utilization and growth of clams.

In terms of the potential harmful effects of algae, significant blooms were observed over the three year study period, but none were associated with observations of severe depression of oxygen levels in the water column. In addition, none of the observed blooms involved known toxin producing algae. It may be suggested that the relatively unrestricted nature of the Suwannee estuary, combined with river discharge rates, provide a hydrodynamic environment that limits the prolonged buildup and retention of algal blooms, despite the high nutrient concentrations found in the river outflow. However, these general conditions do not preclude the potential for the occurrence of stochastic meteorological events that result in harmful algal blooms. For example, in 2005, strong long shore currents emanating from a region of a strong toxic red tide event resulted in the appearance of significant concentrations of the red tide species *Karenia breve* in the Suwannee estuary. Such events, though rare, indicate the importance of maintaining a water quality monitoring program in regions of the estuary used for clam and oyster production and harvest.

References

Phlips, E. J. and E. L. Bledsoe. 1997. Plankton community structure and dynamics in the Suwannee River Estuary. In Lindberg, W. J. (Ed.), Proceedings of the Florida Big Bend Coastal Research Workshop, May 7-8, 1997. Florida Sea Grant Technical Paper 88:47-49.

Bledsoe, E. and E. J. Phlips. 2000. Nutrient versus light limitation of phytoplankton in the Suwannee River and Estuary. Estuaries 23:458-473.

Phlips, E. J. 2002. Algae and eutrophication. In G. Bitton (Ed.), Encyclopedia of Environmental Microbiology. John Wiley and Sons.

Bledsoe, E., E. J. Phlips, C. E. Jett and K. A. Donnelly. 2004. The relationships among phytoplankton biomass, nutrient loading and hydrodynamics in an inner-shelf estuary, the Suwannee River estuary, Florida, USA. Ophelia 58:29-47.

Bergquist, D.C., J.A. Hale, P. Baker, and S.M. Baker. 2006. Development of ecosystem indicators for the Suwannee River Estuary: Oyster reef habitat along a salinity gradient. Estuaries and Coasts 29(3):353-360.

CLAMMRS Project
Funded by USDA

Investigators:
Shirley Baker, University of Florida, Department of Fisheries and Aquatic Sciences
Ed Phlips, University of Florida, Department of Fisheries and Aquatic Sciences
Clay Montague, University of Florida, Environmental Engineering Sciences
Leslie Sturmer, University of Florida, Cooperative Extension Services
Sherman Wilhelm, Florida Department of Agriculture and Consumer Services, Division of Aquaculture
Kal Knickerbocker, Florida Department of Agriculture and Consumer Services, Division of Aquaculture

Project Summary:
Like land-based agriculture, the clam industry faces challenges that limit yield, efficiency and profitability. However, unlike land-based agriculture, the use of technologies in meeting those challenges for the clam industry is at a primitive stage of development. The long-term goal of the CLAMMRS Project is to enhance the sustainable development of open-water clam farming through adoption of remote sensing technologies.

Specific objectives of this project were to: 1) Provide near real-time water quality data to growers, 2) create a water-quality database, 3) determine impact of food resources on clam growth and survival, 4) fill gaps in our knowledge of Florida clam physiology, and 5) build a model to simulate farmed clam growth and survival (summarized separately).

Beginning in 2002, water quality monitoring sondes were installed by FDACS at 10 aquaculture sites around the state: Alligator Harbor, Horseshoe Beach, Pine Island, Gulf Jackson, Dog Island, Sandfly Key, North Pine Island, Body A, Body F, and Indian River. Sondes collected data on temperature, salinity, dissolved oxygen, turbidity, and depth. Data from some locations was transmitted by cell phone to FDACS, where it was placed on a public website http://www.floridaaquaculture.com/index.htm. Following a quality assurance/quality control (QAQC) process, data was graphed and made available on the Florida Shellfish Aquaculture Extension website http://shellfish.ifas.ufl.edu/.

Logistical obstacles arose from time-intensive instrument maintenance, technological limitations, and high rates of biofouling. Despite these problems, we now have a database of over 1.2 million data points that allow us to see details of daily and seasonal variability in the environment. In addition, salinity and oxygen data factored in over 2/3 of crop loss indemnity during 2003-2005.

We characterized the spatial and temporal variability in phytoplankton biomass and composition. Increased phytoplankton biomass was associated with increased nitrogen load and years of high rainfall. The growth and survival of clams grown at different lease sites were positively associated with phytoplankton biomass.

Most of the physiological information available on hard clams is for northeastern clams. We conducted a series of laboratory experiments to examine the effects of temperature, salinity, dissolved oxygen and food on clam survival and burial behavior. This information is being incorporated into a series of extension publications (ie: http://edis.ifas.ufl.edu/FA128). Studies on food consumption and metabolism are ongoing.

Although this grant is completed, work is still in progress. Analysis of the >1.2 million data points by personnel experienced with large data sets may reveal additional spatial and temporal patterns in water quality. Using the data we have to date, we are continuing to explore the relationship between phytoplankton biomass/composition and clam growth/survival. Further model-building (summarized separately) and clam physiology experiments are ongoing. In addition, water quality monitoring is continuing at some locations with a grant from USDA-ARS.

CLAMMRS Model: Simulation of Farmed Clam Growth and Survival
Funded by USDA

Investigators:
Clay Montague, University of Florida, Environmental Engineering Sciences
Ben Loughran, University of Florida, Environmental Engineering Sciences
Shirley Baker, University of Florida, Department of Fisheries and Aquatic Sciences

Project Summary:
Computer simulation of farmed clam growth was built and found to be inadequate. In part, this is because knowledge about clam growth under the conditions they experience in nursery and grow-out bags is inadequate. Clam farming conditions differ from those in reported scientific studies. Knowledge gaps specific to farmed clams make predictions of clam harvest unreliable for reasons given below. The gaps must be filled before reliable predictions from such a model can guide clam industry decisions.

The ultimate goal is to make dependable forecasts of clam harvest from monitored water conditions. Monitored variables include: salinity, temperature, water level, dissolved oxygen, and chlorophyll. A common result of the model-building process is a shopping list of missing information. Scientific studies were not available to quantify some relevant linkages between these variables and the growth and survival of farmed clams. To achieve the goal of trustworthy prediction, the missing information must be supplied, which will require experimentation and a rigorous record of harvest.

The model-building process has revealed specific knowledge gaps that must be filled before reliable predictions can be made. Two major limitations in understanding of farmed clams have been identified: 1) the effect of clam densities used in nursery and grow-out bags on clam growth, survival, and microenvironment (densities are much higher than used in reported clam studies); and 2) the dynamic responses of farmed clam growth and survival under known environmental conditions.

Introduction
Clam farming in Florida began very recently. Methods are evolving by trial and error. Theories among the farmers differ depending on what they believe accounts for their own successes and failures. Methods therefore differ from one farmer to another and from one planting to another. Over time, farmers discover what seems to consistently work for them and try to explain it.

A model is a quantified record of such a hypothesis of cause and effect based on the best available scientific knowledge and farming practice. It consists of the set of cause-and-effect sequences thought to occur between monitored environmental conditions and the growth and survival of clams from initial seeding to harvest. The most reliable predictions are made from knowledge based on careful study of growth and survival of the clams themselves under various densities and environmental conditions.

At the core of the model's inadequacy are feedback effects of clams on their own growth and survival. Feedback occurs when the clams themselves alter their environment in ways that significantly affect the ultimate harvest. Feedback automatically produces dynamic patterns –

cycles of good harvests and bad harvests, or longterm upward or downward trends. Feedback produces such effects even if the environment otherwise remains constant.

Feedback from crowding

Because very high densities of clams are living together in bags, feedback can occur between farmed clams, chlorophyll, and dissolved oxygen. Chlorophyll, for example, indicates the level of phytoplankton in the water. Phytoplankton in certain size ranges are the primary food for clams. Clams filter the water and remove both food non-food particles. Although more phytoplankton means more food for clams, more clams mean more filtering and therefore less phytoplankton. In a similar kind of feedback, respiration by clams reduces the dissolved oxygen required for respiration.

Crowding intensifies these feedbacks. The effects of crowding on growth and survival in nursery and grow-out bags must be quantified and suitable relationships incorporated into the simulation model. When crowding effects alter the microenvironment, the response may be unexpected. Harvest may be affected so much, that predictions from a model without the effect of crowding would be very different from actual harvested quantities.

Microenvironment of farmed clams. Feedback from crowding also disconnects measured environmental variables from the actual environment experienced by the clams. In the immediate vicinity of clam siphons, food and oxygen levels may be much lower than indicated by monitored variables. For example, existing studies of clams may indicate good survival when dissolved oxygen is at a given level indicated by a meter located in water above a lease. The oxygen level among the clam siphons, however, could be much lower – so much so that growth is retarded. To use existing scientific information, the alteration of the microenvironment at the siphons must be incorporated in the model. The necessary information to quantify this effect is not available, so must be obtained experimentally.

Flow and turbulence of water across the lease can refresh the microenvironment and make more of the dissolved oxygen and food in the water available at the clam siphons. The degree of the effect may relate to changes in water level that are being monitored. Quantifying the effect of flow and turbulence on refreshing the microenvironment requires careful experimentation.

Types of experiments needed

Quantitative experimentation with clam growth, death, and physiological responses under various farming techniques is necessary (clams per bag, bags per lease area, burial depths, etc). Several kinds of experiments would be helpful. Longterm experimentation in the lease area will tell a valuable part of the story. Experiments in large tanks that can simulate aspects of the lease setting and will give results sooner. Tank experiments allow better control of environmental conditions and more precise measurements of growth and survival. Laboratory studies offer the best control of density and environmental conditions, and the purest biological response of clam growth and survival. With laboratory studies, interference from uncontrollable variables is minimized. Once the experimental methods are worked out, laboratory studies can produce a series of tests quickly. Results may need field verification, however. One way to accomplish this is by basing model harvest predictions on laboratory results and comparing the resulting harvest with that produced in tanks that simulate field conditions. The ultimate proof will be in the ability of the model to predict real harvests. Validating the model will require field experimentation and longterm monitoring, the second research need identified above.

Long term records

A long term record of both harvest and environmental conditions provides evidence of cause and effect, confirmation of feedback, and a target for measuring the success of the model. Satisfactory records can be obtained in a number of systematic ways. Harnessing the failures and successes as farming methods develop would be very valuable to the simulation modeling effort. Interviews with clam farmers do not seem to be a sufficient way to gather the needed information. To make data collection systematic requires a random selection of farmers rather than volunteers. It also requires potentially unwelcome scrutiny of farming practices by independent observers. Observers would have to record actual methods and quantitatively collect the data from each selected lease using consistent, scientifically valid methods.

Scientific monitoring of clam harvest from leases set aside for experimental purposes is a less intrusive way of producing a satisfactory record. It does not produce as extensive a record, but it has several advantages. Farming techniques would be completely controlled and consistent. Data collection might require fewer trained people, and individual farmers would not be under scrutiny. Measurement devices can also be set up in the immediate surroundings of the clams, specific test clams can be marked and recaptured, and the microenvironment of the clams can be tested for crowding effects. In other words, field experiments and longterm monitoring could both be accomplished on the same experimental leases.

Closing

Simulation modeling is longterm process. The most common result of a simulation modeling effort is failure to predict what is known to be true. Yet a model incorporates all relevant quantitative knowledge and principles. The model becomes a special kind of record of current understanding. It is quantitative and interactive. Running the model illustrates the ability of that record of understanding to account for known harvest records based on known environmental measurements. The predictions improve as the understanding improves and is represented in the model. To know how well the model is doing, however, its harvest predictions must be compared to unbiased records of the actual harvest.

An analysis of an incorrect model will identify needed information, as has been done here. When that information has never before been sought, measurement and experimentation are necessary. This will slow the process, but both the reasons for the missing data and the results of the required studies enlighten everyone involved. By continuing to cycle between model results, experimental results and field harvest data, the process will converge on a useful predictive tool available for all to use and improve.

Independently collected experimental results will not only supply the information needed for a simulation model, but also will have direct benefits to the farming community, accelerate the development of methods that work, and will level the playing field for all clam farmers.

Sulfide Concentrations in Sediments and Water: Effects on Hard Clams
Funded by Florida Sea Grant

Investigators:
Derk Bergquist, South Carolina Department of Natural Resources
David Julian, University of Florida, Department of Zoology
Shirley Baker, University of Florida, Department of Fisheries and Aquatic Sciences

Project summary:
The coastal areas in which hard clam culture takes place are typically characterized by high phytoplankton productivity. Some of this phytoplankton will die and sink to the bottom where it is consumed by bacteria. As the bacteria decompose the organic matter, they use oxygen. The bacteria may, in fact, use up the oxygen in the sediments, creating an anoxic (no oxygen) environment. Under these conditions, other types of bacteria decompose the organic matter and, in doing so, produce hydrogen sulfide. Sulfide is responsible for the black sediments found in many estuaries and is the source of the "rotten-egg" smell. Hydrogen sulfide is a metabolic toxin and is known to decrease the growth and survival of many bivalve species.

Our objectives were to 1) examine sediment sulfide levels in the Suwannee River estuary, and 2) determine the effect of sulfide on hard clam survival. Sediment porewater samples were collected at 11 sites, both inside and outside of leases. In the lab, 2 sizes of clams were challenged with both sulfide and hypoxia (low oxygen).

All sites had sulfide in the sediments. Porewater sampled from clam lease sites had mean sulfide levels up to 110μmol/L. Non-lease sites had higher levels, with mean sulfide levels up to 300μmol/L. Sulfide levels varied significantly with the temperature, with highest levels occurring in the warm months of August and September.

Laboratory experiments determined the survival of nursery and growout sized seed clams in conditions of normoxia (normal oxygen) or anoxic (no oxygen) and four sulfide levels, 0, 50, 250, and 1000 μmol/L. These experiments indicated that the sulfide levels present in sediments can have an impact on the survival of small clams.

In conclusion, we found that sulfide occurs in clam lease sediments, levels are highest in warm summer months, and clams are vulnerable to sulfide toxicity in the lab. This project, however, brought up more questions. Does sulfide really cause losses in the field? Since clams have siphons and pump water from above the sediments, do they bring in water containing sulfide? Are larger clams less susceptible to sulfide or, are they more likely to be exposed to sulfide because they are deeper in the sediments?

Investigation of Blood Ark and Ponderous Ark Culture and Marketability

Leslie Sturmer, Jose Nunez, LeRoy Creswell, Robert Degner, Kimberly Morgan, Shirley Baker; University of Florida, Institute of Food and Agricultural Sciences
Alan Power, Randal Walker; University of Georgia, Marine Science Extension
John Baldwin; Florida Atlantic University

Ponderous ark, Top
Blood ark, Bottom

Over the past two decades, a dramatic increase in aquacultured shellfish production has occurred in Florida, USA. The industry grew from $0.4 million (13 farmers) in 1987 to $18 million (336 farmers) in 2001. However, the industry is built on a single species, the hard clam *Mercenaria mercenaria*. Diversifying the hard clam culture industry by developing farming technology and markets for other bivalve species would increase economic stability and growth. The blood ark *Anadara ovalis* and ponderous ark *Noetia ponderous* are native bivalve species found to naturally set and grow in clam bottom bags. The project team assessed the culture and market potential of these ark clams to introduce new molluscan species to producers and provide a different revenue source to small-scale hard clam culture enterprises.

The annual reproductive pattern of the blood ark and ponderous ark off the east (Atlantic) and west (Gulf of Mexico) coasts of Florida, respectively, was histologically determined. In both arks, the sexes were separate, with a low incidence of hermaphrodites observed in the blood ark. Arks of both species were found to dribble spawn over most of the year, with peaks in gonadal development occurring during the late spring-early summer months for the blood ark and during the summer and fall months for the ponderous ark. Typical spawning techniques used in hard clam hatcheries were successful when applied to ripe ark clams and early developmental events of both were congruent with that of the hard clam. Differences were found in the larval rearing period with time from fertilization to setting varying from 16 to 21 days in the blood ark and from 21 to 28 days in the ponderous ark as opposed to 10 to 14 days for the hard clam. Setting was problematic in that no visual cues were apparent to determine competency. Further, metamorphic induction experiments conducted to evaluate physical substrates and chemical cues on settlement were not successful. Rather, size determined when to transfer larvae to downwellers; setting percentages were low. Post-set ark clams were reared using similar systems and methods as hard clams. Nursed in land-based wellers, blood arks increased from 1 mm in shell length to 13 mm in 60 days, whereas ponderous arks reached 16 mm in 142 days. Field-planted in polyethylene (hard) and polyester (soft) bottom bags, juvenile blood and ponderous arks reached market size (35-40 mm shell length, 25 mm shell width) in 9 and 12 months, respectively. Following post-set, mortality was negligible with survival exceeding 80% in soft bags and 90% in hard bags. A nationwide survey of certified shellfish dealers was conducted to determine the current state of the market and sales for cultured ark clams. The consensus of responding firms was that both had limited appeal to traditional clam customers, but could be successfully marketed to ethnic consumers. Product attributes, nutritional analyses and shelf life were also determined for both ark clams.

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

Investigators:
John Scarpa (HBOI), Leslie N. Sturmer (UF), Charles M. Adams (UF), R. LeRoy Creswell (UF), and Jose Nunez (UF)

Institutions:
Harbor Branch Oceanographic Institution (HBOI) & University of Florida (UF)

Project Status:
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.

Overall, the project is following the original timeline. Methods for the shipment and maintenance of broodstock clams have been examined. "Dry" shipment methods used for hard clams were effective and have resulted in <10% initial mortality. Shipping tests with seed clams still needs to be performed. Broodstock were able to be maintained in a temperature-controlled conditioning system and used for spawning attempts. Histological analysis of broodstock has shown an approximate 1:1 ratio of females to males. Sunray venus clams responded to thermal-cycling for spawning, although the number of animals spawned has been minimal. Two successful spawns were accomplished with females producing from 200,000 to 1.1 million D-stage larvae at 24 hr. Larvae developed similarly to hard clams and metamorphosed without an exogenous cue from day 7 to 10. Salinity and temperature ranges for larvae culture need to be established. Larvae were allowed to "settle" with no substrate or with sand substrate. Sand substrate resulted in a higher return (79%) compared to no substrate (42%). Post-set clams have been cultured in a land-based nursery and our now being deployed to other commercial land-based nurseries. When the sunray venus clams reach grow-out seed size (15-20 mm length), clams will be deployed in the field and with commercial growers. Product will be tested and finances considerations examined.

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.

IFAS Clam Workshop PRESENTERS and Contact Info

Dr. Patrick Baker
UF/IFAS Department of Fisheries and Aquatic Sciences
P.O. Box 110600, Gainesville, FL 32653
Phone: (352) 392-9671, ext. 281 E-mail: pbaker@ufl.edu

Dr. Shirley Baker
UF/IFAS Department of Fisheries and Aquatic Sciences
P.O. Box 110600, Gainesville, FL 32653
Phone: (352) 392-9671, ext. 264 E-mail: smbaker@ufl.edu

Dr. Ruth Francis-Floyd
UF/IFAS College of Veterinary Medicine
P.O. Box 100136, Gainesville, FL 32610
Phone: (352) 392-4700, ext.5638 E-mail: Francis-FloydR@mail.vetmed.ufl.edu

Dr. Karl Havens
UF/IFAS Department of Fisheries and Aquatic Sciences
P.O. Box 110600, Gainesville, FL 32653
Phone: (352) 392-9671, ext. 0 E-mail: khavens@ufl.edu

Dr. Clay Montague
UF Department of Environmental Engineering
P.O. Box 116450, Gainesville, FL 32611
Phone: (352) 392-6222 E-mail: montague@ufl.edu

Dr. Denise Petty
UF/IFAS Department of Fisheries and Aquatic Sciences
P.O. Box 110600, Gainesville, FL 32653
Phone: (352) 392-9671, ext. 229 E-mail: pettyd@ufl.edu

Dr. Ed Phlips
UF/IFAS Department of Fisheries and Aquatic Sciences
P.O. Box 110600, Gainesville, FL 32653
Phone: (352) 392-9671, ext. 248 E-mail: phlips@ufl.edu

Dr. John Scarpa
Harbor Branch Oceanographic Institution
5600 U.S. 1 North, Ft. Pierce, FL 34946
Phone: (772) 465-2400, ext. 404 E-mail: scarpa@hboi.edu

Leslie Sturmer
UF/IFAS Shellfish Aquaculture Extension Program
P.O. Box 89, Cedar Key, FL 32625
Phone: (352) 543-5057 E-mail: LNST@ufl.edu