Gulf States Marine Fisheries Commission
MARINE AQUACULTURE PILOT PROJECTS: FINAL REPORT

Project Title: Aquaculture Potential of the Angelwing Clam: The Gulf Geoduck?

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Executive Summary

The potential for commercial aquaculture development of the angelwing clam *Cyrtopleura costata*, a burrowing bivalve found along the US Atlantic and Gulf of Mexico coasts, was reexamined. Studies conducted in the 1980s demonstrated angelwings could be spawned using hatchery methods similar to those for commercial bivalve species. Preliminary results also indicated angelwings grow rapidly and could reach a potential harvest size in six months. However, the lack of economical production methods and harvesting techniques stymied further consideration of angelwings as an aquaculture candidate species. Despite its excellent flavor and attractive shell, another drawback was its short shelf life as most bivalves until recently were marketed as live shellstock. In the past two decades, aquaculture of the geoduck *Panopea generosa*, North America's largest phollad clam, has advanced due to its high market value. By adapting methods developed for geoduck aquaculture, it was hypothesized that reliable production of the angelwing clam could be achieved.

In this study, adult angelwing clams were sourced from local populations and successfully spawned and reared in a commercial hatchery with similar results as previous studies. A notable exception was that pediveligers set equally well in sand substrate and without substrate. Post-set (approximately 2-3 mm shell length, SL) were nursed in sand-filled tanks reaching 10.8-11.7 mm SL in 14-22 days, at which time juveniles were of the size to be planted in the field. Several field and land-based culture methods were evaluated: PVC tubes under bottom nets, submerged bottom cages, modified bottom bags, and raceway tanks. After 23-24 weeks (six months from spawning), angelwings reared in the field (bottom plant) averaged 61.6$\pm$7.0 mm SL and 24.1$\pm$7.4 grams in total weight, whereas angelwings in raceway tanks averaged 46.3$\pm$3.4 mm and 5.0$\pm$1.9 grams, respectfully. Although survival in the bottom plant was low (16.5%), size distribution of recovered intact valves (shells) was similar to harvested live angelwings. Mortalities may have been related to buryment; survival could have exceeded 40% if angelwings had been harvested even one month earlier. With improved management practices, the bottom plant is a potentially viable growout method.

Two post-harvest processes were tested at a commercial processing facility: modified atmosphere packaging for live product and partially cooked, flash frozen in vacuum packed bags. Preliminary evaluation of these processes for shelf life, breakage, taste, and appearance was conducted and compared to live shellstock product, which had a shelf life of two days in refrigerated storage. In terms of overall marketability, live was considered the best way to

market, which would require angelwings to be held in seawater during the entire distribution channels. Post-harvest treatments used commercially for hard clams proved to be of no benefit for angelwings.

Purpose

The overall goal of this project was to re-examine the potential for commercial aquaculture development of the angelwing clam, *Cyrtopleura costata*, a burrowing bivalve found in shallow waters along the US Atlantic and Gulf coasts. It has an attractive while shell valued by collectors and is commercially harvested in the Caribbean and Mexico (Figure 1). Preliminary studies conducted in the 1980s by Gustafson et al. (1991) demonstrated that angelwings could be spawned using hatchery methods similar to those for commercial bivalve species with a potential harvestable size of 50 mm shell length attained in five months from spawning. However, the lack of economical field production methods and harvesting techniques stymied further consideration of angelwings as an aquaculture candidate species. Despite its excellent flavor and attractive white shell, another drawback was its relatively short shelf life as most bivalves until recently were marketed as live shellstock. Over the past decade, aquaculture of the geoduck, *Panopea generosa*, North America’s largest and deepest burrowing phollad clam, has advanced in Washington state due to its high market value. By adapting methods developed for geoduck aquaculture, it was hypothesized that reliable production of the angelwing clam may be achieved.

The specific project objectives were to:

1) Document procedures of producing post-set angelwings in a commercial hatchery,
2) Evaluate culture methods at a land-based facility and open-water site, and
3) Assess post-harvest processing methods for market-size angelwings.

Approach/Method

<u>Broodstock Collection</u>

Four collection trips (March 17, March 21, April 18, May 4) were conducted in Cedar Key, Florida during 2020. A local seafood company, Cedar Key Seafood Distributors, was contracted to collect broodstock. On each occasion, five to seven adults (shell lengths ranged from 11.5–15 cm) were sourced from local assemblages (Figure 2a). Clams were placed in a cooler with aerated seawater and delivered to the participating commercial hatchery, Wray Clam Wranchos, located in Cedar Key. Collection trips were scheduled around low tides, which facilitated removal of clams from the bottom substrate; adults were burrowed 2-3 feet. A technique was developed which allowed removal without breakage of the shell, resulting in less than 15% mortality of collected clams.

Angelwing clams were placed in aquaria at the participating commercial hatchery and observed for 24 hours to detect if there was any spawning activity (Figure 2b). Clams were held at ambient temperatures and feed cultured algae. On each occasion, a clam was sacrificed to assess reproductive status. On April 18, there was evidence of gonadal development. On May 4, a male was ripe with active sperm.

No mortalities were observed during this period. Further, it was observed that adults could be kept without the addition of substrate, which is necessary for sunray venus broodstock, or without a rubber band placed around the valves (shells), which is required for adult geoduck clams held in a hatchery environment.

Spawning

A spawn was conducted on May 7, which coincided with a full moon. Temperature and salinity of the broodstock holding tank was 24-25ºC and 24-25 psu, respectively. Thermal cycling was initiated with water temperature increased to 30ºC over 15-20 minutes and then lowered to 22ºC. After one cycle, a male released sperm, resulting in all angelwings releasing gametes. Four females were removed and placed in a separate tank. Sperm from four males was pooled and used to fertilize eggs from these females. It was noted that eggs (about 25 microns) were smaller than *Mercenaria mercenaria*.

Larviculture

Approximately 3 million D-stage larvae from the 4x4 spawn, which held on a 10-micron screen, were stocked into a 300-gallon tank at approximately one million per 100 gal (Figure 3a). Larvae were feed *Nannochloris oculata* initially as the hatchery operator observed that larvae were not feeding. *Isochrysis galbana* (T-iso), a larger algal cell typically used as first feed in hard clam culture, was added after the third day. Other than this exception, standard hard clam procedures were followed. The first drain down occurred on the third day and larvae held on a 35-micron screen (Figure 3b). Subsequently, drain downs of the larval tank occurred daily and screen sizes were increased from 55 to 75 microns at 3-day intervals. After which, a 100-micron screen was used to retain larvae. Survival was high in the larval culture period, requiring the hatchery operator to reduce the number of larvae during drain downs. Larvae were observed under a microscope daily and no mortalities or deformities were observed (Figure 3c).

Setting and Post-set Rearing

Pediveligers were observed on May 22, 15 days from spawning. Following protocols by Creswell and Schilling (1985), setting wellers (20"x14" plastic bins with 120-micron screen on the bottom) were placed inside the larval tank. Graded silica (beach) sand (>300 and <500 microns) was added to each weller to a depth of about one inch (2 cm). Mortalities were observed in the setting wellers the following day during drain down; wellers were removed from the tank. Larval stages collected during drain down on May 24 were placed in a 4'x8' fiberglass tank in which a thin layer of graded sand was added to half the tank. Settlement of pediveligers occurred within 17-18 days from fertilization at about 300 microns in size, similar in time and size as reported by Creswell and Schilling (1985). Pediveligers set equally well on the bare tank bottom as on sand substrate (Figure 4a). Creswell and Schilling (1985) noted high mortalities of setting angelwings placed on screens or sand-coated surfaces due to biofouling. Mortality in this system was low based on observations of empty shells to live clams.

Post-set angelwings were maintained in the setting tank with water exchanges occurring every other day. Algae (T-Iso at maximum cellular density) was initially fed at 15 gallons per day and increased to 60 gallons per day within two weeks. On June 5 (29 days after fertilization, 10 days post-metamorphosis), post-set averaged 2.3 mm in shell length (Figure 4b).

Land-based nursing

Newly set juveniles were transferred on June 10 to the University of Florida (UF) land-based nursery facility in Cedar Key. The post-set were siphoned from the setting tank into buckets and transferred in salt water with no shell breakage or mortality observed. The post-set were stocked into two (7.7'x3.7'x0.8') fiberglass tanks, filled with graded silica sand (>300 and <500 microns) to a depth of two inches (5 cm) (Figure5a). Although difficult to determine numbers, it was estimated about 7-8,000 post-set were stocked per tank. During the day, ambient surface water (salinity, 25-26 psu) filtered through 100-micron bags was provided at a flow rate of two gpm. Tanks remained static overnight, and aeration was added. Tanks were drained every morning and refilled with saltwater. After 24 hours, siphon holes in the substrate were observed indicating that post-set were burying. Within four days, all angelwings had buried. One week later, post-set averaged 8.5 mm in shell length, whereas those that remained in the hatchery averaged 5 mm.

Gustafson et al. (1991) determined that angelwing juveniles larger than about 15 mm in shell length were unable to rebury and had to be manually buried beneath the sediment during field planting. Therefore, we planned to test several growout methods when juveniles reached 10-12 mm in size. From June 24-July 2 (48-56 days from spawning), juveniles were transferred from nursery tanks to the field. Angelwings averaged 10.8 mm (shell length) in one tank and 11.7 mm in the other (Figure 5b, 5c). Shell width of angelwings from both nursery tanks averaged 4.4 mm. Water temperatures and salinities during the 22-day nursery period averaged 28.7 ± 2.5^{o}C and 22 ± 4 psu, respectively. Maximum water temperatures of 92^{o}F (33^{o}C) recorded in late afternoon seemed to have no adverse effect on angelwings.

Develop / construct growout culture systems

In earlier studies, juvenile angelwings were field planted with and without protection. It was concluded that economical field production methods were needed for angelwing clam culture to reach its potential. Four growout systems that would allow juveniles to bury into naturally occurring sediments were developed for this evaluation. Cages (n=4, 3'x3'x0.8') were constructed of 1" mesh vinyl coated wire and lined with 9 mm mesh polyester netting (Figure 6a). Prior to stocking, cages were submerged into sediments (0.5') using a high-volume pump. Tops constructed of the same materials were secured to the cages with bungee cords.

The typical growout method used in Florida for hard clams is the bottom bag. The bag provides predator protection and retains the clams at harvest, making it an efficient gear type. For this study, a 4'x4' polyester mesh (9 mm) bag was tested along with two bag modifications. PVC pipe frames (1" and 2" in diameter) were placed inside the bags to facilitate sediment accumulation within the bag (Figure 6b). Bags were staked to the bottom using ½-inch PVC pipe. The bottom plant method, which is used in the northeastern US, allows clams to bury into the substrate without restriction. An 8'x8' bottom plant was tested using a single layer of 9 mm mesh polyester netting covered with ½-inch polyethylene netting (Figure 6c).

In addition, nine 3-gallon buckets (1' diameter,) were filled with beach sand to about 0.67 feet. The bucket lids were cut out and the remaining ring was used to snap netting (polyester and plastic) onto the bucket top (Figure 6d). Replicate buckets (n=9) allowed growth and survival of angelwings to be monitored monthly.

Field and Land-based Growout Trials

Growout trials were conducted at the UF experimental lease located within the Dog Island Aquaculture Use Zone off Cedar Key. The site is characterized by sandy substrate and medium salinities (20-25 psu). The four bottom cages were stocked on June 30. Juveniles were scooped from a nursery tank using small plastic shovels and sieved on a 4.0 mm screen to remove sediments and sort the larger clams for planting (60% of a test sample was retained on this screen size). It had been determined earlier that angelwings could be sieved in salt water without shell breakage. Juveniles were counted and placed in beakers with salt water for transporting to the field site. Unlike hard clam juveniles, that close their valves (shells) and can be handled out of water for prolonged periods (24 hours), angelwings cannot. We observed if angelwing juveniles remained out of water for less than 1-2 hours, they desiccated. Technology used in geoduck culture was adapted for stocking the cages. Nine PVC pipe pieces (4" diameter, 7" length) were placed into the sediments within each cage to a depth of about 3-4 inches. Fifty juveniles were added to each pipe for a total of 450 clams stocked per cage ($50/ft^2$). It was assumed that the pipes would minimize effects of tidal and wind-driven currents and facilitate buryment of the juveniles. The pipes were removed from the cages after 10 days.

The bottom bags and bottom plant were stocked on July 1-2 (Figure 7a, b). Juvenile angelwings were handled in the same manner (sieving, counting) as the bottom cages. For the bottom plant, 10-15 juveniles were placed in beakers (n=32 per day) with saltwater and transported to the field site in coolers. The bottom plant area was divided into four quadrants. Within each quadrant, four rows of four PVC pipes were placed into the substrate. The stocking method was further refined from that used in stocking the bottom cages. Even though the tide was low, conditions were subtidal. A smaller 3"-diameter PVC pipe was placed inside the 4" pipe and extended above the water level (Figure 7c). Angelwings were then funneled into the 4" pipes through the extension, which was removed after several minutes. Once a row was stocked, the netting was rolled out to cover the pipes until all 32 pipes were stocked each day. To secure the cover netting, rebar (5/8") was placed along the entire perimeter of the netting. A total of 670 juveniles were planted under the cover netting. The three bottom bags were stocked each with 450 juveniles at a density of 28 per square foot.

During June 24-July 2, nine 3-gallon buckets were deployed at the field site, each stocked with 50-75 angelwing juveniles. They were placed inside the buckets filled with sand and saltwater and allowed to partially bury before transporting to the field site. At the site, the buckets were buried about half-way into the sediment.

The saltwater supply for the UF shellfish nursery facility in Cedar Key is classified conditionally approved for shellfish harvesting. For this reason, a portion of the juvenile angelwings were restocked into raceway tanks to evaluate growout in a land-based facility. After the field trials were stocked, two raceway tanks were prepared by adding graded sand to a depth of about 7 cm (3") in each tank. Thirty-five PVC pipe pieces (4" diameter, 5" length) were placed randomly within each tank to a depth of 2-3 inches. On July 7-8, angelwings from the nursery tank were sieved on a 4 mm screen (average size 10.5 ± 2.1 mm, 0.4 grams), counted, and stocked at 35 per pipe for a total of 1200 per tank ($40/ft^2$) (Figure 8). Pipes were left for 24 hours before removing. For several days, tracks were observed in the substrate before angelwings completely buried. Saltwater was initially filtered through 200-micron bags at a flow rate of 8-10 gpm.

During the growout period, covers (polyester and polyethylene netting) to the bottom cages and buckets in the field were replaced as biofouling, consisting primarily of barnacles, tunicates, and *Gracileria*, was limiting water exchange. Also, it was decided not to remove the PVC pipes from under the bottom plant as pulling up the cover net may have resulted in exposure to predators. Maintenance of the raceways consisted of weekly siphoning of the tanks to reduce accumulated silt. Initially, saltwater to the tanks was filtered through 200-micron bags. To increase water flow, bags were replaced with distributor bars, resulting in rates of 15-20 gpm.

Findings and Results of Growout Trials

Hydrological conditions

Hydrological conditions were monitored at the land-based and field-based growout sites. A YSI 6600 sonde recorded water temperature and salinity continuously (every 30 minutes) at the UF lease. Water temperature and salinity were measured twice daily in the raceway tanks using a thermometer and refractometer. Figures 9 and 10 summarize the water temperature and salinity data for both locations. From June through January, temperatures were similar for both locations, averaging 22.6$\pm$6.2 ^oC on the lease and 23.6$\pm$6.5 ^oC in the raceways, with the greatest range in the field of 6.7 to 33.4^{o}C. Salinities averaged 23.5$\pm$4.0 on the lease and 22$\pm$2.1 psu in the raceways.

Note that salinities fell below 10 psu in the raceways several days after stocking which could have affected survival. The sonde at the lease was not operational during this period, but most likely salinities were not as low. Further, during the growout period temperatures exceeded 32^{o}C (maximum 34.8^{o}C) on six days and salinities fell below 20 psu (minimum 16 psu) on 12 days in the raceways. However, these conditions did not seem to affect angelwings as mortalities were not observed at that time.

Buckets

Replicate buckets allowed growth and survival of angelwings to be monitored monthly, serving as a proxy for the other field growout methods, which could not be sampled. Sampling occurred at 3 to 4-week intervals on August 5, August 26, October 1, November 4, December 8, and January 6, 2021. One bucket per sample period was harvested from the experimental lease with the remaining three buckets harvested at the end of the field trials on January 13. Shell length and total weight were measured; live and dead (shells) angelwings were counted.

Growth of angelwing clams in the field (buckets) is summarized in Figure 11. From stocking in late June to October 1, angelwings grew at an average rate of 11.6 mm per month. From spawn (May 7) to the October 1 sampling, a period of five months, angelwings reached an average shell length of 47.2 mm (0.32 mm/day) in buckets. It was anticipated that when angelwings reached 50-60 mm, they would be a suitable size for harvest. Rapid growth rate is characteristic of pholadid clams, where shell growth rates of 0.22 mm per day over the first six months of life have been recorded (Gustafso et al. 1991). The rapid growth of *Cyrtopleura costata* observed in this study (0.32 mm/day) exceeds rates previously reported. These rates indicate juvenile angelwings (10-12 mm) could reach potential market-size in 4 to 5 months during the growout stage.

Shell length and total weight rapidly increased reaching 62 mm and 26 grams in the first 167 days (5.5 months of growout, December 8 sample date), with little growth obtained in the remaining period. This may have been related to colder water temperatures during that period. Since a maximum harvest size of 60 mm was targeted, it is plausible we could have terminated the field trials earlier.

Survival reported in Figure 12 is not cumulative, but rather is the survival of angelwings in each bucket on each sampling date. Survival in the bucket pulled on August 5 was high, estimated at 97%. On the next sampling date (August 26), survival in the buckets declined to 56% and one blue crab (2.5-inch carapace) was found inside the bucket. A larger blue crab (3.5-inch carapace) was found in the bucket harvested on October 1; survival was 14%. Survival over the last 36 days of the field trials (sample dates: December 8, January 6, January 13) ranged from 43 to 60%.

Bottom Bags and Cages

As was expected, the bottom bag was not a viable culture method for angelwings even with the internal PVC pipe frames. Only a few small shells were found at harvest on January 12 (Figure 13a). Not expected was the low number of live angelwings recovered from the cages with survival less than 10% (Figure 13b). Very little shell was found and there was no evidence of predation. The angelwings recovered from one cage averaged 69.0±5.0 mm in shell length and 36.0±10.4 grams in total weight (Figure 13c). It is assumed that juveniles did not bury with mortalities occurring soon after planting.

Bottom Plant

The bottom plant was harvested on a winter minus tide on January 13-14. Once the cover netting was removed, most of the 4"-PVC pipe tubes were found to be above the bottom sediments (Figure 14a). Siphon holes of up to six angelwings were observed in some of the tubes (Figure 14b). A commercial clam suction harvester was used (Figure 14c). After a PVC pipe tube was removed from the sediment, the harvester extracted a soil core the same diameter of the pipe and about 6-8" in depth. No angelwings were recovered from outside the pipes. Shell breakage due to harvesting was less than 7%. Angelwings averaged 61.6±7.0 mm in shell length, a growth rate of 0.28 mm/day at the high end of reported growth rates of other clam species (Table 1, Figure 15a). Weights (total, 24.1±7.4 grams; wet meat, 6.5±3.1 grams; dry meat, 1.1±0.5 gram) were also determined; condition index (7.2±2.2) was calculated. Using this culture method, angelwings reached a potential harvest size of 50-60 mm SL in 6.5 months (197 days), which is longer than that projected in the HBOI report (1992) of 90-120 days.

Survival was low at 16.5%. However, intact valves (shells) of angelwings were recovered from the soil cores and measured for shell length (Figure 15b). The size distribution of these whole shells compared to the live angelwings was similar (Figure 16). Mortalities may have been related to buryment as we noted increased sediments over portions of the nets most likely due to winter storms. If harvest had occurred even one month earlier, survival could have exceeded 40%, making the bottom plant a potentially viable growout method with improved management practices, such as use of higher PVC pipes to aid in stocking juveniles and reducing sedimentation of cover netting.

Land-based Raceways

Shell length and total weight of angelwings in raceway tanks were measured monthly by sampling 35-50 animals (Figure 17). From stocking on July 7 to the October 1 sample period, angelwings grew at an average rate of 9.3 mm per month, lower than that obtained in the field over a similar period. From spawn (May 7) to the sampling date of November 4, a period of six months, angelwings reached an average shell length of 42.3±4.0 mm in the raceways. After November 4th, growth of angelwings basically ceased. At harvest on January 19-20, angelwings averaged 46.3±2.8 mm in shell length, a growth rate of 0.18 mm/day (Table 1). Total weight decreased from 6.1±1.8 grams in December to 5.0±2.1 grams at harvest. Average meat weight of 1.0±0.3 gram and dry meat weight of 0.1±0.1 grams was 7 to 10 times lower than values obtained in the field bottom plant. Angelwings were in poor condition with an index of 3.1±2.2. The water flow in the raceway tanks was not adequate to provide the amount of food (phytoplankton) necessary to support growth. Survival of 36% was higher than values obtained in the field trials, most likely due to better success of juveniles burying at stocking under more controlled conditions (i.e., no exposure to winds, tides, predators). Interesting to note was that during several sampling periods angelwings released gametes when handled.

Post-Harvest Processing Assessment

To evaluate post-harvest methods, samples of harvested angelwings (n=300, 65 mm average shell length, 31 grams average total weight) were delivered in coolers containing aerated saltwater to Southeastern Seaproducts, a certified shellfish processor, in Melbourne, Florida (*http://frozenliveshellfish.com*). At the processing plant, angelwings were purged in chilled sea water for 12 hours. After which, two treatments were evaluated – live packaged in modified atmosphere trays and partially cooked, flash frozen in vacuum bags – and compared to live shellstock held in refrigerated storage (45^{o}F) (Figure 18). Preliminary evaluation of these processes was conducted in-house by Southeastern staff. The processed forms were evaluated for percent shell breakage and shelf life defined as survival after 14 days in storage. Appearance and taste were rated on a 10-point scale where 0 was extremely dislike, 5 neither dislike or like, and 10 extremely like. A full evaluation (i.e., consumer acceptance, sensory profiling) of these post-harvest methods was beyond the scope of this project.

For the modified atmospheric packaging, shell breakage was 15% and survival after 14 days was 30%. However, at seven days in refrigerated storage, survival was 100%. Staff extremely disliked (rating of 1) the appearance and taste of angelwings processed in this manner. For the cooked frozen, vacuum packed product, shell breakage was 20% and shelf life was 100% as it was frozen. This product form fared better with appearance being rated as neither like or dislike (5) and taste rated at slightly liked (6).

These methods were compared to live shellstock product which had a shelf life of 2 days in refrigerated storage (Figure 19). Purging for 12 hours was effective in removing grit in all product forms. In terms of overall marketability, live was considered the best way to market; however, this would require angelwings to be held in seawater during the entire distribution channels. Post-harvest treatments used commercially for hard clams proved to be of no benefit for angelwing clams.

Discussion / Evaluation

To summarize the project's results, angelwings are rated as a potential candidate for aquaculture based on this and previous work. First consideration in selecting a species to culture is the prospects of adequate seed availability though closure of the life cycle. Whereas this is a major obstacle for many promising species, this is not for angelwings. Spawning and larval rearing are similar to those methods used for hard clams. In this study, it was observed that angelwing pediveligers set successfully without the use of substrate, a concern in prior studies. Priority should also be given to those species that grow rapidly, which is why there is continued interest in angelwing clams, but growout methods must be economical and viable. Through refinement of bottom culture methods, this could be achieved for angelwings. Further, water temperatures and salinities experienced in this study suggest that angelwings are tolerant of a wide range of water quality conditions. With limited shelf life, angelwings are not an acceptable shellstock product, but other product forms evaluated in this study were also not acceptable. Lastly, the primary stimulus of species diversification is economic, thus highly priced species are preferred candidates. The marketability and value of angelwings as a domestic molluscan shellfish product are still unknown.

Overall, the project goals and objectives were met. However, several factors limited field work and subsequently limited replication of field growout methods, in particular the bottom plant. Restrictions placed on research by the University of Florida due to the COVID-19 pandemic hampered activities. Also, the window of opportunity to plant juveniles prior to losing their ability to bury (>15 mm) was constrained to 1-2 weeks given their weekly growth rates, even with an adequate supply of juveniles available. Although field growout results were not commercially acceptable in terms of survival, the use of PVC pipe tubes under cover netting, similar to methods used in geoduck culture, may be a viable method for culturing angelwings. However, refinement of techniques is necessary. The highest survival obtained in the field was of angelwings reared in buckets used to monitor growth. Juveniles partially buried into the substrate before moving the buckets to the field. Trying to scale this method for commercial application would be difficult as sand and salt water-filled containers of adequate size would be heavy and difficult to handle.

In the HBOI research report (1992), recommendations for future research to reach commercial success of angelwing aquaculture included determination of shelf life and evaluation of processing methods. This project was initiated due to the interest of a Florida commercial processor, who has the capabilities of quick flash freezing and vacuum packaging clams and oysters. Preliminary results of two post-harvest methods were not encouraging and may not warrant additional research on angelwing product quality and marketing.

Dissemination of Project Results

- Updates on the project were posted to the University of Florida/IFAS Florida Shellfish Aquaculture Facebook page.
- The project was presented at the 113th Annual Meeting of the National Shellfisheries Association (virtual conference) on 24 March 2021, and an abstract was published in the conference processings.
- The final project report will be posted on the UF/IFAS website, *Online Resource Guide for Florida Shellfish Aquaculture*, http://shellfish.ifas.ufl.edu.

References

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

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FIGURES

Figure 1. Angelwing clam, *Cyrtopleura costata*.

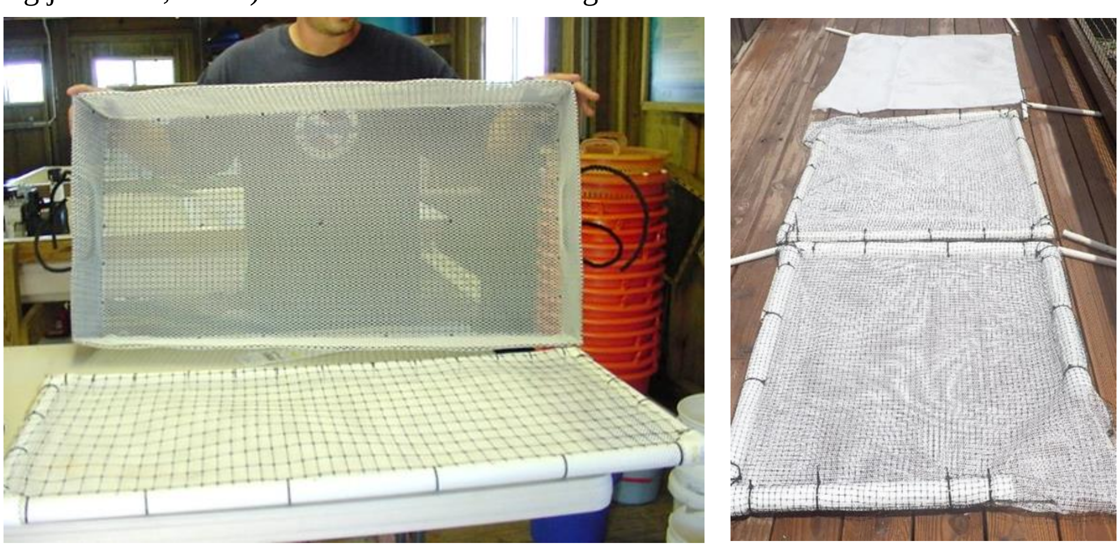

Figure 2. a) Adult angelwings sourced from local assemblages, b) adults held in an aquarium at the participating commercial hatchery in Cedar Key, Florida.

Figure 3. a) Angelwing larvae reared in a 300-gallon tank, b) drain downs occurred daily and larvae sieved on various mesh size screens, c) larvae observed under a microscope (40X, note pink color).

Figure 4. a) Post-set transferred to setting tank (not buried into sand substrate yet), b) post-set in a petri dish.

Figure 5. a) Nursery tank (raceway) filled with a layer of graded silica sand, b) juvenile angelwings transferred from nursery tanks to growout systems, c) juveniles under a microscope.

Figure 6. Systems developed for field growout evaluation of angelwings: a) bottom cages, b) bottom bags with internal PVC pipe frames, c) bottom plant netting with PVC pipe tubes used in stocking juveniles, and d) buckets used to monitor growth in the field trials.



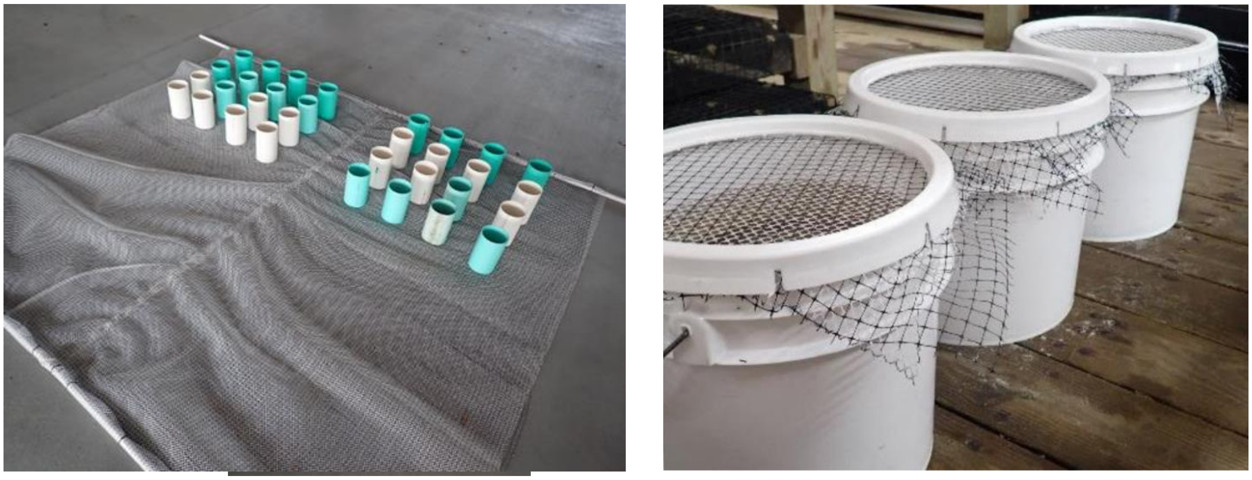


Figure 7. Stocking field growout systems with juvenile angelwings: a) bottom bag with internal PVC pipe frame, b) bottom plant netting, c) small PVC pipes extending above the water level used to facilitate stocking of PVC pipe tubes in the bottom plant.

Figure 8: Stocking land-based growout system with juvenile angelwings using PVC pipe tubes.

Figure 9. Water temperatures monitored at the land-based and field-based locations during the growout evaluation.

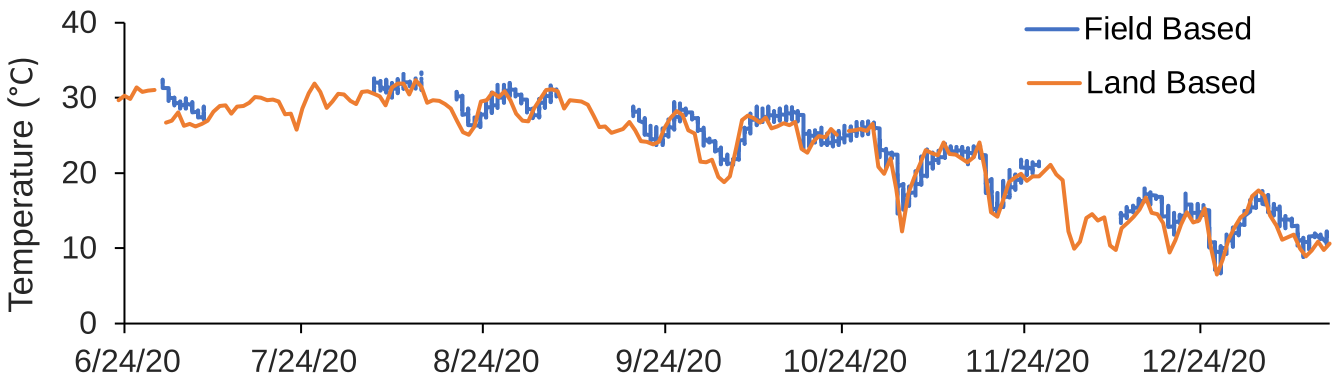


Figure 10. Salinities monitored at the land-based and field-based locations during the growout evaluation.

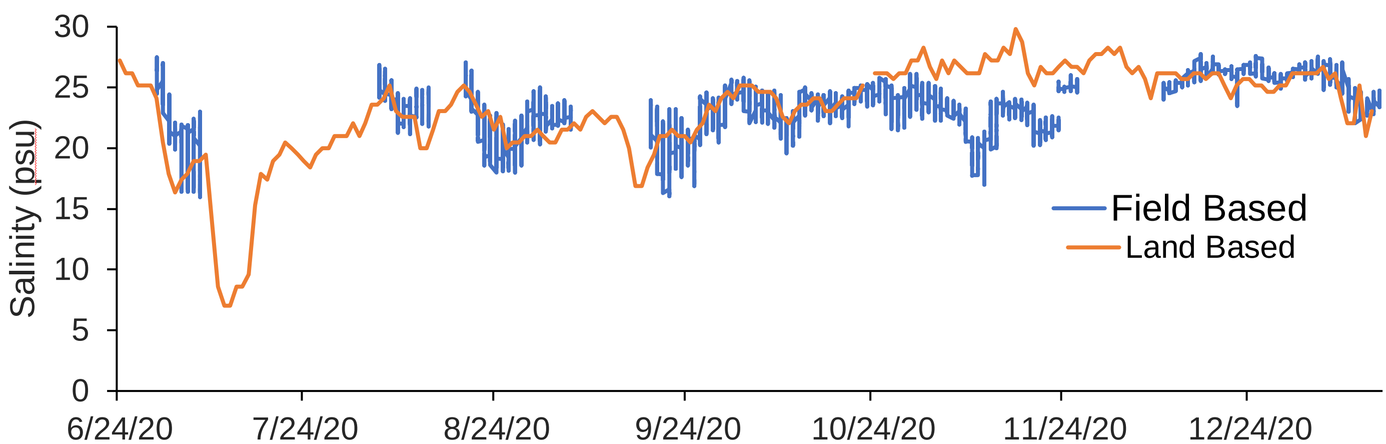


Figure 11. Growth of angelwing clams in the field (using buckets as a proxy) from stocking in late June 2020 to harvest in mid-January 2021.

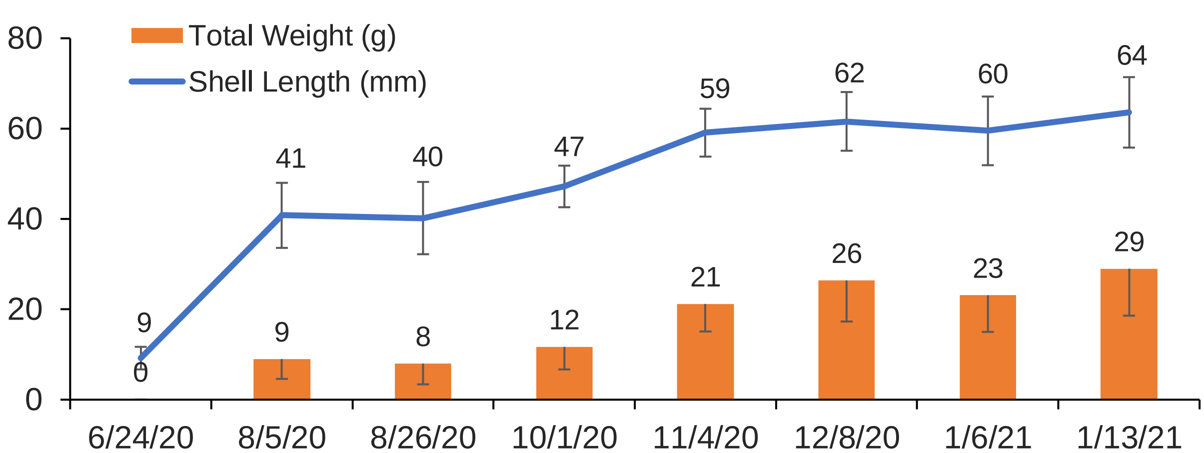


Figure 12. Survival of angelwing clams in the field (using buckets as a proxy) from stocking in late June 2020 to harvest in mid-January 2021. Note survival reported is not cumulative.

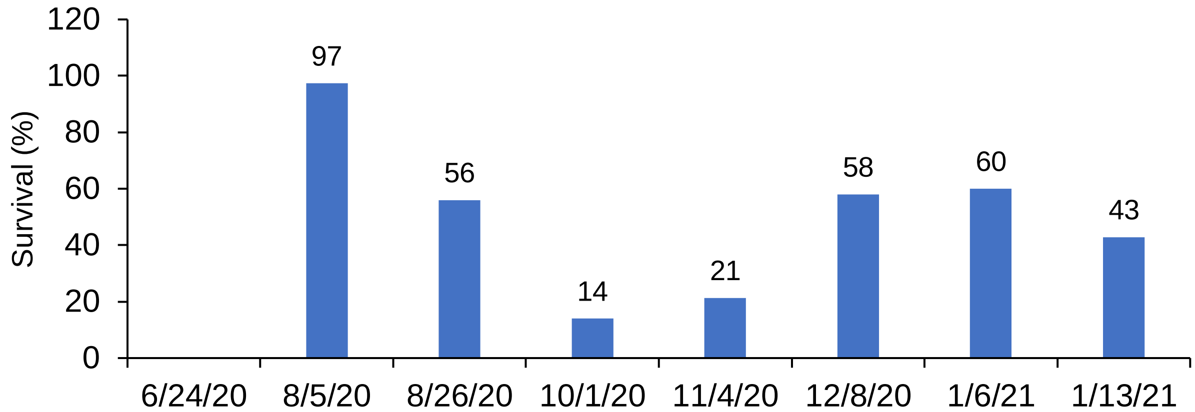


Figure 13. Harvesting a) bottom bag with internal PVC pipe frame and b) bottom cage, c) angelwing clams harvested from a bottom cage after 6.5 months in the field.

Figure 14. Harvesting bottom plant: a) cover netting removed revealing 4”-PVC pipe tubes, b) siphon holes of six angelwings in one of the tubes, c) commercial clam suction harvester used to harvest angelwing clams.

Figure 15. a) Angelwing clams harvested from the bottom plant after 6.5 months in the field, b) intact valves (shells) of dead angelwings obtained from extracted soil cores during harvest.

Figure 16. Size distribution of harvested angelwings both live clams and intact shells (dead) from the bottom plant.

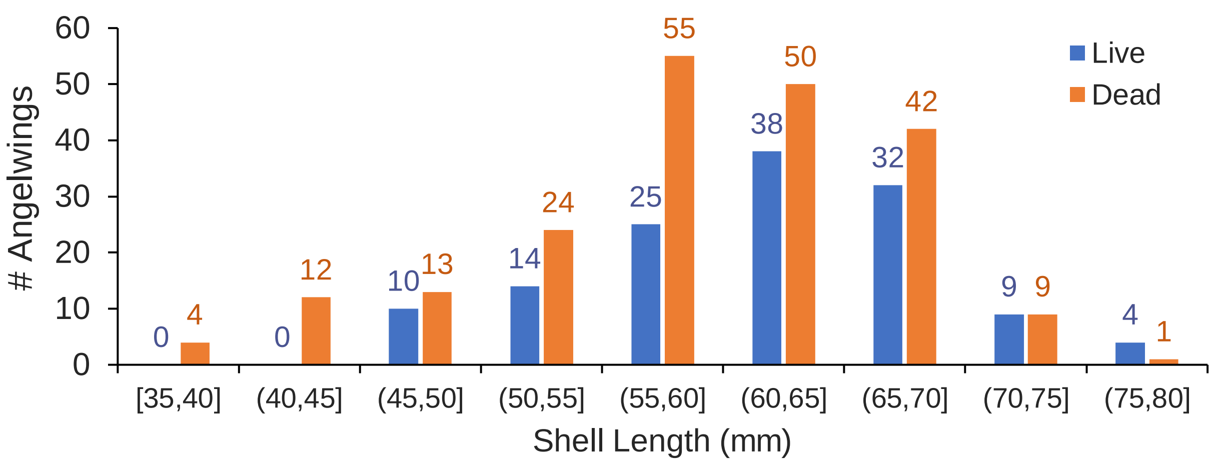


Figure 17. Growth of angelwing clams in the land-based raceways from stocking in July 2020 to harvest in mid-January 2021.

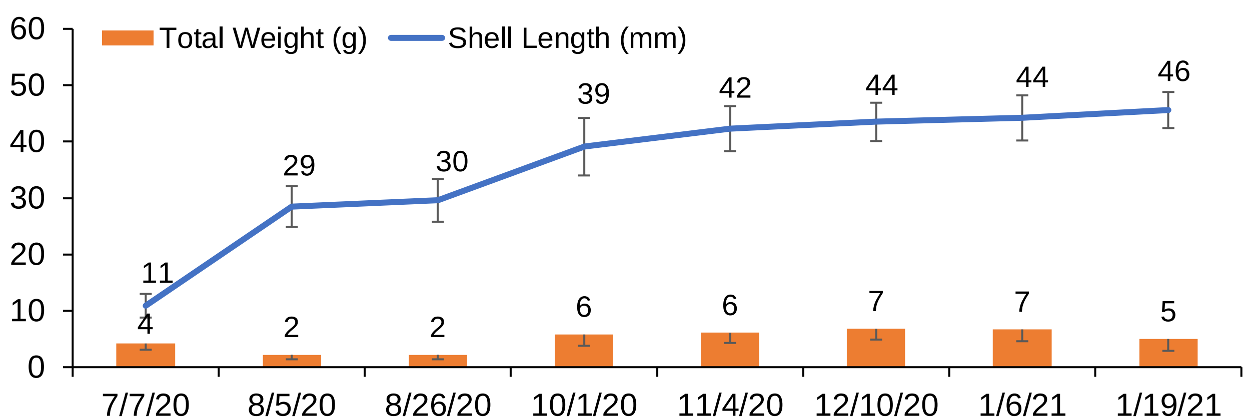


Figure 18. a) Angelwings clams transported to processor in saltwater; post-harvest methods evaluated: b) live packaged in modified atmosphere trays, c) partially cooked, flash frozen in vacuum bags.

Figure 19. Purged live angelwing clams, spawned on 7 May 2020, planted in the field using a bottom plant method on 1-2 July 2020, and harvested on 13-14 January 2021, just over 8 months from spawn to harvest.

Table 1. Summary of growth metrics, condition index, and survival of angelwings cultured over a 6.5-month period using a) field-based method (bottom plant) and b) land-based method (raceways).

Growout Method	Shell Length (mm)	Total Weight (grams)	Meat Weight (grams)	Dry Meat Weight (grams)	Condition Index	Survival (%)
Bottom Plant	61.6 ± 7.0	24.1 ± 7.4	6.5 ± 3.1	1.1 ± 0.5	7.2 ± 2.2	16.5
Raceway Tanks	46.3 ± 2.8	5.0 ± 2.1	1.0 ± 0.3	0.1 ± 0.1	3.1 ± 2.2	35.8 ± 3.8