THE NURSERY AND POND CULTURE OF BROWN SHRIMP

(*Farfantepenaeus aztecus*) IN ALABAMA

AS A LIVE BAIT PRODUCT

Except where reference is made to the work of others, the work described in this thesis is my own or was done in collaboration with my advisory committee.

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Stuart Padgett

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Stuart Padgett

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VITA

Stuart Padgett, son of Stanley Padgett and Auxiliadora Zeledon, was born in Managua, Nicaragua on November 2, 1976. He attended high school at the American Nicaraguan School in Managua, Nicaragua, and graduated in 1996. He entered college at the University of Mobile, San Marcos, Nicaragua, in August 1996 and earned a Bachelor of Science degree in Agribusiness with Emphasis in Aquaculture in May 2000. In August 2001, he entered graduate school at Auburn University to pursue a Master of Science degree in Fisheries and Allied Aquacultures. He married Regina Rivas, daughter of Ernesto Rivas and Ligia Mendieta, on December 21, 2002.

THESIS ABSTRACT

THE NURSERY AND POND CULTURE OF BROWN SHRIMP

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Stuart Padgett

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There are three native penaeid shrimp species of commercial importance in the northern Gulf of Mexico: *Litopenaeus setiferus* (white shrimp), *Farfantepenaeus duodarum* (pink shrimp), and *F. aztecus* (brown shrimp). These species not only have supported the food shrimp industry economy, but have also played an important role in the recreational and sport fishing industry in the Gulf of Mexico. Live shrimp for bait have been obtained through different methods, but demand continues to increase. Demand for bait shrimp has not been met by traditional capture methods in the Gulf area due to weather, currents, and environmental conditions, which vary among the different states in the Gulf. Research in different states has allowed for a better understanding of how to culture native shrimp species until desirable or marketable sizes are attained, providing a constant supply of the product.

In order to better understand the requirements of the species, a nursery and a grow-out phase culture system to produce live bait shrimp was studied in Gulf Shores, Alabama, in the summer of 2002, where brown shrimp *F. aztecus* were used in the study. The nursery phase was conducted in 15 fiberglass tanks where PL 10 were stocked. The nursery phase was a 21-day trial designed to evaluate the effect of salinity acclimation from 28 ppt to 15 ppt at day 2, day 6, day 12, and day 20, on growth and survival. No significant differences ($P>0.05$) between the treatments with respect to final mean weight (22.9 mg), survival (41.4 %), and estimated feed conversion ratio (1.58) were found. The nursed shrimp were then cultured in six brackish-water, plastic-lined ponds at Claude Peteet Mariculture Center to evaluate production at two stocking densities.

Shrimp were stocked at 20 and 40 post-larvae /m^2 in replicated ponds and cultured for 112 days. At harvest, shrimp were marketed as live bait shrimp in local bait shops. Growth rates for the two treatments were 0.54 and 0.44-g/ week, respectively. Final mean weights were 6.8 and 5.7grams for the low and high densities, respectively. Yields for the two treatments were: 742 and 838 kg/ha and survival and FCR's were: 58 and 35% and 5.1 and 7.1, respectively. There were no significant differences between treatments, but research did demonstrate that brown shrimp can be cultured, harvested, and sold into a live bait market.

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Style manual or journal used: Journal of the World Aquaculture Society

Computer software used: Microsoft Word, Statistical Analysis System v8.

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I . REVIEW OF LITERATURE

During the summer, millions of tourists travel to the Gulf of Mexico coast to enjoy warmer weather and activities associated with the coastal environment. Some of the favorite activities include tournament and recreational fishing. In 2001, states around the Gulf of Mexico, excluding Texas, experienced over 3 million marine recreational fishing participants who made 22.8 million trips and caught a total of 163 million fish (U.S. Marine Recreational Fisheries 2001). In 1998, over 250,000 anglers participated in Alabama's Marine Recreational Fishery, making over 968,000 fishing trips. The most important species of fish caught were sand sea trout, red snapper, Spanish mackerel, red drum, and spotted sea trout (Osborn 1999).

Fishermen in the Gulf report that the primary choices for live bait are shrimp and fish; and that "nine times out of ten, live bait outperforms any lure used," (Warren 2003). One of the biggest problems faced by anglers is that live bait products are only available seasonally, and supply for the products can be scarce at times, especially during peak fishing periods. Demand in the food shrimp industry also increases as tourists travel to the Gulf cities during the summer season, creating a challenge for this valuable resource and a conflict on who gets shrimp in the area.

The National Marine Fisheries Service announced that the western Gulf of Mexico should expect brown shrimp total production of approximately 65.5 million pounds during the 2002-2003 season making it the most valuable fishery in the Gulf (Smith 2002).

The three most important native species that support the commercial fisheries along the Gulf states are *Farfantepenaeus aztecus*, brown shrimp; *Penaeus duorarum,* pink shrimp; and *Litopenaeus setiferus*, white shrimp (Davis and Arnold 1994). In 1995, approximately 20.5 million pounds of the three species of shrimp were landed in Alabama, with an estimated value of $ 45 million (Wallace 1997). Commercial landings from the Gulf of Mexico account for the vast majority of the fishery, although geographic distribution of landings for each species fluctuates widely (Dixon 2001).

The natural distribution of *F. aztecus* extends from the Gulf of Mexico to the W. Atlantic, and from Yucatan to New York (Ackefors et al. 1994). In the U.S., besides their importance to commercial fisheries as food shrimp, all three species can be sold as a live or frozen bait product used by fishermen (Samocha et al. 1998). Special attention is given the government to the food shrimp industry, compared to the bait industry, since it is larger, more organized and brings in more money to the economy.

There are several problems associated with the current techniques used to obtain live bait and food shrimp. One of the concerns is that commercial shrimp trawling has a negative impact on both commercial and recreational marine species, as well as other species in the coastal bays. These losses have resulted in a concern advocating the reduction of shrimp-trawl by-catch (Texas Parks and Wildlife Department 1997).

Research has shown that a major source of mortality for red snapper is caused by shrimp trawling since this activity is done over sand and mud bottoms, where red snapper spend their first two years of life (National Marine Fisheries Service 1996). Another concern in the Gulf is the impact of shrimp by-catch on the Spanish and king mackerel resources, indicating the need for a reduction in the by-catch of non-target finfish and invertebrates in the shrimp trawl fishery (Surdi 1995). In Alabama, waters were closed to commercial and recreational shrimping on May 15, 2003, due to a drastic increase in the amount of by-catch washing ashore on the Gulf beaches of Alabama, which created a social problem in tourism (Alabama Department of Conservation: Shrimping Information 2002).

Irrespective of ecological and social concerns, it is necessary to respect the natural life cycle of shrimp, where catch rates are seasonal and vary with geographic location. Furthermore, natural spawning, variability of wind, currents, and other environmental factors affect larval transport and/or survival (Berkeley et al. 1985). In Florida the lowest harvests are in the summer and the highest catches are in the winter. In other regions, bait-size shrimp are available in the summer but very limited in the spring and fall, when demand is high.

Sub-adult shrimp in the Gulf of Mexico can be found in estuaries and are present spring through fall, but are most abundant in late spring and early summer (Copeland 1965; Trent, L 1966; Cook and Lindner 1970; Parker 1970). Capture of bait shrimp in the area is limited, and supply is dependent on capture, which varies with season. In the Mobile Bay area there are only 10 locations open to bait shrimping (Alabama Department of Conservation 2002). This was done to protect the food shrimp industry as the shrimp migrate to the ocean later on. Thus, opportunity for culturing marine shrimp so that they might be available throughout the year is an attractive alternative. Shrimp of a desired size for bait, available when needed and not subject to seasonal fluctuation, would be a valuable commodity.

Research on shrimp native to the northern Gulf of Mexico including *F. aztecus*, brown shrimp; *P. duorarum*, pink shrimp; and *L. setiferus*, white shrimp has been conducted at a variety of institutes in the United States. The first reports of pond culture research began almost 50 years ago in South Carolina by G. Robert Lunz of the Bears Bluff Laboratories Inc. (Sandifer et al. 1993).

In 1962, ponds for marine shrimp culture were constructed at Grand Terre Island, Louisiana. Brown shrimp and white shrimp used in these experiments were obtained from the wild in several ways and in unlimited amounts. The shrimp were then cultured in 0.25-acre ponds in order to determine stocking and feeding rates of cultured shrimp. Production ranged from 54 to 728 kg/ha and feed conversion ratios from 1.7 to 9.7 (Broom 1969).

In 1967 post-larval brown shrimp were used to stock two different treatments, which were reared from eggs spawned in the laboratory at the Commercial Fisheries Biological Laboratory, Galveston, Texas. The post-larvae were stocked at a rate of 22 shrimp per square meter with one pond fertilized with rice husks and the other one was not fertilized (Wheeler 1967).

In the seventies, culture experiments with *F. aztecus* and *L. setiferus* were conducted in 0.2 ha earthen ponds located in Brazoria and Orange Counties, Texas. Five experiments utilizing 32 individual ponds provided information on growth, production, survival, feed conversion, and condition of shrimp in commercial ponds. The shrimp used for these experiments were collected from the wild by using bait shrimp trawls in both counties. It was determined that *L. setiferus* was better suited for pond culture as a food size shrimp than *F. aztecus* (Parker and Holcomb 1973). Additionally, monoculture and polyculture studies with *F. aztecus*, *P. duorarum*, and *L. setiferus* and pompano (*Trachinotus carolinus*) were conducted at the Claude Peteet Mariculture Center (CPMC) in Gulf Shores, Alabama. Post-larval penaeid shrimp were obtained from a shrimp farm (Marifarms, Inc., Panama City, Florida). The post-larvae were nursed in nursery ponds fertilized with chicken manure. They were stocked at 750,00/ha and were reared for a month (April 19- May 20, 1977) and then transferred into grow-out ponds. A two-crop system was studied in 0.08 ha brackish water ponds, where consecutive 75-to 81-day crops of brown and white shrimp produced mean yields of 349 and 600 kg/ha. Survival ranged from 69 and 96%, feed conversions ranged from 4.0 and 2.3, and weights averaged 8.3 and 10.0 g (Tatum and Trimble 1978).

More recently, two pond experiments were conducted, at the Waddell Mariculture Center in 1985, to compare production characteristics of the native *L. setiferus* and Pacific *L. vannamei* in South Carolina. Post larvae of the two species were stocked in one 0.1 ha and one 0.25 ha ponds, at a density of 12 shrimp/m^2. They were fed a 25% protein commercial feed during a 147-day culture period. Survival in all ponds was greater than

90%, but growth and production of *L. setiferus* was lower than those obtained for *L. vannamei*. Growth and total yields of *L. setiferus* was 12.8 g and 1,555 kg/ha/crop compared to 19.7g and 2,477 kg/ha/crop for *L. vannamei*. In 1989, ponds were stocked at 60 *L. setiferus* PL's/m^2 and a final size of 15.2 g, survival of 87.5%, and a yield of 7,995 kg/ha was obtained. This study produced what is thought to be the highest production levels achieved with *L. setiferus* in pond culture (Sandifer *et* al.1993). Throughout the 1990's, most shrimp aquaculture research was directed toward food shrimp production and *L.vannamei* was the species of choice.

Due to high demand for bait shrimp, research efforts were renewed in 2001 at Claude Peteet Mariculture Center in Gulf Shores, Alabama where a study was designed to determine whether a native species could be produced and marketed as bait shrimp along the northern Gulf coast. The research involved the nursing and grow-out of native brown shrimp, *F. aztecus* through harvesting and marketing. Post larval shrimp were purchased from a private hatchery in Texas. Six ponds (0.1 ha) were stocked at densities of 88 and 44 PLs/m^2. A commercial 35% shrimp feed was provided twice a day and aeration as needed. A minimal size of 5 to 6 g shrimp was reached in approximately 10 weeks. Percent survival and final yields ranged from 8.3% to 16% and yields ranged from 490 kg/ha to 576 kg/ha. Low survivals were thought to be due to excessive handling during partial harvest techniques (Mays et al. 2003). A second trial was conducted and shrimp were stocked at 28 PL's/m^2. Survival and total yields were 41% and 559 kg/ha (Mays et al. 2003).

Mays (2003) also conducted a survey among bait shop operators in order to assess the needs, methods and quantities preferred by the bait dealers. This survey provided a better understanding of the seasonality and most importantly the desire of the sports and recreational fishermen for live bait shrimp. The survey indicated a significant demand for bait shrimp produced in culture ponds rather than harvested from the wild.

The following study was conducted to evaluate the influence of PL age on acclimation to brackish water, as well as the effect of stocking grow-out ponds different stocking densities. Four tanks of PL's were acclimated from 28 ppt to 15 ppt at four different points during a 21-day nursery period. The four treatments evaluated were: acclimation at Day 2 (Treatment 1), acclimation on Day 6 (Trt. 2), acclimation at Day 12 (Trt. 3), and acclimation on Day 20 (Trt. 4). The production of native brown shrimp raised in a nursery system for bait at two stocking densities 20 and 40 shrimp/m^2. This was determined by measuring harvest yield, mean weight, growth rate, survival, and feed conversion ratio (FCR).

II. MATERIALS AND METHODS

Nursery

Research was conducted at the Claude Peteet Mariculture Center (CPMC) in Gulf Shores, Alabama. The nursery system consisted of a series of tanks divided into two separate re-circulating systems; each system consisting of culture tanks, circulation pump (0.33 HP), and a biological filter. The first system consisted of twelve circular polyethylene culture tanks (795 L) and one reservoir tank (850 L). The second system was composed of three culture tanks (795 L) and one reservoir tank (795 L). In each culture tank, the water volume (550 L) was maintained by an internal standpipe (55.3 cm height), which was surrounded by an external screened pipe (250 mm mesh). A central regenerative blower (0.44 HP) was responsible for providing aeration to the tanks via two air stones in each tank.

All tanks were filled with filtered saltwater adjusted to 28 ppt salinity. After filling, water was chlorinated with 253 mL of liquid chlorine per tank. The tanks were aerated for seven days before stocking to allow the chlorine to dissipate. Once the system was dechlorinated, the water in the 17 culture tanks was treated with ethylenedinitrilo tetraacetic acid (EDTA) at a concentration of 2 ppb to chelate heavy metals that might be found in the water. One day before stocking, the system was inoculated with *Thalassiosira weissflogii* algal paste (Reed Mariculture Inc., San Jose, California, USA), at a rate of 0.1 ml paste/L.

Brown shrimp (*F. aztecus*) post larvae (PL 9), were obtained from Lone Star Shrimp Farms in Corpus Christi, Texas. Approximately 500,000 PL's were shipped to CPMC via Federal Express air on July 11, 2002. Upon arrival, the post larvae appeared healthy but were not very active due to the low temperature. Two of the shipment bags were randomly sampled for the determination of water quality parameters, which were as follows: Temperature 21.7 °C, salinity 34.1 ppt, dissolved oxygen (DO) 18.75 mg/L, and pH of 6.8. The PL's were acclimated to the temperature and salinity of the nursery tank water over a period of two hours in a 1,000 L acclimation tank containing oxygenated water (15 mg/L). To initiate the acclimation process the bags were unboxed and placed in the acclimation tank to allow temperatures to equilibrate. The PL's were then released from the bags into the acclimation tank and concentrated. New saltwater (28 ppt), was added to the acclimation tank in order to reduce the salinity over a period of about one hour.

At the end of the acclimation the parameters were: DO 11.7 mg/L, salinity 28.3 ppt, pH 7.3 and temperature was 26.1 °C. Once the shrimp were acclimated, the post larvae were siphoned into a plastic concentrator (57 L). The water was then agitated in order to distribute the PL's through the water column. Four sub-samples were collected and the PL's in each sample were counted and the average number of PL's per liter determined. Two concentrations were required in order to account for all the PL's. Once the PL's were counted, they were divided by volume into 15 plastic buckets and transferred into the 15 culture tanks in the nursery where they were stocked at a density of 60PL per liter. The total count for the PL's was 491,150. To evaluate the influence of

PL age on acclimation to brackish water, four tanks of PL were acclimated from 28 to 15 ppt at four different points during the 21-day nursery period.

On the second day of the nursery period, four tanks (1-4) in Treatment 1 were acclimated down from 28 to 15 ppt in a period of four hours. This was accomplished by using a PVC pipe with holes, which distributed well water evenly to the tanks at an adjusted flow rate of 3-ppt/ hour. On day 6, four tanks (9-12) in Treatment 2, were acclimated down from 28ppt to 15ppt using the same procedure mentioned above in a three hour period. The four tanks (5-8) in Treatment 3, were acclimated down to 15 ppt on day 12. The last three tanks (13-15) in Treatment 4, were acclimated down to 20 ppt on the 20th day. On the 21st day, all the tanks were acclimated up to 20 ppt to facilitate stocking into ponds with salinities of 20 ppt.

During acclimation and after stocking, PL's were fed *Artemia* (INVE Americas, Inc., Salt Lake City, Utah, USA) at a rate of 100-nauplii/ PL/ day for the first 3 days. In addition to *Artemia*; the PL's were offered a commercial feed four times per day. Biomass was estimated by weighing a known sample of PL's per culture tank in a beaker of water every three days. The average weight was calculated per tank in order to determine feeding rates. During the first six days the PL's were fed at an estimated 50% biomass per day with PL Ready Reserve (Zeigler® Bros, Inc., Gardners, Pennsylvania, USA). Between day seven and 16, they were fed at 25% of the estimated biomass with Rangen feed (Rangen Inc., Angleton, Texas, USA); and during the final seven days they were fed at 15% of their estimated biomass with Rangen feed (Table 1). Water parameters such as: temperature, D.O., pH, and salinity were recorded twice a day.

Table 1. Feeding regime utilized in the nursery phase of *F. aztecus* conducted at Claude Peteet Mariculture Center, Gulf Shores, Alabama, for a 21-day culture period (June 11-July 31, 2002).

Date	Feed Type	Feed Rate (% Biomass)
11-Jul	Artemia[a], PL Ready Reserve[b]	100/PL, 50
12-Jul	Artemia[a], PL Ready Reserve[b]	100/PL, 50
13-Jul	Artemia[a], PL Ready Reserve[b]	100/PL, 50
14- July- 16-July	PL Ready Reserve[b]	50
17-Jul	PL Ready Reserve[b], # 0 Crumble[c]	25
18-Jul	PL Ready Reserve[b], # 0 Crumble[c]	25
19-Jul	PL Ready Reserve[b], # 0 Crumble[c]	25
20-Jul	PL Ready Reserve[b], # 0 Crumble[c]	25
21- July- 25-July	# 0 Crumble[c]	25
26-Jul	# 0 Crumble[c], # 1 Crumble[c]	15
27-Jul	# 0 Crumble[c], # 1 Crumble[c]	15
28-Jul	# 0 Crumble[c], # 1 Crumble[c]	15
29-July – 31-July	# 1 Crumble[c]	15

[a]INVE Americas, Inc., Salt Lake City, UT, USA.

[b]Zeigler Bros, Inc., Gardners, PA, USA.

[c]Rangen, Inc., Angleton, TX, USA.

A sub-sample of water and PL's were collected every three days to determine TAN and mean weight, respectively. TAN was determined spectrophotometrically by using the Nessler methods (American Public Health Association et al., 1989).

At harvest, average weight, biomass and percent survival was calculated for each tank. To determine final number, four sub-samples of PL's were obtained from each culture tank, weighed and counted in order to determine an average number of PL's per gram. The number per gram and the harvested biomass was then used to determine the number of PL's per tank. Average final mean weights were determined by individually weighing 30 shrimp on an analytical balances.

Mean weight, yields, survival rate, and feed conversion ratios from each growth trial were analyzed by using a one-way analysis of variance to determine significant differences ($P<0.05$) among treatment means. Student-Newman-Keuls's multiple range test was used to identify significant differences among treatment means. All statistical analyses were conducted using the Statistical Analysis System v.8 (SAS Institute Inc. 2002).

Grow Out

The second component of this study was to determine the influence of stocking density on the performance of bait shrimp under pond production conditions. Two different stocking densities (20 and 40 shrimp/m^2) were evaluated in six, 0.1-ha plastic lined ponds. Each pond was equipped with a concrete harvest basin and an earthen bottom.

Shrimp were pooled and equally distributed to six ponds at a stocking density of about 20 and 40 shrimp/m^2, therefore three ponds per treatment. Before filling and stocking, ponds were prepared by drying and tilling the pond bottoms. After tilling, the ponds were filled with brackish water supplied from the Gulf Intracoastal Waterway, between Mobile Bay and Perdido Bay. The water was filtered through a fine mesh sock as it entered each pond to prevent the introduction of larval predators. Prior to stocking, all six ponds were fertilized with 32-0-0 and 10-34-0 at a rate of 4 kg/ha and 8 kg/ha, respectively. One additional application was repeated for ponds that did not develop a good algae bloom.

In order to help distribute the fertilizers through the water column and when needed to maintain a dissolved oxygen level higher than 3 mg/ L, one 2 HP spiral type paddle wheel aerator (Little John, Quinton, Alabama, USA) and a 1HP aspirator aerator (AireO_2, Minneapolis, Minnesota, USA) were used in each pond. Morning and afternoon water quality parameters recorded on a daily basis were temperature, salinity, D.O., and pH. Twice each week a sample of water was taken from each pond and TAN concentration was determined by using a spectrophotometer by the Nessler method (American Public Health Association et al., 1989). Growth sampling took place weekly using a cast net to capture shrimp. Between 60 and100 shrimp per pond were weighed and counted in order to calculate average weights as well as weekly growth.

The shrimp were fed a 35% protein pelleted feed (Burris Mill and Feed Inc., Franklinton, LA, USA) during the culture period. PL's were fed at an initial amount of 800 grams per day per pond (8 kg/ ha) divided into morning and afternoon feedings during the first two weeks. Starting on week three and until week seven, shrimp were fed at 15 % biomass. From week seven to week eleven, a 2:1 estimated feed conversion ratio 1-g/week growth and an estimated 80 % survival was used to determine the feeding rates. From week eleven through the end of the culture period at week 16, a 0.5g/wk growth rate and an estimated 50 % survival rate were used to calculate feed rates.

Ponds were harvested in alternating treatments (high or low) on October 17, November 1, 15, and 22, 2002; representing 112 days of pond culture. The night before harvesting, the water level in the ponds was dropped to about 1/3 of the volume. Early the next morning, the water level was dropped until bottom sediment was exposed at the shallow end. A vortex-type shrimp harvester pump was placed in the concrete harvest basin located in the deep part of the pond. The shrimp harvester (Aqua-Life Harvester Magic Valley Heliarc, Idaho, USA) was used to pump the water out of the ponds through a hose connected to a de-watering tower, which separated the water from the shrimp.

Once the shrimp were passed over the tower, they were moved into one of two hauling tanks containing oxygenated seawater on the back of a hauling truck. Once in the tank, the truck was driven to a holding area. Approximately 100 shrimp were randomly collected from each pond and individually weighed. The shrimp in the hauling tanks were gravity drained into shrimp baskets (which allowed for the water to drain off) and weighed. The shrimp were then placed in two flow through 17 m^3 concrete holding tanks, where they were kept alive until they were sold to the local bait and tackle stores. Each holding tank had a set of seven air stones per side to mix and aerate the water. A 0.3-HP submersible pump located inside one holding tank was set up with two oxygen injectors (one in each tank) in order to inject oxygen and maintain dissolved oxygen levels above 6mg /L throughout the system while the shrimp awaited their buyers.

Bait shop operators were called on the day of harvest and requests were taken to have shrimp ready for pick up. Before the buyers arrived, the shrimp were weighed and placed in a 1000 L tank, which was prepared with pond water and diffused oxygen. Dip nets were used to transport the shrimp into the live haul tanks provided by the bait shop operators.

Mean weight, yields, survival rate, and feed conversion ratios from the two culture densities were analyzed by a one-way analysis of variance to determine significant differences ($P<0.05$) among treatment means. Student-Newman-Keuls's multiple range test was used to identify significant differences among treatment means. All statistical analyses were conducted using the Statistical Analysis System v.8 (SAS Institute Inc. 2002).

III. RESULTS AND DISCUSSION

Nursery

One of the most important aspects when replicating the behavior of a species in an artificial environment is to adapt the species to site specific parameters and study its behavior through different life stages. This study evaluates the influence of PL age on acclimation to brackish water from 28 to 15 ppt at different points in a 21-day nursery period. During the nursery period, morning dissolved oxygen readings in the tanks ranged from 3.4 to 6.8. Higher recorded DO values were observed in the tanks closest to the air blower. The lowest DO values were observed in the tanks furthest from the blower, where an independent biological filtration system was in place. Morning mean temperatures ranged from 24.5 to 29 °C. pH values in the morning ranged from 7.45 to 8.15, and TAN values ranged from 3.13 to > 15 ppt (Table 2).

At the conclusion of the nursery trial, growth, final weights, yield, survival and FCR were determined and presented in Table 3. Growth by treatment over the 21-day nursery can be observed in Figure 1. The statistical analyses reveal that there were no significant differences between the treatments for final weights, yield, FCR, or survival. There is suggestive, but inconclusive evidence of a difference for biomass between the treatment 1 (Day 2) and treatment 4 (Day 20). Two sided p-value = 0.0589 (Table 3).

Table 2. Temperature, dissolved oxygen (D.O.), pH, total ammonia-nitrogen (TAN) observations from nursery phase. Figures are displayed as mean ± standard deviation and minimum/ maximum values (below in parenthesis).

	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Temperature °C	26.8 ±1.61	26.3 ±1.30	26.7 ±1.60	26.5 ±1.38
	(24.5, 28.9)	(24.4, 28.4)	(24.4, 29.1)	(24.6, 28.7)
D.O. (mg/L)	5.66 ±0.99	5.54 ±1.06	5.30 ±1.17	5.14 ±0.83
	(4.26, 6.79)	(4.00, 6.09)	(3.38, 6.74)	(3.89, 6.09)
pH	7.86 ±0.16	7.94 ±0.11	7.96 ±0.14	7.82 ±0.18
	(7.61, 8.16)	(7.80, 8.15)	(7.90, 8.11)	(7.45, 8.13)
TAN (ppm)	10.87 ±3.82	11.14 ±2.82	11.78 ±2.70	11.27 ±2.86
	(3.13, >15)	(5.62, >15)	(6.57, >15)	(5.77, >15)

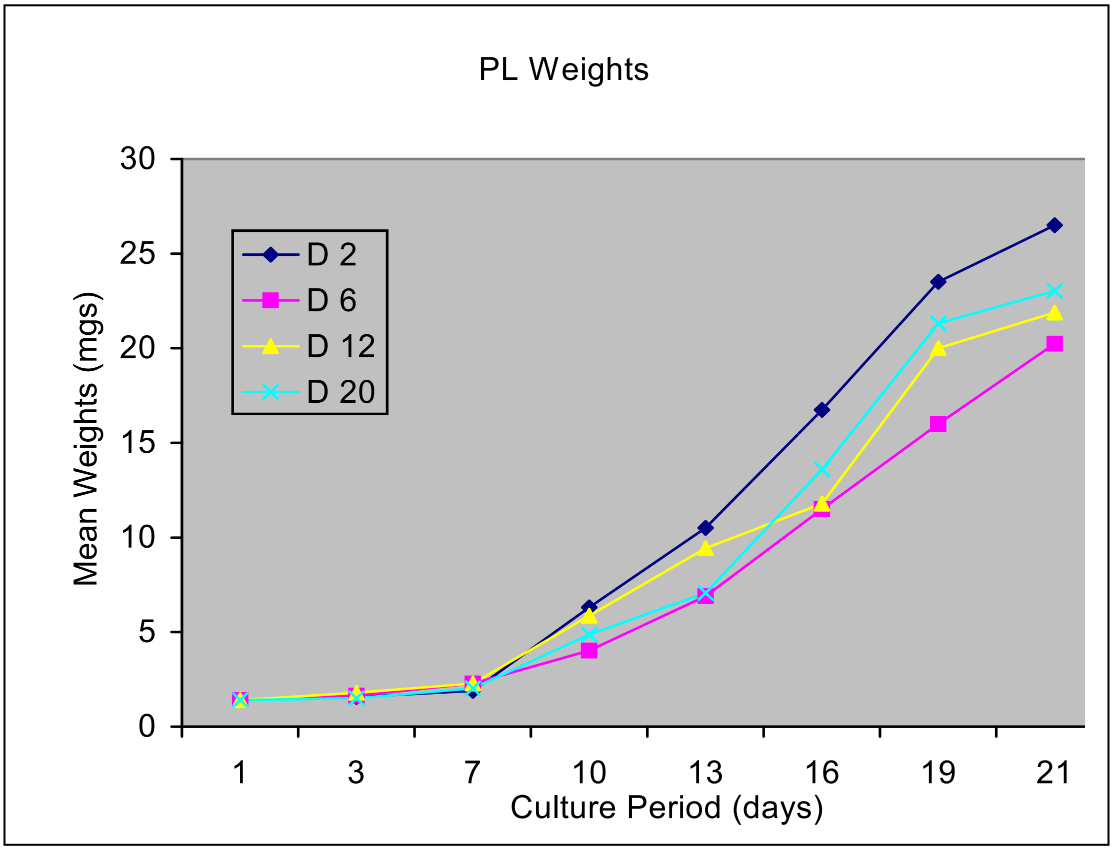
Treatment 1 = At day 2 salinity was reduced from 28 to 15 ppt.

Treatment 2 = at day 6 salinity was reduced from 28 to 15 ppt

Treatment 3 = at day 12 salinity was reduced from 28 to 15 ppt

Treatment 4 = at day 20 salinity was reduced from 28 to 15 ppt

Figure 1. Periodic weights of *F. aztecus* acclimated from 28 ppt to 15 ppt at different points in time (Age) during a 21-day culture period (June 11-July 31, 2002).



Treatment 1 = at day 2 (PL 12) salinity was reduced from 28 to 15 ppt

Treatment 2 = at day 6 (PL 16) salinity was reduced from 28 to 15 ppt

Treatment 3 = at day 12 (PL 22) salinity was reduced from 28 to 15 ppt
.
Treatment 4 = at day 20 (PL 30) salinity was reduced from 28 to 15 ppt

Table 3. Harvest results for the nursery phase of *F. aztecus* conducted at Claude Peteet Mariculture Center, Gulf Shores, Alabama, for a 21-day culture period (June 11-July 30, 2002). Figures are displayed as mean ± standard deviation and minimum/ maximum values (below in parenthesis).

Paramenter/ P-value	Treatment 1	Treatment 2	Treatment 3	Treatment 4
% Survival 0.6773	29.1 ±5.72	43.5 ±5.25	41.7 ±4.14	41.4 ±4.54
	(32.7, 45.4)	(36.6, 49.2)	(38.6, 47.9)	(36.6, 44.7)
FCR 0.0821	1.51 ±0.09	1.79 ±0.29	1.55 ±0.11	1.42 ±0.12
	(1.39, 1.59)	(1.55, 2.22)	(1.41, 1.65)	(1.28, 1.50)
Yield 0.0589	638.9 ±40.4	583.3 ±85.2	668.4 ±50.0	727.3 ±67.3
	(647.2, 740.5)	(463.1, 662.7)	(622.6, 731.2)	(686.9, 804.9)
Final weight (mg) 0.0564	26.5 ±2.41	20.2 ±1.26	28.9 ±3.67	23.0 ±3.79
	(23.8, 28.7)	(18.5, 21.3)	(17.9, 26.7)	(19.6, 27.1)

Treatment 1 = at day 2 (PL 12) salinity was reduced from 28 to 15 ppt

Treatment 2 = at day 6 (PL 16) salinity was reduced from 28 to 15 ppt

Treatment 3 = at day 12 (PL 22) salinity was reduced from 28 to 15 ppt
.
Treatment 4 = at day 20 (PL 30) salinity was reduced from 28 to 15 ppt

Survival in the four treatments ranged from 39.1% to 43.4% (Table 3). The average survival across all treatments was 41.1%. Survival for all treatments was low and showed no significant difference among treatments. Research in the past has suggested that the post larvae of *F. aztecus* grew equally well at salinities of 2 to 40 ppt. It was also found that the growth rate of *F. aztecus* increased rapidly between 15 and 20^0C, but at a slower rate between 20 and 25^0C (Zein-Eldin and Griffith 1969). In a recent study done at Auburn University, it was observed that the capacity of brown shrimp to acclimate to low salinity water improves after PL 13 and that before this age, the PL's are not tolerant to low salinity waters (Saoud and Davis 2002).

The 22-day nursery trial done by Mays (2003) compared the effects of two different salinities and the effects of EDTA water treatments on the survival and growth of brown shrimp. The results indicated that at 32 ppt, there was a significantly higher survival (51.3%) when compared to the 16 ppt treatment (44.4%). Also, there was a lower mean weight and FCR at 32 ppt (11.8mg, 1.75) compared to (21.2 mg, and 2.09 obtained in the 16 ppt treatment The EDTA treatment did not influence growth or survival (Mays et al 2003).

At the end of the culture period, ammonia levels in the tanks were higher than 15 ppt in all tanks. This represent 0.54 mg/L of un-ionized ammonia calculated at a pH of 7.9 and at 26°C (Boyd and Tucker 1998). Wickins (1976) exposed ten species of penaeids to ammonia chloride in a series of acute and chronic static bioassays. The calculated 48-hour LC_{50} value for *F. aztecus* was 1.29 mg/L of NH_3-N at 28°C and 33 ppt salinity. The LC_{50} of total ammonia-N, NH_3-N, and nitrite-N on shrimp decreased with exposure time (Jiann-Chu 1990).

Growth and survival (41.1%) were low at 24.5 to 29°C during the 21-day nursery period. There was no observed difference in the survival of the PL's when comparing the treatments as the treatments were acclimated down in salinity. In a 1982 study comparing the growth and survival of *P. stylirostris* and *F. aztecus* in polyculture at different ratios, indicated that mean weight gains were higher at 30°C than at 20°C for all the treatments, respectively. Survivals were better at 20°C than at 30°C, where survival rates of 91 and 81% were obtained at 20°C and 30°C (Rubino et al 1983). The water source (in the site) used for the nursery fluctuates with the changes in tides, currents and other environmental interactions on a seasonal and almost a daily basis. This could cause a problem as runoff from farmlands, or other pollutants could be present in the site when water is obtained, since the only parameter monitored at the site is salinity.

The PL's were fed an algae paste, *Artemia* and artificial feed, which helped in starting the biological filter and bacteria in the culture tanks. In the tanks, the water parameters were negatively affected three days into the culture and this could have been the major cause of mortality in the system. In order to prevent this from happening in future research, an algae culture of *chaetoceros, tetraselmis*, or any other type of local algae and rotifers could be cultured and stocked in the culture system in a small scale algae room to allow for better bacterial and food sources which could help in starting and having a good biological filter running several days before the stocking date.

Grow-out Ponds

Two different stocking densities were used to determine their influence on the performance of bait shrimp under pond production conditions. In the 11 to 16 week culture period of this study, DO readings ranged from 1.3- 7.7, and 2.0 – 8.2 mg/L for the 20 and 40 shrimp/m^2 treatments, respectively. The highest recorded DO readings were in November, when water temperatures were the coolest. Feed inputs were reduced when cooler temperatures were observed in order to reduce over feeding. The lowest morning DO values were during August, and coincided with the highest temperatures. Morning temperatures ranged from 7.1 °C to 31.6 °C. The warmest observed temperatures were in August. pH readings ranged from 6.74 to 9.59 in both treatments. Total Ammonia-Nitrogen values ranged from below detectable levels to 4.29 ppm. Salinity during the culture period ranged from 10 to 21 ppt (Table 4).

At the conclusion of the pond grow-out study, growth rates, final weights, yields, survival, and FCR for the two densities were determined and presented in Table 5. By week 11, the shrimp had reached marketable size (Fig. 2). After ponds were harvested, growth rates of the PL's were determined to be at 0.55 g/wk for the 20-shrimp/m^2 treatments and 0.44 g/wk for the 40-shrimp/m^2 treatments. Average shrimp weights for the treatments were 6.8g and 5.7g for the 20 and 40 shrimp/m^2 treatments, respectively.

Table 4. Temperature, salinity, dissolved oxygen (D.O.), pH, total ammonia-nitrogen (TAN) observations from grow out phase of *F. aztecus* for a 112-day culture period (August 1- November 22, 2002). Figures are displayed as mean ± standard deviation and minimum/ maximum values (below in parentheses).

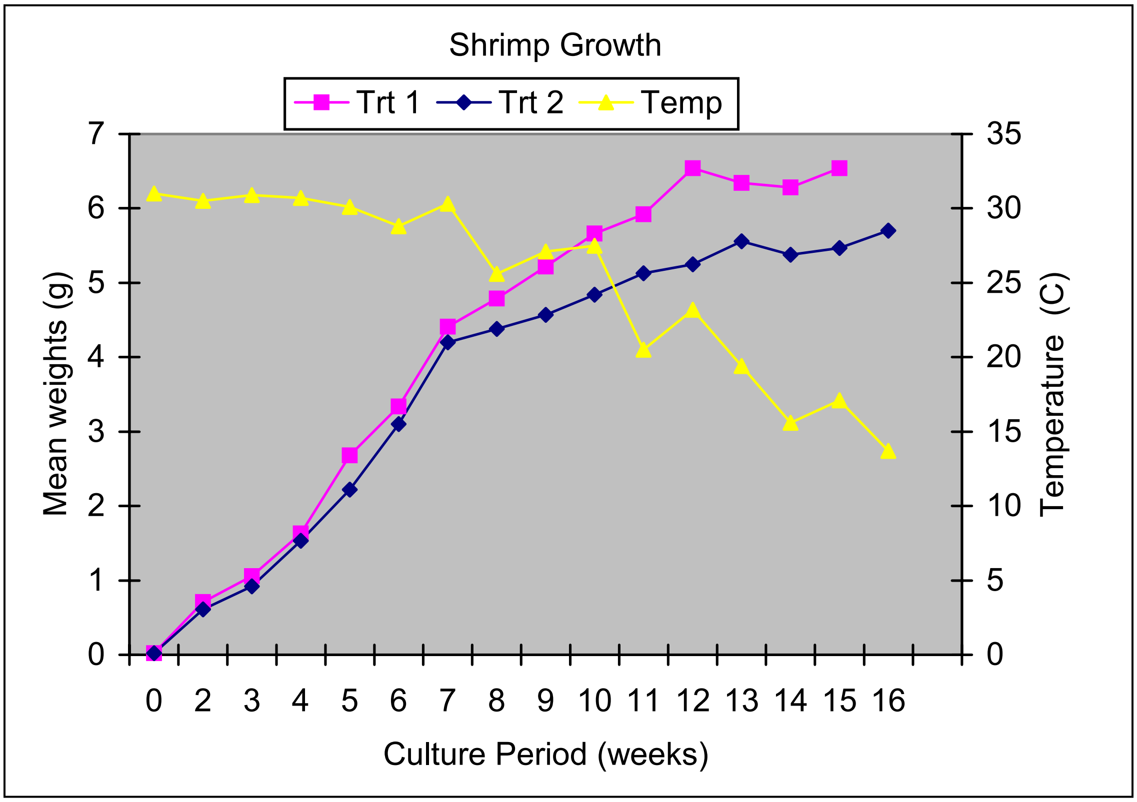
	20 Shrimp/m^2	40 Shrimp/m^2
Temperature °C	24.3 ± 7.04	24.3 ± 7.01
	(7.91, 31.7)	(9.04, 31.6)
D.O. (mg/L)	6.07 ± 2.87	6.04 ± 2.58
	(2.00, 14.12)	(2.20, 12.37)
PH	8.13 ± 0.46	7.95 ± 0.54
	(6.94, 9.31)	(6.74, 9.59)
Salinity (ppt)	14.6 ± 3.39	14.7 ± 3.33
	(10.3, 20.6)	(10.4, 20.9)
TAN (ppm)	0.30 ± 0.31	1.96 ± 1.26
	(ND, 1.42)	(ND, 4.29)

ND – Indicates below detectable limits.

Table 5. Harvest results for the grow out phase of *F. aztecus* for a 112 day culture period (August 1- November 22, 2002). Figures are displayed as mean ± standard deviation and minimum/ maximum values (below in parentheses).

	20 Shrimp/m^2	40 Shrimp/m^2	P-values
% Survival	58.3 ± 26.3	35.3 ± 2.52	0.2057
	(38.0, 88.0)	(33.0, 38.0)	
FCR	5.06 ± 1.30	7.10 ± 0.44	0.0622
	(3.80, 6.40)	(6.60, 7.40)	
Yield (Kg/ ha)	741.9 ± 293.0	838.1 ± 104.7	0.6206
	(458.8, 1043.8)	(770.6, 958.7)	
Final weight (Grams)	6.80 ± 0.27	5.64 ± 0.06	0.0019
	(6.54, 7.08)	(5.60, 5.71)	

Figure 2. Growth curves for the two stocking densities (20 and 40shrimp/m^2) in the pond grow out phase of the culture of *F. aztecus* during a sixteen-week culture period (August 1-November 22, 2002).



Trt 1 = 20 Shrimp/m^2 stocking density.

Trt 2 = 40 Shrimp/m^2 stocking density.

Survival rates for the two treatments were 58% for the 20 shrimp/m^2 and 35% for the 40-shrimp/m^2 treatment. Average harvest yields for the two treatments were 742 kg/ha for the 20-shrimp/m^2 treatments and 838 kg/ha for the 40-shrimp/m^2 treatments. Feed conversion ratio (FCR) for the two treatments was 5.1 and 7.1 for the 20 shrimp/m^2 and 40-shrimp/m^2 treatments, respectively.

Broom (1969) had similar results with brown shrimp, where yields ranged from 54 to 728 kg/ha, FCR ranging from 1.7 to 9.7, salinity fluctuation from 16 to 35 ppt, and a temperature range from 8 to 37°C, respectively. In two different studies comparing unfertilized with fertilized pond production of brown shrimp Wheeler (1967); survivals of 22.9% and 30.6%, yields of 192 lbs/acre and 451 lbs/acre, and final mean weights of 5.3 and 9.3g, respectively.

In his two-crop system at CPMC culturing brown shrimp during a culture period of 75- 81 days, Tatum (1978) obtained yields of 349 kg/ha, FCR 4.9, 69% survival, and a final mean weight of 8.3g, respectively. He also mentioned that FCR and survival were inversely related. Mays (2003) in his 2001 study had yields of 559 kg/ha, survivals of 41% and final weight of 5-6 grams in a 10 week culture period when culturing brown shrimp for bait in CPMC.

Feeding rates were based on stocking rates and an assumed survival rate initially set at 80% and later adjusted down to 50%. Realized survivals of 35% to 58% led to over feeding. Initial feeding rates were also calculated based on an expected feed conversion ratio of 2:1 and later on a 1-g/ wk. The actual growth rates of 0.4-0.5g/wk also constituted to excess feeding and high FCR's. The statistical analyses reveal that there are no significant differences between the two treatments for final weights, yield, FCR and survival.

An important factor that affected survivals and possibly FCR was the fact that almost 400 Kgs/ha of speckled trout were collected from one of the high-density ponds, which had 35% survival, and almost 100 Kgs/ha of speckled trout from another of the high-density ponds having 33% survival in the study. Speckled trout are carnivorous and would have predated on shrimp in the ponds. Heavy infestations of glass shrimp were also observed in the three ponds, which could have affected FCR in the culture ponds, since glass shrimp could compete with brown shrimp for food.

Survival in one of the high-density ponds could have been influenced by the fact that a good algae bloom was never obtained in this pond, after several fertilization treatments. A reason for this problem was the heavy infestation of mussels in the pond, making the water in the pond transparent for all the culture period. Fertilization and high feeding rates had no effect in providing a bloom during the warmer months of the culture period.

Awaiting the advent of warmer temperatures before entering the estuaries; it has been observed that over-wintering brown shrimp in the Gulf of Mexico may burrow into the bottom. There is laboratory evidence of this burrowing behavior in brown shrimp at temperatures below 18 °C (Lassuy 1983). This factor was also taken into consideration for the low survivals in both treatments at the time of harvest when temperatures were in the 18 to 20 °C ranges. Shrimp were found burrowing in the mud in the post-harvest period in the ponds. One possibility to minimize this problem could be to harvest during the warmer part of the day, or to harvest the ponds at night and prevent shrimp from burrowing in the mud as this species burrows more than the other species in the Gulf. The fishery for brown shrimp is a nighttime fishery. These shrimp usually burrow during the day and are active at night. Also, the differences in day and night catch rates are not as apparent in deeper waters as in the shallow waters (Cook and Lindner 1970). This could help in improving production results. Salinity over the culture period was reduced from 20.9 to 10.4. This fact along with the changes in temperature ranging from 34 to 7°C at the end of the culture period could have caused additional stress resulting in lower survivals in the pond culture. Laboratory experiments by Zein-Eldin and Griffith (1965) suggested that the temperature influences growth through a change in the molting rate rather than by affecting the increase in size per molt (Cook and Lindner 1970).

Another possibility for improving survival particularly during holding, would be to employ a molt test prior to harvest. Shrimp in the first two ponds harvested were in molt and post molt stages during harvest. Harvesting may be impaired since shrimp can burrow in the mud. Also, shrimp in their molting process have a lower possibility for survival during and after going through the harvester. At this point, water pressure, crowding, and selecting the shrimp over the dewatering stage of the harvest process can cause extra stressors and possible mutilations, which will later result in additional mortality, water quality deterioration, and a loss in the product profits in the live bait production process. The possibility of using a seine over the water surface at night, when shrimp are mostly active, could be an alternative for partial harvest when demand for the product does not merit the harvest of an entire pond and as a result a loss in the price due to mortality in the holding tanks.

In similar studies, results have varied not only due to management techniques, and available technology, but also because different areas along the Gulf and within a state have different geological and hydrological characteristics, making the water sources an important aspect to consider. Salinities within estuaries in the Gulf of Mexico, for example, can vary from 1 ppt to above 20 ppt in less than an hour (Saoud and Davis 2002). Techniques used in different studies can help in providing basic and important aspects to consider when trying to culture a species in an area different from where it naturally thrives. The hydrology in the Gulf of Mexico is different from the one in the Mobile Bay area. The water source used for aquaculture varies when looking at the different work done along the Gulf. Alabama's aquatic riches include 77,000 miles of streams, >500,000 acres of standing water, and most importantly, 1/12 of the flowing water in the 48 states go through Alabama and coastal rivers which end up in the Mobile basin (Wright, 2001). The water quality in Mobile Bay varies also from the one in Perdido Bay. The water quality in Perdido Bay fluctuates seasonally and on a daily basis, where surface runoff from agricultural and other production lands end up in the water.

A possible problem faced in the site where this study took place could be the location where the water used for culture is obtained. Surface runoff from the city of Gulf Shores ends up in the Gulf Intracoastal Waterway, where cargo vessels do continuous transportation of different materials, including their ballast, and recreational boating can affect the water quality. Water used at the site for culture is filtered by using mesh materials on inlets, reducing the entry of possible predators and disease vectors to a certain extent, but it does not help in reducing any pollutants, including pesticides. This is another variable that can have a negative effect in the culture of this particular species in an artificial environment since pond filling is done at different times and results vary when compared to hardier species like *L. vannamei*.

This study provides basic information on the different methods used in the nursery phase dealing with salinity acclimation at different early life stages and grow-out at different stocking densities of *F. aztecus* in brackish water ponds in Gulf Shores, Alabama. Research did demonstrate that brown shrimp can be nursed, cultured, harvested, and sold into a live bait market. Sequential research is needed in order to improve techniques in the nursery and in pond grow-out. This can further provide information to determine how salinity affects the post larvae through the different life stages, and how the interaction between fluctuating salinity and temperature at different densities can affect the production of live bait shrimp when observing or analyzing a specific site. In order to culture *F. aztecus* effectively, it would be practical to adapt to the species behavior, resulting in better performance of the shrimp and improved management techniques from established protocols in various areas of production.

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