To the Graduate Council,

I am submitting herewith a thesis written by Erin L. Marcus entitled "The Effects of Substrate Orientation and Color on Survival and Growth of Freshwater Prawn *Macrobrachium rosenbergii*". I have examined the final paper copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Masters of Science, with a major in Wildlife and Fisheries Science.

J. Larry Wilson

Dr. J. Larry Wilson, Major Professor

We have read this thesis and recommend its acceptance:

Thomas K. Hill

Accepted for the Council:

Vice Provost & Dean of Graduate Studies

The Effects of Substrate Orientation and Color on Survival and Growth of Freshwater Prawn *Macrobrachium rosenbergii*

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Erin Leigh Marcus
August 2002

DEDICATION

This thesis is dedicated to my parents, who supported me in my decision to attend graduate school, and to my soon-to-be-husband, who drove four hours every weekend to see me. I also dedicate this to my grandmother, a beautiful and wonderful woman, always full of life and happiness. I hope that my future holds the fullness and love that her life did.

ACKNOWLEDGEMENTS

I thank Dr. Larry Wilson for his tremendous support and generosity throughout my graduate school experience. Without his patience, guidance, and encouragement, I never would have had this opportunity. I also thank the rest of my committee, Drs. Thomas Hill and Richard Strange, for being patient and supportive throughout this effort.

Additional thanks are extended to John Taylor, Justin Laughlin, and Todd Sink for their great time commitment in helping to build the culture system in such a short time. I greatly appreciate their support during my grandmother's illness and death. Also, thank you to Aggy Spicer, Mike Doosey, Kim Cooper, and Alison Tanguay for helping with feedings, water quality readings, and prawn counts throughout the experiment. Finally, thanks to the University of Tennessee staff at Joseph E. Johnson Animal Research and Teaching Unit for all their hard work and assistance throughout the project.

ABSTRACT

Post larvae (PL) freshwater prawn (*Macrobrachium rosenbergii*) were reared in rectangular and circular tanks to determine the effects of orientation and color of added substrate. In the rectangular tanks (400L), 2000 prawn, with a mean initial weight of 0.05 grams per animal, were nursed for 65 days at 25.5°C (78°F). Brown polyester mesh netting (6 X 6 mm) was added to each of the six tanks, increasing the surface area of each tank by 99% (9335 cm^2). In three tanks, substrate was arranged in horizontal rows; the other three tanks had substrate arranged vertically. There were no significant differences in survival of prawn between the horizontal (56%) and vertical (53%) substrates. Differences in growth were also insignificant. Final mean growth was 0.34 grams on horizontal substrate and 0.34 grams on vertical substrate.

In the 400 L circular tanks, polyester mesh netting material (6 X 6 mm) was used in four horizontal substrate pieces per tank, increasing surface area by 186% (21677 cm^2). Three tanks contained the addition of brown substrate and the other three contained tan substrate. Prawn were stocked at 1950 per tank, with an average initial weight of 0.1 grams per prawn, and nursed for 60 days. There were

statistically significant differences in survival rates between brown (46%) and tan (40%) colored substrates. There was a slight difference in prawn growth between the substrate colors, but not statistically significant. Prawn on tan substrate had a final mean weight of 0.37 grams while prawn on brown substrate weighed 0.34 grams per animal. As the prawn grew larger, they became more aggressive and more cannibalistic, which resulted in decreased survival rates and increased size of the survivors.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

TABLE PAGE

CHAPTER I

INTRODUCTION

Commercial production of the freshwater prawn, *Macrobrachium rosenbergii* (Figure 1), has become increasingly popular in the southeastern United States during the past decade. Biologists and farmers have utilized technical studies and first-hand experiences to transform culture of the freshwater prawn into a fast-growing, potentially money-making business. As a result of these studies, breeding and rearing prawn in aquacultural environments have been successful. *Macrobrachium* production is limited to a single seasonal crop in temperate regions. Sandifer and Smith (1977) reported that South Carolina had a growing season of six months, while in Florida, it was reported that the growing season was nine months (Willis and Berrigan 1977).

It has also been observed that particularly in the nursery phase, prawn begin to show signs of increased aggression and cannibalism. In order to meet optimal production numbers, cannibalism and aggression should be limited in both nursery and grow-out stages of production.

Figure 1. *Macrobrachium rosenbergii*, the freshwater prawn.

Using substrate material to increase surface area has been studied in order to minimize territorialism and cannibalism. Smith and Standifer (1979a, 1979b) found that prawn concentrate on the edges of substrate and a layered mesh design was recommended. When black mesh and green mesh were compared, they found that the prawn did not prefer one color design over the other. Kneale and Wang (1979) found that the number of habitat pieces per tank had no effect on survival, but increased growth was seen with additional pieces.

In the nursery phase, postlarvae are reared in a climate-controlled building for 30-60 days. Either small ponds or tanks should be used in either flow-through or recirculating systems. By increasing the surface area in ponds or tanks, prawn have been stocked successfully at 5 animals per liter.

The objectives of this experiment were: 1) to determine differences in prawn survival when using either horizontal or vertical substrate, and 2) to determine if tan or brown substrate resulted in greater prawn survival. Growth rates of prawn were also determined during the 60-65 day experiments.

CHAPTER II

LITERATURE REVIEW

Since the freshwater prawn have become an aquaculture species, only a few studies have been done. Such studies are important in order to help farmers and scientists achieve maximum survival and weight gain in prawn. Many studies related to influence of temperature variation, stocking densities, surface area, increased biomass, and weight gain have been reported. All of these studies have been influential in initiating studies related to substrate types and amounts.

In an experiment performed by D'Abramo et al. (2000), weight gain was evaluated in combinations of varying water volume, bottom surface area, and water replacement levels. After the 60-day experiment, prawn were found to show significant differences in weight gain under conditions of greater water volume and bottom surface area and under conditions of greater bottom surface area and a lower rate of water replacement.

Marques et al. (2000) studied density differences in cages during the nursery stage. They discovered that biomass increased with higher stocking densities when compared to lower stocking densities. However, average weight gain was higher in the lower density cages than it was in the higher density cages. They reported no significant differences in survival among varying density rates.

In another experiment that evaluated survival and growth rates, Kneale and Wang (1979) also showed that survival rates were greater in tanks with lower stocking densities (84%) versus tanks with higher stocking densities (39%). The mortality shift occurred between weeks eight and nine of nursery production. In the same experiment, they also studied survival rates as influenced by temperature. They found that at 24°C, survival rates were 78% versus 43% survival at 28°C. However, overall growth rates were greater at the higher temperatures (0.41 g) than at lower temperatures (0.23 g).

Sandifer and Smith (1974, 1975, 1976, 1977) have conducted laboratory experiments on the use of artificial habitats in rearing postlarvae. Smith and Sandifer (1975) compared horizontal and vertical substrates versus no substrate in a 4-week study. In the tanks containing horizontal substrate, two frames of five-tiered fiberglass screen were used. The tanks with vertical substrate contained one frame with ten-tiered fiberglass. In tanks with no substrate, they found that survival was 25% lower (mean survival of 53.4%), after four weeks, than in tanks containing substrate (mean survival of 88.7%). There was a slightly higher survival rate in tanks containing horizontal substrate than in tanks containing vertical substrate. However, survival rates remained similar until after the eighth week of the experiment. Mean mortality was reported at 34.7, 45.5, and 67.6% for tanks with horizontal substrate, vertical substrates, and no substrate, respectively.

Tidwell et al. (1999) investigated the effect of stocking density on nursery production of juvenile freshwater prawn. Tanks were stocked at densities of 2.3 prawn/L, 4.6 prawn/L, and 9.3 prawn/L. In the 60-day experiment, average individual weight for all stocking densities was the same (0.58 g). Survival was significantly lower in tanks with higher stocking densities (62%); however, greater numbers of juveniles on a prawn/L basis (5 g/L) were produced.

In an investigation performed by Molina (1990), white and black habitats were compared to the lack of substrate. No significant differences in average weight gain (0.55 g), mean survival (76%), total yield, and food conversion ratios were found among prawn on black substrate of varying material and mesh sizes. The white substrate, however, produced greater prawn survival (83.5%). When no substrate was used, mean survival was very low (33%), but mean final weight was high (0.75 g).

Cohen et al. (1983) observed that added substrate in outdoor ponds increased total pond production by 14% and the average size of prawn was increased by 13%. In a similar experiment, added substrate of 80% increased total production by 18% (Tidwell et al. 1999). Horizontal plastic mesh and strips of "oyster netting" were used to increase substrate by 80%. They found that after stocking 120,000 prawn per hectare compared to 60,000 prawn per hectare, total yield was greater (1557 prawn) in the higher density ponds than in the lower density ponds (1156 prawn). However, final weight was greater in the lower density ponds (25 g) than in the higher density ponds (18.2 g). Ra'anan et al. (1984) reported that added substrate was more effective when systems were intensively stocked; however, Tidwell et al. (1998) found that when systems were stocked at lower densities, production increased by 20% and size was increased by 23%.

When handling prawn, some mortalities are expected. Few experiments have shown the influence of increased handling throughout experiments with prawn. In a study with the Australian freshwater crayfish, *Cherax destructor*, Farrell and Leonard (2000) found that handling and interacting with the animals decreased growth rates. They hypothesized that increased handling promoted aggression, possibly due to increased contact when the animals were returned to the tanks. Another stress factor negatively related to weight gain was the temperature change during the 10-minute handling procedure.

CHAPTER III

EARLY LIFE HISTORY

Freshwater prawn, *Macrobrachium rosenbergii,* has been commercially produced as a food item for many decades. *Macrobrachium rosenbergii* is native to the Indo-Pacific area, specifically in the countries of Thailand, Malaysia, Vietnam, and India. As a result of overfishing and habitat destruction, freshwater prawn production in these countries could not meet consumer demand. During the 1970's and 1980's, South Carolina, Florida, Texas, and Louisiana began studying production techniques. The freshwater prawn, also known as the giant river prawn or giant Malaysian prawn, belongs to the family Palaemonidae. Along with *Macrobrachium*, Palaemonidae also includes the genera *Palaeomonetes*, *Palaemon*, and *Leander*. *Palaeomonetes* includes the freshwater glass shrimp and *Palaemon* and *Leander* includes the marine shrimp.

Biology and Life Cycles

Breeding

Freshwater prawn breed and spawn in warm water. Female prawns may lay 10,000 to 50,000 eggs, four to five times a year, after they have reached six months of age. All prawn have a hard outer skeleton that must be shed regularly with increased growth. Breeding takes place at about 21°C (70°F) between a soft-shell female that has just molted, and a hard-shell male. The male protects the female with his long claws until her shell hardens. The male then deposits a sperm pouch between the female's third and fourth pair of walking legs. Within a few hours, the female lays her eggs and they are fertilized. The female then incubates the eggs underneath her abdomen. Water is circulated around the egg mass using abdomenal appendages called pleopods. This helps to oxygenate water and remove debris. In 28°C (82°F) water or higher, the eggs will turn from orange to brown and then to gray before they hatch, which is approximately three weeks after fertilization.

Life Stages

As larvae, the prawn swim upside down and tail first. The larvae must migrate to brackish water with a salinity of 9-19 ppt within 48 hours in order to survive. The larvae feed on large phytoplankton, small zooplankton, and the larval stages of other aquatic invertebrates. The larvae molt 11 times, each a different stage of metamorphosis. After the last molt, the larvae transform to the post-larvae stage. The time that expires during these molts depends on environmental conditions such as food availability, temperature, light, and water quality. Under appropriate conditions, larvae become postlarvae within 15-40 days.

After undergoing 11 molts, the prawn reach the postlarvae stage. Juvenile prawns weigh 6-9 mg and are approximately 7-10 mm long. They are no longer free-swimming, but prefer to crawl around in benthic areas of nursery water. As postlarvae, the prawn migrate back to freshwater where they eat larger pieces of animal and plant material, including insects, algae, mollusks, worms, fish, and feces of animals and fish (D'Abramo et al. 1995). If food and space become limited, the prawn is likely to become cannibalistic.

The last stage of prawn growth is the adult stage. Adults have a blue-green color that may change slightly with diet variation. At this stage males and females are easily distinguishable. The males are larger, specifically in the head region, with larger claws. The walking legs of males are set closer together. The base of the last pair of walking legs expands inward to form a flap over the gonopore through which sperm are released. The female has a wide gap between her last pair of walking legs and they have a genital opening on the base of the third pair of walking legs (D'Abramo et al. 2000).

There are three types of male *Macrobrachium*. The blue-claw male (BC) has long, spiny blue claws. The blue claws are generally more reproductively active and more successful in mating. The other two are the orange-claw (OC) and the strong orange-claw (SOC). Males usually begin their development as orange claws, then, mature to strong orange claws, and finally to blue claws. There are also three types of female *Macrobrachium*: the ovigerous female (OV) are the egg carriers, the open females (OP) once had eggs, and the virgin females (V) that have never had eggs (Ra'anan and Cohen 1985).

Culture Methods

The three phases of freshwater prawn culture are hatchery, nursery, and pond grow-out. The hatchery phase should begin with healthy broodstock. Broodstock should be held in a temperature controlled building in large tanks or raceways. Temperature should remain between 25 and 30°C, with salinity ranging between 0-5 ppt and dissolved oxygen should be greater than 5 mg/L. The pH should range between

7.7 and 8.4 and ammonia, nitrite, and nitrate should be at minimal levels, close to 0.0 mg/L. Finally, hardness and alkalinity should be greater than 50 ppm.

Prawn broodstock should be stocked at a density of 1.0 g prawn per liter of water at a ratio of 10 females per 3 males. Broodstock should be fed a high energy, 35% protein, 3.0 kcal/g, pelleted diet with 0.5% highly unsaturated fatty acids. They should be fed 1-3% of their body weight per day divided into approximately three feedings. Substrate to increase surface area is necessary to minimize aggression and cannibalism. Two days after stocking females, the salinity should be increased to 5-8 ppt. There should also be plenty of oxygen, water flow, and light, since light is important in visual feeding (Moller 1978).

After the larvae have hatched, they should be removed and added to the larval culture system. Larval prawn should be stocked at a density of 50-80 per liter and the salinity should be raised again to 8-12 ppt over a 2-day period. Physical water quality parameters should be kept similar to the broodstock holding requirements. Larvae should be fed a diet of brine shrimp at a rate of 1000 shrimp per liter of water. After the 11 growth stages have been completed, the larvae are called postlarvae.

Postlarvae should then be transferred into the nursery to grow to juveniles, which generally takes 30 to 60 days. Small ponds and/or tanks in a climate-controlled building are the best habitat for postlarvae. Water recirculation tanks are recommended to conserve water and heat, but flow-through systems with heaters can also be used. Biological filtration can be accomplished with a biofilter that contains at least 6% of the total volume of the tanks. Any biofilter can be used as long as it removes toxic ammonia and nitrites from the system. Crushed oyster shell is recommended as the filter substrate (Daniels et al. 1995). Again, surface area should be increased with a good substrate and ponds/tanks should be no deeper than 1.22 meters. Stocking densities should be about 5 postlarvae per liter. Their diet should consist of a small trout pellet with high crude protein, fed twice each day. Three times a week, beef liver can be fed as a supplemental protein source. After the nursery phase, postlarvae should weigh about 0.3 grams with a survival rate of 65-75% expected.

The final stage of prawn culture is the grow-out phase. When postlarvae have reached 0.3 grams, they can be transferred to the outdoor grow-out ponds. Grow-out ponds should have a good supply of fresh water, plenty of aeration, and soil with a good water retention time. Water quality characteristics should include a pH range of 7-8.5 and a water hardness range of 15-150 ppm. Temperature in the ponds must be above 20°C to stock juveniles. This temperature occurs in early to mid-June in southeastern states. Pond surface area should range between 0.4 to 2.0 hectares with a minimum depth of 0.6 meters; the bottom should be free from obstructions.

Juveniles should be acclimated to pond conditions by gradually replacing the water in which they are being held with the water from the pond. The prawn should be stocked at a density of 28,920 to 39,535 per hectare, with a grow-out period ranging from 120-150 days. Prawn will eat insect larvae and worms and can also be fed a sinking channel catfish feed (D'Abramo 2001).

Finally, harvesting of the prawn occurs at the end of the grow-out season. Half of the water should be drained from the ponds for seine-harvesting and drained completely for drain-harvested. It is often useful to selectively harvest large prawn about a month before the final harvest. By removing the larger, more aggressive prawns early, smaller prawn are given more space to reach marketable size by final harvest.

Marketing and Economics

Today, farm raised prawn make up 25% of the world's prawn market. Live prawn have been sold for $4 to $12 per pound, depending on size. Following harvest, prawn must either be killed on ice or sold alive in aerated tanks. They must be properly handled after death to avoid enzymatic breakdown of the tissue. Profitability of prawn operations is due to factors such as marketing season, competition with other products, and the demand for certain sizes and quality. The hatchery period for freshwater prawn is twice that of marine shrimp. In Mississippi, it is estimated that postlarvae production with an 80% survival rate would be economically beneficial with a selling price of $8 per 1000 prawn. If imported, they would cost $20-$50 per 1000 prawn.

With the decreasing tobacco sales, farmers have become interested in turning their tobacco farms into prawn farms. However, it is estimated that it will take many years to show a profit. New studies such as substrate designs and feeding methods will greatly increase profitability and decrease mortality rates. The future of the freshwater prawn business is taking a positive turn that can boost the economy, provide jobs, and satisfy consumers.

CHAPTER IV

METHODS

From 14 June 2001 until 5 September 2001, freshwater prawn postlarvae, *Macrobrachium rosenbergii*, were cultured at the Joseph E. Johnson Animal Research and Teaching Unit at the University of Tennessee, Knoxville. Two separate experiments were conducted, the first evaluating substrate orientation, horizontal versus vertical, and the second testing substrate color, tan (prawn colored) versus brown. Six rectangular tanks were used for the first experiment and six circular tanks were used for the second experiment.

Prawns were obtained from Craig Upstrom at Aquaculture of Texas (Weatherford, Texas) for the substrate orientation experiment and from Clay Gutierrez at Global Seafood Technologies (Aquaculture Division, Ocean Springs, Mississippi) for the color experiment.

On 14 June (day 1), 2000 prawn (at 5 per liter) were counted into each of six 400L rectangular tanks; the average weight of stocked prawn was 0.05 grams. Tanks were randomly selected as having horizontal or vertical substrate. On days 35, and 50, the prawn were counted, weighed, and replaced into their designated tanks. On 19

August (day 65), the final count was made for prawn in the rectangular tanks.

On 5 August, 1950 prawn, with an average individual weight of 0.1 grams, were counted into six circular tanks, each tank containing either tan (three tanks) or brown (three tanks) substrate. Similar to the substrate orientation experiment, counts and weights took place on days 30, 45, and 60. The prawn were replaced, in their respective tanks, after counts and weights were recorded. On 5 September, the final counts and weights were taken on prawn in the circular tanks.

Culture System Design

The project design consisted of six rectangular tanks and six circular tanks (Figure 2). Heated water was distributed by gravity flow to each tank from the elevated head tank. The air lines were run from a linear magnetic piston pump (#MAPXL-MAXAIR XL, 70-watt air pump by Ultralife Reef Products) to each tank by air-line tubing. The head tank was an 1135.5-liter (300 gallon) Rubbermaid container, set up on a metal stand (Figure 3), approximately one meter above the rearing tanks. A deionization unit and two carbon filters were attached to

Figure 2. Tank arrangement for substrate orientation and substrate color experiments.

Figure 3. Head tank design with water lines.

the side of the stand. Two immersion heaters were placed inside of the head tank, maintaining water temperature at 27°C, and a float valve was used to control the water level in the head tank. Water and air-lines were made from PVC pipe and were run separately to both sets of culture tanks.

Feeding and Water Quality

Prawn were fed twice daily, totaling 4% of their average body weight. Water quality parameters, including chlorine, ammonia, pH, dissolved oxygen, and temperature, were monitored daily. Wastes were siphoned from tanks as needed, which was approximately twice weekly. The temperature in the room was held constant at 25.5°C. There were no windows in the room, so the prawn only received the low, artificial light the room provided. The lights came on automatically at 0745 hours, which was 15 minutes before the morning feeding. The lights were then automatically turned off at 1900 hours, one hour after the evening feeding.

Counting and Weighing

For both experiments, counting methods were similar. For the substrate orientation experiment, prawn were weighed and counted on days 35, 50, and 65. These days were chosen so as not to interfere with a similar experiment being performed in another lab room. For the substrate color experiment, prawn were weighed and counted on days 30, 45, and 60. On these days, the tanks were individually drained and the prawn were netted into plastic containers. Groups of 300 prawn were counted out and placed in a dip net. The net was then spun around to remove any excess water and the 300 prawn were weighed and mean prawn weights were determined. After the weights were recorded, feeding amounts for each tank were recalculated and changed accordingly.

Orientation Experiment

Six rectangular tanks (400 L) were used for the orientation experiment; the other five tanks were used as display and holding tanks. The rectangular tanks used were 208.3 cm (82 in) long and 57.2 cm (22.5 in) wide (Figure 4). Each tank had a standpipe 5.08 cm (2 in) in diameter and 40.6 cm (16 in) long. The tanks were 53.3 cm (21 in) deep, but only contained 40.6 cm (16 in) of water. This was to provide free-board to help prevent prawn from jumping out of the tanks. Underneath each tank, the standpipe drained into PVC pipe that directed the excess water to a drain in the floor. Each tank was set on four legs, each 38.1 cm (15 in) high and 11.4 cm (4.5 in) in diameter.

Three tanks contained horizontal substrate and three tanks contained vertical substrate. PVC pipe was used to construct frames for the mesh substrate; holes drilled in the PVC were used to attach the netting to the frame with nylon ties and to allow the substrate frame to sink, as it filled with water. Three layers of (6 X 6 mm) brown, polyester mesh netting were constructed, approximately 9.0 centimeters apart. The vertical substrate frame was built the same way as the horizontal substrate frame, and was turned sideways for the experiment.

As seen in Figures 4 and 5, the substrate frame was constructed from 1.3 cm PVC pipe. The frame was approximately 27 cm tall, 165 cm long, and 28 cm wide. Each frame with the attached netting substrate increased tank surface area by 99% to a total of 9335 cm^2.

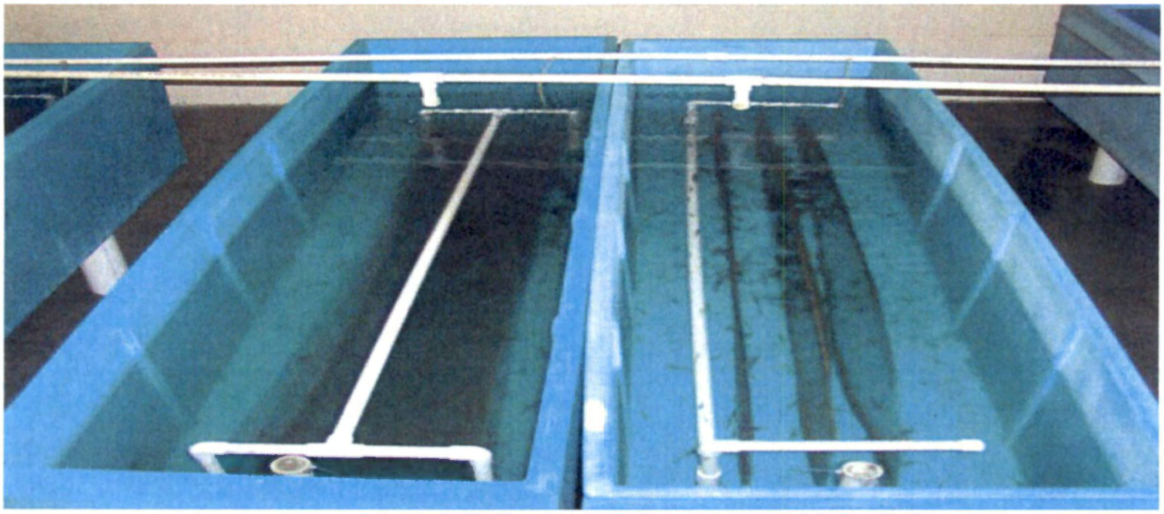

Figure 4. Orientation of substrate in tanks: horizontal (*left*), vertical (*right*).

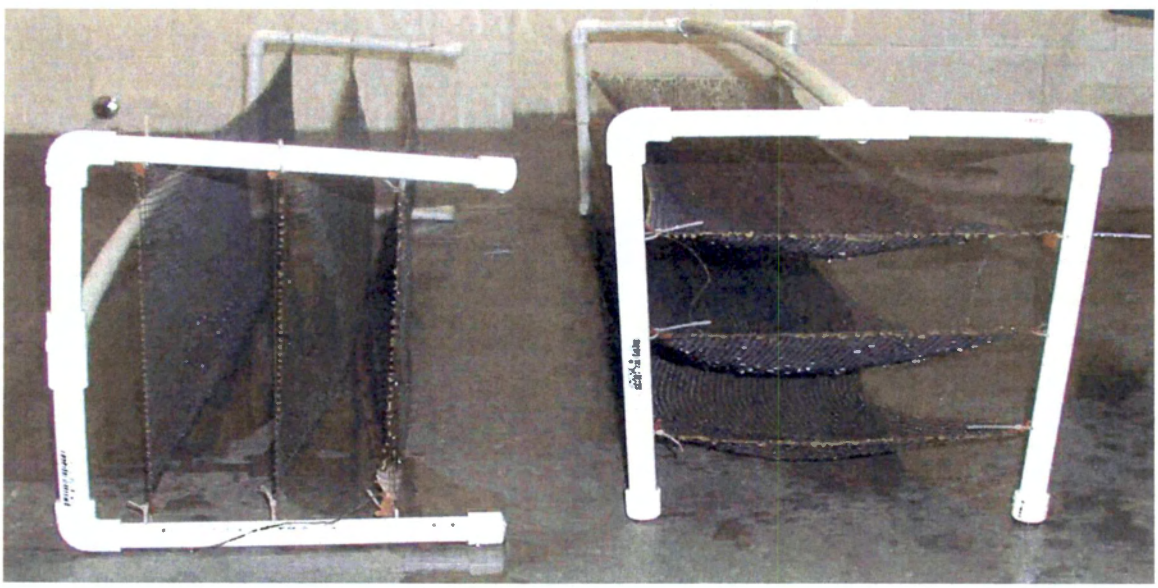

Figure 5. Orientation experiment design: PVC frames with horizontal and vertical mesh.

Color Experiment

The color experiment involved the use of six circular tanks (Figure 6). Each tank was 121.9 cm (48 in) in diameter, 49.5 cm (19.5 in) deep towards the side, and 54.6 cm (21.5 in) deep in the middle (Figure 5). The standpipe was 6.4 cm (2.5 in) in diameter and 55.9 cm (22 in) in length; the tank volume ws maintained at 400 L. As in the rectangular tanks, the round tanks also had PVC pipe attached underneath the standpipe that connected each tank and led water overflow into a drain. Four legs, 11.4 cm

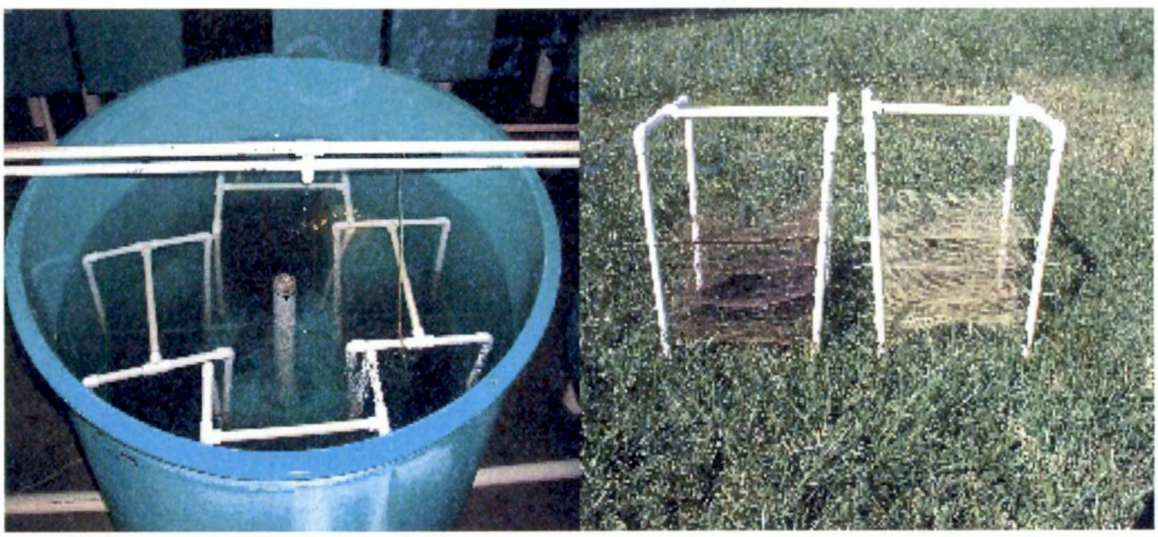

Figure 6. Color experiment design: PVC frames with horizontal mesh in circular tank (*left*), substrate frames with brown and tan mesh (*right*).

(4.5 in) in diameter and 12.7 cm (5 in) high, were used for support under each circular tank.

The substrate frames used in this experiment were built similarly to those used in the rectangular tanks, with three tanks containing frames with tan netting and three tanks containing frames with brown netting. Each tank contained four frames of substrate, adding 6828 cm^2 of additional surface area to each tank. The frames were 46 cm tall, 50 cm long, and 33 cm wide. Each frame had four layers of 6 X 6 mm, polyester mesh netting that were 31 cm wide and 36 cm long. The layers were attached to PVC pipe with nylon ties, approximately six centimeters apart from each other, adding 6,828 cm^2 of surface area to each tank.

Statistics

Treatments were evaluated using the final mean survival numbers and final average individual weights of prawn in the tanks with horizontal substrate compared to the tanks with vertical substrate and tan substrate compared to brown substrate. Statistical analyses were calculated using SPSS (2002). One-way ANOVA tests were run to show the significance of means at an alpha level of $P < 0.05$.

CHAPTER IV

RESULTS AND DISCUSSION

Orientation Experiment

As illustrated in Figure 7, there were no significant differences in survival rates between horizontal and vertical substrates (sig 0.417). On days 35, 50, and 65, mean survival numbers were 1597, 1470, and 1120 for the tanks with horizontal substrate and 1614, 1325, and 1056 for tanks that contained vertical substrate, respectively.

The average survival rates for prawns in the tanks with horizontal substrate were 80, 74, and 56% for days 35, 50, and 65, respectively. For the vertical substrate, survival rates were 81, 66, and 53%, also for days 35, 50, and 65, respectively. These figures represent total average survival rates of 56% using the horizontal substrate and 53% using the vertical substrate.

Similarly, mean weights (Figure 8) were not significantly different for the horizontal versus the vertical substrate (sig. 0.475). In the tanks with horizontal substrate, individual prawn weights increased

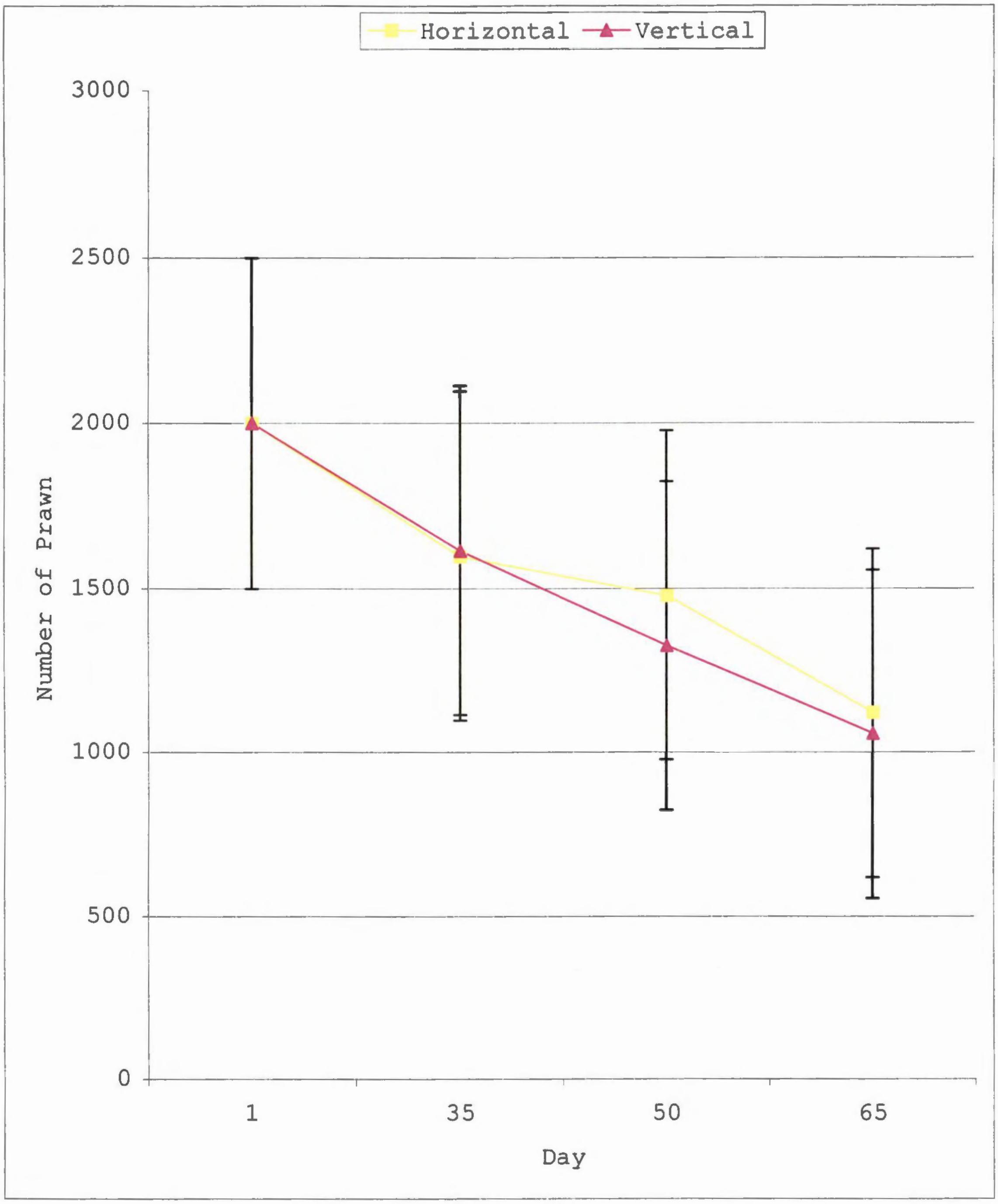

Figure 7. Mean prawn survival for days 1, 35, 50, and 65 for the horizontal and vertical substrates with standard error bars.

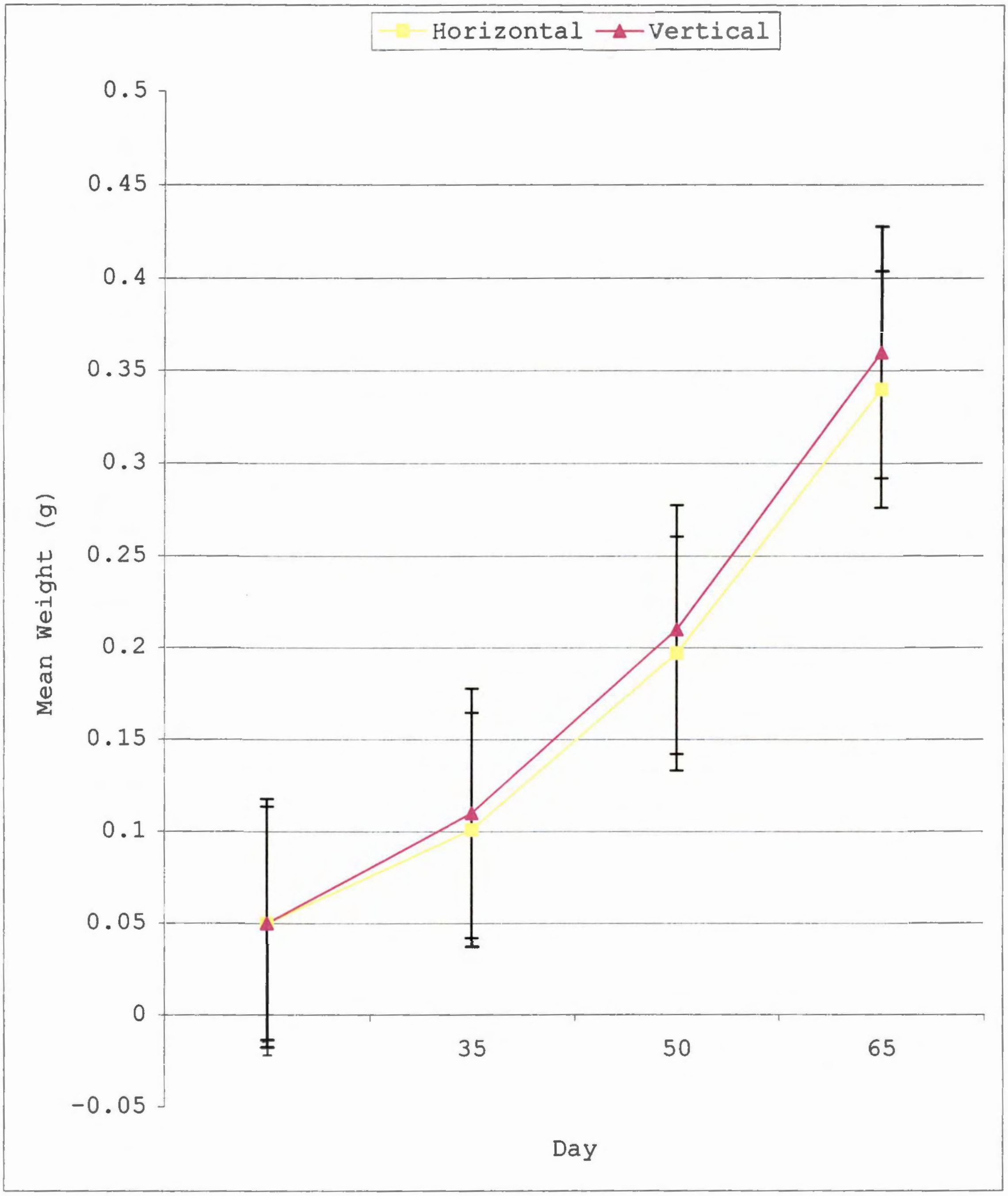

Figure 8. Mean prawn individual weights for days 1, 35, 50, and 65 for the horizontal and vertical substrates with standard error bars.

from an average of 0.05 grams on day one of the experiment to 0.10 grams on day 35, doubling to 0.20 grams on day 50, and to a final weight of 0.34 grams on day 65. In the tanks with vertical substrate, the average weights of the prawns were 0.10 grams on day 35, 0.21 grams on day 50, and 0.36 grams on day 65.

Overall, between days 1 and 35, an average of 20% mortality was seen. During the following 15-day interval, an additional 11% mortality was averaged and finally, between days 35 and 50, 16% mortality was calculated. There was an average of a 0.05 grams weight gain between days 1 and 35, an additional gain of 0.1 grams between days 35 and 50, and finally, between days 50 and 65, an average individual gain of 0.15 grams. From these numbers, we concluded that mortality and growth rates were greatest between the 50 and 65-day counts.

Using SPSS (2002) (Table 1), a one-way ANOVA was run yielding a significance value of 0.417 for the final number of prawn and 0.475 for the final weight of the prawn. Therefore, neither substrate was significant over the other in producing higher survival numbers or greater individual weight gain during the experiment.

Table 1. One-way ANOVA comparing survival and weight gain of prawn as influenced by substrate orientation.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SURVIVAL	Between Groups	4966.533	1	4966.533	.880	.417
	Within Groups	16928.667	3	5642.889		
	Total	21895.200	4			
WEIGHT	Between Groups	.000	1	.000	.662	.475
	Within Groups	.002	3	.001		
	Total	.002	4			

Color Experiment

In the color experiment, significant differences in survival of prawn on tan versus brown colored substrate were found. As shown in Figure 9, mean prawn survival of prawn on the tan substrate was 1545 (77%), 1046 (52%), and 799 (40%)for days 30, 45, and 60, respectively. The brown substrate yielded numbers of 1584 (79%), 1115 (56%), and 910 (46%) for the same days.

The mean weights can be seen in Figure 10. Individual prawn on the tan substrate showed a weight gain of 0.266 grams throughout the experiment. On day 30, mean weights were 0.165, on day 45, mean weights continued to increase to 0.241, and finally, on day 60, average weights were

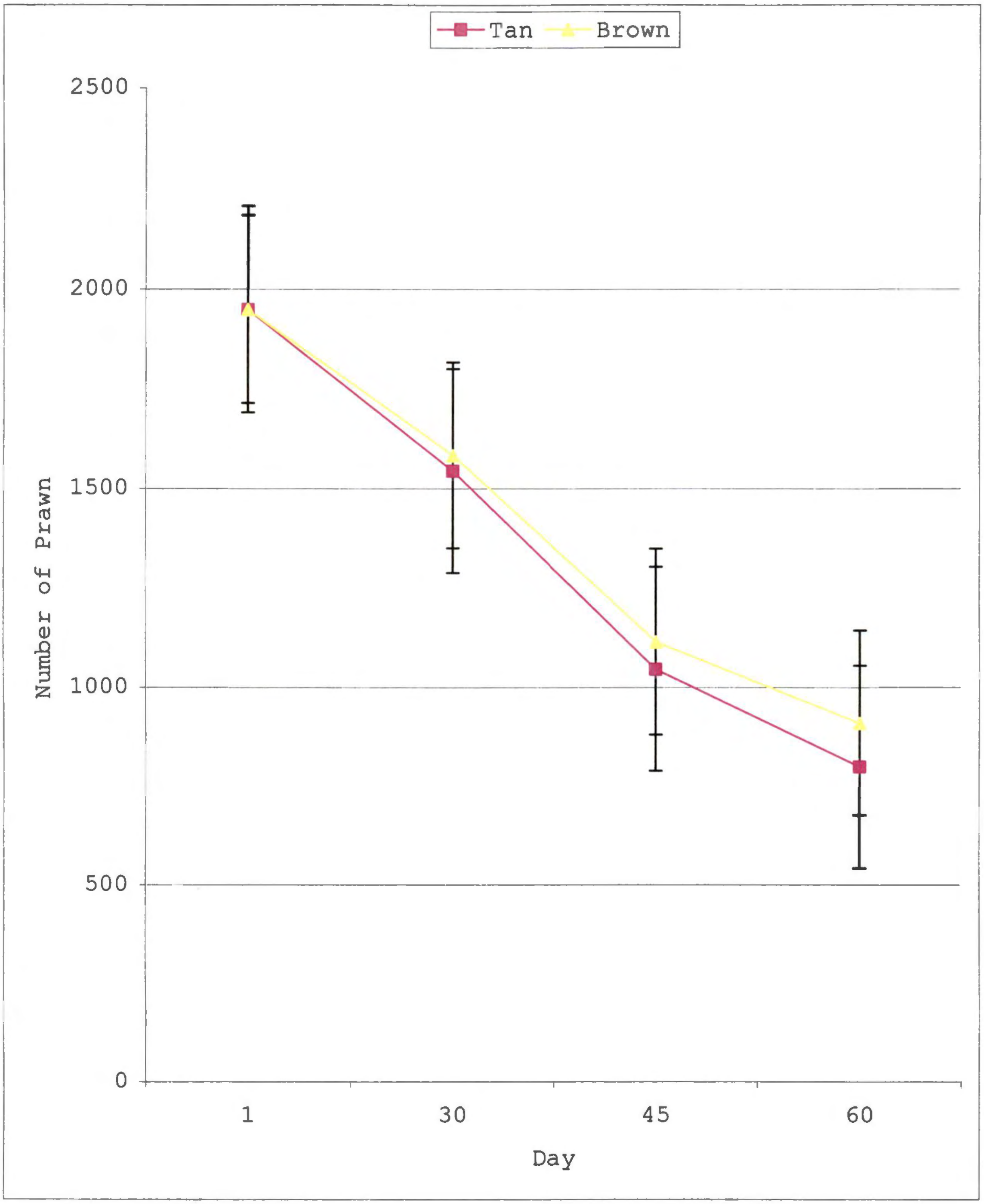

Figure 9. Mean prawn survival for days 1, 30, 45, and 60 for the tan and brown substrates with standard error bars.

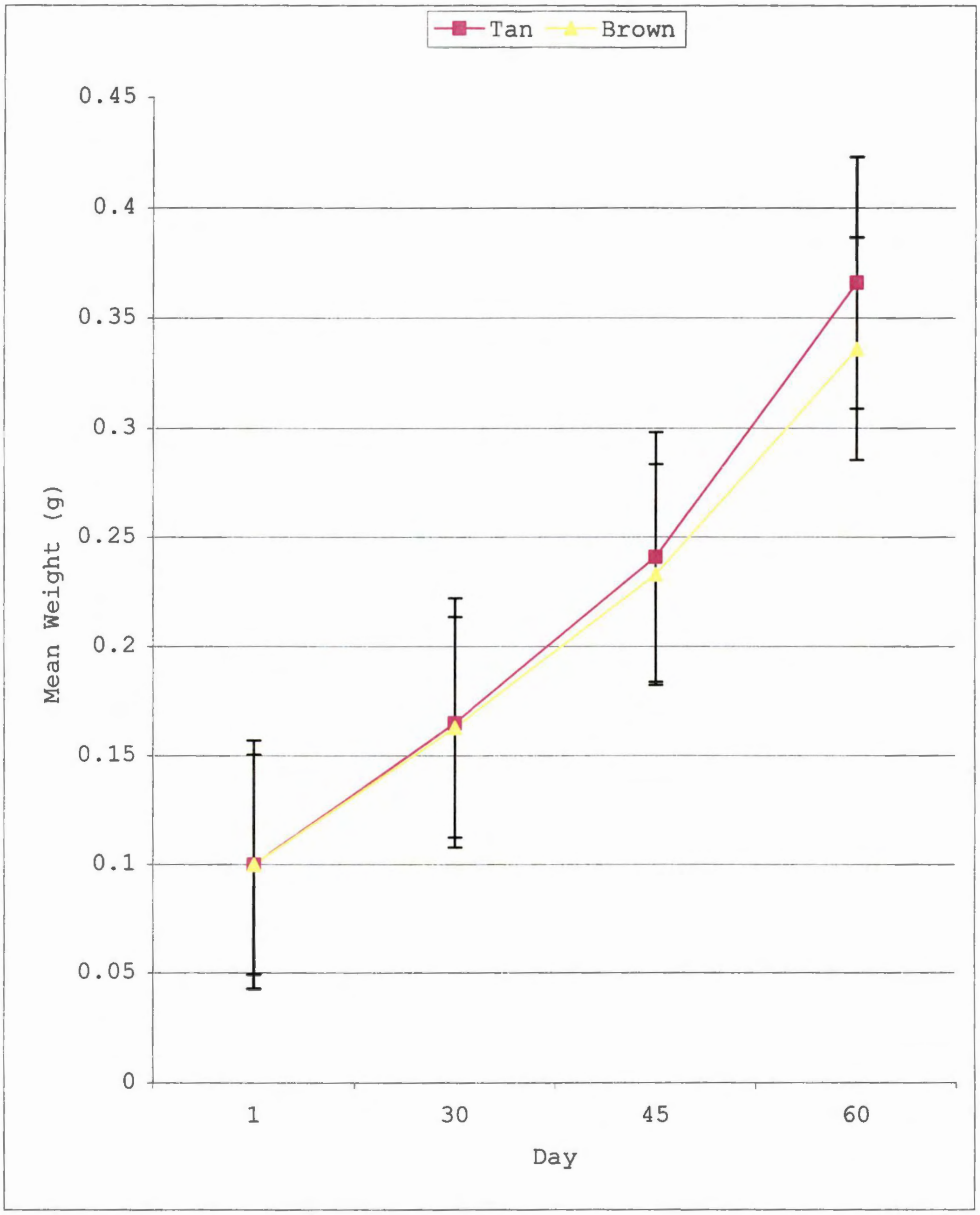

Figure 10. Mean prawn weight for days 1, 30, 45, and 60 for the tan and brown substrates with standard error bars.

0.366. Prawn on the brown substrate also showed a continual increase in growth, from 0.1 on day 1, to 0.163 on day 30, to 0.233 on day 45, and a final average individual weight on day 60 of 0.336.

A one-way ANOVA was run, using a SPSS (Table 2). Substrate was highly significant (0.008) comparing prawn survival, with a moderate difference, though not statistically significant, with prawn weight (0.069). From Figure 11, it can be seen that the prawn in tanks with brown substrate showed better survival with lower growth; however, the prawn in tanks containing tan substrate showed greater growth rates, but lower survival.

Table 2. One-way ANOVA comparing survival and weight gain of prawn as influenced by substrate color.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SURVIVAL	Between Groups	18481.500	1	18481.500	24.339	.008
	Within Groups	3037.333	4	759.333		
	Total	21518.833	5			
WEIGHT	Between Groups	.001	1	.001	6.121	.069
	Within Groups	.001	4	.000		
	Total	.002	5			

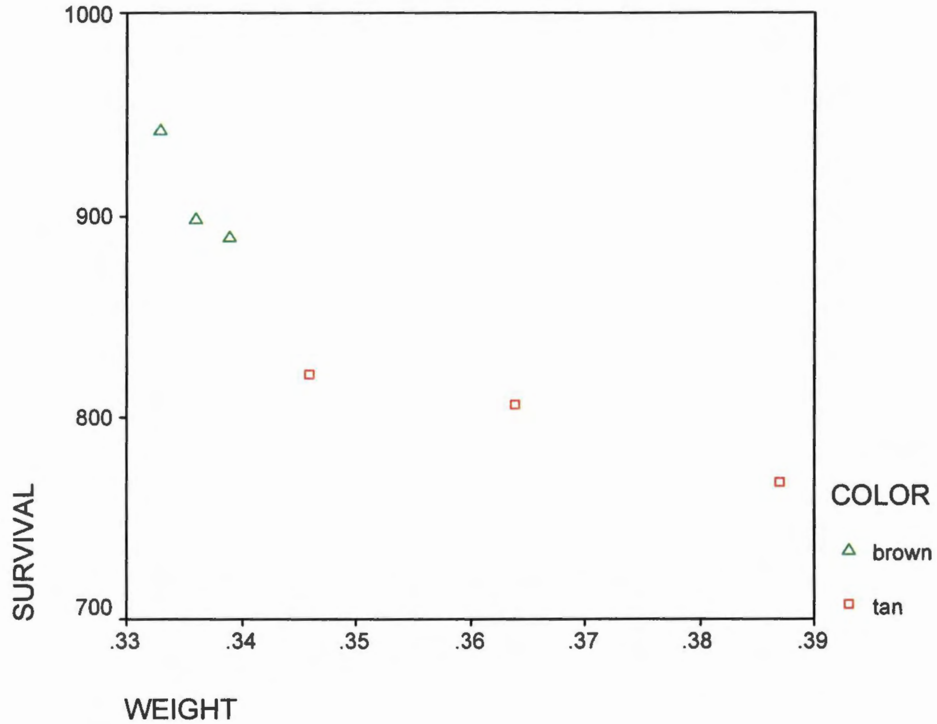

Figure 11. Scatter plot comparing survival and mean individual weight for prawn tan and brown substrate

Frequent handling of the prawn in this study may have led to lower survival numbers and growth rates. We have no estimation on how many prawn died during or shortly after each of the counts. Results from these studies suggest that as prawn grow, they become more aggressive. This aggression leads to cannibalism, therefore decreasing prawn survival. As numbers decrease from cannibalism, however, the surviving prawn gain more weight due to less populated environments. Current and future studies related to stocking densities, substrate types, and feeding methods will attempt to gather information on ways to increase survival numbers and overall weight gain in order to attain optimal production yield.

CHAPTER VI

SUMMARY

As freshwater prawn grow, they become cannibalistic and territorial. Horizontal versus vertical substrates and tan versus brown substrates were studied to determine which, if any, yielded greater survival rates and increased growth rates. The major findings were:

1. In the orientation experiment, prawn in three tanks containing horizontal substrate were compared to prawn in three tanks containing vertical substrate. For prawn on horizontal substrate, the final average survival was 56%. A final average survival rate of 53% was calculated for prawn in tanks containing vertical substrate, indicating no significant differences in survival rates for prawn on the two substrates.
2. In the same experiment, final average weight for prawn in tanks with horizontal substrate was 0.34 grams, compared to 0.34 grams for prawn on vertical substrate. Again, there was no significant difference in weight gain due to orientation of the substrate.
3. In the substrate color experiment, survival and growth of prawn in three tanks containing tan substrate were

compared to prawn in three tanks containing brown substrate. The average survival rate for prawn in tanks with tan substrate was 40% while the average survival rate for prawn in tanks with brown substrate was 46%, indicating a significant difference in survival rates when comparing tan and brown substrates.

4. In the substrate color experiment, the final average weight for prawn in tanks containing tan substrate was 292 grams. For prawn in tanks containing brown substrate, their final average weight was 306 grams. No statistically significant differences in weight were observed when comparing growth on tan and brown substrates.

LITERATURE CITED

Cohen, D., Z. Ra'anan, U. Rappaport, and Y. Arieli. 1983. The production of the freshwater prawn *Macrobrachium rosenbergii* in Israel: Improved conditions for intensive monoculture. Bamidgeh 35: 213-234.

Coyle, S., J. H. Tidwell, A. VanArnum, L. Vitatoe, and C. Weibel. 2001. The effect of stocking density on nursery production of juvenile freshwater prawns *Macrobrachium rosenbergii*. Journal of the World Aquaculture Society 31: 627-631.

D'Abramo, L. R., W. H. Daniels, P. D. Gerard, W. H. Jun, and C. G. Summerlin. 2000. Influence of water volume, surface area, and water replacement rate on weight gain of juvenile freshwater prawns, *Macrobrachium rosenbergii*. Aquaculture 182: 161-171.

D'Abramo, L. R., and M. W. Brunson, W. H. Daniels. 1995. Freshwater prawns; pond production and grow out. Mississippi State Cooperative Extension Service. 4 pp.

Daniels, W. H., L. R. D'Abramo, and L. De Parseval. 1995. Design and management of a closed, recirculating "Clearwater" hatchery system for freshwater prawns, *Macrobrachium rosenbergii* (de man). Journal of Shellfish Research 11: 65-73.

Farrell, P., and B. Leonard. 2000. Frequent handling adversely affects the growth of the Australian freshwater crayfish, *Cherax destructor*. Journal of Applied Aquaculture 10: 29-36.

Kneale, D. C., and J. Wang. 1979. A laboratory investigation of *Macrobrachium rosenbergii* nursery production. Proceedings of the World Mariculture Society 10: 359-368.

Marques, H. L. D., J. V. Lombardi, and M. V. Broock. 2000. Stocking densities for nursery phase culture of the freshwater prawn *Macrobrachium rosenbergii* in cages. Aquaculture 187: 127-132.

Molina, R. E. 1990. Assessment of practical diets, artificial habitat quality and quantity, and stocking density for nursery culture of the freshwater prawn *Macrobrachium rosenbergii*. M.S. Thesis, Mississippi State University, Mississippi. 61 pp.

Moller, T. H. 1978. Feeding behaviour of larvae and postlarvae of *Macrobrachium rosenbergii*. Journal of Experimental Marine Biology and Ecology 35: 251-258.

Ra'anan, Z., D. Cohen, U. Rappaport, and G. Zohar. 1984. The production of the freshwater prawn *Macrobrachium rosenbergii* in Israel: The effect of added substrates on yields in a monoculture situtation. Bamidgeh 36: 35-40.

Ra'anan, Z., and D. Cohen. 1985. The ontogeny of social structure in the freshwater prawn *Macrobrachium rosenbergii (de* man). Crustacean Growth 277-311.

SPSS Inc. 1999. SPSS Base 10.0 Applications Guide. SPSS Inc., Chicago, Illinois.

Sandifer, P. A., and T. I. J. Smith. 1974. Development of a crustacean mariculture program at South Carolina's Marine Resources Research Institute. Proceedings of the World Mariculture Society 5: 431-439.

Sandifer, P. A., and T. I. J. Smith. 1975. Effects of population density on growth and survival of *Macrobrachium rosenbergii* reared in recirculating water management systems. Proceedings of the World Mariculture Society 6: 43-53.

Sandifer, P. A., and T. I. J. Smith. 1976. Experimental aquaculture of the Malaysian prawn, *Macrobrachium rosenbergii* (de man), in South Carolina, U.S.A. FAO Technical Conference on Aquaculture, Kyoto, Japan, 26 May-2 June 1976. FIR:AQ/Conf/76/E.3, 7 pp.

Sandifer, P. A., and T. I. J. Smith. 1977. Intensive rearing of postlarvae Malaysian prawn, *Macrobrachium rosenbergii*, in a closed-cycle nursery system. Proceedings of the World Mariculture Society 8:225-235.

Smith, T. I. J., and P. A. Sandifer. 1975. Increased production of tank-reared *Macrobrachium rosenbergii* through the use of artificial substrates. Proceedings of the World Mariculture Society 6: 55-66.

Smith, T. I. J., and P. A. Sandifer. 1979a. Development and potential of nursery systems in the farming of Malaysian prawns. Proceedings of the World Mariculture Society 10:369-384

Smith, T. I. J., and P. A. Sandifer. 1979b. Observation on the behavior of the Malaysian prawn *Macrobrachium rosenbergii* (de man) to artificial habitats. Mariculture Behavioral Physiology 6:131-146.

Tidwell, J. H., S. D. Coyle, and G. Schulmeister. 1998. Effects of added substrate on the production and population characteristics of freshwater prawns *Macrobrachium rosenbergii* in ponds. Journal of the World Aquaculture Society 29: 17-22.

Tidwell, J. H., S. Coyle, C. Weibel, and J. Evans. 1999. Effects of interactions of stocking density and added substrate on production and population structure of freshwater prawns *Macrobrachium rosenbergii*. Journal of the World Aquaculture Society 30: 174-179.

Willis, S. A., R. W. Hagood, and G. T. Eliason. 1976. Effects of four stocking densities and three diets on growth and survival of postlarvae *Macrobrachium rosenbergii* and *Macrobrachium acanthurus*. Proceedings of the World Mariculture Society 7: 655-665.

Willis, S. A., and M. E. Berrigan. 1977. Effects of stocking size and density on growth and survival of *Macrobrachium rosenbergii* (de Man). Fisheries Investigations Series II, 27(5): 1-25.

VITA

Erin Marcus was born on April 9, 1977 in Chattanooga, Tennessee. She graduated from the Chattanooga School for the Arts and Sciences in 1995, after spending two months of her junior year in Israel. She then attended the University of Georgia, where she was in Sigma Delta Tau sorority. In 2000, Erin received a Bachelor of Science degree in Fisheries and Aquaculture and moved to Knoxville to pursue her Master's degree. In May of 2002, Erin received her Master of Science degree in Wildlife and Fisheries Science from the University of Tennessee, Knoxville. She is currently working for Dr. Steven Johnson as the Zebrafish facility manager at Washington University Medical Center in St. Louis, Missouri.