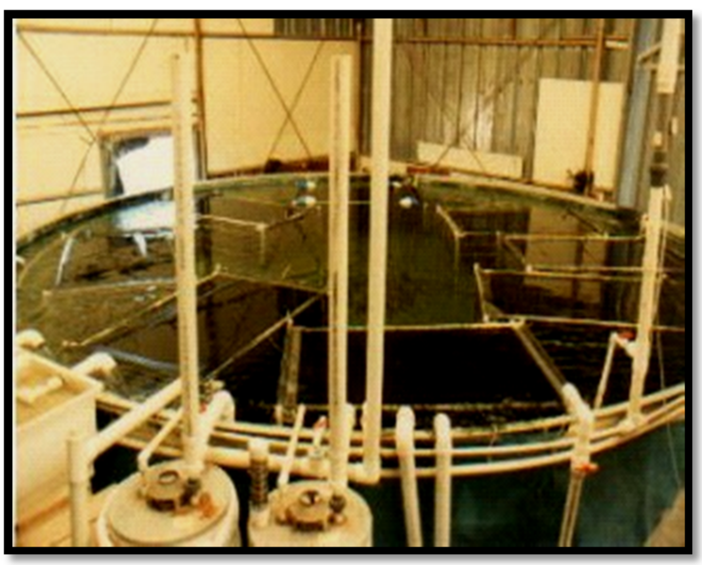
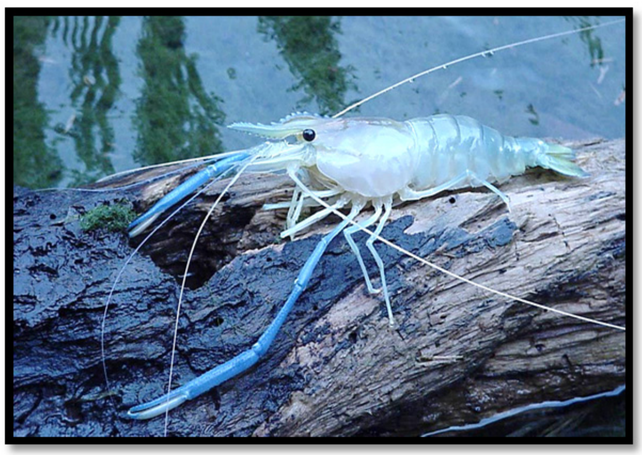
Freshwater Shrimp Farming in Texas
Compiled by Granvil D. Treece*

Freshwater shrimp (*Macrobrachium rosenbergii)* have been cultured in Texas since the early 1970s. There is a *Macrobrachium* hatchery in Weatherford, Texas that has been in operation since 1987, and sells PLs and juveniles to producers worldwide. There is presently only one hatchery and a few growout producers of the freshwater shrimp in Texas, most of which are located in North Central and Northeast Texas. Research and commercial trials in Kentucky and Tennessee have shown that the tropical animals actually do better in the cooler climates because they put more energy into growth than they do in the warmer climates of Texas and Mississippi. They apparently put more energy into reproduction in the warmer climates and do not grow as rapidly. This explains why the economics of freshwater shrimp culture looks better in cooler climates, and why there is a resurgence in the industry growth along the Eastern seaboard of the USA. Marketing of the product has always been a challenge in Gulf of Mexico states, where consumers are accustomed to the marine shrimp's differing texture and flavor.

Aquaculture of Texas, Inc., Weatherford, Texas





Male, *Macrobrachium rosenbergii* (Malaysian prawn). Photo from Jim Tidwell.

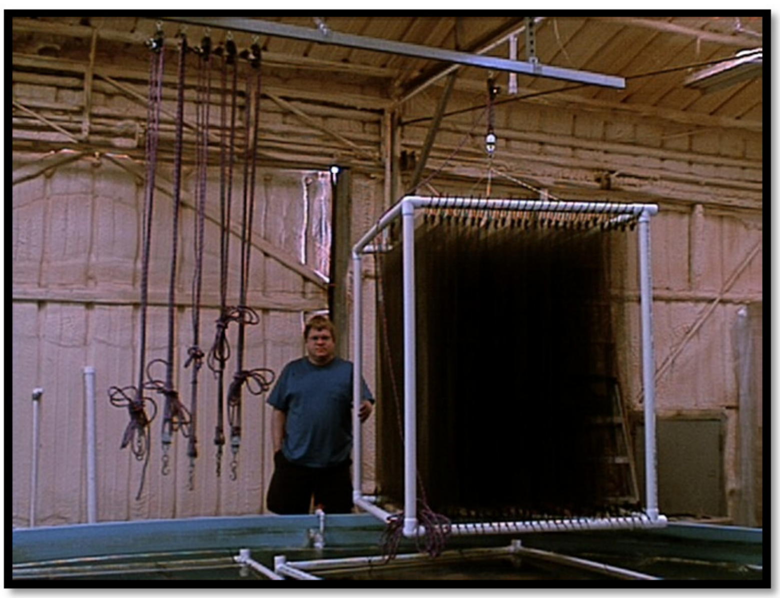
Gravid female prawn with eggs on the ventral side. (photo from Jim Tidwell)

The Aquaculture of Texas, Inc. hatchery is located in a 15,000 sq. ft. metal building on IH-20 just west of Fort Worth, which has a 6 million postlarval shrimp production capacity each spring. Owner, Craig Upstrom, says that it takes about $100,000 to pay the bills each year, but somehow it gets done. According to Craig there have been two other prawn hatcheries built in the Eastern USA recently which have affected sales and overall business. The prawns are selling locally for about $8.00/lb after they are grown in outdoor ponds on several farms during summer months and reach a size of around 8 to10 to a pound. Since Craig runs the hatchery himself, with a part-time assistant, he needs more time to work on genetics and developing a substitute larval diet to replace expensive *Artemia.* Our hats go off to Craig Upstrom for his hard work in this industry and we hope that he continues to find a niche to survive in this business. More information can be found on their web site at www.aquacultureoftexas.com.

Craig Upstrom, Aquaculture of Texas, Inc. with adult *Macrobrachium.*

Aquaculture of Texas, Inc. *Macrobrachium* broodstock holding.

Trolley tracks for tank substrates



Stocking One Acre with 20K 60-day old juveniles takes 114 shipping boxes, so its more practical to stock 20K 30-day old juveniles in 25 boxes, and even more practical to ship 20K PLs in only 4 boxes. 100,000 PLs or more can be air shipped. Live hauling juveniles in insulated “TOTE” containers, holding 280 gallons of water, holding 20K 60-day old juveniles is probably the most practical way to transport shrimp on a regional basis and each tote would weigh 2500 lbs.

Growout tank for *Macrobrachium*

The final product (below) some of Craig's shrimp purchased by an area farm, grown out in ponds, individually frozen with head on and stored in plastic bag and cardboard box. 10 pounds of shrimp which sells for $80.00. Growout results in the above tank can be seen on Aquaculture of Texas web site.

The species grown in Texas is *Macrobrachium rosenbergii,* the Malaysian prawn, and is considered an exotic. Permits must be obtained from TPWD to grow exotics. There are native species of *Macrobrachium* in Texas, which are found in rivers and upper estuaries, but none of the native species are cultured.

Background on Freshwater Shrimp (*Macrobrachium rosenbergii)*

Introduction

The Malaysian prawn *(Macrobrachium rosenbergii*) has been grown for centuries in Asia, but it has only been the subject of research and commercial enterprise in the U.S. during the last 40 years. The information in this section, except where noted, was taken directly from or summarized from D'Abramo and Brunson (1). Other species of *Macrobrachium* are indigenous to the U.S., but none are as suitable for aquaculture as the Malaysian prawn. The other species (*M. acanthurus, M. carcinus, M. ohione* and M*. olfersii*) do not reach sizes that are considered desirable for aquaculture (2). Basic production techniques were developed in the late 1950s in Malaysia, and refined in Hawaii and Israel during the last 30 years. Mistakidis (2) published an excellent biological account of the freshwater shrimp, with line drawings of eggs and larval stages.

A major breakthrough was when Fujimura and Okamoto at the University of Hawaii made the mass production of PL possible in 1970 (3). Once this bottleneck was removed, freshwater shrimp culture began to spread to areas such as Mauritius, French Polynesia (4), Israel and the state of Florida, USA. Weyerhaeuser, in Florida, started an R&D program in 1974, then other countries started theirs (Puerto Rico, 1975; Martinique, French West Indies, 1977; Jamaica and the Dominican Republic, 1978; Central America, 1979; Brazil, 1981. Bardach et al. wrote a classic paper on the species in 1972 (4).

At the same time Weyerhaeuser, in Florida, USA and companies in other countries were developing R&D programs. The states of South Carolina, Texas, and Louisiana, USA conducted research into basic production techniques, as well as marketing, processing, and hatchery procedures (5). In 1974, Sun Oil Company established a pilot freshwater shrimp farming company (Aquaprawns, Inc.) near Brownsville, Texas. The firm developed several new techniques for cultivation of freshwater and saltwater shrimp, including use of a harvest pump (6). In 1977, Hanson and Goodwin (7) reviewed the culture practices developed for *M. rosenbergii*, and S.K. Johnson described the diseases found in the species (8). In 1978, Sun Oil Co. closed its non-petroleum-related subsidiaries and a new company (CSCI), was formed. In 1980, CSCI built a (27.2 ha) 68 ac freshwater shrimp farm near Los Fresnos, Texas. The operation was located several miles inland, but used saline ground water to operate the hatchery.

Even though it is called a freshwater shrimp, a certain part of its life cycle is spent in saltwater. The natural life cycle involves the adult shrimp migrating down rivers to estuaries to have their young, and juveniles return to the rivers to complete the cycle. Freshwater shrimp require brackish water (12-15 ppt) for larval development and can tolerate up to 5 ppt during growout. They are tropical in temperature requirements and do not do well in water temperature below 50^0F (10^0C). In 1981, population profile development and morphotypic differentiation in the species was described (9), and a fact sheet was published on the culture of the species (10).

In 1983, Aquaculture Enterprises, Inc. acquired an unsuccessful prawn farm in Puerto Rico (Shrimps, Unltd. Inc.), and John Glude restarted the farm at Sabana Grande, on the southwest coast. It experienced a large debt service and construction delays for five years before it became what was considered an economically viable size in 1988 (58 ha or 143.3 ac). The Weyerhaeuser technology was inappropriate for the environment in Puerto Rico, and production failed to achieve projected levels. A change in production strategy, termed the "Modified Batch System" was developed and tested in 1989 and 1990, and a production rate of 3,000 kg/ha (3,000 lb/ac) per yr. was achieved. A disease called the "white PL disease," caused by Rickettsia, hit the company hard, while a recession in the U.S. caused a drop in demand for the product, and the company was forced to put production on hold in 1992 (11). Additionally by 1992, inexpensive Taiwanese frozen shrimp had appeared in the world market at US$10/kg (US$4.54/lb), and created fierce competition in the industry. Many producers' costs were higher than the shrimp were bringing on the market.

In Texas, CSCI produced large amounts of shrimp, but closed in 1985, unable to find a large, high-value market for the product. At least three companies in Texas produced and sold freshwater shrimp. In south Texas, Sweet Water Aqua-Farms, Inc., re-opened the CSCI farm in 1989, raised freshwater shrimp, and distributed nationwide. Sweet Water had been marketing the Malaysian prawn for a number of years from Brooklyn, New York, and decided to move into production. They sold mainly to "white table cloth" restaurants, had a toll-free telephone number, and an agreement with one of its investors (Federal Express) for overnight delivery of the product. In 1990, Sweet Water Aqua-Farms, Inc. produced 544 kg (1,200 lb) of *Cherax* (Australian red claw), and 9,979 kg (22,000 lb) of freshwater shrimp. Although the numbers are not large when compared to the Texas marine shrimp production, the product was marketed as a specialty item for a niche market. The freshwater shrimp were shipped fresh, killed and heads-on at 1 – 3^0 C or 35 – 38^0 F. The farm suffered the loss of 9,979 kg (22,000 lb) of shrimp (valued at US$254,540) due to an Arctic cold front in November, 1991. The owner was able to save the broodstock and still made a little money, despite the freeze loss. The farm re-located to Puerto Rico where year-round production was possible, without the threat of cold weather.

Freshwater shrimp PL are quite expensive relative to saltwater shrimp. Even in the 1980s, freshwater shrimp PL cost between US$25-50/1000. Now they are generally selling for US$ 60-65/1000. By comparison, saltwater shrimp PL sell for US$ 8-10/1000 if purchased in the U.S., and US$ 6-7/1000 purchased from Central or South America or in large quantities. Part of the reason for the price difference is the larval cycle is longer for freshwater shrimp (25-45 days), whereas the saltwater shrimp hatchery cycle generally takes 18 days, or less if the temperature is raised above 28^0C (82.4^0F).

Cannibalism has been a major problem in the freshwater shrimp industry. As is the case in most crustaceans, the larger shrimp prey upon the smaller ones. Producers of freshwater shrimp provide habitat or hiding places, vegetation in the pond, and harvest the larger animals routinely to minimize the problem. Another problem faced by the freshwater shrimp industry is two thirds of the animal is head and one-third tail muscle. Most producers are forced to sell the product fresh, head-on. Digestive enzymes in the cephalothorax cause deterioration of the muscle if not properly handled after harvest, and producers say the animal cannot be held on ice very long because the shells becomes soft.

During recent years, new management practices have dramatically increased the potential for economic success of freshwater shrimp culture in the southern U.S. Research efforts have been complemented by demonstration projects designed to evaluate methods under large-scale, commercial conditions. Freshwater prawns, like all crustaceans, have an exoskeleton or shell that must be shed regularly in order for growth to occur. As crustaceans grow, they shed the shell, or molt, and weight and size increase occur soon after each molt. When crustaceans molt they have approximately 12% more water in the bodies and they are soft, lethargic, and subject to attack by others. Because of these periodic molts, growth occurs in distinct increments, rather than on a continuous basis.

Females generally become reproductively mature before six months of age. Mating can occur only between hard-shelled males and freshly molted females. The male deposits sperm into a gelatinous mass that is held on the ventral side of the female, between the fourth pair of walking legs (1).

Eggs are laid within a few hours after mating and are fertilized by the sperm contained in the gelatinous mass. The female then transfers the fertilized eggs to the ventral tail, into a brood chamber, where they are kept aerated and cleaned by movement of the abdominal swimming appendages (pleopods). Eggs remain attached to the abdomen until they hatch. As in saltwater shrimp, the number of eggs produced in each spawn is directly proportional to the size of the female. As long as water temperature exceeds 70 F (21^0C), multiple spawns per female can occur annually and eyestalk ablation is not necessary with the freshwater shrimp, as it is for commercial production of saltwater shrimp. Females carrying eggs, or 'berried' females, are easily recognized by the bright yellow to orange color of newly spawned eggs, which gradually change to orange, then brown, and finally gray a few days before hatching. At 82^0F (28^0C), the eggs hatch approximately 20 days after spawning.

After hatching, larvae are released and swim upside down, tail first, like the mysis stage of saltwater shrimp. The larvae cannot survive in freshwater more than 48 hr and survive best in brackish water of 9 - 19 ppt. As larvae grow they become aggressive sight feeders and feed almost continuously, primarily on small zooplankton, worms, and larval stages of other aquatic invertebrates. Daniels et al. (12) found that larval feeding habits could be modified or improved with light manipulations and by keeping bacterial counts low. That work can be summarized as follows: In a 30 day larval cycle; 60 larvae/L (0.26 gal) stock; 80% survival after 30 days; allow one week for wash down, dry out, and disinfecting; building 9.1 m 27.4 m; 6.3 million larvae for two runs, 3.15 million each run; large center drain for cleaning, disinfecting; 3.1 m x 3.1 m required to house blowers; six, 11,000 l (2,860 gal), conical tanks, not to exceed 10^0 slope; 6% volume of rearing tanks should be the biofilter's size (3,960 L or 1,029 gal); five tanks used for conditioning water, salt water storage, conditioning of filter media; broodstock held at 4 per m^2 (10.8 ft^2) in intense light; from juveniles on, growout in freshwater or below 5 ppt salinity best; ponds stocked at 39,520/ha (16,000/ac) stunt growth; larvae salinity range 7-15 ppt, 12-15 ppt is acceptable, but 7-10 ppt is best; larvae stocked at 50 to 60/l (0.26 gal), with 80-90/l (0.26 gal) at most should result in 90% survival.

Most larvae are fed *Artemia* nauplii throughout the hatchery phase, up to 45 days Fuller et al. (13) looked at the economics of operating a closed, recirculating "clearwater" hatchery for the commercial production of PL.

During the hatchery period, larvae undergo 11 molts, each representing a different stage of metamorphosis. Following the last molt, larvae transform into PL. Transformation from newly hatched larvae to PL requires 15 to 40 days, depending upon food quantity and quality, temperature, and a variety of other water quality variables. Optimum temperatures for growth are 28 - 31^{0}C (82.4-87.8^{0}F).

After metamorphosis to PL, the shrimp resemble miniature adults, about 7 to 10 mm (0.3 to 0.4 in) long and weigh 6 to 9 mg (50,000 to 76,000/lb). PL change from planktonic to benthic, crawling individuals. When they do swim, they move like adults with the dorsal side up and swim or crawl in forward direction. PL can tolerate a range of salinities and migrate to freshwater upon transformation. In addition to the types of food they consume as larvae, larger pieces of animal and plant materials are ingested The diet includes larval and adult insects, algae, molluscs, worms, fish, and feces of fish and other animals. At high densities, or under conditions of food limitations, prawns become cannibalistic. PL are translucent and may have a light orange/pink head. As they change to the juvenile stage, they take on the bluish to brownish color of the adult stage. PL are juveniles, but through common usage the term juvenile is reserved for the stage between PL and adult; however, no standard definition for the juvenile stage exists.

Older juveniles and adults usually have a distinctive blue-green color, although sometimes they may take on a brownish hue. Color is usually the result of the quality and type of diet. Adult males are larger than the females, and the sexes are easily distinguishable. The claws (chela) and the head region of males are larger than those of the females. The base of the fifth or last pair of walking legs (periopods) of males is expanded inward to form a flap or clear bubble that covers the opening (gonopore) through which sperm are released. The walking legs of males are set close together in nearly parallel lines, with little open space between them, which helps distinguish immature males from females. A wide gap exists between the last pair of walking legs in females, and they have a genital opening at the base of the third pair of walking legs. Three types of males have been identified, based upon external characteristics. Blue-claw males are easily distinguishable and are characterized by long, spiny blue claws. Eventually, the male will either die or molt and return to a growth phase and later regain its blue-claw status. Two other classes of non-blue-claw males exist, orange claw and strong orange claw males (1).

There are three phases of culture of freshwater shrimp: hatchery, nursery, and growout. For detailed information on the pond growout phase, refer to (14). Those contemplating starting a freshwater shrimp production enterprise should forego, the hatchery phase at least initially and possibly the nursery phase by purchasing juveniles from a supplier (15). As production increases through successful pond growout plans can be made to develop a nursery, and possibly a hatchery. There is a limited number of juvenile shrimp suppliers, but increased demands will lead to a need for more enterprises that deal exclusively in the production and sale of PL.

Ponds should have a minimum depth of 0.6 to 0.9 m (2 to 3 feet) at the shallow end and a maximum depth of 1 to 1.5 m (3.5 to 5 feet) at the deep end. The slope of the bottom should allow for rapid draining. Publications that provide additional information on pond design and construction are available on the internet at Southern Regional Aquaculture Center web site, under fact sheets.

A soil sample should be collected from the pond bottom to determine whether lime is needed. Take soil samples from about six different places in the pond, and mix them together to make a composite sample that is then air-dried. Send the soil sample to a soil testing laboratory and request a lime requirement test. There may be a small charge for this service. If the pH of the soil is less than 6.5, you must add agricultural limestone to increase the pH to a minimum of 6.5, and preferably 6.8.

The final phase of freshwater shrimp production is growout of juveniles to adults for market as a food product. Research in Mississippi, Kentucky, and other southern states of the USA has demonstrated this can be a profitable enterprise (14,15, &16). Unless you have a hatchery/nursery, you must purchase juveniles for the pond growout phase.

Shipping costs can be minimized if the hatcheries are located within a one day driving distance of the growout facility. Otherwise, it is best to have the shrimp shipped via air or express courier, but this significantly increases the cost.

Ponds used for raising freshwater shrimp should have many of the same basic features of ponds used for the culture of channel catfish (14). A good supply of freshwater is important, and the soil must have excellent water-retention qualities. Well water of acceptable quality is the preferred water source for raising freshwater shrimp. Surface runoff water from rivers, streams, and reservoirs can be used, but quality and quantity can be highly variable and subject to uncontrollable change. The quality of the water source should be evaluated before any site is selected.

The surface area of growout ponds ideally should range from 0.4 to 2 ha (1 to 5 ac), but larger ponds have been successfully used. The pond should be rectangular to facilitate distribution of feed. The bottom of the pond should be smooth and free of obstructions to seining (14). After filling the pond, fertilize it to provide an abundance of natural food organisms for the shrimp and to shade unwanted aquatic weeds. If a water source other than well water is used, it is critically important to prevent fish, particularly members of the sunfish family (e.g., bass, bluegills and green sunfish) from getting into the pond when it is filled. Screening or filtering the incoming water is advised if it is not from a well. The effects of predation by these kinds of fish can be devastating. Birds, especially cormorants and anhingas can also be a problem. If there are fish in the pond, remove them before stocking shrimp, using 0.95 L (1 quart) of 5% liquid emulsifiable rotenone per acre-foot (325,900 gal) of water when water temperatures exceed 21°C (70^0F). Rotenone is a restricted use pesticide, and either a commercial or private pesticide applicator license is required to purchase and apply this material in the USA.

Juvenile freshwater shrimp must be gradually acclimated to conditions in the growout pond to prevent temperature shock or other types of stress. The water in which they will be stocked should gradually replace water in which PL and juveniles are transported. This acclimation procedure should not be attempted until the temperature difference between the transport and culture water is less than 2 to 4^0 (C or F). The temperature of the pond water at stocking should be consistently at least 20^0C (68^0F) to avoid stress because of low temperatures. Juvenile prawns are more susceptible than adults are to low water temperature exposure. Juveniles, preferably derived from populations that have been size-graded, ranging in weight from 0.1 - 0.3g (0.0002 – 0.0006 lb), should be stocked at densities of 29,640 - 39,520/ha (12,000 - 16,000/ac). The size grading results in more uniform growth and helps to reduce the percentage of smaller, non-marketable individuals at harvest. Lower stocking densities will yield larger shrimp, but lower total harvested weight. If the market demands whole, live or fresh ice-packed shrimp, stocking at lower densities will result in larger, more marketable individuals. The duration of growout depends on the water temperature, and the time generally is 120 to 180 days in the southern U.S. fresh-water shrimp could be grown year-round if a water source is found that provides a sufficiently warm temperature for growth (14).

Juvenile shrimp stocked into growout ponds are able to initially obtain sufficient nutrition from natural pond organisms. At the stocking densities recommended D'Abramo and Brunson (1), begin feeding when the average weight is 5.0g (0.01 lb.) or greater. Commercially available, sinking channel catfish feed (28 - 32% crude protein) is an effective and economical feed at the recommended stocking densities. The feeding rate is based upon the mean weight of the population. A feeding schedule can be developed based upon three factors: 1.) A feed conversion ratio of 2.5; 2.) One percent mortality in the population per week; and 3.) Mean individual weight determined from samples obtained every three weeks. At the end of the growout season, survival may range from 60 - 85%, if you have practiced good water quality maintenance. Yields typically range from 600-1,200 kg/ha (600 - 1,200 lb/ac). Weights of shrimp range from 35 - 45g (10 - 13/lb or 22 - 28/kg). These yields and average sizes will be significantly influenced by initial stocking density.

Water quality is important in raising freshwater shrimp, as it is in raising saltwater shrimp, catfish, or any other aquatic species. Dissolved oxygen is particularly important and must be monitored several times daily, especially in the early morning hours.

Selective harvest of large shrimp during a period of 4 - 6 weeks before final harvest is recommended to increase total production in the pond. Selective harvesting usually is performed with a 2.54 cm – 5 cm (1- 2 in) bar-mesh seine, allowing animals that pass through the seine to remain in the pond and to continue to grow, while the larger shrimp are removed. Selective harvest may also be accomplished with properly designed traps. Shrimp can be trapped using an array of traditionally designed crawfish traps. Selective harvest can help extend the duration of the availability of the fresh or live shrimp product to the market. However, there is a lack of research to show whether selective harvesting or complete bulk harvesting is the most economical approach. Regardless of the harvest method employed, some shrimp will remain in the pond and will have to be manually picked up. Rapid draining or careful seining can minimize this residual crop. Harvested shrimp should be quickly chilled to preserve the integrity of the muscle tissue, thus maintaining a firm, high quality texture. The product may be marketed fresh on ice, processed and frozen, or frozen whole for storage and shipment (1).

Culture of freshwater shrimp in combination with fingerling catfish has been successfully demonstrated under small scale experimental conditions and appears possible under commercial conditions. Before introduction of catfish fry, D'Abramo and Brunson (14) recommends stocking juveniles at a rate of 7,410 – 12,350/ha (3,000 - 5,000/ac) and recommends stocking catfish fry at a density to insure that they will pass through a 2.54 cm (1") mesh seine used to harvest the shrimp at the end of the growing season. Soft water (<7 ppm total hardness) can be expected to cause a softening of the shell. Hard water (>300 ppm) has been implicated in reduced growth and lime encrustations on freshwater shrimp.

Polyculture of channel catfish and freshwater shrimp may be best achieved through cage culture of the fish. A scheme for intercropping of freshwater shrimp and red swamp crawfish was developed and evaluated in the U.S.A. Intercropping is the culture of two species that are stocked at different times of the year with little if any, overlap of their growth and harvest seasons. Intercropping provides for a number of benefits that include: 1.) Minimizing competition for resources; 2.) Avoiding potential problems of species separation during or after harvest; and 3.) Spreading fixed costs of a production unit (pond) throughout the calendar year. Adult mature crawfish are stocked at a rate of 8,892/ha (3,600/ac) in summer (late June or early July). Juvenile shrimp are stocked at a density of 39,520/ha (16,000/ac) in late May and harvested from August through early October. In late February, seine harvest of the crawfish begins and continues through late June before stocking of new adult crawfish. Freshwater shrimp are small enough to pass through the mesh of the seine used to harvest crawfish during the May-June overlap period. Other intercropping scenarios involving such species as bait minnows, tilapia, and other fish species may be possible, but to date no research has been conducted in the U.S.A. (1).

Nitrites at concentrations of 1.8 ppm have caused problems in hatcheries, but there is no definitive information as to the toxicity of nitrite to shrimp in ponds. High nitrite concentrations in ponds would not be expected given the anticipated biomass of shrimp at harvest. Levels of un-ionized ammonia above 0.1 ppm in fish ponds can be detrimental. Concentrations of un-ionized ammonia as low as 0.26 ppm at a pH of 6.83

have been reported to kill 50 % of the shrimp in a population in 144 hrs. Therefore, you must make every effort to prevent concentrations of 0.1 ppm or higher un-ionized ammonia.

A high pH can cause mortality through direct pH toxicity, and indirectly because a higher % of the total ammonia in the water exists in the toxic, un-ionized form. Although freshwater shrimp have been raised in ponds with a pH range of 6.0 to 10.5 with no apparent short term adverse effects, it is best to avoid a pH below 6.5 or above 9.5, if possible. Constantly high pH stresses the shrimp and reduces growth rates. High pH values usually occur in waters with total alkalinity of 50 ppm or higher and when a dense algae bloom is present. Liming ponds that are built in acid soils can help minimize severe pH fluctuations. Another way to avoid problems with high pH is to reduce the quantity of algae in the pond by periodic flushing the top 30 cm (12 in) of water. Alternatively, organic matter, such as corn grain or rice bran, can be distributed over the surface area of the pond. This procedure must be accompanied by careful monitoring of oxygen levels, which may dramatically decrease due to the decay processes.

Other than the “white PL disease,” caused by Rickettsia, discussed earlier, diseases do not appear to be a significant problem in the production of freshwater shrimp, but as densities are increased to improve production, disease problems are certain to become more prevalent. We know that White Spot Syndrome Virus (WSSV) is spreading worldwide and affects many crustaceans.

Production levels and harvesting practices should match marketing strategies. Without this approach, financial loss due to lack of adequate storage (holding) facilities or price change is inevitable. Marketing studies strongly suggest that a “heads off” product should be avoided and that a specific market niche for whole freshwater shrimp needs to be identified and carefully developed. To establish year-round distribution of this seasonal product, freezing, preferably individually quick frozen (IQF), is an attractive form of processing. Block frozen is an alternative method of processing. Adult freshwater shrimp can be successfully live hauled for at least 24 hr, at a density of 0.22 kg/3.8 L (0.5 lb/gal) with little mortality and no observed effect on exterior quality of the product. Transport under these conditions requires good aeration. Distribution of shrimp on shelves stacked vertically within the water column assists in avoiding mortality due to crowding and localized poor water quality. Use of holding water with a comparatively cool temperature (20 – 22 ^{0}C or 68 – 72 ^{0}F) minimizes incidence of water quality problems and injury by reducing the activity level of the prawn’s (14).

Economics of raising freshwater shrimp

Based on an average feed cost of US$500 to US$800/907 kg (2,000 lb), a cost of US$65/1,000 juveniles, a 2.5: 1 FCR, expected mean yields of 1,000 kg /ha (1,000 lb/ac), and a pond bank selling price of US$8.00/lb, the expected return can be as high as US$ 5,000 – US$8,000/ha (US$2,024 - US$3,238/ac). Revenue and ultimate profitability depend on the type of market that is used. This estimated return does not include labor costs or other variable costs that differ greatly from operation to operation. Some thorough economic evaluations that incorporate annual ownership and operating costs under different scenarios for a synthesized firm of 17.4 ha (43 ac), having 4 ha (10.25 ac) of water surface in production, are provided in (15). There are several operations in North central Texas operating under the above listed economics as of 2008.

Nutrition

The nutritional requirements of *Macrobrachium rosenbergii* were summarized and compared with species of penaeid shrimp by D'Abramo (17). Other important contributions toward our knowledge of the nutrition requirements and other aspects of these animals have been published (18-27). According to D'Abramo (17), the quantitative amino acid requirements for *M. rosenbergii* remain undefined, a situation generally attributed to the common lack of success in using crystalline sources of amino acids in shrimp diets to supplement protein sources deficient in one or more essential amino acids. In contrast, crystalline amino acids have been successfully used in investigations of amino acid requirements of fish. Farmanfarmaian (28) showed evidence of growth enhancement achieved with a 1% supplementation of either arginine, phenylalanine, leucine, or isoleucine to a commercial diet. Analysis of the free amino acid content of whole body and tail muscle tissue of juvenile shrimp revealed that arginine is the predominant amino acid (29). The quantitative dietary protein requirement for juveniles has generally fallen within the range of 30-40% (dry wt.), but lower values have been reported by (30). Using soybean meal, fishmeal, and shrimp meal reported that the optimum dietary protein levels are between 35 and 40%, (31, 32). All other dietary requirements were detailed by D'Abramo (17). Distinct dietary differences exist between *M. rosenbergii* and other species of *Macrobrachium*.

A list of citations on the freshwater shrimp since 1972 may be obtained from (33).

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