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Bait Shrimp Culture

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The live bait shrimp industry in the southeastern U.S. is dependent on three shrimp species: the Atlantic white shrimp (*Litopenaeus setiferus*), the Gulf brown shrimp (*Farfantepenaeus aztecus*) and the Gulf pink shrimp (*F. duorarum*). All three species occur along the southern and eastern U.S. coasts from Texas through North Carolina. The live bait shrimp industry within this extensive coastal region is mostly a capture fishery. Juvenile shrimp within a size range of 150- to 60-count shrimp (3.0- to 7.5-g) are harvested from inshore waters with trawling gear. Recently, farm-raised, live bait shrimp were introduced as an alternative to wild-caught shrimp.

Bait shrimp market

The wild product is highly seasonal and the supply rarely meets demand, especially during the peak demand period of March through September.

Shrimp are sold as both a live and a frozen product, with live shrimp commanding a premium price. The dockside (ex-vessel) price wholesalers pay to boat captains for live bait shrimp ranges from \$2.75 to \$4.00 per pound. The wholesale price bait retailers pay ranges from \$7.50 to \$14.00 per pound. This wholesale price includes delivery from the shrimp boat to the retail bait shop and so it varies with the distances involved. Retailers who own their own shrimp boats may charge fishermen as little as \$7.00 per pound; in general, fishermen pay \$10 to \$16 per pound for live bait shrimp (Fig. 1).

Live hauling bait shrimp

Wild-caught bait shrimp are transported to market in oxygenated holding tanks at densities of 1 to 2 pounds per gallon of water. Mortality rates can be 25 to 50 percent within 24 hours of delivery. However, live-haul trials of farm-raised, live bait shrimp showed that commercial volumes (200 to 500 pounds per shipment) could be successfully transported to retail bait shops with more than 95 percent survival 24 hours after delivery.

Seed supply

The main impediment to bait shrimp aquaculture has been the lack of consistent supplies of disease-free postlarvae (PL). Without them, both researchers and commercial aquaculturists have relied on two methods of obtaining PL.

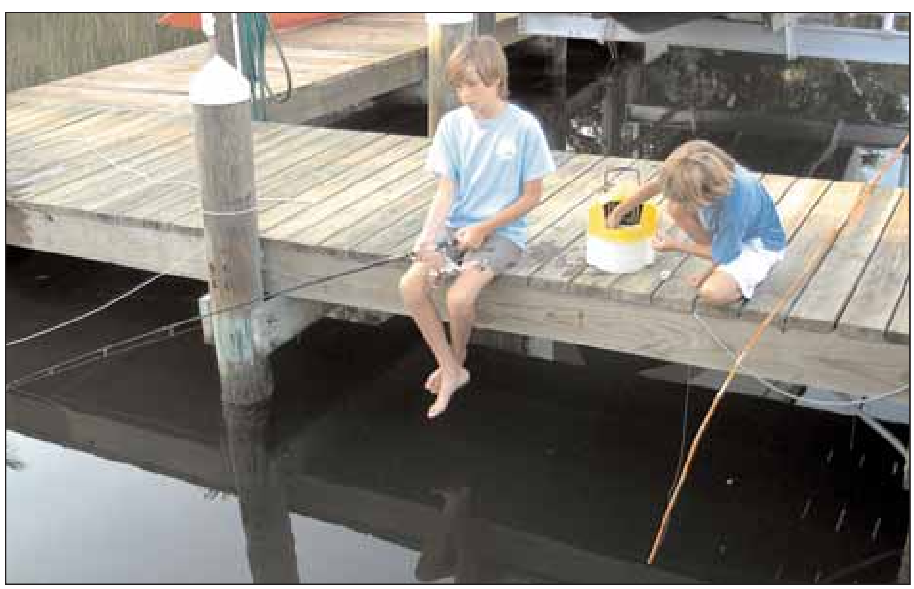

Figure 1. The most valuable consumers of live bait shrimp.

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Method I - sourcing wild, mated, gravid females

This method entails leasing coastal shrimp boats during the full moons of spring and early summer to trawl the spawning grounds for mated, gravid (egg-bearing) females (Fig. 2). Once gravid females are caught, they are either spawned in individual tanks onboard the vessel or transported to land-based spawning tanks. Each gravid female is kept in an individual tank for 12 to 36 hours under dark conditions, at a temperature of about 28 °C (82.4 °F), and at a salinity of 30 to 35 ppt. After spawning, the female is removed from the tank and the fertilized eggs hatch within 24 hours.

Sourcing wild, mated, gravid females is a cost-effective technique for acquiring fertilized eggs, but it is not a reliable year-round production method. There also is a high risk of acquiring shrimp infected with viral pathogens that will jeopardize the biosecurity and sustainability of the farm.

Method II– hatchery

Developing and operating a biosecure hatchery is both capital and labor intensive. However, a biosecure hatchery ensures a sufficient year-round supply of PL for commercial operations. Healthy broodstock must be developed and maintained in a disease-free hatchery. The quantity of viral pathogen-free broodstock is limited. Researchers at the Mote Marine Laboratory in Sarasota, Florida, the Waddell Mariculture Center in Bluffton, South Carolina, and the Texas Agricultural Experiment Station in Corpus Christi, Texas, are isolating and developing "high-health" broodstock populations of the Atlantic white shrimp and Gulf pink shrimp.

"High-health" broodstock are developed through a process of quarantine and routine population testing using histological examination and a polymerase chain reaction (PCR) technique. Continuous screening of broodstock and offspring with these diagnostic tools detects organisms with specific pathogens so they can be eliminated from these populations. Once a "high-health" wild population has been isolated, it is induced to spawn and its offspring are tested for known viral pathogens. Once the offspring are determined to be "clean," they are moved to a biosecure grow-out facility where they are raised to broodstock size. The broodstock are then reproduced in maturation facilities and their offspring are used to supply farmers with PL.

The maturation and reproduction of broodstock occur in a climate-controlled maturation system (27 °C, 80.6 °F) with 14-hour light and 10-hour dark photoperiods (Fig. 3). Broodstock are kept in 10.5- to 16.4-m^2 (12-ft to 15-ft diameter) maturation tanks at densities of six shrimp per m^2. During maturation, broodstock are supplied with a combination of fresh squid, adult enriched *Artemia* and bloodworms fed on a wet-weight basis (20 percent of body weight per day, bw/d). Dry maturation diets are added to reduce the cost of fresh food.

Once acclimated to the maturation system, females are unilaterally ablated—a process in which one eyestalk is removed to induce maturation. Ovarian development ensues within 72 hours and mating and spawning begin thereafter. Broodstock ranging from 25 to 35 g have a reproductive capacity of 100,000 to 250,000 eggs per spawn and can spawn every 3 to 7 days.

Fertilized eggs will hatch within 24 hours of fertilization at 28 °C (82.4 °F). The nauplii are allowed to remain in hatching tanks until they metamorphose into the last

Figure 2. Sourcing gravid females at night onboard a shrimp boat.

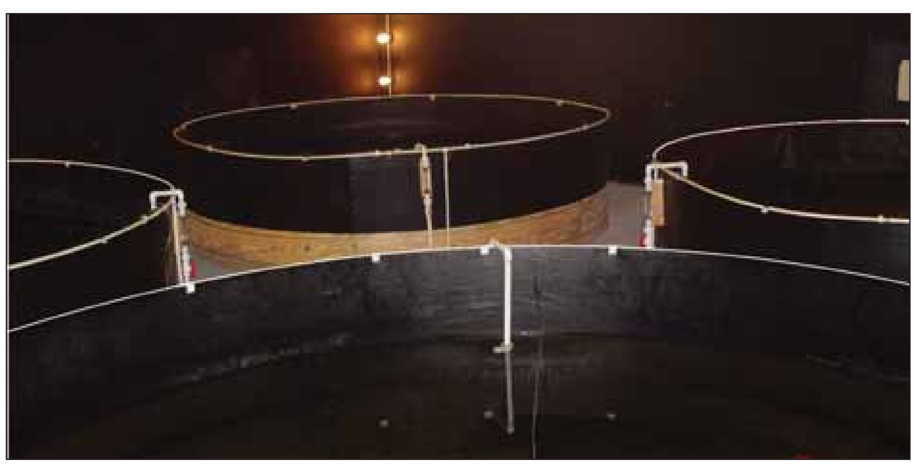

Figure 3. Maturation system.

naupliar stage (N_5). During the naupliar stages, no feed is provided as nauplii feed on their yolk sacs. Nauplii (N_5) are then collected and transferred to larval-rearing tanks maintained at 28 to 29 °C (82.4 to 84.2 °F) where they are fed marine algae (*Chaetoceros gracilis* and *Isochrysis galbana*), live, newly hatched *Artemia* nauplii, and dry larval and postlarval diets, depending on the stage of development and the dietary needs of that stage.

Shrimp larvae go through six larval stages over a 9-day period in the larval-rearing tank before they metamorphose to a postlarval (PL_1) stage. The entire larval cycle from N_5 until the shipment of the PL_{8-13} lasts 17 to 22 days, depending on the age of the PL requested by the farm. In general, farmers request PL_8 - PL_{13} for stocking production systems.

Shipping post-larvae

Post-larvae are removed from larval-rearing tanks and concentrated for counting, packing and shipping. Shrimp PL are shipped at densities of 1,000 to 2,000 per L in polyethylene bags containing seawater (30 to 35 ppt) that is saturated with oxygen and cooled to 18 °C (64.4 °F) before packing. The bags are usually packed in insulated foam coolers to maintain temperature during shipping. Some farmers save on the high cost of freight by transporting high densities of PL (more than 1 million) in live-haul trucks with oxygenated tanks.

Acclimation

When a PL is at least 8 days old (PL_8), it is sufficiently robust to handle the stress of transport and acclimation. The culture system must be more than 15 ppt salinity and warmer than 20 °C (68 °F) for the acclimation to proceed. Acclimation is accomplished in small, temporary tanks near the pond (direct stocking) or in a nursery tank (a temporary tank for holding animals before they are released into the grow-out system). During acclimation, the density of shrimp is more than 500 per L. Pure oxygen is provided to the tanks and bags during acclimation. As a general rule, the acclimation temperature is changed by 1 °C (1.8 °F) every 15 minutes until it matches the culture system temperature. Once temperature is adjusted, salinity can be changed by 1 ppt every 15 minutes until it matches the culture tank salinity. If the pond has less than 15 ppt salinity and/or a temperature of less than 20 °C (68 °F), it is advisable to use a nursery phase and stock older, heartier juveniles later on.

Zero exchange intensive nurseries

Intensive nurseries (1,000 to 50,000 PL/m²) with biomass capacities of 2 to 4 kg/m² operated under zero exchange have become an important tool for shrimp farmers. Zero exchange nursery systems can have survivals of more than 80 percent and a harvest biomass of 1 to 7 kg/m², depending on the skill of the management and the investment in capital infrastructure (filters and oxygenation). Basic systems consist of a green house enclosure; a 20- to 60-mil, high-density, polyethylene (HDPE) liner; a sand or bead filter; a regenerative blower for aeration; a propane or electric heat source; and oxygen injection for large biomasses (more than 2.5 kg/m²) and emergencies. With increased experience and capital expenditure, farmers may increase production densities to more than 2.5 kg/m².

Intensive nurseries increase grow-out survival by allowing farmers to stock larger shrimp (0.25 to 1.0 g) into grow-out systems. In the temperate climate of the southeastern U.S., greenhouse-enclosed nurseries are used to give shrimp a head start in early fall (Fig. 4). A "head start" nursery is an effective way to increase the number of crops each year and have better control over production by stocking known quantities of heartier juveniles. In regions where early spring temperatures are cooler than 20 °C (68 °F), greenhouse nurseries are essential so that the crop can be held until water in the grow-out system warms up.

Nursery management

Nursery culture water is maintained at a temperature of 28 to 29 °C (82.4 to 84.2 °F), a dissolved oxygen level of 5 to 7 mg/L, a pH of 7.5 to 8.5, and a Secchi depth of 25 to 30 cm. Ten to 14 days before PL arrive from a hatchery, the culture tanks are filled with seawater (20 to 35 ppt). Then the water is sterilized with sodium hypochlorite (household bleach at 10 ppm) to prevent the introduction of pathogens from incoming waters. The treated culture water is allowed to sit for 24 hours without aeration to prevent a rapid reduction of chlorine. During this period

Figure 4. Intensive greenhouse nursery at Mote Marine Laboratory.

the chlorine concentration will remain above 1 ppm to provide the necessary disinfection level. After 24 hours, the water is heavily aerated to remove residual chlorine, a process that takes 3 to 5 days depending on temperature and organic load. The dechlorinated culture water is then fertilized and inoculated with algae.

The raceway water is fertilized with inorganic fertilizer (5 mg/L urea, 0.5 mg/L triple super phosphate and 1 mg/L sodium metasilicate). Water from an adjacent raceway with a healthy algal bloom is generally used to inoculate the new raceway with algae. Moderate aeration is maintained in the raceways as the algal bloom develops over the next 7 days to a Secchi reading of approximately 25 to 30 cm. It is important to check pH as the bloom develops. The high pH (higher than 8.75) created by the algal bloom can be a problem for young PL. To counteract it, carbon dioxide from a compressed CO_2 cylinder is added to the culture water with an air stone to decrease the pH to 8.0 before PL are stocked. Nursery aeration is then reduced to a minimum and PL are acclimated and stocked in the nursery system.

Nursery feeds

A diet of newly hatched *Artemia* (five nauplii/L/day) and dry postlarval feed (50% protein) is fed at 10 to 25 percent of the total body weight per day (bw/d) for the first 5 days after stocking. Then the feed rate is reduced to 7.5 percent bw/d and the feed is changed to a 40% protein crumble #0 feed. The crumble size is gradually increased (0, 1, 2, 3 and 4) as the shrimp grow. Shrimp feed is provided at 7.5 percent bw/d for days 6 through 14, then reduced to 6 percent bw/d for the remainder of the culture period.

Nursery growth rate

Under intensive nursery culture, native shrimp have grown from a PL_{10} to 0.5 g in 50 to 60 days. Supplemental oxygen and periodic filtration (using a sand or bead filter) are necessary to complete the nursery cycle as the biomass increases to more than 2.5 kg/m^2.

Nursery harvesting

Nurseries should be equipped with a harvest basin and constructed to drain fully. Harvest begins in the early morning when the nursery is drain-harvested into a harvest basin. Shrimp are removed from the harvest basin with collection nets and transferred to hanging balances for group weights. During the weighing process, a periodic sub-sample of the population is weighed and counted to determine the average weight of the population. The average weight and total biomass are used to determine total shrimp harvested and the survival in the raceways

Total shrimp harvested = Total biomass weighed ÷ Average weight

Survival rate = (Total shrimp harvested ÷ Number of shrimp stocked) x 100 %

The shrimp are rapidly weighed and placed in hauling tanks equipped with oxygen injection for transportation to the pond.

Intensive pond production

For optimum production, pond water should have a temperature of 28 to 29 °C (82.4 to 84.2 °F), a salinity of 20 to 30 ppt, a dissolved oxygen level higher than 5 mg/L, a pH higher than 7.5, and a Secchi depth of 25 to 30 cm. Ponds may be disinfected with 10 ppm chlorine upon filling to kill viral vectors and pathogens that may be introduced from wild sources. However, this may not be economically feasible, given the cost of chlorine and size of the operation. Whether or not a pond is dechlorinated, incoming water should always be filtered with 200-micron socks.

Ponds are filled and fertilized with 200 pounds per acre of cottonseed meal 5 to 7 days before stocking. Culture water from an established pond is transferred into the new pond to inoculate it and expedite the algal bloom. The algal bloom should be well established (25 to 30 cm Secchi depth) when shrimp are stocked.

Once in the ponds, shrimp are fed a 30 to 35% protein feed at rates of 3 to 6 percent bw/d. Feed trays are used to prevent overfeeding. The water must be aerated at a rate of 10 to 18 hp per acre (Fig. 5). The general pond culture period for 90-count shrimp (5.0 g) is 90 days. Ponds stocked with 0.5-g shrimp at a density of 200 per m^2 can grow at a rate of 0.5 g per week, have 70 percent survival, and produce up to 7,000 kg/ha (6,160 lbs/ac) of market size (5.0-g) live bait shrimp.

Figure 5. Intensive pond production at the Texas Agricultural Experiment Station in Corpus Christi, Texas.

Pond harvesting

Shrimp are harvested in the early morning when the temperature is low. A seine can be used to manually harvest the pond, though this method is labor intensive. Another method uses a hydraulic fish pump attached to the harvest basin to drain-harvest the pond. Harvested shrimp are rapidly weighed in small batches (less than 35 pounds each) before being loaded into a hauling truck. The hauling truck is equipped with oxygen injection to maintain saturated oxygen conditions (more than 10 mg/L) during transport. The temperature is also lowered to about 20 °C (68 °F) to reduce stress.

Farmers who harvest and sell live shrimp to wholesalers at pond bank can expect prices of $4.50 to $5.50 per pound. Farmers who invest in hauling trucks and equipment can expect to receive more than $7.50 per pound for delivered shrimp.

Other culture systems

Since the mid 1990s, researchers have been developing super-intensive, closed-recirculating shrimp production systems. Recent advances in this technology have made it possible to produce shrimp year round under high density conditions (3 to 7 kg/m^2). These systems are still in the research and development phase so capital and operating costs are much higher (more than $3.50 per pound) than with pond production methods ($1.25 to $2.50 per pound). The economic feasibility of these production systems is currently limited to markets where prices are consistently high (more than $5.00 per pound). Super-intensive production systems are marginally profitable when the price falls below $5.00 per pound. These systems are not economically feasible when there is considerable competition or profit margins are low, but they do show promise for year-round production or for facilities that must be located inland in biosecure areas.

Bait shrimp aquaculture information

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