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Pond Production of the Freshwater Prawn in Temperate Climates

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Pond production of freshwater prawns, *Macrobrachium rosenbergii*, in temperate climates involves stocking nursed, juvenile prawns into ponds, followed by 3½ to 6 months of growout until they are ready for harvest. The exact growout time depends on the temperature range within the growing season. Successful pond production of prawns begins with site selection, pond construction, and planning for a water source. The production cycle requires pre-stocking preparation, stocking, feeding, and managing water quality until harvest. A recent examination of the economics of pond production of freshwater prawns in temperate climates has been published (Dasgupta, 2005). Other aspects of prawn culture in ponds, as well as hatchery and nursery culture and general biology, can be found in Tidwell et al. (2005), New and Valenti (2000), D'Abramo and Brunson (1996), and Daniels et al. (1992).

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Site selection

The proper design and construction of ponds for freshwater prawns are extremely important. When selecting a site, avoid areas that are prone to flooding. The location must be suitable for pond construction and have an adequate water supply. The soil should have good water retention qualities. Both the soil and water must be free of chemical residues such as pesticidal organic compounds that could be harmful or lethal to prawns. Have the soil tested for pesticides known to have been used on the site. County Extension offices have instructions and containers for soil samples. To prepare samples, collect small soil samples from several (six to eight) locations in the area where you intend to locate a pond. Samples from the lowest lying areas must be included because they generally have the highest levels of contaminants if any are present. Thoroughly mix the samples and allow the soil to dry. Then fill the container with a sample of the dried soil for analysis. Most states operate laboratories that will process the samples and send a prepared report for a small fee. It is important to inform the laboratory about your plans to use this land for a pond site so they can conduct the appropriate tests (generally pH and particle size analysis) and offer the proper recommendations.

Pond construction

Properly designed and constructed ponds can have a tremendous effect on harvest efficiency. Harvesting freshwater prawns is extremely labor intensive if ponds are poorly designed or constructed. The first decision should be the placement of the harvest basin (internal versus external) and the drainage from that basin. The depth of the harvest basin and the drainage leaving the basin will determine pond configuration.

A prawn pond is about 3 to 3.5 feet deep at the shallow end and slopes to 4.5 to 5.5 feet at the deep end. A shallow-end water depth of 3.5 feet is recommended to discourage the growth of nuisance weeds (aquatic rooted plants and filamentous algae) during the production season and keep the water from cooling too rapidly when cooler air temperatures arrive at the end of the growing season.

The inside slopes of levees generally range from 2:1 to 3:1. Slope may vary somewhat with pond size and soil type, but a slope of 2:1 is recommended for highly effective control of unwanted aquatic vegetation. Levee tops that are 20 feet wide should be adequate, though some farmers prefer a wider main levee (working levee), usually located at the deep end of the pond. This wider working levee gives equipment and laborers better access to the harvest basin. Erosion from wind and waves generally has a modest effect on prawn ponds, which are usually smaller than 3 acres. There should be about 1 foot of extra soil height (levee freeboard) above the operating water level of the pond to add structural stability and capture rainwater.

Bottom contours and drain harvest structures are the most important aspects of freshwater prawn pond design because they affect efficiency of harvest. The pond bottom should have no obstructions or deep depressions to interfere with the goal of concentrating all prawns into one area during drain harvest. Slopes of 7 to 9 inches per 100 feet of pond length and about 7 inches per 100 feet from the side levees to the center of the pond are recommended. These measurements are taken from the toe (bottom of the slope) of the inner levees. During harvest, pond contours should direct the movement of the prawns as they follow the water flow into a wide, shallow, V-shaped channel along the length of the pond. The channel flow will then be directed toward either an internal concentration basin or an internal harvest basin. An external harvest basin is combined with an internal concentration basin, whereas the internal harvest basin design is a singular feature.

Pond size and shape

Prawn pond sizes will be site-specific as determined by land topography, desired pond shape, and the associated feeding, harvesting and processing capacities. Pond shape and size should fit management practices and capabilities. However, size typically ranges from 1 to 5 acres and the preferred shape is rectangular.

A plan that allies design and construction decisions with harvest intentions (product form and processing capabilities) is very important. Chances for success greatly increase when pond design and logistics (harvest plan) are compatible. Total pond acreage and rate of harvest should be determined by the number of pounds of prawns that can be sold fresh or on ice, or processed and frozen without suffering holding losses, and the potential for losing unharvested prawns when temperature falls at the end of the growing season. In a properly designed and constructed pond, about 75 percent of the prawns may leave the pond as the last 20 percent of the water exits (if harvesting to an external harvest basin). The ability to manually remove all prawns (including any stranded on the pond bottom) and process them on site depends on the availability of a sufficient labor force and/or ice-packing facility. Ponds smaller than an acre may yield more per acre than larger ponds if the shape of larger ponds reduces the ratio of perimeter to total surface area. Under similar management practices, higher ratios are believed to promote higher yields.

If a formulated feed is to be used, the pond shape should allow feed to be distributed over the entire surface of the pond because freshwater prawns are territorial. Feeding with the wind increases the range of feeding equipment. The topography may allow for siting a pond to take advantage of prevailing winds. If fertilization is the feeding strategy, distribution across the entire pond surface is probably not critical.

Design for harvest

Harvesting by seine is not recommended. The process is labor intensive and may damage prawns if they become entangled and are dragged through the mud of the pond bottom. Prawns naturally follow a flow of water, so drain harvest is a passive, yet efficient, method of collecting prawns. If the pond is poorly designed for draining, a large number of prawns may be left stranded in muddy depressions and have to be removed manually. If this is not done quickly, their condition may become unacceptable for processing.

Harvest basins can be external or internal, but should be designed so that all pond water drains rapidly into them.

External harvest basin

The external (outside the levee) harvest basin design consists of a fan-shaped (wide V from overhead), deepened area (6 inches deep, 20 to 30 feet wide, and approximately 30 feet from the drain pipe) within the pond where prawns are initially concentrated. This area is called an internal concentration basin. The fan is tapered and slopes to the focal point (V-shaped end), which is located at the opening of the drain harvest pipe (Fig. 1). Shallow trenching within the internal concentration basin may help direct the flow of prawns farther and concentrate them as they follow the water flow to the drain harvest pipe, and then to the harvest basin located outside the pond levee. Prawns that do not exit will remain in the internal harvest basin. The bottom of the drain harvest pipe(s) should be about 6 inches below the lowest point in the pond; this is referred to as "6 inches below the low." The pipe should extend slightly past the toe of the inner levee and through the outer levee to a point suitable for emptying water into the external harvest basin. The pipe(s) must have an adequate slope to move the water and prawns (Fig. 2).

The purpose of the external harvest basin is to collect the prawns

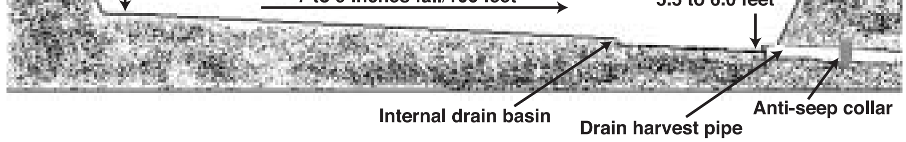

Figure 1. Cross-sectional side view of a pond designed for drain harvest to an external harvest basin.

and hold them under good water quality conditions until time to transport them for live holding or processing. Therefore, the water will need to be well aerated to maintain adequate levels of dissolved oxygen. Otherwise, the prawns will be stressed. The external harvest basin must allow the water to drain from the pond while holding all prawns. Livecars staked out in drainage ditches and expanded metal boxes with mesh have been used to hold prawns. A concrete basin equipped with mesh drainage areas is a permanent and highly effective option.

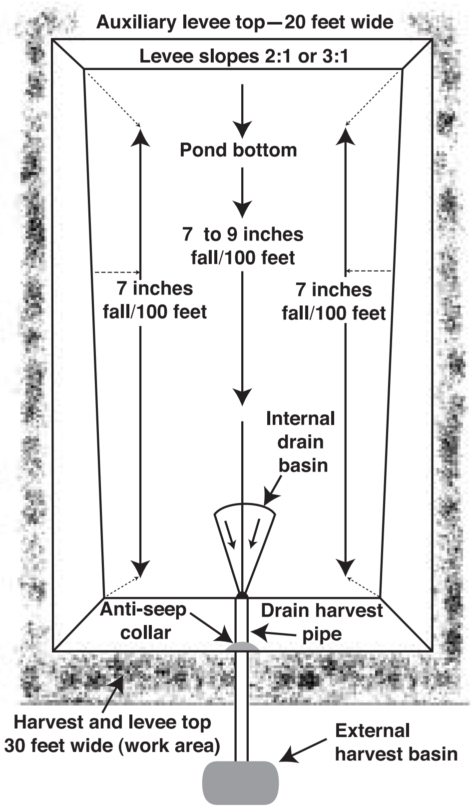

Figure 2. Overhead view of a pond designed with an external harvest basin.

The diameter of the drainage pipes should be based on the acreage of the pond; all water should drain from the pond within 6 to 8 hours. It is important to be able to drain the entire pond rapidly and to vary the rate of flow exiting the pond. Drain harvests of properly designed 1- to 3-acre ponds have demonstrated that a single 12- to 16-inch-diameter pipe or two 8- to 10-inch-diameter pipes will drain ponds within the desired time. If grass carp have been stocked to control aquatic weeds, workers must be careful to keep the carp out of drain pipes less than 12 inches in diameter. Carp tend to lodge themselves sideways in the pipes, preventing prawns from exiting. Removing the carp can be a laborious, time-consuming task.

If standpipes are used, a second smaller pipe that extends through the levee to control water level is recommended. This design is generally more cost-effective than the fittings, pipe and screen required to make the drain harvest pipe also serve for pond water overflow. Regardless of its size and design, the standpipe should be fitted with screening of adequate mesh size to prevent prawns from escaping the pond. Being able to exchange screens of increasing mesh size throughout the production period also can be beneficial.

Several types of pipe are available and cost is always an important factor. Underground, smooth-walled pip (piping used in the irrigation industry) may be a more economical choice than schedule 40 PVC. Pipe can be purchased at businesses specializing in irrigation equipment. Rate of flow through the harvest drainpipe is often controlled by a piece of plywood or some other flat, sturdy surface and an alfalfa valve (Figs. 3a and 3b). Plywood or another suitable material also is used as a primitive gate or guillotine valve on the inflow end (pond side) of the drainpipe. It should be put in place before stocking the pond. It serves as a safety valve if problems in the operation of the alfalfa valve arise. Check the placement of this gate before opening the alfalfa valve. The alfalfa valve is used to stop the flow of water leaving the pond and should be located on the outside of the pond at the external harvest basin. Be sure the valve and pipe are compatible and that the alfalfa valve has an arch, a removable central yolk within the valve. After this arch (yolk) is removed from the valve, water passes without obstruction through the harvest pipe and into

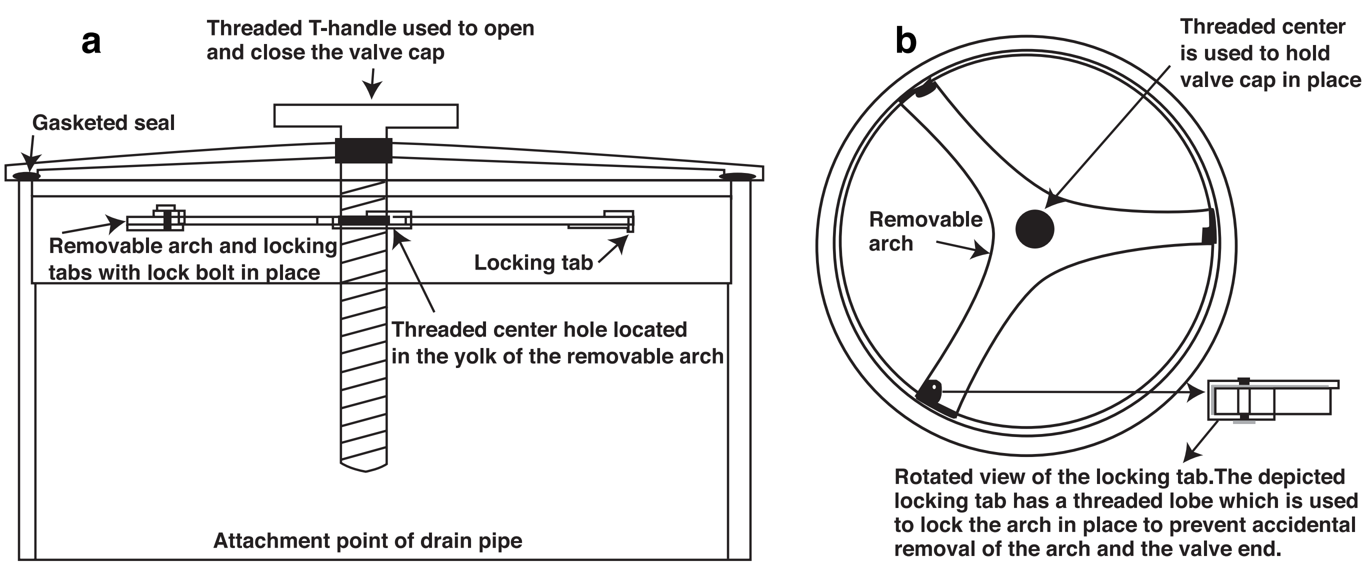

Figure 3. Cross-sectional side (a) and overhead (b) view of an alfalfa valve with a removable arch.

the harvest basin. An alternative to a standpipe for the control of water level within a pond is an in-line water control structure. Slats within the drain structure are either added or removed to maintain the desired water level.

Clean pond water must flow through the catch basin. As the harvest progresses, prawns should be removed from the catch basin periodically. To keep prawns clean, water may need to be added from a well or a neighboring pond to flow through the catch basin and external harvest basin of a harvested pond. Water leaving the harvest basin must have adequate drainage so it will not back up into the harvest basin and cause it to overflow. Structures such as rip-rap should be placed along the drainage ditch that is receiving the flow of water to reduce erosion, because a large volume of water flows when harvest begins.

Internal harvest basin

Having only an internal harvest basin requires few changes in overall pond design. Levee slopes and tops, grade, and pond bottom contours are similar except for the incorporation of a rectangular internal harvest basin. The internal harvest basin is located at the deep end of the pond and is 1 to 2 feet deeper than the rest of the pond bottom. It is much larger and deeper than the fan-shaped internal concentration basin used with an external harvest basin. An internal harvest basin stretches across most of the width and about 15 feet along the length of the pond bottom. Harvest is conducted by lowering the pond water level to the level of the internal harvest basin, where prawns are concentrated and then removed with a small seine or, if necessary, manually. It is absolutely essential to be able to aerate the water in the internal harvest basin (using a vertical lift or similar type of aerator). The slope within the basin must be directed to the drainpipe (Figs. 4 and 5). A single 12-inch pipe screened at the top, with a swivel type elbow at the bottom, should be sufficient. This pipe serves as both a drain pipe and a standpipe, so there is no need for another standpipe. The placement of the drain pipe within the internal harvest basin should be determined by external drainage features or cost. The internal harvest basin must be drained as completely as possible to ensure complete harvest.

If an external pond drain valve is fitted to the drainage structure and all prawns are to be harvested from the basin within the pond, then an alfalfa valve with a removable arch is not necessary. Various types of valves can be used, including an alfalfa valve with a fixed arch.

Substrate

Adding substrate to a prawn pond changes it from a two-dimensional area to a three-dimensional area. In ponds without natural (perimeter vegetation) or artificial substrate, the territorial prawns are confined to the benthic (bottom) area of a pond. Therefore, as the growing season progresses, the total weight (biomass) of the prawns in a pond increases and the corresponding amount of bottom area available per unit of body weight decreases. As a result, growth rates decrease and mean individual weights at harvest are lower in ponds with comparatively higher densities of prawns. This response is called density-dependent growth.

Adding substrate removes or delays problems associated with density-dependent growth because there is more area for prawns within the pond. As a result, production increases. The preferred substrate is the orange polyethylene safety fencing that is often installed around construction sites. It is comparatively inexpensive and durable. Alternative materials should be equally effective, such as large-mesh, less expensive monofilament netting.

Studies suggest that using a mesh substrate equivalent to 25 percent of the bottom surface area increases harvest yield by 15 to 20 percent. The actual amount of mesh substrate required is calculated by including the area (excluding mesh) of both sides of the substrate. The size of the mesh may not be as important as the overall amount of substrate used. Generally, 11,000 to 15,000 square feet of substrate (calculation based on one side) are required per water surface acre, assuming the average depth of the

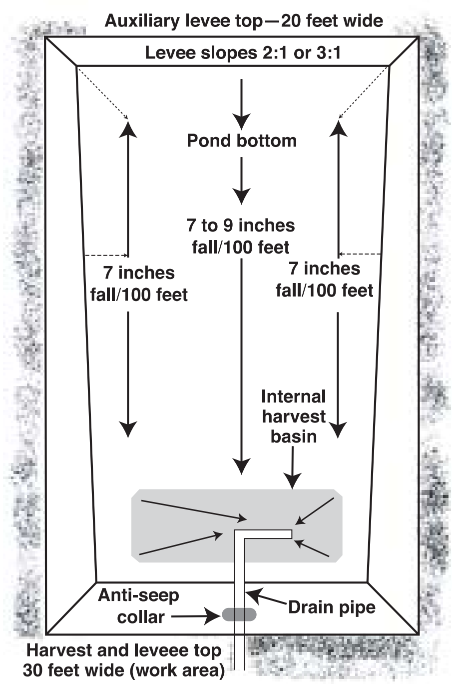

Figure 4. Overhead view of a pond designed with an internal harvest basin.

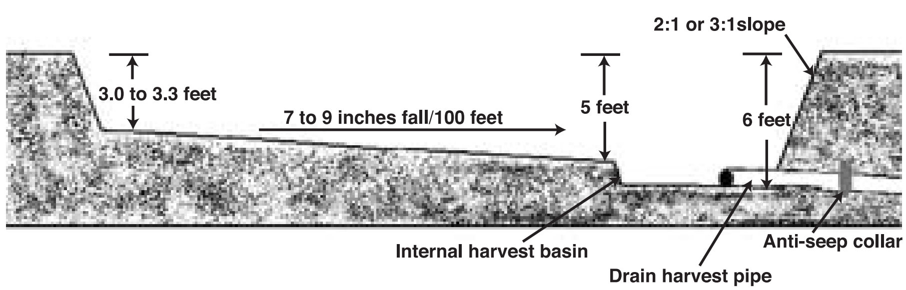

Figure 5. Cross-sectional view of a pond designed with an internal harvest basin.

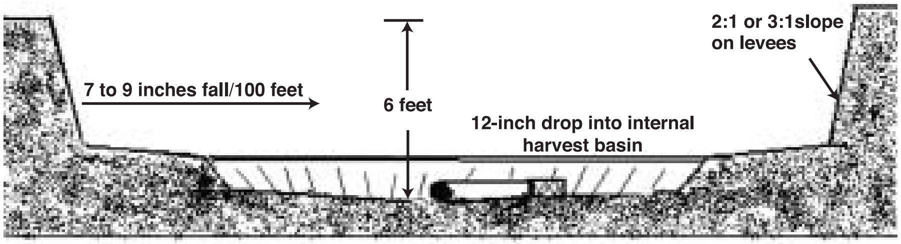

Figure 6. Cross-sectional view of a pond with focus on the internal harvest basin.

pond is approximately 3.5 feet. To get maximum use of the substrate, it should be suspended vertically within the water column and positioned about 6 inches above the bottom and below the surface of the water. It may not be practical to install substrate in ponds larger than 2 to 3 acres. This is the size of most commercial ponds used for the culture of *Macrobrachium*.

Studies have demonstrated that using substrate increases yield regardless of stocking density. The cost and durability of the material used must be weighed against the increase in production that is realized.

Water sources and quality

Well water is recommended for freshwater prawn production. Water sources that may have been contaminated by pesticide runoff should be tested to be sure they are suitable for raising prawns. If surface water is used to fill ponds, be careful to keep fish from entering. Some species of fish will eat small prawns and the feed or fertilizer that is added to ponds as a source of nutrition for the prawns.

Besides chemical pollution, the principal water quality concerns in freshwater prawn production are hardness, alkalinity and pH. Water hardness should range between 50 and 200 mg/L. Lower levels reduce the hardness of the calcium-based shell of prawns; higher levels may reduce growth and produce lime ($CaCO_3$) encrustations on the shells. To increase the hardness of the water, calcium must be added; agricultural gypsum ($CaSO_4$ $2H_2O$) is recommended. The purity of this compound varies from 70 to 98 percent. Assuming the product used is 100 percent pure, total hardness can be increased by 1 mg/L for every 1.73 mg of gypsum added per liter of water. Alkalinity should range from at least 50 mg/L to 150 mg/L. Agricultural lime can be used to increase both alkalinity and hardness. The pH of the water should be between 7.0 and 8.5. A total alkalinity of 100 to 150 mg/L will stabilize pH by buffering from the carbonate fraction of the limestone (Wurts and Durborow, 1992).

Pond preparation and stocking

Prawns should not be stocked in ponds containing fish. Fish are potential predators and/or competitors for natural food resources and feed. Fish must be eradicated before stocking prawns, either by draining the entire pond or by applying 3 pints (1.41 L) of 5% emulsifiable rotenone (Fintrol®), a piscicide, per acre-foot of water. This product can not be applied without a certified pesticide applicator's license or direct supervision by someone who has been licensed. Rotenone is potentially toxic to prawns. The rate at which it breaks down after application is influenced by temperature, light, levels of dissolved oxygen, and alkalinity. Generally, prawns can be stocked 2 to 3 weeks after application. To ensure that conditions are safe, place four or five juvenile prawns into two or more small cages suspended from floats and let them drift within the water column at different locations in the pond. If the prawns survive for 48 hours, any chemical residue is probably gone.

Ponds should be filled with water and fertilized about 2 to 3 weeks before they will be stocked. Ponds should be fertilized with inorganic and organic fertilizers to stimulate an algal bloom and a bacteria-based system within the water column. This will keep sunlight from reaching the bottom of the pond and prevent the growth of aquatic weeds such as *Chara* sp. and *Naja*s sp. (Brunson et al., 1994).

A liquid inorganic fertilizer—either a 10-34-0 or a 13-38-0—gives the best results. It should be added to the pond water at a rate of 1.9 L (½ gallon) per surface acre to stimulate blooms of microscopic algae. Inorganic fertilization is most effective when pond water temperatures exceed 65 degrees F. If water has low hardness, adding lime will increase the effectiveness of the inorganic fertilizer. If possible, this procedure should be complemented by adding water from ponds with already established populations of desirable phytoplankton (a process called seeding). If either rooted plants or floating filamentous algae ("moss") plants appear, no additional inorganic fertilizer should be applied because it will encourage the growth of these undesirable aquatic plants. Dense nuisance plants can interfere with applying feed and fertilizers and with harvest.

Organic fertilizers that can be used in a prawn pond include distillers dried grains and solubles (DDGS), cottonseed meal, alfalfa meal, soybean meal, sinking catfish feed or combinations of these materials. Make the first application, at a rate of 200 pounds per acre, within a day after filling the pond. Thereafter, apply the chosen fertilizer at a rate of 15 to 20 pounds per acre every other day until stocking to enhance production of natural food organisms for the prawns. Once the prawns have been stocked, follow the recommendations for organic fertilization (see the Feeds and Feeding section). The choice of an organic fertilizer should be based on cost and availability.

If pH values fail to stabilize naturally in ponds before stocking, sodium bicarbonate should be added. However, this compound does not change pH significantly and its effect is not long lasting (see the Water Quality and Management section).

Ponds should be stocked as soon as it is certain that water temperatures in the early morning will consistently remain above 68 degrees F. Stocking may occur from late April though mid-June, depending on the region. Because of the limited growing season, only juveniles should be stocked, regardless of stocking density. The mean stocking weight should be 0.25 to 0.40 g to realize the best return for the purchase cost of juveniles. In regions where the growing season is shortest, the stocking weight should be at the high end of the range. The range in juvenile stocking weight is usually the result of postlarvae having been held in the nursery phase of culture for different lengths of time (generally 40 to 60 days). Smaller juveniles are less expensive, but just a small increase in stocking weight, from 0.14 g to 0.25 g, can result in a 40 percent increase in production for a 120- to 130-day growout period. Purchasing juvenile prawns with a mean weight of more than 0.40 g is not an efficient alternative because transporting them requires larger volumes of water, an expense that is aggravated if they must be transported a considerable distance. In addition, purchasing these more expensive juveniles will substantially increase the variable costs of an enterprise, usually without enough additional revenue to compensate for it.

Before stocking, make sure the temperature of the pond water is similar to that of the transport water. If the difference is greater than 5 degrees F, the prawns should be gradually acclimated to the temperature of the pond water. This can be accomplished by gradually mixing the pond water (at least 50 percent replacement) with the prawn holding water, allowing about 5 minutes for each degree of temperature increase.

Stocking rates that will provide marketable prawns after a 4- to 5-month growth season generally range from 8,000 to 28,000 per acre. Mean individual weight at harvest is inversely proportional to stocking density because individual growth is influenced by the total amount of prawn biomass in the pond. Therefore, choice of a stocking density will probably be determined by the market and marketing strategies.

Feeds and feeding rates

As in other types of animal agriculture, successful prawn culture is based upon realizing high-value outputs (prawns) from low-cost inputs (fertilizer and feed). The objective is to achieve maximum growth by providing a continuous source of nutrition as inexpensively as possible without overfeeding. Overfeeding not only reduces potential revenue but also can lead to poor water quality that can impair growth.

Organic fertilizer enhances the natural productivity of ponds so that sufficient natural food organisms (insect larvae, worms, etc.) are available for prawns. Organic fertilization continues throughout the growing season, provided that the demand for food by the prawns does not exceed the rate at which natural food organisms are being produced. Sinking catfish feed has traditionally been the recommended feed/fertilizer, but other pelleted forms of agricultural feeds or feedstuffs, such as corn gluten pellets, wheat midds, or range cubes, also have been used. The protein content of these products ranges from 17 to 20 percent (as is) or 20 to 20.3 percent on a dry weight basis. The survival, mean individual harvest weight, and harvest yield achieved with these fertilizers in production experiments have been comparable to those using sinking catfish feed. Therefore, using these less expensive fertilizers, either alone or in combination, may reduce variable costs considerably.

Table 1. Recommended percentages of total organic fertilizer/ feeds for the pond culture of *Macrobrachium rosenbergii* during specific time intervals of a 20-week maximum growout period.

Weeks	Percentage of total
1 to 6	16.0
7 to 11	27.8
12 to 16	32.6
17 to 20	23.6

Recommended feeding rates are estimates based upon two factors—water temperature and prawn biomass (determined by estimates of individual weight, density and survival). The daily rate of fertilizer application increases as the length of the growing season increases, but generally should not exceed 70 lb/A. The total amount of post-stocking fertilizer/feed needed, expressed as a ratio relative to the total anticipated production, is approximately 3.5 to 4.0. A recommended rate of application for a 20-week growout period, expressed as a percentage of total fertilizer/feed, is presented in Table 1. With higher initial stocking densities, production is anticipated to increase and the total amount of feed and corresponding daily rates of application per acre will increase based upon these percentages. Applying this level of organic fertilizer will probably be sufficient for stocking densities up to approximately 24,000/A. At higher stocking densities, this amount of fertilizer probably will not produce the quantity of natural food required for maximum prawn growth rate during the final 3 to 4 weeks of growout. At this last stage of growth, prawns may need to be fed a water-stable, nutritionally complete prawn diet as a supplement. However, the cost-effectiveness of using a supplement is questionable. Formulated feeds may be cost-effective only when yields are expected to exceed 1,500 lb/A.

Polyculture

The concept of prawn and fish polyculture is based upon the belief that the amount of biomass in prawn ponds that have been stocked at the lower end of the range of density can be increased without any detrimental effect. The ecological balance (chemical and biological) in a pond can be better realized through the culture of two species. A number of fish species have been cultured in the same pond with prawns, including channel catfish, yellow perch and tilapia. The best application of this polyculture management strategy is to confine the fish in cages floating in the prawn ponds. This design prevents fish from consuming prawns, aids in managing water quality, and facilitates the harvest of the two species. To be suitable for polyculture, a fish species must be a warm-water species, adaptable to cage culture, and able to reach marketable size within 4 to 5 months. Based on these criteria, the best candidate appears to be *Tilapia* sp.

In experimental ponds, tilapia have been stocked in cages at a density of 1.5 to 3 fish per cubic foot of cage volume, up to a total of 1,000 to 2,000 fish per acre. Tilapia weighing 100 g have been stocked in experimental ponds. Their mean weight at harvest has ranged from 470 to 500 g. In commercial culture, the stocking size has ranged from 50 to 400 g, depending on the size demand of the market the producer desires to serve. The cages are located in the deepest areas of the pond, so that at least 2 feet of clearance can be maintained between the bottom of the cage and the pond bottom. Cages should be located to benefit from water circulation produced by an aerator in the pond. Convenient access to the cages must be planned so that fish can be fed daily. A floating 32% protein catfish diet is adequate and tilapia should be fed as much as they will actively consume (to satiation) in 10 to 20 minutes. In polyculture, prawns benefit from two additional sources of organic material, undigested food and any uneaten food that sinks to the bottom of the pond. It has been suggested that the rate of application of fertilizer/feed for the prawns could possibly be reduced by about 25 percent without any corresponding need to reduce the prawn stocking rate. Polyculture can be combined with added substrate in intensively managed ponds and may have its best application in these same smaller ponds. These systems require more frequent monitoring of water quality and possibly more aeration.

Water quality requirements and management

Other than the quality and quantity of food consumed and water temperature, dissolved oxygen and pH are the principal water quality variables that influence prawn growth and survival. These factors must be monitored and maintained at satisfactory levels.

Dissolved oxygen

Oxygen is the variable that can be managed most effectively to improve annual yields. There must be some way to aerate ponds, even when the stocking density and fertilization rate are low. Although prawns can survive when dissolved oxygen is below 2 ppm, at least 3 ppm should be maintained to avoid stress and achieve the highest growth rates. When levels fall below or are anticipated to fall below this concentration, pond water should be aerated by an electric, in-pond aerator (1 hp per water surface acre) and/or a tractor-driven, paddlewheel aerator. When water temperatures and feeding rates increase, dissolved oxygen should be monitored and recorded more often (at least early morning, late afternoon and late evening). Levels of dissolved oxygen are generally lowest just before sunrise. An alternative is to aerate prawn ponds for 12 to 14 hours (2000 h to 0800 -1000 h) each day, but this may still be insufficient to prevent low levels of dissolved oxygen so ponds still must be monitored. Aerators should be located at the deep end and near the drain basin area to minimize the accumulation of sediment there. If aerators are located in the shallow end, a shallow depression will form below them and cause prawns to be stranded in a large pool during a drain harvest. If pond depth exceeds what is recommended (see the Pond Construction section), then stratification can occur, causing levels of dissolved oxygen in the bottom water layer to be low or even reach lethal levels.

pH

To avoid stress and possible mortality, the pH of the water should remain within the range of 7.0 to 9.0. Prawns grow best at a pH of 7 to 8.5, but will still grow and survive at a pH as low as 6.5 and as high as 9.5. A pH higher than 9.0 is undesirable for stocking and anything higher usually is lethal to juvenile prawns (see the Pond Preparation and Stocking section). Problems with high pH generally occur in the late afternoon on sunny days during the early part of the production period, when inorganic fertilization is used to promote fast-growing blooms of microscopic algae. Water of low alkalinity (0.5 to 50 mg/L) is more prone to undesirably high pH because its capacity to buffer against high pH is reduced (Wurts and Durborow, 1992). Total alkalinity should be 50 to 150 mg/L (ppm), and can be increased to desired levels by applying agricultural lime ($CaCO_3$). Juvenile prawns appear to be more susceptible to the harm of high pH values. High afternoon pH generally ceases to become a problem as organic matter begins to accumulate and is routinely introduced into the pond. As the organic matter decomposes, carbon dioxide is produced and it usually keeps the pH below 9.0. If pH begins to rise toward an undesirable value during the early period of production, organic matter should be added at a rate of 15 lb/A, in addition to what has been recommended (see the Feeds and Feeding Practices section), for about 7 days. To avoid pH increasing to lethal levels, a rapid reduction in pH can be achieved through the addition of DePhos-A®, buffered alum (sodium bicarbonate and aluminum potassium sulfate $AlK(SO_4)_2$ at a ratio of 1:1 in powder form). For every 0.5 reduction of pH desired, the added alum must be dissolved in the water to produce a concentration of 10 ppm (approximately 42 lb/A each of both alum and sodium bicarbonate). pH should be monitored before and within a few hours after introduction to determine whether more might need to be gradually added to achieve the desired pH. Initial additions should not exceed a concentration that will produce a one unit decrease in pH. Additional amounts may be needed if pH begins to increase again toward potentially lethal levels (> 9.5).

An alternative way to prevent lethally high pH from occurring, particularly from infestations of filamentous algae, is to apply an algal herbicide such as Hyrothol®. Tests have shown that Hyrothol® has no effect on prawn survival when the level of application for treatment does not exceed 0.2 ppm. Another possibly effective herbicide is Green Clean® (sodium carbonate peroxyhydrate), but information about whether it is lethal to prawns under the recommended levels of application is lacking. The application of a herbicide must be accompanied by frequent monitoring of dissolved oxygen, as the decomposition of dead algae consumes oxygen. Although these herbicides are short-lived (rapidly decomposed), they should be used as a last resort because their possible effect on prawn growth has not been determined. Copper sulfate should never be used as an algicide in prawn production ponds because extremely low levels of copper are toxic to prawns.

Harvest

Depending on the latitude of the pond, the length of the growout phase may be 110 to 170 days. Harvest should be planned when daily water temperatures range from 62 to 68 degrees F for 4 to 5 days, or before an anticipated cold front may cause lethal water temperatures (≤ 55 degrees F) to occur. Harvest is most efficient in ponds designed for drain down into harvest basins located either within the pond or on the outside of the pond levee (see Harvest Methods and Basin Design section). The harvest basins must be well aerated as the prawns are concentrated and removed. Where the growout phase is more than 160 days, it may be helpful to seine out the largest prawns 25 to 40 days before complete harvest. This often causes a sufficient compensatory growth response in the remaining population to make the practice cost-effective.

Currently, yield from a single-batch harvest (no selective harvest) of most commercial enterprises in the U.S. ranges from 600 to 1,800 lb/A. Yield is influenced by a combination of factors that include stocking density, stocking size, duration of growout, shape of pond, presence of substrate, and selective harvest. Stocking density is inversely related to growth rates, but directly related to overall production at equivalent levels of survival. The presence of plants around the perimeter of the pond is believed to improve yield and is probably associated with the beneficial effects of substrate. Water circulation may also improve yield, but there has been no definitive demonstration of this effect.

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