

Sustainable Farming of Freshwater Prawns and the Assurance of Product Quality



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INTRODUCTION

The quality and safety of the freshwater prawn, *Macrobrachium rosenbergii*, are directly linked to its value to the consumer and ultimately to its ability to compete within the global marketplace. This bulletin details best management practices (BMPs) to optimize production and product quality of *M. rosenbergii* through husbandry practices (land selection, water resource management, pond design, nutrition management, harvest), postharvest transport and handling, and processing. Low-input production practices are recommended and are based upon a semi-intensive culture strategy that has been demonstrated to be highly suited for the optimization of husbandry of *M. rosenbergii*. Such a management approach is characterized by efficient use of land resources, comparatively low input as established by the initial number of juveniles that are stocked, the type of feeding strategy, and reduced energy consumption and labor to achieve the lowest cost of production.

BMPs broadly refer to those practices that are founded upon efficient use and best management of available resources combined with the proper handling during harvest, after harvest, and in processing. Adherence to these recommended practices would ensure the production of a safe and high-quality product, while preserving the environment and contributing to the social well-being of society. Codes of practice or management principles are often aligned with product quality assurance. Generally, these practices are voluntary and established within the industry itself, but they

could include regulations established by governmental agencies as well as recommendations by governmental and nongovernmental organizations. Implementation and adherence to BMPs establish ongoing credibility and confidence among consumers and are the foundation for earning environmental certification that indicates sustainable/environmentally responsible production practices.

The implementation of BMPs should be comprehensive and extend from farm to table or from hatchery to consumer. In 2006, the Food and Agriculture Organization (FAO) of the United Nations agreed to a set of eight core international principles for responsible shrimp farming. These principles address farm location, social responsibility, good health management, impact of water use, farm design and construction, responsible use of brood stock and postlarvae, efficient use of feeds and feed management, and food safety and the quality of shrimp products. The practice of environmentally responsible farming is site-specific and flexible but overall is founded upon guidelines devoted to the preservation of resources and adherence to environmental stewardship. The quality of the freshwater prawn product (including safety) is affected by practices that characterize each stage of production and depends on strict adherence to BMPs before, during, and after harvest. The following BMPs are recommended for the pond production, harvest, and postharvest handling of freshwater prawns.

LAND (SITE) SELECTION FOR PRODUCTION PONDS

For land under consideration for pond construction, the soil must have a high water-retention capacity but still be manageable enough to form stable embankments. Soil tests are available to evaluate physical properties to estimate the extent of water leaching. In addition, you should know any history of the use of the land for agricultural activity. Pesticides, herbicides, other residual chemicals (from a mine, for example), and antibiotics (from animal rearing operations) may persist in soil proposed for use in pond construction and could affect prawn growth and quality. Therefore, if any concerns exist, conduct analyses that determine the nature and concentration of possible soil contaminants

to define the risk of farming prawns on the site. If the proposed site is near agricultural land still under production, it is essential to know about herbicide/pesticide application and the probability of pond contamination through runoff from heavy rain. BMPs require you to avoid any potential contamination of pond water from lethal herbicides and pesticides. If livestock farms are located near an intended site, evaluate the threat of contamination from aerial application runoff entering ponds during heavy rain or other extreme weather conditions. Eliminate the potential introduction of microbial pathogens to pond water through runoff or animals wandering onto the aquaculture farm site.

POND DESIGN

Construct ponds using either an embankment or an excavation process. Embankment ponds are constructed using the soil removed from a nearby ditch/trench or from the area that will become the pond bottom. Excavated ponds are similarly constructed, but the pond bottom is located deeper than the original ground level that characterizes embankment ponds. Levees of production ponds generally range from 2:1 to 3:1, but a slope of 2:1 is best. We recommend slopes between 7 and 9 inches per 100 feet for the length of the pond (shallow end to deep end) and about 7 inches per 100 feet from each side levee to the center of the pond. These measurements originate from the toe (bottom of the slope) of the inner levees. During drain harvest, this recommended contour facilitates the movement of prawns with the flow of water and their concentration into a wide, shallow, V-shaped channel situated along the middle of the long axis of the pond bottom. Flow in this channel is further directed toward an internal concentration basin where prawns congregate and from which they are directly harvested. Alternatively, flow can be directed through a drainpipe to an external concentration basin for removal (see the subsection titled *After Harvest*).

The efficiency (speed) of prawn removal from the pond for harvest directly influences product quality. Therefore, the pond bottom must be free of all obstructions and deep depressions that interfere with free prawn movement in the flow of water. Prawns stranded in low-volume depressions as the pond drains often become exposed to sediment-filled, oxygen-depleted water. The longer prawns remain stranded in such depressions, the more likely overall product quality will suffer because of

stress-related changes caused by intense sunlight, warm air temperatures, and other conditions. Prawns left in depressions have to be removed manually — a labor-intensive process that in most cases also compromises quality.

An internal harvest basin that collects prawns for harvest is located at the deep end of the pond and is between 1 and 2 feet deeper than the rest of the pond bottom. The internal harvest basin includes an area that extends across almost the entire width of the pond and approximately 15 feet along the length of the pond from the deep end. To preserve product quality, aerate water in the internal harvest basin. Use a seine to carefully remove prawns from the internal harvest basin as water continues to drain into the basin. The drainpipe located in the harvest basin must be equipped with a swivel-type elbow at the bottom and screened at the top to prevent escape of prawns.

An external harvest basin — constructed outside the levee of the pond — is fed from a fan-shaped (wide “V” from overhead), deepened area (6 inches deep, 20–30 feet wide, and approximately 30 feet long from the drainpipe) within the pond where prawns are initially concentrated (internal concentration basin). The fan is tapered and slopes to the focal point (V-shaped end), which is located at the opening of the harvest drainpipe. Shallow trenching within the internal concentration basin may also assist in directing the flow of prawns and concentrating them as they follow the flowing water to the harvest drainpipe. A proper design will effectively cause prawns to remain within or follow the water flow, exit through the harvest drainpipe, and collect in the har-

vest basin outside the levee. For properly designed 1- to 3-acre ponds, a single 12- to 16-inch-diameter pipe or two 8- to 10-inch-diameter pipes are sufficient for complete pond drainage within the recommended time.

We recommend smaller pipes (6 inches) that extend through the levee to control water level. These pipes generally are more cost-effective than the fittings, pipe, and screen required to make the harvest drainpipe also serve to regulate water level and overflow. Regardless of size and design, the standpipe should be fitted with screening of adequate mesh size to prevent prawns from escaping. As the prawns grow larger, it is helpful to switch to

larger-meshed screens to avoid clogging of the drainpipe with organic debris.

Design of the external harvest basin can vary as long as the basic principle is maintained: collecting prawns and holding them in good-quality water so they can be removed and transported for live holding or processing. Design of the external harvest basin must allow for excess water to drain into another location while the prawns remain in the basin. A highly effective permanent design includes a concrete basin equipped with reinforced-steel-mesh areas to either drain the water or maintain the level at a workable depth of 2–3 feet.

WATER: SOURCE, CONSERVATION, AND PRESERVATION OF QUALITY

Water is a primary resource consideration and must be effectively managed through conservation practices and monitoring of quality both during the production cycle and in preparation for release at drain harvest. A properly constructed and protected well is an ideal water source for pond culture; you can feel highly confident that its water is not subject to unknown microbial or chemical contamination that may affect prawn growth, survival, and product quality. An optional water source can be a reservoir pond where water is collected from a surrounding, pesticide-free watershed and then used to fill ponds (watershed ponds) and compensate for losses resulting from evaporation and seepage. Watershed ponds are a potential problem because runoff that fills the reservoir may be affected by unknown or seasonal land-use activities in the watershed area.

Pumping water from other bodies of surface water, such as adjacent creeks or streams, is a high-risk option that you should avoid. For this source of water, there is no control over the introduction of chemical or microbial contaminants, especially wastes of wild or domestic animals. In addition, the availability is unpredictable because droughts reduce the amount of water to a level insufficient to fill ponds and compensate for losses at particular times during the annual pond production period.

The pond water source must have adequate levels of alkalinity and hardness. These measurements can range from 50 ppm to about 150 ppm, but preferably, they should be between 100 ppm and 150 ppm. Alkalinity and hardness levels should not be disproportionately different from one another. Sufficient levels of hardness and alkalinity are needed to mitigate fluctuations in pH of the pond water. Imbalances can cause increases to very high alkaline levels that are stressful and may alter the quality of the product, or even cause mortality. In addition, sufficient levels of dissolved calcium must be available to

maintain proper hardness of the prawn's outside shell (exoskeleton). To maintain shell rigidity, water hardness should range between 50 mg/L and 200 mg/L. At hardness levels less than 50 mg/L, the prawn's shell will be more susceptible to fouling by bacteria, fungi, or parasites. Even in the absence of shell fouling, inadequate levels of hardness may cause a soft shell condition that may not be appealing to the consumer.

Water conservation and a high-quality effluent must be effectively addressed to merit product certification based on environmentally friendly production practices. For proper water quality management, never routinely drain part of the water from a pond and pump in fresh water. In addition, you should minimize the need for water replenishment caused by evaporation. Maintain water level in a pond below the top of the drainage structure to accommodate the collection of rainfall and thereby reduce the amount of water needed to compensate for losses from evaporation and seepage. It minimizes the need for pumping water from a well and is most effective in embankment (with levees) ponds, where loss of effluent due to overflow is minimized.

There is no net loss of water when ponds are filled and eventually drained. However, because freshwater prawn ponds are drained each year (pond production phase) as part of the harvest process, the quality of the drained water (effluent) is an important consideration. The low-input strategy for freshwater prawn production minimizes any adverse condition of water quality. This system is based upon the simple enhancement of natural productivity, and the daily input of organic matter is generally less than 25 pounds per acre for the entire growing season. Under these conditions, the overall quality of the discharge water at harvest is as good as, or possibly better than, the quality of the water originally used to fill the pond.

POND PREPARATION BEFORE STOCKING

If the soil that constitutes the pond bottom is acidic (pH < 6.5), apply lime at a rate to achieve the desired pH increase before stocking the prawns. This recommended practice is a component of an overall management strategy to reduce the incidence of high pH that commonly occurs after initial inorganic and organic fertilization of the pond water, particularly for newly constructed ponds (see *Water Quality Management* section).

After filling the pond, perform an initial organic fertilization of the water approximately 3.5–4 weeks before stocking by adding about 200 pounds per acre of materials such as corn gluten pellets, soybean meal, or cottonseed meal. After approximately 4–5 days, continue applications of an organic fertilizer at a rate of 15 pounds per acre every other day until stocking. Add an inorganic fertilizer to the ponds at the same time. Inorganic fertilization is designed to initiate a microalgal bloom that will prevent nuisance weeds from growing on the bottom and ultimately interfering with an efficient drain-down harvest.

Determine rates of application for inorganic fertilizer by the history of the pond and the chemical characteris-

tics of the water. Rates of inorganic fertilization for a particular pond can vary from year to year. Generally, a combination of nitrogen and phosphorus in liquid form — either 10-34-0 or 13-38-0 applied at a rate of 0.5 gallon per water surface acre — is sufficient for ponds with a calcium hardness less than 50 mg/L. If calcium hardness ranges between 50 mg/L and 100 mg/L, it may be necessary to increase the rate to 1 gallon per acre. Alternatively, you may add phosphoric acid at a rate of 0.5 quart per acre to provide inorganic fertilization. As each pond is different, you may need to add an additional application of 0.5 quart per acre if a phytoplankton bloom does not start. In some cases, nitrogen may be the limiting nutrient to stimulate an algal bloom. Adding either urea (33–44 pounds per water surface acre) or ammonium nitrate (44–59 pounds per water surface acre) may be necessary to deliver 15–20 pounds of nitrogen per water surface acre. Organic and inorganic fertilizers help develop and maintain a desired level of pond water turbidity. That level is 24–32 inches as measured by the use of a Secchi disk.

INITIAL STOCKING OF PRAWNS

Due to the limited growing season, we recommend stocking juvenile freshwater prawns with a mean weight between 0.25 g and 0.40 g. To reduce the level of variation in size, grade (cull) juveniles from a population before stocking. A grading that results in the numerical division of a population at 60% (high) and 40% (low) will reduce the level of size variation that

also will be reflected at harvest. Graded populations within the recommended proportional division should collectively outperform the production of an equivalent ungraded population. The low-grade population can be returned for continued growth and eventually stocked at a density lower than that of the high-grade juvenile prawn population.

ORGANIC FERTILIZATION AFTER STOCKING

At stocking densities that range from 8,000–12,000 per acre (low-input farming practice), it is unnecessary to provide relatively expensive, commercially manufactured, nutritionally complete, water-stable, formulated feed. Instead, provide a pelleted nutrient supplement to meet nutritional requirements for good growth rates. Prawns consume some of the pellets, but the remainder rapidly breaks apart due to poor water stability and thereby fertilizes the pond bottom and enhances secondary productivity, which is complemented by a good algal bloom. At the low-input stocking density, worms, aquatic insects, insect larvae, and other live food organisms — combined with low-protein feed pellets — should support

Table 1. Recommended percentages of the total calculated amount of organic fertilizer (see text) for the low-input pond culture of freshwater prawns.

Weeks ¹	Percent of total ²
1–5	15
6–10	30
11–15	30
16–18	25

¹Specific time intervals that compose an 18-week growing season in temperate climates.

²Daily input is calculated by multiplying the total amount determined for a growing season by the percent for a time period and dividing by the number of days in that time period. For example, the daily rate of application for weeks 1–5 would be calculated by (total amount for season x 0.15) divided by 35 (number of days in 5 weeks).

growth throughout the growout season. In fact, freshwater prawns preferentially consume natural foods as long as they are available, even when you provide a formulated feed. Through the range of water temperatures during the season, maximum growth rates are the norm when the diet principally consists of these natural food items. Prawns produced on natural foods and plant-based pellets could merit a label that the product was grown in an ecologically conscientious manner — maybe even “organically grown.” Such attributes should help to increase product value to fill this expanding market niche.

Several commercially available livestock feed supplements, such as range cubes, corn gluten pellets, and wheat middlings in pelleted form, alone or in combination, are suitable for use as nutritional supplements. Such nutrient sources should contain at least 20% crude protein to be highly effective. Apply nutrient supplements daily

in a pelleted form to facilitate distribution throughout the pond surface. To calculate the total amount of pelleted nutrient supplements needed per production pond for a growing season, multiply the anticipated harvest weight (pounds per acre) by a factor of 2.5–3.25, and then multiply by the acreage of the pond. This total amount of supplementation is based upon the estimated pounds of prawns to be produced, combined with the effect of pond water temperature on food consumption and growth. Divide the total supplementation (pounds per acre) proportionally among groups of weeks during the growing season. Table 1 presents the percentages recommended for the different groups of weeks during an 18-week growing season. Calculate the daily feeding rate for each group of weeks by dividing the appropriate number of days into the calculated amount of feed needed for that respective period.

USE OF VERTICAL SUBSTRATE

We strongly recommend the use of vertically oriented substrate in organically fertilized, low-input production ponds. Vertical substrate has been consistently effective in increasing annual pond production of freshwater prawns by approximately 20%. Plastic highway barrier fencing (generally an orange color) serves as an effective substrate. Less-expensive substitutes, such as bird netting or old gill nets, are equally effective. Researchers have tested a variety of other substrates based on differences in color, mesh size, and texture, and they observed no significant differences in effectiveness.

Substrate within the water column of the pond probably provides additional surface area for microorganisms to grow (biofilm) and serve as a food source for prawns or for their prey. In addition, substrate may provide addi-

tional areas of refuge to physically separate prawns in three dimensions and thereby reduce the incidence of aggressive encounters and possibly cannibalism. This spatial separation may be particularly beneficial for a prawn rendered temporarily defenseless when it sheds its exoskeleton (shell) to grow before producing a new shell.

We recommend substrate equivalent to 25–35% of the area of the pond bottom. Area is easiest to calculate when using two-dimensional, meshed material because it can be derived by multiplying length by the height of one side. Install substrate material approximately 6 inches below the water surface and 6–8 inches above the pond bottom so that prawns can freely move across the bottom and within the water column of the entire pond.

WATER QUALITY MANAGEMENT

Minimizing and eliminating stress caused by poor water quality ensures that prawns are not susceptible to disease or other factors that can adversely affect growth and product quality. Pay careful attention to specific water quality variables, particularly dissolved oxygen and pH, throughout the production season. The ideal dissolved oxygen level is 5 mg/L or above.

Daily monitoring of oxygen is an extremely important management practice. Monitor oxygen levels at least during the early morning and late afternoon of every day. Even at low stocking densities that typify low-input, semi-intensive culture, sudden depletions in oxygen con-

centration can occur and produce stressful conditions that can reduce growth rate or even cause mortality. To effectively manage actual or anticipated oxygen depletions — particularly late at night or very early in the morning — mechanical aerators must be available. When dissolved oxygen actually decreases or is anticipated to decrease to critically low levels, in-pond, electrically powered aerators or tractor-driven PTO paddlewheels can increase dissolved oxygen to levels recommended for maintaining good health and growth.

Manage water quality to avoid alkaline pH extremes that often occur during midafternoons of the growing sea-

son. High pH problems also appear to be more common in waters with low total hardness and moderate to high total alkalinities (hardness-alkalinity imbalances). It is not fully understood why this imbalance of hardness and alkalinity leads to greater risk of high pH problems. Production ponds often experience problems with high afternoon pH during the first weeks of growout because the inorganic fertilization used to prepare ponds for stocking (see previous section) promotes fast-growing algal blooms. These blooms remove carbon dioxide from the water, causing a shift to higher pH in the absence of sufficient buffering capacity (relative levels of hardness and alkalinity). After the initial onset of rapid plant growth, high afternoon pH values typically subside. Therefore, in temperate climates, preparing ponds for stocking as early as possible (preferably 4 weeks) can prevent the risk of poststocking mortality caused by high pH. Early preparation allows this early period of high pH to pass before you stock the ponds.

When water pH reaches 9.0 about 6–12 inches below the surface and is expected to continue rising, you must consider a pH reduction strategy to avoid reduced growth and possible mortality. Quick management response can prevent further increases in pH. The recommended action is either to reduce the rate of plant growth or to add an acid-forming substance to the pond.

Herbicides, including copper sulfate, cannot be applied to the pond to kill algae and reduce pH. Rather, a low-risk, simple strategy to effectively reduce plant growth (photosynthesis) is to decrease the amount of sunlight penetrating the surface to about the first 3 feet of the water column. Adding an approved dye to the pond is a very cost-effective approach. Dyes that tint the water a blue color to reduce light penetration are sold as weed-control agents and can be added in graded amounts, depending upon the magnitude of the pH problem. Afternoon pH should begin to drop within 24 hours and remain at a safe level for several weeks. Periodic paddlewheel operation, in association with management of dissolved oxygen levels, or some other mechanism to gently circulate water from the pond bottom will increase the level of suspended sediment (turbidity) and thereby reduce light penetration.

An indirect method of reducing high-alkaline pH is to stock grass carp into production ponds to consume (crop) algae and reduce overall productivity (photosynthesis). However, at harvest, the carp can become lodged in drainpipes that are less than 12 inches in diameter. This obstruction will slow or stop the passage of prawns

through the pipes, and any time required to remove the carp potentially compromises the quality of the prawns harvested. Therefore, we do not recommend this practice.

Levels of carbon dioxide (an acid) will increase after the decay of organic materials such as cracked corn, soybean meal, or cottonseed meal in the ponds. Reduction in pH is not immediate, but organic input is a safe and relatively dependable practice that yields results rather quickly. Generally, an application of about 15 pounds per acre daily for about 1 week should help to keep pH from rising to undesirable levels. Adding 20 pounds of sugar per acre provides an immediate reduction, but it does not have long-lasting effect. Such organic supplements are in addition to any assigned daily input of pelleted nutrient sources that are part of the low-input production strategy. Generally, this method of treating dangerously high pH is confined to newly constructed ponds early in the growing season. As ponds age, organic matter accumulates in the bottom sediments, and its decomposition produces carbon dioxide that helps to keep pH below stressful or lethal conditions. After the first 5 weeks of the pond production season, the amount of organic fertilizer added daily should generate enough carbon dioxide to help correct any imbalances that would lead to high pH.

Addition of organic material can be used exclusively or in combination with dye application or turbidity increase. The decomposition of organic material also results in consumption of oxygen. Therefore, some means of adequately aerating pond water must be available to maintain satisfactory oxygen levels.

An emergency treatment to rapidly reduce pH is the application of alum (aluminum sulfate), which is a safe, relatively inexpensive chemical that reacts in water to form an acid. Alum may also help to reduce pH indirectly by removing phosphorus, an important nutrient for plant growth. The effect of alum application is not permanent, and additional applications may be necessary until the rate of plant and/or algal growth subsides. Precise reductions of pH using alum are difficult to achieve because a number of conditions in the pond, especially the water's total alkalinity, influence response. Overtreatment with alum can cause a dramatic drop in pH to a level that can be more dangerous than the initial high pH problem. Experience dictates a cautious approach: start with an initial dose of 10 mg/L, followed by additional applications of 5–10 mg/L as needed to reduce to the desired pH. Do not use alum in water where total alkalinities expressed as CaCO_3 are less than 20 mg/L.

HARVEST PRACTICES

Generally, the most critical phase in freshwater prawn farming occurs just before, during, and after the harvest. Unless you follow a series of simple, yet critical best management practices, an entire crop can become an unfortunate failure.

Drain Harvest

We do not recommend seine harvest of freshwater prawns from production ponds because it is labor-intensive and not cost-effective. In addition, seines can entangle prawns and drag them through the muddy pond bottom, likely compromising the quality of the product. Instead, we recommend passive draining of a production pond because prawns naturally follow flowing water. The *Pond Design* section presented information on designing ponds to ensure a successful drain harvest. By following those directions, it should require between 6 and 8 hours to completely drain all water from a pond of approximately 2 acres. Having the ability to drain an entire pond rapidly and to vary the flow rate of exiting water is very important in achieving efficient removal of prawns and thereby preserving a high-quality product.

Flow rate through the harvest drainpipe is commonly controlled by a piece of plywood or other flat sturdy surface and an alfalfa valve. As the pond water containing the prawns flows into the catch basin, you must maintain low levels of suspended sediment to ensure a high-quality, harvested product. To help flush out excess sediment, you can pump in additional water from a well or neighboring pond to produce an appropriate rate of flow through the internal and external harvest basins of the pond being harvested. When the prawns begin to accumulate in either the internal or the external harvest basin, begin removing them as quickly as possible. Periodically check the dissolved oxygen concentration in the basin; it should remain above 4 mg/L. To avoid potentially lethal low dissolved oxygen levels, always keep a tank of compressed oxygen next to the harvest basin. Connect a hose with a diffuser to the tank regulator to create a stream of small bubbles that effectively transfer oxygen into the water as needed. Adequate drainage must be available to maintain water flow out of a pond or external harvest basin and prevent the water from backing up and eventually overflowing. Control water flow rates by constructing a ditch with the proper profile to minimize damage to embankments and maintain existing vegetation. When draining a pond, pay close attention to proper water discharge to control the release of environmentally hazardous effluents.

If grass carp have been stocked to control aquatic weeds in production ponds, be careful to prevent them from becoming lodged sideways in drainpipes with diameters less than 12 inches. Trapped carp will obstruct passage of prawns through the drainpipes, and removing the fish can be a laborious, time-consuming task. Clogged drainpipes can compromise product quality by exposing prawns to air for an extended period during harvest.

Before Harvest

Conduct harvests when water temperature is at least 18°C. At lower water temperatures, decreased activity of prawns may cause them to become stranded on the pond bottom rather than move with the flow of water toward the harvest basin. In addition to the extra labor needed to remove the prawns, long exposure to air or becoming covered in bottom mud can potentially diminish product quality.

Finalize plans for obtaining the necessary equipment and labor at least 1 week before harvest. While needs may vary according to site, all necessary equipment must be ready for removing prawns from the harvest basin, up to and including final storage of the product (on ice in a cooler for short-term storage or in a freezer for long-term storage).

To facilitate material and product transport, levee roadways must be in good condition, especially to avoid problems that may arise from unanticipated rain or other poor-weather events. In preparation for pond draining, remove mud and debris that may have accumulated in the harvest basin and transfer it to another area of the pond. Also, the week before scheduled harvest, finish repairs to the retention screening.

An accurate estimate of the time required to drain the pond is necessary. Extended drain time represents an added cost in paying workers who must wait until harvest activities can begin. Pond water level may change from year to year and thereby affect the time needed for total draining. Record the depth of the pond water just before the beginning of each drain harvest. Use this information to estimate draining time for subsequent years.

During Harvest

Opening of the pond drain(s) commonly occurs the night before the scheduled harvest day. Working in darkness increases the risk of accidental injury to farm workers, so suitable preparations are necessary: lighting the pond area, marking utilities (especially electrical), and

cordoning off the external harvest basin. Potential dangers at night warrant immediate access to phone communications and basic first aid supplies at the pond site. During drain harvest, remove material that clogs the outflow screen in the external harvest basin to avoid an excessively high water level that can interfere with prawn removal efficiency and safe movement of workers. Most prawns exit from a pond within the last 10–15% of the total volume of water. It is at this time that steps may be needed to maintain adequate dissolved oxygen levels in the internal or external harvest basin in order to avoid creating stressful conditions while prawns are concentrated and removed. For internal harvest basins, creating a flow of water from the output valve is the best approach. High levels of suspended soil (turbidity) and/or methane and hydrogen sulfide (indicated by foul odors arising from the pond sediment) represent a stressful, possibly injurious, environment for the prawns. If these conditions arise, rapidly remove prawns from the harvest basin.

At the harvest basin site, you need long-handled dip nets, mesh baskets, and a scale(s). Use a sturdily constructed dip net with a metal handle on the frame throat for grasping heavy loads. Perforated plastic baskets with a mesh of about 1 square inch will retain prawns but allow a fast drain of water and debris. Too large a mesh can cause prawn claws to break off, thereby reducing the market value of the whole product. The baskets need strong handles to hold the harvested prawns for transfer to transport tanks. If a thin coating of mud appears on the gills or within the gill cavities of prawns removed from the catch basin, place them into tanks of clean, well-oxygenated rinse (purge) water before weighing. Generally, this recommended cleansing process successfully removes all silt within 30 minutes.

If a sufficiently large number of prawns remain on the pond bottom, then manual harvest, referred to as “scrapping,” is necessary. Careless scrapping sacrifices quality, especially if there is no plan for efficient removal when these conditions arise. If water temperature is below 70°F and water quality is good, then prawns will usually survive on the pond bottom for up to 1 hour in a drained pond. At warmer water and air temperatures, product quality will deteriorate at a higher rate.

After Harvest

After removing and rinsing the prawns, weigh them in pre-tared mesh baskets on a platform scale. After weighing the prawns, use the “chill-kill” process (see *Chill Killing* subsection) as soon as possible, preferably at the pond bank. Alternatively, you can place the prawns into transport containers like insulated totes or plastic

sheet-lined, low-sided trailers. The type and number of containers depend on the anticipated weight of prawns harvested and distance of transport. Insulated containers are generally very sturdy and retain the desired water temperature when air temperatures fall outside the preferred range for transport. Converted trailers (2 feet deep) offer ease of handling and observation. During transit in a trailer, prawns purge themselves of waste remaining in their intestines, which eliminates the need for purging tanks at the postharvest site.

Fill transport tanks with well water before the harvest. If the well water is 4°C warmer than the pond water, then add ice to attain the desired temperature. If pond water is 4°C warmer than well water, then some means of increasing its temperature is beneficial. On a sunny day, placing a plastic over the tanks should achieve the desired water temperature through solar heating. After several loads, fresh transport water may be necessary if the quality of the existing water deteriorates (suspended sediment) to the point it becomes stressful to prawns.

Supersaturate the transport tank water with oxygen before adding the first load of prawns and then monitor and maintain saturation levels during transport. Monitor oxygen levels at the tank bottom, where demand for oxygen is greatest. Regardless of transport distance, inadequate oxygen can cause stress and possible mortality, particularly at warm air temperatures.

Each cubic foot of water can hold approximately 2.5 pounds of prawns. Stacking of prawns should not exceed 1 foot because localized oxygen depletions in the transport water can occur quite rapidly, and immobilized prawns are unable to move to areas where the oxygen concentration in the water is higher. Therefore, the most effective method of transport is to use totes with a height of about 2.5 feet.

Chill Killing

At the processing site, prawns must be chill-killed to ensure superior quality before immediate sale or additional processing. This simple, but critical, procedure calls for completely immersing live prawns in a slurry of a clean water (20%) and ice (80%), preferably crushed ice. To begin the procedure, remove prawns from holding tanks and add them to perforated plastic baskets, similar to those recommended for weighing and transport. Fill the baskets about $\frac{2}{3}$ full and place them into prepared slurry tanks that can accommodate several baskets at once. The ice water mixture must cover the tops of the baskets and flow among all the prawns. Keep prawns in this slurry for at least 20 minutes but no more than 45 minutes (see the *Safety Regulations and Temperature Management* subsection). Agitate the baskets approxi-

mately every 5 minutes to circulate cold tank water with water warmed by prawns inside the baskets. This periodic flushing process ensures the homogeneous cooling of each prawn and preserves the best-quality product. Measure the core temperature of a sample prawn to confirm adequate cooling has occurred after 20 minutes of chilling. Remove a prawn from the surface of the slurry and insert a thermometer directly into the center of its tail

meat. The insertion site is the joint between the tail and the rear part of the midbody (thorax); simultaneously bend the prawn thorax and tail downward to access the site. If procedures are followed properly, prawns will normally chill to a core temperature of 34–36°F within 20 minutes. If the prawn is handheld to record temperature, take the measurement quickly to avoid transferring heat from your hand and thereby invalidating the readings.

SAFETY AND QUALITY STANDARDS

Harvest

During harvest, the number of personnel and amount of activity on the farm increase, thus requiring careful monitoring of activities to prevent product contamination. Provide sanitary facilities as necessary, and properly dispose of waste materials. Provide adequate basic hygiene training for personnel and screen them for possible contagious diseases or other health problems that may contaminate the product. Always provide adequate sanitary and hand-washing facilities — either permanent or portable — near the harvest site. Personnel involved in postharvest processing must wear protective gear that is clean and sanitized. Properly sanitize tanks used to transport the harvested product during processing. Water and ice used in initial processing must be contaminant-free and properly handled to prevent contamination.

Processing, Storage, and Distribution/Transport

Processing, storage, and distribution facilities must be adequately designed and built to comply with minimal good manufacturing practices, 21CFR110 (<http://vm.cfsan.fda.gov/~lrd/cfr110.html>). Within the facility,

always follow sanitation standard operating practices (SSOPs), as described in 21CFE123.11 (<http://www.cfsan.fda.gov/~lrd/fr951218.html>). Table 2 lists the eight minimum requirements described under SSOPs. Recommended processing procedures for freshwater prawns and related research results have been published (see publications by Silva et al. in the *Sources of Information* section).

Safety Regulations and Temperature Management

Seafood HACCP (Hazard Analysis and Critical Control Point) regulations (21CFR123, <http://www.cfsan.fda.gov/~lrd/fr951218.html>) additionally require the conduct of a hazard analysis followed by development of a HACCP plan if critical control points are identified. A generic model of a hazard analysis for the BMPs for production and harvest of freshwater prawns (Table 3) is based upon actions that avoid food safety problems. Hazards that may be present in prawns harvested from production ponds are pesticides, chemicals, therapeutic drug residues, and environmental chemical contaminants. Prevention of such occurrences is

Table 2. The eight minimum requirements of sanitation standard operating practices (SSOPs).¹

- Safety of the water that comes in contact with food or food contact surfaces or water that is used in the manufacture of ice;
- Good condition and cleanliness of food contact surfaces, including utensils, gloves, and outer garments;
- Prevention of cross-contamination from unsanitary objects to food, food packaging material, and other food contact surfaces, including utensils, gloves, and other outer garments, and from raw product to cooked product;
- Maintenance of hand washing, sanitizing, and toilet facilities
- Protection of food, packaging materials, and food contact surfaces from adulteration with lubricants, fuel, pesticides, cleaning compounds, sanitizing agents, condensate, and other chemical, physical, and biological contaminants;
- Proper labeling, storage, and use of toxic compounds;
- Control of employee health conditions that could result in the microbiological contamination of food, food packaging materials, and food contact surfaces; and
- Exclusion of pests from the food plant.

¹FDA Seafood HACCP, 21CFR123.8, FDA, 1997.

Table 3. Example of a hazard analysis for freshwater prawn production, harvest, and postharvest handling.

Firm Name: Firm Address:		Product Description: Method of Storage and Distribution: Intended Use and Consumer:			
Step	Identify potential hazards introduced, controlled, or enhanced at this step	Are any potential hazards significant? (Yes/No)	Justify your decisions for column 3.	What preventative measures can be applied to prevent the significant hazards?	Monitoring and Records
Soil and sediment	Biological Pathogens (manure) Chemical Residues (dioxin) Pesticides Antibiotics Physical	No Yes	Unless used recently, pathogens do not survive. Chemicals may persist for years or decades in the soil.	Testing and taking prevention measures	Test soil and sediment Test results
Water	Biological Pathogens Chemical Pesticides Physical	Yes Yes	Pathogens can be carried in the water, including well water. Chemical contaminants can be carried by water. Prawns are very susceptible to these.	Test water and apply adequate treatments	Test water, treatment parameters
Feed	Biological Pathogens Chemical Chemical contaminants Drugs Physical	Yes Yes	Salmonella, Aspergillus can be present in feed and/or grow.	Receive/buy feed from a certified supplier	Letter of guarantee
Harvest personnel	Biological Pathogens Chemical Physical	Yes	Personnel can bring pathogens from unhealthy people or through clothing.	Train personnel, health screen	Health records Training records Sanitary facilities records
Water discharge	Biological Pathogens Chemical Salt Organics Physical	No	Unlikely to carry pathogens if handled properly. Water can have salt (if added) and organics from feed, etc.	Proper disposal/collection of salt water and waste water before discharge	Water treatment records
Processing	Biological Pathogens Chemical Sanitizer residues Physical Metals	Yes Yes Yes	Pathogens from the plant can contaminate prawns. Sanitizer and other chemicals can come in contact with prawns. Metal pieces from equipment	Clean and sanitize before, during, and after processing. Use SSOPs Check for equipment wear	
Storage	Biological Pathogen growth Chemical Physical	No	Manage temperature during life of product. Spoilage will occur if temperature is not managed well.		

controlled by review of detailed records from the production farm to confirm that hygiene and sanitation control procedures were followed, and a letter of guarantee is then prepared by the farmer. Any other regulations pertaining to labeling should be followed. A farmer or processor must have a plan that addresses the occurrence of a product recall.

If the facility prepares a postharvest, “as is” product ready for consumption, either raw or cooked without further processing, then it must strictly follow certain sanitation requirements. An adequate HACCP plan that ensures destruction of microbial pathogens and prevention of contamination will satisfactorily fulfill this need.

Temperature management is a key factor in preventing decomposition and thereby preserving product quality. After chill-killing prawns in an ice slurry (see the *Chill Killing* subsection), they are ready for market or further processing. To hold prawns for further processing or later distribution, refrigerate them at about 38°F or place them on ice at a ratio of 2 pounds of ice for every pound of prawns. Flake ice is best because it allows the most effective maintenance of cold storage temperature. Never hold prawns in cold water. Dehead prawns as soon as possible if you intend to hold them fresh on ice or refrigerated for up to 2 days. For long-term storage, freeze prawns (ice-packed or refrigerated; whole or deheaded) after a 1-day holding period. Prawn tails may be block frozen in watertight, air-removed plastic bags. Whole prawns or tails may be individually quick frozen and then packaged. Store prawns at or below 36°F for the duration of their refrigerated/iced shelf life. Proper processing allows a frozen shelf life of at least 12 months for whole prawns and even longer for tails.

Traceability and a Food Security Plan

Each food processor, distributor, and handler must comply with the regulations of the Bioterrorism Act of 2002. Two key sections apply: (1) the registration of the processing/distribution/storage facilities and (2) the establishment and maintenance of records. The latter is required so that the facility can trace the movement of its product both one step backward and one step forward. Product traceability is mandated by not only the Bioterrorism Act, but also buyers and regulatory agencies. To establish product traceability, you must record certain information (Table 4) for each pond and each production cycle.

In addition, we recommend assessing the risks facing your facility and forming a security plan with the goal of preventing intentional product contamination. The plan

should include procedures that address several key areas: (1) traceability; (2) emergency contacts; (3) monitoring of operations; (4) monitoring, storage, and disposal of toxic materials; (5) assignment of a team, including a coordinator, responsible for security; (6) evaluation of all personnel, particularly the use of background checks; (7) restriction of visitors and others not affiliated with the facility to specific areas; and (8) construction of physical barriers to the facilities and surroundings, including visual monitoring equipment.

Monitoring, Corrective Actions, Verification, and Record-Keeping Procedures

Verify the BMPs and related quality and safety plans initially. Evaluate each section and the whole plan as needed, at least annually. Promptly incorporate corrective actions. It is critical to the success of the system to record and save all relevant activities for at least 1 year, as needed or required.

Proper Sanitation and Sanitary Conditions/Facilities (Pathogens)

Sanitary facilities must be available on site, located no farther than 400 meters from where personnel work and as far away from water sources or ponds as possible. We recommend at least one toilet per every 20 workers. Adequately equip the sanitary facilities, whether portable or not. Locate hand-washing areas outside, if possible, to permit better monitoring and control. Properly dispose of waste, and monitor disposals as appropriate.

Table 4. Information needed to establish product traceability.

<p>Stocking to Harvest</p> <ul style="list-style-type: none"> Pond identification number Pond area Source of postlarvae/juveniles (hatchery/nursery) Stocking date Quantity stocked Herbicide, algicide, other pesticide use Antibiotic and drug use Manufacturer and lot number for each feed/fertilizer used <p>Postharvest</p> <ul style="list-style-type: none"> Harvest date Harvest quantity Sulfite use and protocol Processing plant or purchaser Process date and line Product type Storage conditions Distribution/shipping date and to whom
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CONCLUSIONS

Assurance of product quality and safety through adherence to BMPs for production and processing is rooted in the practice of environmental stewardship and is pursuant to fulfilling a societal responsibility. To meet the ever-increasing demand and consumption of farmed seafood and the challenge of competition within a global

seafood economy, a focus on sustainability of natural resources and the assurance of a high-quality product is essential. All prawn producers must be dedicated to following the best management practices to ensure long-term consumer confidence and preference, and the continuing success of the commercial industry.

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