Practical Manual for Semi-intensive Commercial Production of Marine Shrimp

Aquaculture

Jose R. Villalon

with support from
Granvil D. Treece
Texas A&M University Sea Grant College Program

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TAMU-SG-91-501
April 1991

Publication of this manual was supported in part by Institutional Grant NA89AA-D-SG139 to Texas A&M University Sea Grant College Program by the National Sea Grant Office, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

$15.00
Additional copies available from:
Texas Sea Grant Program
P.O. Box 1675
Galveston, Texas 77553-1675
U.S.A.

TAMU-SG-91-501
2M April 1991
NA89AA-D-SG139
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Foreword

The world's population has moved into an age where it must rely increasingly on farm-raised products and less on wild populations for food. People are moving away from being hunters and gatherers and more toward being farmers and culturists. Shrimp farming, the production of marine shrimp in impoundments or ponds, has developed rapidly in recent years. More than 40 countries around the world now raise shrimp in ponds. For the tenth year in a row, the world's shrimp farmers produced a record crop in 1990, a total of 633,000 metric tons of whole shrimp, up 12 percent from the previous year. One million hectares of ponds yielded an average of more than 630 kilograms per hectare. Shrimp farmers now produce 25 percent of the shrimp placed on world markets and fishermen supply 75 percent of a total market of 2.6 million metric tons. Shrimp farmers produced only 2 percent of the world's needs in 1980. If production continues to expand at the current rate, farm-raised shrimp will capture 50 percent of the total market by the year 2000.

To a large extent, development is driven by market demand. Shrimp farming, however, is constrained in many countries and inefficient use of existing resources is widespread in many of the countries now culturing shrimp.

This book represents a significant step toward defining the basic principles and most important steps in the pond culture of marine shrimp. Variations of these techniques and principles described may be used at different locations with different species for both semi-intensive and, to some extent, intensive culture systems.

There is a great deal of printed matter concerning shrimp mariculture, but there is very little written material from a commercial standpoint. This manual describes the methods used by a private company on a commercial scale to raise penaeid shrimp successfully in earthen ponds from the fry or postlarval stages to market size.

The Texas A&M University Sea Grant College Program welcomes the opportunity to publish this manual and hopes to extend the distribution of this information to the global aquaculture community. Hopefully, it will be useful to shrimp farmers and researchers worldwide. Perhaps this manual will stimulate others to share more from a commercial standpoint in the development of culture systems that will result in more efficient use of our earth's resources.

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Acknowledgments

I wish to thank Dr. Samuel P. Meyers for initially suggesting publication of my working manual. I would also like to acknowledge the cooperation of my employers of the past eight years, G.R. Foods of Woodbridge, New Jersey, and Empacadora Nacional, C.A., of Guayaquil, Ecuador, for their commitment to the publication of this work. My personal friends and respected colleagues, Padge Beasley, Jr., and Granvil Treece also deserve special mention for critical review of the manuscript; and, most of all, I thank my wife Anita for her continual support and encouragement during the drafting of this manual.

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Chapter 1

Introduction

The shrimp mariculture industry in Latin America has expanded dramatically since it turned commercial in the late 1960s.

This expansion has been characterized by an increase in the total hectares developed and by the equally important development of improved technology, which have resulted in more efficient production operations.

Several production manuals have been published exclusively for shrimp. The majority of these manuals discuss production topics and procedures in a very general way but cannot always be applied and scaled-up to the commercial level necessary for the industry.

It is not the intent of this manual to present an in-depth overview of commercial production techniques currently practiced by the industry, nor is it meant to reflect the most advanced or efficient means for obtaining successful results. It is designed to be used as a specific guide for semi-intensive commercial operations, and the reader must be aware that there should be flexibility for procedural changes as dictated by specific situations. It covers one of several approaches with step-by-step procedures involved in all aspects of the shrimp grow-out production facility.

The manual has been used in current production operations from 1983 to 1991 in South America. The operational procedures described have directly resulted in annual production averages of 1,820 gross kilograms per hectare-year of 26-30 and 31-35 count shrimp (23 gm). These production figures have been consistently obtained in more than 600 hectares on four independent farms, utilizing semi-intensive culture techniques. Stocking densities of under 12 postlarvae/m^2 and feed conversions of under 2.5:1.0 have been achieved.

This manual, tailored specifically for the field operator, discusses the steps necessary to grow shrimp successfully at a commercial facility in a detailed manner.

Chapter 2

Pond Disinfection

Proper pond disinfection between culture cycles reduces the probability of toxic metabolites or pathogens from being transmitted to the subsequent shrimp population to be cultured. A careful adherence to disinfection procedures will significantly prolong the productivity of pond bottoms and oxidize accumulated organic matter.

Drying

After each harvest, pond bottoms should be allowed to dry and crack, primarily to oxidize the organic components left from the previous culture cycle. Mineralization of this organic matter liberates more nutrients, which become available for enhancement of primary productivity, mainly phytoplankton, during the following culture cycle.

Secondly, adequate drying allows for the oxidation of hydrogen sulfides in any anaerobic sediment. The presence of hydrogen sulfide not only inhibits primary productivity but may reach levels during the next culture cycle sufficient to inhibit productive shrimp growth. Shrimp will generally select the deeper areas of a pond and high levels of black anaerobic mud are often found in such areas. It is essential that hydrogen sulfide be sufficiently oxidized so that during molting and subsequent burrowing by the shrimp in these deep areas they will not be exposed to detrimental concentrations of sulfide.

Finally, drying eliminates fish eggs, crab larvae and potential predators that exist in the humid and wet areas. It has been well documented that a "carp-like" species of fish, *Dormitator latifrons*, is able to burrow and survive for up to one week in humid areas.

Disinfection

It is virtually impossible to implement complete drying of pond bottoms during the rainy season. During the dry season, however, this can be carried out more efficiently without major difficulties.

Dry season disinfection

After confirming the absence of shrimp in the pond following harvest, the pond should be completely drained. This is easily accomplished if effluent weirs are available. It may be necessary to open small trenches in the pond bottom to remove pools of stagnated water. In ponds where all of the water cannot be drained through the effluent weir, portable pumps may be necessary. Regardless of the techniques utilized, elimination of water at the earliest possible time is essential to achieve maximum oxidation with minimum pond "down-time". Although the pond may not be in productive operation, it is still incurring costs. The goal is to disinfect harvested ponds efficiently and adequately in the shortest time possible.

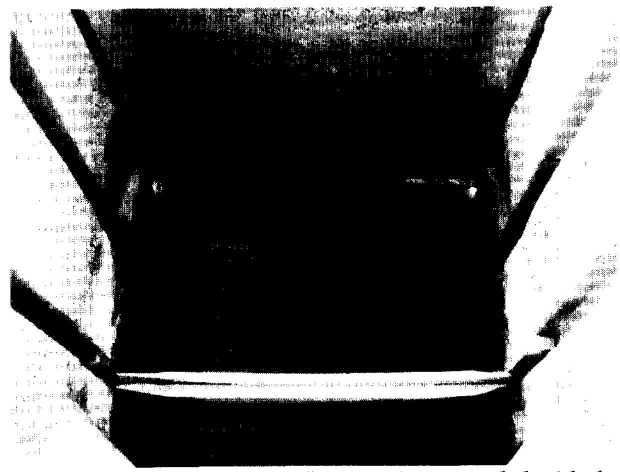


Plate 1. Boards in place in effluent weir gate sealed with the "cebo" mixture. Wedge inserts provide pressure. This set-up eliminates water seepage through board seams and edges.

After all water has been eliminated, the entrance and effluent weirs should be sealed to prevent seepage from the reservoir canal and the effluent canal. A sealant that has proved to be very effective is called "cebo." This is a mixture of animal lard and chalk at approximately 1:10 ratio. This sealant should be periodically maintained and monitored for leakage, especially during long dry-outs, since it is attractive as a food source for ants and rodents (Plate 1).

Use of sunlight is the most cost effective method of oxidizing pond bottoms. For most of the pond bottom surface area, solar oxidation may be adequate if the bottom is allowed to dry and crack to a depth of from two to five centimeters (Plates 2 and 3).

In the deeper areas, which characteristically border the pond dikes and the deeper zones of irregular pond bottoms, solar drying may be insufficient for the relatively limited drying time allowed. In these deeper zones, which are generally areas of high organic deposits with relatively high concentrations of hydrogen sulfide (anaerobic conditions), chemical treatment may be necessary.

There are two types of chemical applications:

1. Quick lime can be used at a dosage of 0.25 kg per square meter over the affected area. The disad-

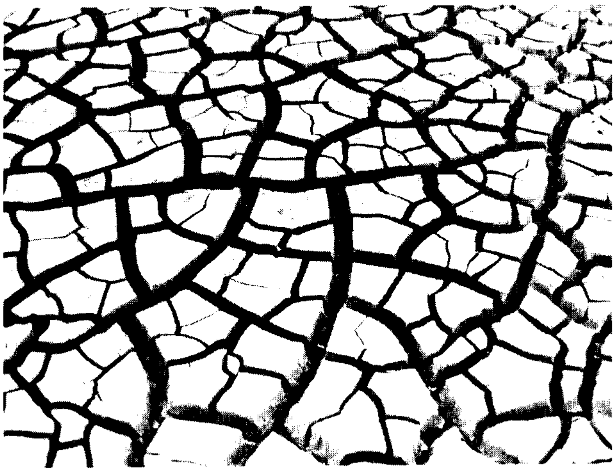


Plate 2. Pond bottoms cracked by solar energy.

Plate 3. Cracked pond bottoms effectively oxidized can sustain the weight of a person.

Plate 4. Quick lime application in deep zones of pond bottom, which are contaminated with hydrogen sulfide anerobic mud.

vantage of this treatment is that the activity of quick lime decreases rapidly in high ambient humidity conditions. It should not be stored for more than 15 days before application, creating logistical problems, since orders and transportation must be coordinated on a pond-by-pond basis. In addition, application should be performed with caution; protective clothing and goggles should be worn to avoid chemical burns. Caution should also be exercised during transportation of this highly reactive raw material. However, quick lime is a highly effective and economical oxidizer. The recommended dosage is applied to the affected areas in powdered-dust form and allowed a minumum of two days to react and become deactivated (Plate 4).

2. In areas characterized by anaerobic soils (where a person can sink more than 30 cm into black muck) (Plate 5), it may be necesary to use a strong chemical oxidizer such as chlorine, and hand till the affected area with shovels and rakes. The procedure is as follows:
   1. A saturated solution of chlorine is mixed in a 500 l container;
   2. The solution is then loaded into a backpack plastic field sprayer;
   3. Approximately one liter per square meter of the solution is sprayed over the surface of the affected area (spray nozzle set at the "shower" position) (Plate 6);
   4. Personnel begin breaking up the surface and moving the bottom soil to the surface (Plate 7);
   5. A second and possibly a third application may be needed;
   6. Final confirmation is based on sight and smell. The odor of hydrogen sulfide should be reduced, if not totally eliminated before the disinfection procedure can be considered complete (Plate 8). A minimum of three days is needed to deactivate the chlorine before refilling the pond. A word of caution: Chlorine is used as an algacide and if it is not adequately removed, it may be detrimental to primary productivity during the following culture cycle. The saturated solution is very caustic so extreme caution should be exercised. Protective clothing must be worn and the backpack sprayer should be checked frequently for leaks. Chemical burns from this caustic solution are serious.

Time frame for dry season disinfection

During the dry season, ponds should be completely disinfected in minimal time as follows:

1. Elimination of water after harvest (maximum three days);
2. Adequate sealing of weir gates (maximum one day);

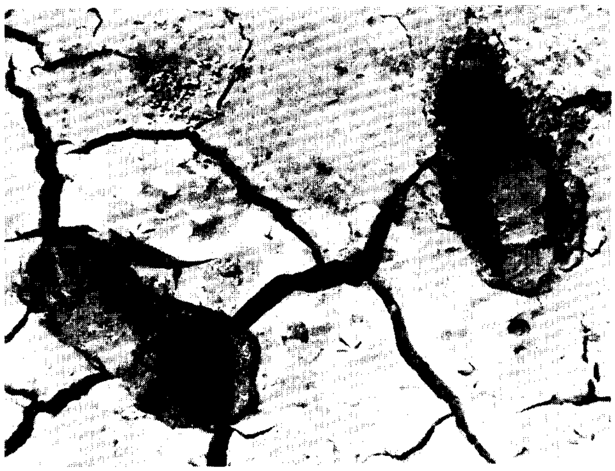


Plate 5. Surface layers of cracked pond bottoms are sometimes oxidized while deeper layers remain contaminated with hydrogen sulfide.

Plate 6. Application of a saturated chlorine solution to pond bottoms that are highly contaminated with hydrogen sulfide.

Plate 7. Manually tilling the surface mud layer in pond bottoms to ensure the complete oxidation of lower layer anerobic mud.

Plate 8. The visual difference between contaminated anerobic mud (on the left) and oxidized mud (on the right). Notice the black coloration of the anerobic mud.

3. Sun-drying of pond bottom shallow zones (maximum eight days);
4. Chemical treatment with quicklime in less affected deep zones (maximum two days);
5. Chemical treatment with saturated chlorine solution in highly affected deep zones (maximum four days);
6. Deactivating and venting time for chemical applications (minimum three days).

Thus, for dry season disinfection, the total time necessary is a maximum of 19 days. This 19-day "downtime" could be considerably reduced by tilling with tractors and cultivation discs. However, the 19-day period is projected as a maximum, and efforts should be made not to exceed this period.

If quicklime application cannot be carried out due to lack of availability or difficult transportation (as in the case of farms located on islands), it will be necessary to treat the affected areas with the chlorine technique.

Rainy season disinfection

All procedures are more difficult in the rainy season but production strategies, where pond disinfection is concerned, remain similar. Rainy season disinfections may require additional farm labor.

The objectives listed in the section on *Weir Gate Configuration* in Chapter 3 are equally valid during the rainy season. The procedures for chemical treatment (*Dry season disinfection*) should also be carried out; sun-drying may prove difficult.

The following changes should be implemented during the rainy season:

1. The portable pump will probably be required continually to remove rainwater;
2. Additional personnel may be required for chemical treatment in sulfide-contaminated areas;
3. As soon as pond bottom examinations confirm a reduction or elimination of hydrogen sulfide odor, the pond may receive sufficient water to cover the areas of chemical treatment (a minimum of 10 cm over the majority of the pond bottom). The purpose of this pre-rinse is to eliminate any trace of active chemical residues that may not have been deactivated due to the reduced amount of ultraviolet radiation during typical rainy seasons. Caution: when allowing the water to re-enter the pond for this pre-rinse treatment, the entrance weir gate screen should have a small 0.5 mm mesh to restrict entry of predators;
4. Once the pond has received approximately 10 cm of water, minimum depth, or at least the treated area has been adequately covered, all the water should be drained through the effluent gates or by portable pumps;
5. When the water has been removed and the entrance and effluent weirs have been adequately resealed, the pond may be considered ready to fill for grow-out purposes.

Time frame for rainy season disinfection

It is difficult to project a realistic schedule for pond disinfection during the rainy season since chemical treatment cannot begin until there is a "break" in the rains. Since it is not necessary to wait for a full dry day, guidelines may be as follows:

1. Elimination of water after the harvest (maximum four days);
2. Adequate sealing of weir gates (one day);
3. Chemical treatment (maximum four days);
4. Pond pre-rinse (maximum four days);
5. Adequate resealing of weir gates (one day).

Thus, for rainy season disinfection, the total time required is a maximum of 14 days "down time."

Weir Gate Preparation

In conjuction with pond bottom disinfection, both the entrance and effluent weir gates should be inspected, and repaired as necessary.

1. All entrance and effluent gates should be scraped clean of barnacles, mussels and filamentous algae (Plate 9).
2. Mud from the gate floors should be eliminated.

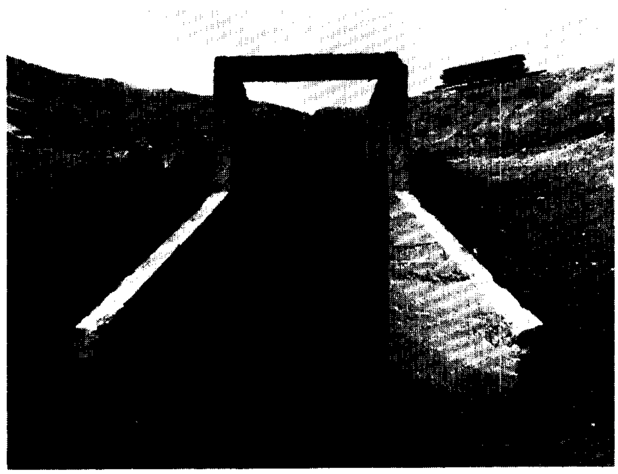


Plate 9. Pond weir gate scraped clean of filamentous algae and barnacles during disinfection. Note that weir boards are stacked in an orderly fashion.

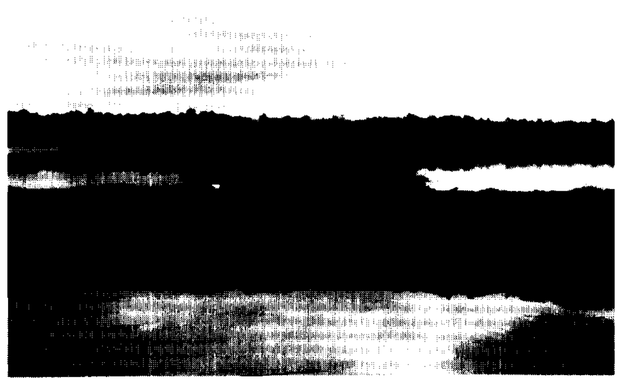


Plate 10. Entrance weir gate with restriction boards in place on the reservoir canal side of gate. If no board slides are on the reservoir side of gate, restriction boards should be nailed in place.

3. Indicators for operating water levels should be repainted if necessary.
4. Confirm that the gate's board and screen sequence is correct (refer to figures 1, 2 or 3) for proper board and screen sequence according to gate design (Plate 10).
5. Seal all boards and screens with "cebo," making sure that all boards have two wood wedge inserts to maintain board pressure against the gate's slide channels. If the board and screens are not firmly in place with the wedge inserts, the "cebo" sealant may crack and lose its effectiveness.

Figures 1, 2, and 3 apply to grow-out production ponds and will be discussed in more detail in the next section.

It is recommended that a complete inspection of the structure of the gate be performed during gate preparation. The ideal time to make repairs on damaged or cracked gates is when the pond is dry.

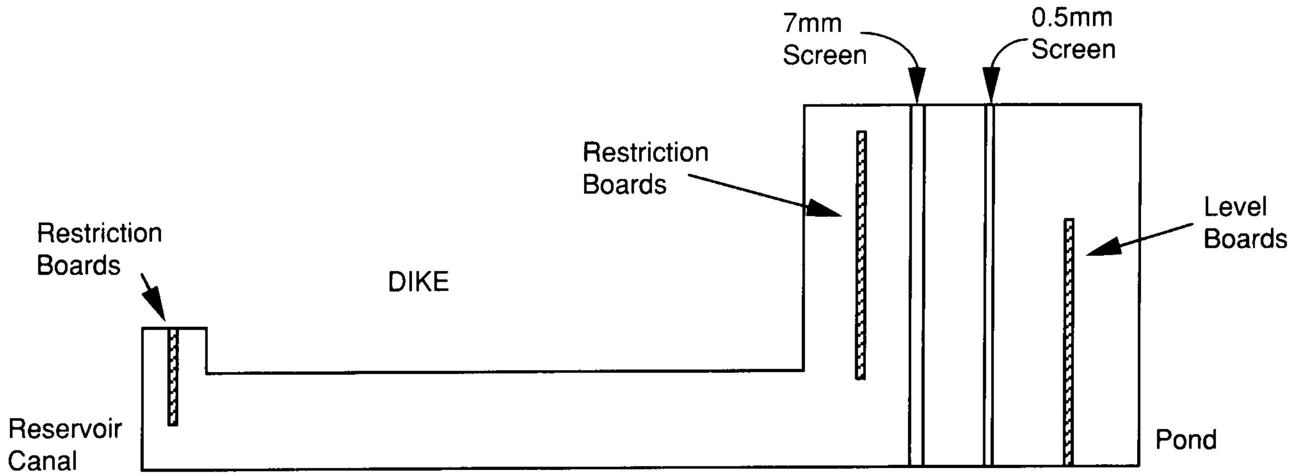


Figure 1. Entrance gate board and screen configuration for gates with reservoir side slide channels.

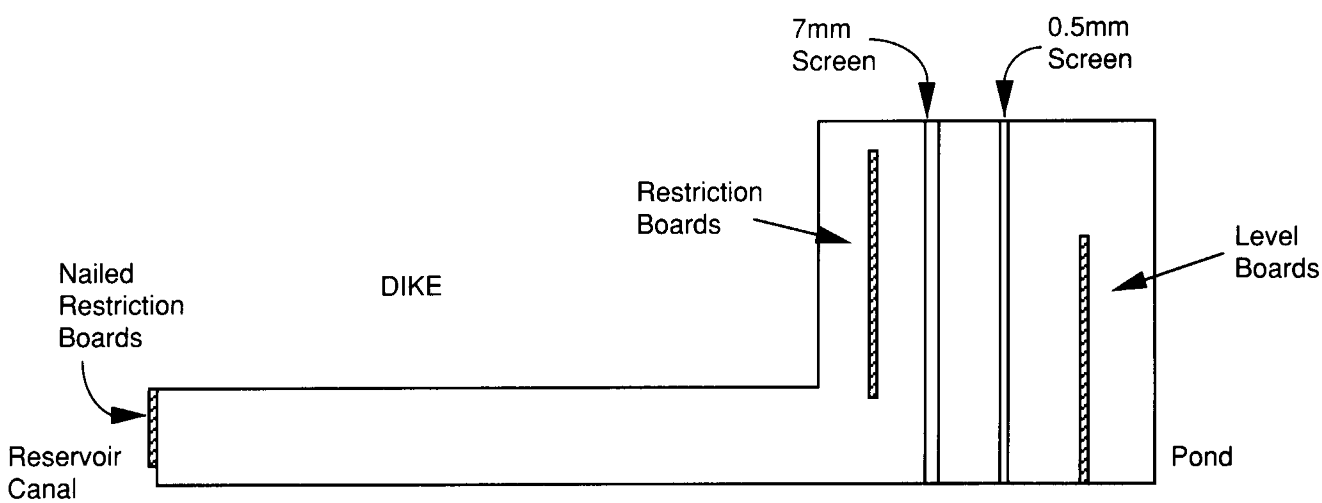


Figure 2. Entrance gate board and screen configuration for gates without reservoir side slide channels.

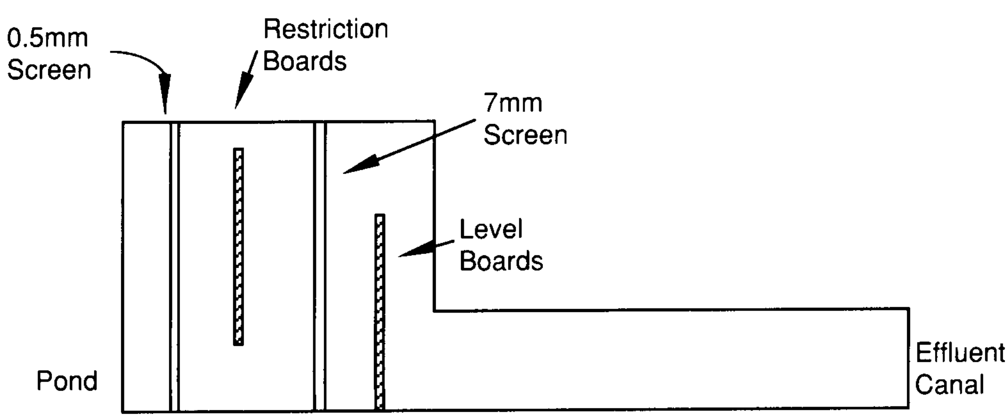


Figure 3. Effluent gate board and screen configuration.

Chapter 3

Pond Preparation

The objective of this section is to increase control of pond conditions prior to stocking to ensure an optimal pond environment. This should reduce nutrition-related stress on stocked shrimp. Since animals will forage pond bottoms, good primary and secondary productivity is needed so that the shrimp expend less energy acquiring food.

If shrimp are unduely stressed, their internal energy mechanisms will be temporarily diverted to "combating" the particular stress factor. Sometimes the latter can be physiologically controlled by the animals, in which case growth may be reduced. At other times, stress may indirectly cause disease-related disorders that not only reduce growth but also result in increased mortality.

Pond preparation is critical in any production grow-out facility. The postlarvae and juveniles being stocked are transferred from one environment (hatchery or acclimation station), where food is readily available and conditions are well controlled, into a less controlled environment. The advantage of adequate pond preparation is that it should reduce the probability of the shrimp finding poor nutritional conditions.

Weir Gate Configuration

After proper disinfection a pond being filled in preparation for stocking should be fitted with a 0.5 mm mesh screen at the entrance weir gate to control the introduction of predators. Although the use of such a small mesh requires more time to fill, it is worthwhile. It may be necessary to station permanent screen cleaners at entrance weirs in ponds if time is a major factor.

The board and screen configuration defined in Chapter 2 is valid for any weir gate (Plate 11). Weir gate screen sizes are determined by the size of the animals (see *Wier Screen Configuration* in Chapter 11).

Screen size determination

Ponds being filled, regardless of whether they are nursery, direct-stocked grow-out or juvenile-stocked grow-out, should be fitted with 0.5 mm mesh screens adequately sealed with "cebo." Screens should be inspected on a more frequent basis to ensure that adequate amounts of water are entering the pond. Without this precaution, it could take as long as one week to fill a 10-hectare pond.

On stocking nursery ponds, or when direct-stocking production ponds, the 0.5 mm filter screen has the added advantage of preventing recently stocked postlarvae from escaping.

For production grow-out ponds stocked with transferred juveniles, the 0.5 mm filter may be replaced with a 2.0 mm mesh filter after the pond has been completely filled and prepared.

Vertical substrate maintenance

All vertical substrates in nursery and production ponds should be examined and required maintenance should be carried out while pond bottoms are being dried (Plate 12).

The vertical substrate is important for various reasons. Primarily, it increases the substrate surface area of the pond. Since shrimp are bottom feeders, increasing the surface area will provide an increase in both benthic fauna and the area where shrimp can forage effectively. The vertical substrate structures can be constructed of bamboo slats and must be maintained since occasionally they may become dislodged from the holding nails. Once a slat has fallen, totally or partially, it can serve as a protective cover for potential predators such as crabs and fish.

Placement of vertical substrates in nursery ponds should be performed with the following dimensions and layout taken into account:

1. They should begin 20 meters from the entrance dike and run the length of the nursery pond, terminating at a distance of 20 m from the effluent dike;
2. The bamboo slats should be nailed to mangrove stakes driven into the pond bottom. A few inverted nails on the top of the stakes will discourage predatory birds from perching;
3. The slats should be placed at a distance of 5 cm from the pond bottom and staggered up the water column to 15 cm from the water surface when the nursery is at its operational level;
4. A minimum of three of these vertical substrate lengths should be placed equidistant from each other. The two lengths closest to the lateral dikes should be placed at no less than ten meters from the said dike. (Refer to Figure 4 for suggested placement of the vertical substrates).

Placement of vertical substrates in grow-out ponds is less regimented. These may be placed in the deep areas of the pond, and each grow-out pond should have at least 200 meters total length of the substrate, preferably intermittently dispersed in the deep zones of the pond.

Fertilization

The objective of fertilization is to encourage growth of phytoplankton, and ultimately, other organisms on which the shrimp feed. Equally important is the reduction in consumption of pelleted feed without inhibiting shrimp growth.

Although there are thousands of algal species, the production facility should be primarily involved with enhancement of the diatom groups.

Before the procedures involved in stimulating healthy diatom growth are discussed, a brief explanation of algal growth dynamics may be helpful.

The growth of algae can be expressed in terms of cell division. With adequate nutrients in pond water, algal populations will exhibit growth as shown in Figure 5.

A summary explanation of algal population dynamics paraphrased as follows (Fox, 1983): the first phase is known as the lag phase. This phase is not completely understood but could possibly be attributed to algal cell size increase without cell division. The second is the exponential phase, during which the cells divide rapidly. The third phase is characterized by the decline of growth and occurs concomitantly with the depletion of a particular nutrient. The fourth stage is the stationary phase, when the rate of algal growth is balanced with the limited nutrients in the water. The final stage is the death of the culture, usually due to extreme levels of nutrient depletion. Although the latter rarely occurs in pond systems, the objective of fertilization is to maintain the algae at the second stage, that of exponential growth. A routine fertilization program should decrease the possibilities of declining growth due to nutrient depletion.

Fertilization procedures

The primary necessity during fertilizer application is to dissolve the fertilizers before or while they are being dispersed. Certain precautions must be taken. Granular forms of inorganic fertilizers may chemi-

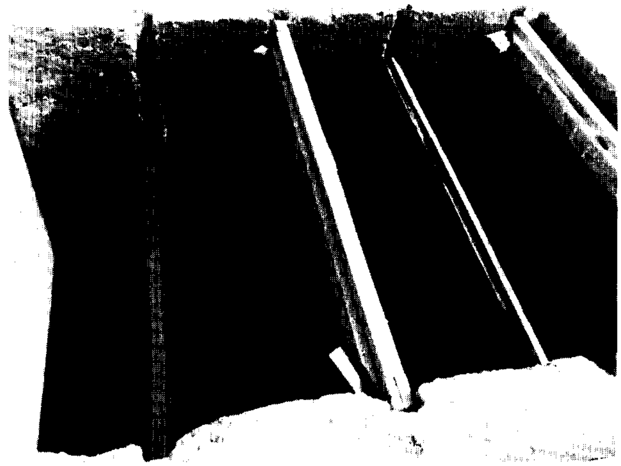


Plate 11. Screen and board configuration in effluent weir gate. Note the restriction boards in place with angle inserts to maintain pressure against board slide channel.

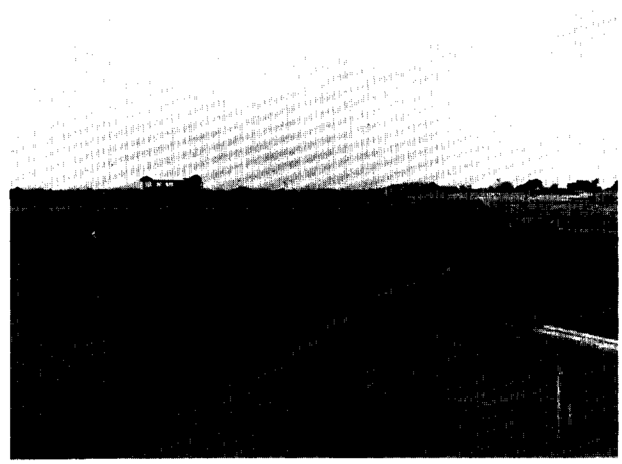


Plate 12. Vertical substrates in place and maintained in nursery ponds.

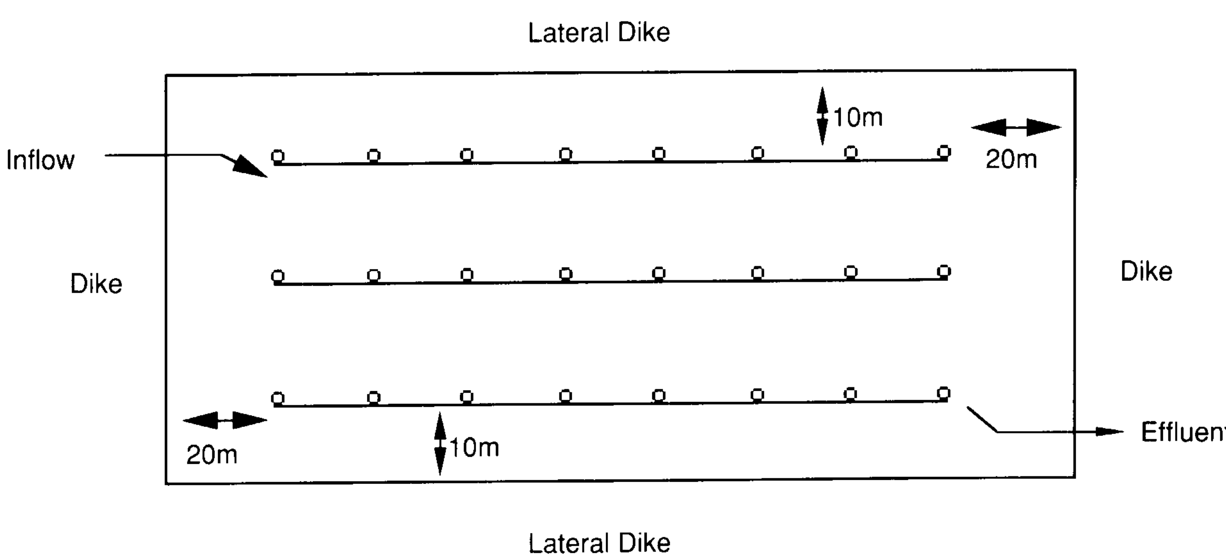


Figure 4. Vertical substrate placement in nursery pond.

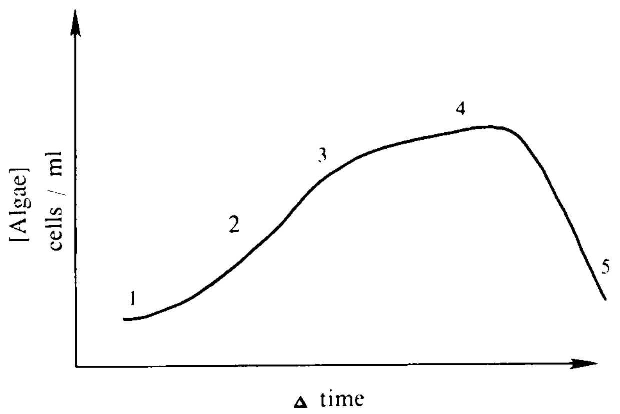


Figure 5. Algal-growth dynamics (adapted from Fox, 1983).

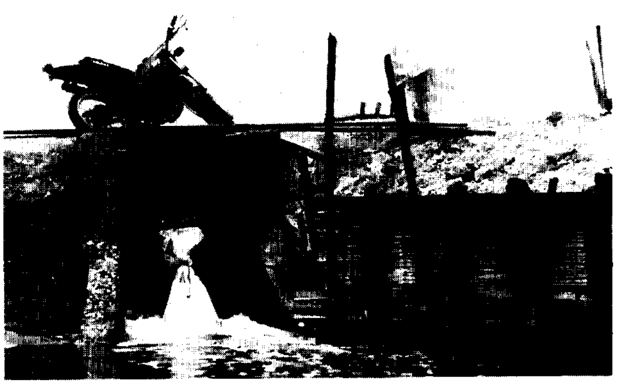


Plate 13. Fertilizer application with an empty feed bag hung in entrance weir gate. This method is most effective when the entrance gate is upwind.

Plate 14. Fertilizer application by boat.

cally bind to components at the mud bottom and reduce the effectiveness of nutrient enrichment of the water column.

There are two procedures for proper fertilizer dispersal:

1. Dissolve fertilizers in a tank of water before applying to the pond. This entails liquid dispersal over the entire surface of the pond by personnel in a canoe or by a metered holding tank at the entrance gate, which gradually drips the nutrient solution into the water;
2. Application of a solid fertilizer in an empty feed bag or a fertilization cage at the entrance gate, thus allowing the water current to dissolve it (Plate 13).

This second alternative should only be implemented when the entrance gate is oriented upwind in relation to the longitudinal axis of the pond, since the wind facilitates uniform dispersal. If the entrance gate is not oriented in the upwind direction, one alternative to ensure uniform dispersal is the use of fertilization cages or empty feed bags attached to the side of a canoe (Plate 14). The cages or feed bags should not drag on the pond bottom and the canoes should carefully and uniformly cover the entire pond surface area.

Fertilization dosage.

The criteria for dosage application is to ensure a pond water nutrient concentration of 1.3ppm nitrogen and 0.15 ppm phosphorous. Although levels of these two primary nutrients will undoubtedly vary from farm to farm, and between two different ponds on the same farm, experience indicates that an approximation may be effective for most facilities. As operations become more efficient it may be necessary to optimize the fertilization program by individually analyzing each pond on the farm to find its particular nutrient enrichment requirement.

In the event that these guidelines prove ineffective, adjustments should be made until the correct dosage has been obtained for each situation. Likewise, because nutrient requirements will change in relation to climatic conditions and seasons, most fertilization programs are dynamic and susceptible to change.

Time frame and dosage

Production facilities currently use inorganic fertilizers consisting of urea with 46 percent nitrogen and triple phosphate with 39 percent phosphorous. Although ammonia-based urea is absorbed more readily by the pond bottom, and, thus, is slightly less efficient to maintain in the water column compared with nitrate fertilizers, it is more economical. Since urea may also enhance benthic growth, its periodic application will maintain an adequate concentration of nitrogen in both the water column and the benthos.

During most stocking procedures of postlarvae or juveniles, the animals will be experiencing post handling stress. Thus, it is important that once the animal has been stocked in the pond, it does not undergo additional stress or weakening due to insufficient food. Proper pond preparation and a conscientious fertilization program are designed to maximize primary productivity in pre-stocked ponds.

Although fertilization is time-consuming, a careful period of time invested in proper preparation and fertilization should be returned in increased final survival of animals.

Start-up procedures are as follow:

1. Sufficient water should be added to cover the majority of the surface area (>60 percent) to a 10 to 30 cm depth.
2. When, or while, the pond is being filled it should be fertilized with 9 kg (20 pounds) urea and 0.9 kg (2 pounds) triple phosphate per hectare of total pond surface area.
3. The pond should then be temporarily sealed and allowed to stand for approximately two to three days until the water color becomes a dark brown with a yellowish-hue.
4. After the two- to three-day time interval, water is added until the pond reaches 50 percent of its operational level. While the pond is filling, 14 kg (30 pounds) urea and 1.4 kg (3 pounds) triple phosphate should be applied per hectare, ensuring that it is adequately dispersed over the pond surface area.
5. After the second application of fertilizer, the pond should again be allowed to remain for two to three days with its weirs temporarily sealed. If, after the third day, the water coloration has not turned a dark brown with a yellowish hue then 92 kg (200 pounds) per hectare of calcium carbonate should be applied. The slight increase in pH may help stimulate the proper bloom.
6. Once the water has turned a dark brown with a yellowish hue after the second stagnation period, the pond should be filled to its standard operative water level.
7. On final filling of the pond to its operative level, the final application of fertilizer should be made at a dosage of 23 kg (50 lbs) of urea and 2.3 kg (5 lbs) of triple phosphate per hectare.
8. Once the pond is at its operative water level, it should be sealed completely prior to stocking with postlarvae or juveniles. At this time the pond is officially on "stand-by," but ideally it should not be stocked until it has been allowed to "age" for approximately five days. Only at this time is the pond at an optimal condition for stocking. Secchi disk readings at 25 to 35 cm and a water coloration of yellowish-brown will confirm adequate preparations and optimal conditions for best stocking results.
9. If step 8 has not been realized after the fifth day, then the water level should be dropped by 10 cm and refertilized. This should be done with 6.8 kg (15 lbs) urea and 0.7 kg (1.5 lbs) triple phosphate per hectare.

During the rainy season, while the pond is in the "stand-by" condition, it is recommended that water level down boards be set in the effluent gate at the standard operative levels and that restriction boards be removed. This will help maintain higher salinity, the rain water that enters the pond has a specific gravity lower than saline water and therefore will remain on the surface, ultimately being drained from the pond once the water levels exceed operative levels. **Caution:** This should only to be performed in ponds not yet stocked; all other ponds "in-progress" should drain with the restriction boards in their proper place.

This fertilization program attempts to maintain algal concentrations in the exponential phase (Figure 5). By slowly stimulating the "bloom" and attempting to match algal densities with nutrient availability, the pond should remain in high productivity in relation to its algal population. If proper algal species and concentrations are maintained, a healthy and productive benthic community consisting of polycheates, nematodes, rotifers and copepods should result.

"Down-time"

Although pond "down time" is an economical disadvantage in commercial operations, it is a necessity that technical managers must accept. It is estimated that each day a pond is not in production, it fails to earn approximately U.S. $ 65.00 per hectare. If the time frames for proper disinfectation (approximately 16 days), and for fertilization prior to stocking (14 days) result in a total of 30 days "down-time," the economical implications justify an efficient and effective team to concentrate on this phase, without compromising the technical requirements. Once a pond has been completely harvested, an aggressive attitude toward pond preparation is needed to minimize "down-time."

"On-line" fertilization routine

Conventional laboratory measurements of phytoplankton productivity, or biomass, still are not available to all farms. Farms adequately endowed with laboratory equipment can measure chlorophyll *a* directly and indirectly calculate algal cell densities. Currently, use of the secchi disk provides an estimate of water transparency (turbidity) generally related to plankton abundance. An experienced observer can readily distinguish between turbidity due to plankton and that due to other factors. It should be remembered that plankton blooms do not always cause water to appear green or golden brown for such blooms may also impart yellow, red, brown or black

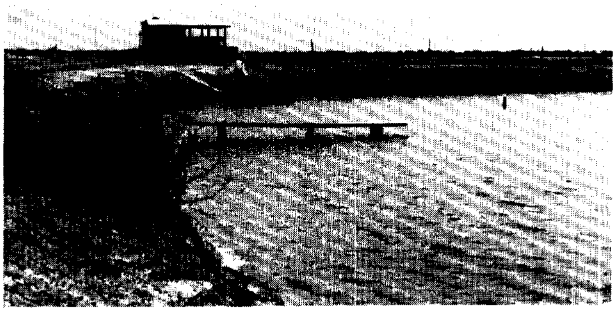


Plate 15. Pond platform station used to monitor daily parameters of secchi disk readings, near effluent weir gate. The platform should extend far enough out in the pond to have a minimum of 60 cm water depth.

coloration to water (Boyd, 1979). It is important to use the secchi disk carefully. Boyd emphasizes that different observers using the same technique may obtain different readings; however, analyses made by the same person may reduce variations and be more apt for comparison between ponds. Measurements taken at various times of day by the same observer may differ appreciably because of differences in light reflection and turbulence at the water surface. For these reasons, it is important that one person be designated for this daily operation, taking the secchi disk measurement on platforms that extend out into the pond near the effluent gate (Plate 15). Measurements should be taken daily at the same hour. For details refer to the section on *Hydrological Parameters* in Chapter 11.

Before discussing procedures of routine fertilization, comments on the economics of fertilization are worthwhile. Since the objective is to increase production and control costs, fertilization should be performed carefully. A single nutrient limiting in the pond water may limit or inhibit phytoplankton enhancement, thus increases in phytoplankton with each equal successive addition of the limiting nutrient are progressively smaller (Boyd, 1979). The economic implication of the relationship between the rate of fertilizer application and yield is straightforward. Fertilizer cost per unit weight increases with each successive unit of fertilizer applied. Because of diminishing returns, a point is reached where cost of an additional unit of fertilizer is greater than the value of the increase in shrimp growth that it produces.

In order to establish an economically feasible active fertilization program, more knowledge, such as soil and water nutrient levels, is necessary on an individual pond level. Since such data are not available for all ponds, a "rule of thumb" fertilization schedule may be adapted for all conditions with the eventual development of a more effective and economical application.

The "rule of thumb" schedule is governed by secchi disk measurements. When secchi disk readings are above 30 cm, the routine fertilization dosage of 1.8 kg (4 lbs) urea and 0.2 kg (0.4 lbs) triple superphosphate per hectare of surface area every three days should suffice.

If secchi disk readings fall between 25cm to 30 cm, the routine fertilization program for that particular pond is tentatively suspended until transparencies increase to above 30cm. If transparencies decrease below 25 cm, fertilization should be tentatively suspended along with the daily feed ration, and water exchange rates should be increased 25 percent to flush out a portion of the algal bloom. This procedure should be maintained until transparencies have increased to 30 cm or above.

In order to maximize the time duration that the fertilizer stays within the system during the routine fertilization program (every three days), it may be necessary to reduce pond water levels 10 cm to 15 cm the day before the programmed fertilization. In this way, as the pond regains its operative water level, nutrients from the fertilizer are not immediately flushed out.

Based on the dosage and the schedule of this fertilization regime, it is calculated that fertilization accounts for roughly 0.5 to 2.0 percent of total production cost per pound of harvested shrimp.

Chapter 4

Pre-Stocking Pond Confirmation

When the procedures outlined in the chapters on *Pond Disinfection* and *Pond Preparation* are completed, the pond should be ready for stocking. This section discusses evaluation and confirmation of pond preparation.

Since growout cycles of four to six months are common for 26-30 classification (tail-count) shrimp, it is extremely difficult to recall preparatory procedures and schedules for any particular pond. Thus, it becomes necessary to maintain a pond preparation sheet commencing on the last day of the harvest of the previous cycle. This sheet should be kept up to date. When the pond has been completely stocked, a copy should remain on file at the farm site. An example of this Pond Preparation Sheet is shown in Figure 6.

Between two days and one week prior to the first stocking or the first delivery of postlarvae, an assessment of predators should be made.

Predator Evaluation

A total of five net casts are necessary: three at one of the entrance gates and two at the effluent gate. The number of fish, crabs, and shrimp are counted and divided by actual surface area of the extended cast net. This technique determines the presence of predators prior to stocking and serves as a guideline in proper pond preparation. The figure for predators per square meter should be recorded on the preparation sheets.

Vertical Substrate Assessment

Nursery ponds and grow-out ponds that contain vertical substrates should also be evaluated at this time. In recording this data, as well as benthic growth, it is suggested that a scale of one to three be used: (1) represents poor, lowest, least; in reference to the amount of benthic blue green algae present on the vertical substrate; (2) represents fair, mid-range, average; (3) represents excellent or highest algal growth. Since these values are subjective it is recommended that only one person be delegated this task so as to reduce variability.

Benthic Fauna Assessment

The same procedure should be used for evaluation of benthic growth on pond bottoms. A total of two samples should be randomly selected somewhere at the mid-point range in the pond. These should be taken so that the surface of the sample of the pond bottom remains undisturbed. Each sample should be approximately 100 cm^2. One should be taken in the deep zone along one of the lateral dikes of the pond, the other should be taken in the center. These samples should be examined under the dissecting microscope and rated in the same manner described for assessing the vertical substrate. Again, it is stressed that one person be delegated to this task to reduce subjectivity. The benthic fauna assessment gives a relative evaluation of the benthic blue green algal mat and evaluation of benthic calanoid copepods, nematodes, polycheates, and other benthic organisms in pond bottoms.

Preliminary Feeding

One day before initial delivery of postlarvae to a pond, an application of 20 kg of feed per hectare of surface area should be made. This is done to stimulate benthic fauna and to have food available for foraging postlarvae. The date and the number of bags applied in this initial feeding should be recorded on the Pond Preparation Sheet.

Pre-stocking Salinity Control

Prior to stocking, but after the pond has been prepared adequately and the ecological factors evaluated, the pond is considered "ready." During the rainy season this "ready" mode can be potentially dangerous since the pond can experience a salinity drop prior to stocking. In order to minimize a reduction in salinity, refer to the last few paragraphs in the discussion on *Time Frame and Dosage* in Chapter 3.

Figure 6 : Pond Preparation Sheet

FARM ______________________ DATES __________ through __________

POND ______________________ HECTARES _______

DATE (last day of harvest) ______________________________________

Percent of surface area remaining with water _________________________ %

Average water depth of above area ______________________________ cm

DATE In-flow and Effluent gates sealed ____________________________

DATE Remaining water evacuated _________________________________

by pump __________ or by drainage __________

No. of days allowed to solar dry ______________________________ days

Depth of cracks in bottom mud ________________________________ cm

Percent of surface area with hydrogen sulfide smell ___________________ %

Quantity of chemical treatment applied __________________________ kgs

DATE Chemical treatment applied ______________________________

IDENTIFICATION of chemical applied ____________________________

DATE POND BEGINS TO REFILL _________________________________

DATE INITIAL FERTILIZATION __________________________________

Quantity of INITIAL APPLICATION: UREA ______________kg

PHOSPHATE _________kg

No. Predators per m^2 ______ $/m^2$

fish ___________ crab ___________ shrimp ___________

Vertical Substrate: 1 ______________ 2 ______________ 3 ______________

Benthic Fauna : 1 ______________ 2 ______________ 3 ______________

Initial feed application __________bags DATE ________________

DATE OF 1ST STOCKING ______________________________________

TRANSPARENCY ____cm

Chapter 5

Postlarval Transportation

To ensure that the farm has a participating role in all aspects of postlarvae manipulation prior to stocking, it is necessary to send a farm representative to the hatchery the day prior to farm delivery. This may not be possible in the case of purchases of wild caught postlarvae since the farm has little control over where and how postlarvae are captured and transported, but it is important for postlarvae purchased from hatcheries.

The objective of this participation, by the farm at the hatchery and during the transportation, is to guarantee minimal stress on the postlarvae.

The primary responsibility of the farm representative is threefold:

1. To participate in the postlarvae counts, which will result in the final calculations to determine the number amount of postlarvae harvested (sold).
2. To maintain control over dissolved oxygen(D.O.) concentration and temperature in the water during transportation, and
3. To ensure rapid transportation without unnecessary delays while maintaining constant communication with farm personnel by radio. The latter allows the farm to adjust water parameters in preparation for postlarval arrival.

Hatchery Visit

The farm representative should arrive at the hatchery site a day before the harvest. Prior to arrival at the hatchery, farm personnel should have ice on hand in polyethylene bags in order to be able to manipulate water temperature during transportation.

On arrival at the hatchery, the farm representative and hatchery personnel should perform a "stress test" on postlarvae to be harvested. Stress tests should be conducted on hatchery-reared postlarvae in an attempt to establish a bench-mark evaluation of quality. Although sufficient evidence has not yet been collected to significantly correlate high stress test results with high postlarvae survival in nursery ponds, the hypothesis appears to have practical and logical validity.

Stress tests should be conducted in triplicate and are performed as follows :

1. Three groups of 100 postlarvae each should be collected from the larval rearing tank to be harvested. Generally, larval rearing tank water will be 29℃ and 33 ppt salinity.
2. 100 postlarvae are deposited into each of three recepticles containing approximately 15 liters of water. Water in receptacles should be at 20℃ and 5 ppt salinity.
3. Postlarvae should be allowed to remain in 15 liters of water for one hour without changes in the hydrological parameters.
4. After one hour, all live postlarvae in each receptacle should be counted and the average survival percentage for all three should be calculated.
5. Survival percentage values below 60 percent are generally not acceptable and harvesting of such populations should be delayed for 24 hours until the stress test can be repeated with acceptable results.

Stress test results should be recorded by the farm representative on the acclimation sheets for future reference.

Water temperature of postlarval culture tanks is normally 29℃. During harvest, hatchery personnel should decrease water temperature to 22℃ in two independent stages. It is considered that less postlarvae stress is caused by decreases in water temperatures than by increases. It is important that the farm representative record personal observations of anormalities in harvesting procedures such as:

- excessive handling of postlarvae,
- prolonged exposure to direct sunlight,
- excessive holding of postlarvae in a high density environment,
- radical fluctuation in water temperature,
- presence of a strong smell of antibiotics or other medications, etc.

All observations should be recorded directly on the acclimation sheets; if more space is necessary, information should be attached to the acclimation sheets.

It is the farm representative's responsibilty to accumulate as much information on the condition of the postlarvae as possible so that this information can be referred to in the future for analyses of acclimation and nursery survival results.

Postlarval counts

There are a multitude of postlarval counting techniques and a high degree of controversy exists on which procedure is the most accurate. Although the farm cannot directly influence hatchery technical policy, there are some established mutually accepted counting standards that are readily accepted.

The counting procedure most widely used is the reduction method as follows :

1. Once the postlarvae start accumulating in appreciable numbers in the hatchery's harvest basin, a

mass of postlarvae, roughly the size of a grapefruit, is extracted and placed in a bucket containig 14 liters of clean water.

2. The postlarvae are then homogenously mixed using a plunger, and two 100 ml samples are extracted and placed in a master bucket containig clean water.
3. The remaining postlarvae and 14 liters of water from the initial bucket are deposited in a double polyethylene bag for shipment by plane or in the transportation tanks for shipment by truck.
4. Steps 1 through 3 are performed continuously until the harvest is completed.
5. The master bucket contains the postlarvae samples collected during the harvest and the water volume is then adjusted to 14 liters.
6. The contents of the master bucket are homogenously mixed using a plunger and two 100 ml samples are taken for each person destined to count.
7. Six counts should be performed, after which the highest and lowest counts are eliminated. The remaining four counts are then averaged and this average is multiplied by a factor of 4900 to find the estimated number of postlarvae harvested (sold).

Note: The multiplicative factor of 4,900 is derived from the following calculation.

$$\frac{\text{200 ml sample}}{\text{14,000 ml bucket}} \times \frac{\text{200 ml sample}}{\text{14,000 ml master bucket}} = \frac{1}{4,900}$$

The farm representative should participate in at least one, or better, two of the six original counts. It should be recorded on the acclimation sheets if the farm representative's count was used in the calculations to determine the number harvested.

Temperature control and transportation

Once the counting procedures have concluded and postlarvae have been packed for transportation, water temperature should be monitored and recorded.

In the case of transportation by land, D.O. concentration and water temperatures should be monitored every hour. D.O. concentration should be maintained between 8 to 12 ppm and water temperature at 22°C.

Truck transportation should be programmed late in the afternoon, so that the ambient air temperatures will be cooler. If water temperature begins to rise, bagged ice should be introduced into the transportation tanks.

It is essential that all unnecessary delays be eliminated to ensure the shortest transportation time possible.

Air transportation should be programmed during the early morning hours. In this case, postlarvae are packed in oxygenated bags. The measurement of D.O. concentrations is generally not necessary unless the trip duration is more than 20 hours. Air transportation time is usually less than two hours, in which case only water temperatures should be monitored every 30 minutes.

This may be performed by sliding the glass thermometer between the plastic polyethylene bag and the carton. The water temperature can thus be indirectly monitored without opening the bag. If water temperature increases, a handfull of crushed ice can be placed in the carton next to the polyethylene bag.

It is important that the farm representative ensure that flight altitude be limited to a maximum of 1,800 meters, so that the oxygenated bags do not rupture as a result of expansion. The airplane should also have window curtains installed to decrease the heat buildup due to sunlight within the cabin.

Chapter 6

Acclimation Station Preparation

The acclimation station is the center of operations during stocking procedures. It is therefore important that it be adequately prepared for postlarvae reception.

Disinfection of the overall area should take place two days prior to receiving postlarvae to eliminate possible contaminants that may have accumulated.

Disinfection and Flushing

The acclimation station should be disinfected as follows:

1. All acclimation tanks should be moved into the open and exposed to direct sunlight.
2. Tanks should be thoroughly scrubbed with a brush and a saturated solution of hypochloride and allowed to remain moist with the chloride solution for one hour.
3. Thoroughly rinse acclimation tanks at least three times while scrubbing the tank's surface.
4. Leave tanks to air dry while exposed to the sun for five hours before returning them to the station.
5. Complete steps 2 and 3 on the outside reservoir tanks, and allow chlorinated water to drain through the five centimeter water pipes.
6. The end cap of the drain pipes should be removed to eliminate any slush build-up.
7. Rinse the drain pipes thoroughly. The reservoir tanks should be filled with 1,000 liters of water and allowed to drain with the end caps in place in order to force the rinse water through the 1 cm nozzle valves.
8. Once this is completed, reservoir tanks should be sun-dried.
9. All other accessories, including nets, siphon tubing, and harvest buckets should also be disinfected with the chlorine solution. Thoroughly rinse each item and allow to air dry.

Note : Since chlorine is toxic to postlarvae, a consciencious effort should be made to remove all traces of this element.

Reservoir Tank Filling

One day prior to receiving postlarvae, reservoir tanks should be filled with water from the pond to be stocked. Portable plastic 1,200 liter tanks should be filled with a 5 cm pump, ensuring that the suction valve of the pump is firmly attached within a fine (0.5 mm) mesh bag so as to filter out living organisms (Plate 16).

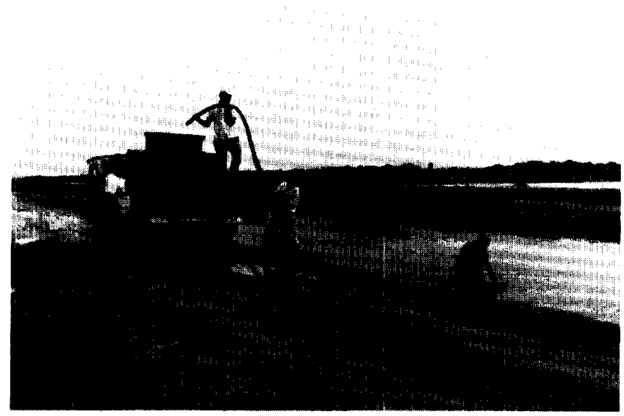


Plate 16. Filling pond water transport tanks to fill acclimation station reservoir tanks. Be sure that the mouth of the suction hose is securely enclosed in a filter box to exclude possible predators.

The suction valve should be maintained 30 cm beneath the water surface of the pond to avoid introducing muddy water from the bottom. Water should be drawn from the effluent dike of the pond approximately 40 m from the effluent weir. This is to ensure that aged pond water is used for the acclimation.

1. Once the acclimation reservoir tanks have been filled with filtered water from the pond to be stocked, 2 ppm of EDTA should be added to each reservoir in the following mannner :
   a. Two grams of EDTA in granular form for every 1,000 liters of reservoir water (2mg / liter), should be weighed separately for each individual reservoir.
   b. If 2,000 liter reservoirs are used, 4 grams per tank should be weighed.
   c. The weighed EDTA is then diluted in one liter of reservoir water.
   d. The one liter solution of EDTA is introduced separately into each reservoir and thoroughly mixed.

Note: When reservoirs need refilling during acclimation, the same dosage should be repeated. Personnel involved with preparation of the acclimation station should not use insect repellent or body lotion. Insect repellent may be lethal to shrimp larvae.

Acclimation Tank Filling Preparation

The acclimation tanks destined to receive postlarvae should be filled with clean water of the same salinity and temperature as that in which the

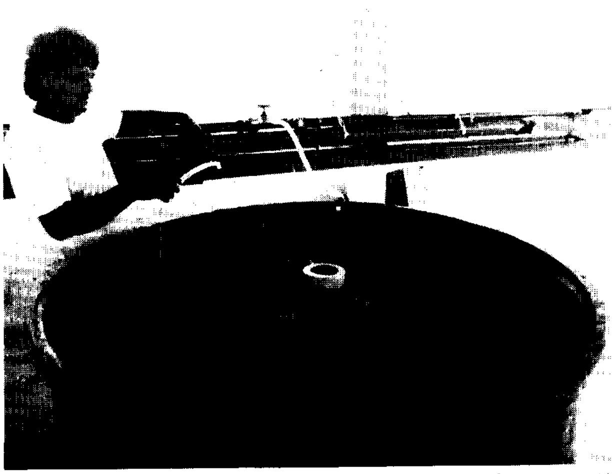


Plate 17. Empty and prepared acclimation tank. Note: 1) water inflow at the tank's bottom; 2) aeration belt at the tank-top perimeter; 3) central standpipe with aeration belt around small mesh screen; and 4) two air lift pumps parallel to the central standpipe.

postlarvae are shipped. All control measures should be taken to ensure that stocking of the acclimation tanks is performed quickly and with a minimum of handling and stress. Necessary preparations must be made well in advance of receiving postlarvae.

Sufficient tanks should be prepared to maintain postlarvae densities in the acclimation tanks at no more than 500 per liter. This pre-determined density is also valid for initial stocking and therefore dictates that acclimation tanks be completely filled with water from the outset (Plate 17).

Dry season acclimation preparation

During the dry season, or when the salinity difference between hatchery water and farm water is less than 10 ppt, pond water salinity in the acclimation tanks may be adjusted with industrial grade rock salt from solar salt plants. If the salinity difference between the postlarval source and the farm pond water is greater than 10 ppt, refer to the next section.

In dry season acclimation, there is generally less difference in salinity between hatchery and ponds. As a result, acclimation tanks can be filled with water from the pond to be stocked. Care should be taken to ensure that the suction hose, which delivers water from the designated ponds to the acclimation tanks, be maintained 30 cm below the pond's water surface and enclosed in a small mesh box net. This ensures that the water used for acclimation purposes is relatively free from mud and other particulate matter as well as water insects and predators. If pond salinity is higher than 33 ppt, salinity must be adjusted "down" using untreated fresh water in the acclimation tanks along with the high salinity water of the pond. The final salinity in the acclimation tanks is thus equalized to the salinity in which postlarvae arrive, usually 33 ppt.

Once the required number of tanks have been filled with pond water, salinity may be adjusted in the following manner if the pond salinity is lower than that of the postlarvae delivery container water.

1. Use industrial grade rock salt in pulverized form from solar salt plants. This must be 100 percent pure and free of processing chemicals.
2. Prepare a saturated solution of salt water by mixing the industrial salt with pond water in a separate tank.
3. After the excess particulate salt has been allowed to settle to the bottom of the tank (30 minutes), pass the saturated saline solution to the waiting acclimation tanks by small, one liter increments, with thorough mixing.
4. Caution should be taken not to end up with higher salinity than that in which postlarvae are expected to arrive.
5. After thorough mixing, allow three minutes before measuring the salinity with the refractometer since there is generally a delay in salinity equilibrium.
6. Once the desired salinity has been reached, recheck several times over a one-hour period to confirm that the final equilibrium has not shifted.
7. Four hours after the acclimation tanks have been mixed and salinity adjusted, most of the debris and particulate matter should have settled. With a small siphon hose (1 cm diameter) quickly siphon the bottom of each prepared tank to remove any particulate accumulation.
8. Once receiving acclimation tanks have been cleared, 2 ppm of EDTA should be added to each tank in the following manner:
   a. Two grams of EDTA in granular form for every 1000 liters of tank water (2 mg/liter), should be weighed separately for each individual tank used in acclimation.
   b. The weighed EDTA is then diluted in one liter of tank water.
   c. The one liter solution of EDTA is introduced into each tank separately and thoroughly mixed.

   NOTE: These procedures should be repeated for each tank.
9. These procedures should be performed on the day prior to receiving postlarvae, or at the latest, the night before.

EDTA (ethylenediaminetetraacetic acid) is a water-soluble chemical additive used primarily as a heavy metal chelator to improve water quality and reduce contamination. By reducing contamination and chemically binding heavy metals, it reduces postlarvae stress, mucus and external debris build-up.

Rainy season acclimation preparation.

Salinity differences between hatchery and ponds is greater during the rainy season. When this difference exceeds 10 ppt, the use of industrial salt should be discontinued. Although it presents logistical problems for the farms, it may be necessary to acquire higher salinity water from the open ocean with tanks set up on boats. With terrestrial transportation, postlarvae will arrive in water of a specific salinity. In the former situation, boats should bring water from the ocean at the same salinity in which the postlarvae are expected to arrive. This water should be used to fill acclimation tanks completely one day prior to receiving postlarvae.

If postlarvae arrive by truck, there is no need to fill acclimation tanks with water. Tanks should be clean and dry when postlarvae arrive. This applies to both hatchery and wild postlarvae since they are transported in relatively large volumes of water.

Oxygenation and Aeration Check

Once the reservoir tanks and acclimation tanks have been prepared, a systems check should be conducted. Bottles of pure oxygen with properly functioning regulator valves should be on hand. Aeration stones as well as tygon tubing should be clean and in good condition.

Since postlarvae generally arrive in water containing 15 ppm of dissolved oxygen (D.O.), acclimation tanks should also have this oxygen concentration. This requires that pure oxygen be actively bubbled through the acclimation tanks for at least 15 minutes prior to initial stocking. It is highly unlikely that the acclimation tanks will reach a D.O. concentration of 15 ppm, but attempts should be made to reach a minimum of 10 ppm for initial stocking.

The compressed air aeration system should be checked and any necessary repairs or modifications made. Compressed air should be used during the acclimation while pure oxygen is used only to increase the oxygen concentration of the water prior to stocking and for the first two hours of acclimation. During acclimation, it should not be used unless oxygen concentration in the tanks falls below 4.5 ppm.

Preparation for Water Parameters

One of the objectives of this manual is the reduction of physiological stress to the postlarvae caused by excessive handling or other adverse conditions.

The remaining aspect that the farms can actively control in the acclimation station prior to stocking is the water temperature of the receiving tanks.

On the morning of postlarvae delivery, sufficient ice should be on hand in polyethylene bags to lower the water temperature quickly in the acclimation tanks if necessary. This serves to reduce the amount of time in which the postlarvae are maintained in their transport bags. It is suggested that at least 15 kg of ice in protective bags be used per acclimation tank to minimize the time needed for final temperature adjustment. The bags should be sealed with rubber bands so that ice and melted water do not contaminate acclimation water. Ice is frequently treated with chemicals and may have toxic levels of chlorine.

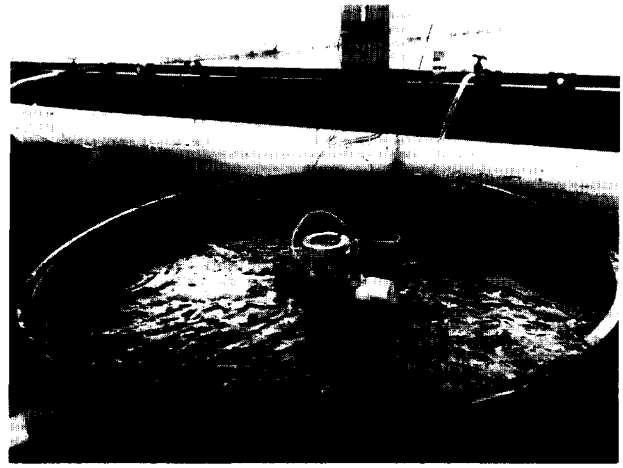


Plate 18. Air lift pumps functioning in filled acclimation tanks. Note: water circulation pattern is circular with pumps directed toward the tank wall.

On the other hand, when the water containing postlarvae arrives at a warmer temperature than that of the tanks it will be necessary to introduce hot water into them to equalize water temperatures before stocking.

To equalize water temperature in a minimum of time, water from the acclimation tanks should be heated in an aluminum or stainless steel container prior to arrival of postlarvae. Approximately 20 liters for every 1000 liters of acclimation water should be adequate if the water is at 100°C.

NOTE: All physical parameter measurements should be monitored with the same instruments since calibration differences affect thermometer readings. To reduce the possibility of error, comparative measurements should be standardized to one refractometer and one thermometer.

Activated Carbon

Although the acclimation station is a flow-through system, it is beneficial to use activated carbon in each of the tanks. Since acclimation procedures (next chapter) entail an aggressive feeding regime, the activated carbon should absorb and deactivate the majority of the toxic metabolites that may accumulate in the tanks.

The two air lifts, located parallel to the central effluent standpipe in the conical acclimation tanks, should be packed with activated carbon granules. In order to maximize the surface area and to economize on the activated carbon, the air lift pumps should contain a mixture of 60 percent carbon and 40 percent homogenous gravel. The air stone should be located within the carbon/gravel mixture approximately 7 centimeters from the bottom of the air lift tube. This will allow water to be forced upward through the activated carbon and discharged, filtered and oxygenated on the surface. The effluent nozzle on the air lift is directed towards the tank wall, which will help maintain a circular water circulation pattern (Plate 18).

The bottom end of the 2-cm air lift is sealed with a 0.5 mm mesh to exclude postlarvae but allow uneaten food particles to pass through the system. Each tank should have two air lifts attached to the central stand pipe. The activated carbon packing in the air lifts should be replaced with fresh carbon after 40 hours of use. During the rainy season, this requires replenishment every two acclimations, while in the dry season, use may be prolonged due to decrease in overall acclimation time. The gravel portion of the packing may be re-used.

Acclimation Feed Preparation

Before the arrival of postlarvae, the quantity of feed ready for acclimation should be checked. Since the feeding regime during acclimation will be discussed in detail in a later section it will not be elaborated on here. Only note that there should be a minimum of three cooked egg yolks and 40 grams of a commercial flake diet for every acclimation tank. Fresh frozen Artemia should be supplied in separate bags along with the postlarvae.

Instrument Preparation

Prior to the arrival of postlarvae, all instruments should be checked and calibrated so as to be "on stand-by" for operation at the acclimation station. The oxygen meters should have the probe electrolyte liquid clear and free of air bubbles. The membrane over the probe should be taut and clear. The pH meter should already be calibrated at buffer 7 and the slope at buffer 4.

The refractometer should be previously calibrated with distilled water.

The glass thermometer should have been calibrated in boiling water (100°C) and the respective correction factor labeled no more than three days prior to arrival of postlarvae.

Chapter 7

Postlarvae Receiving

The preparations and precautions described in the previous section should result in the efficient and careful handling of postlarvae upon arrival. The period of time in which postlarvae are in the acclimation station provides an ideal opportunity to assess their condition and behavior, while feeding generously to optimize their survival in the pond.

Correct preparation of the acclimation station is of upmost importance in order to ensure the quick transfer of postlarvae from the relatively high stress of transportation to the more manageable conditions of acclimation tanks. This movement of postlarvae should be accomplished with minimal changes of the environmental conditions, except pH. Parameters of water temperature, D.O. and salinity should be well adjusted in advance.

Plate 19. Arrival of postlarvae in the early morning hours at the farm. Note that personnel are on standby for quick loading on truck.

Parameter Confirmation

To take advantage of cooler temperatures, arrival of postlarvae at the farm site should generally be scheduled for the early morning (Plates 19 and 20). Immediately upon arrival, all postlarval transport polyethylene bags within cartons, should be off-loaded and placed under roof at the acclimation station. While personnel are off-loading the truck, the technical staff should do the following things :

1. Select four bags from different locations on the truck bed and place on floor near the acclimation tanks.
2. Open one bag at a time and immediately place the oxygen meter probe and pH meter probe into the water of the bag (Plate 21).
3. Once D.O. and pH have been recorded on acclimation sheets (Figure 7), immediately introduce an air stone into the bag and regulate the flow of pure oxygen so that it gently moves the swimming postlarvae. Do not cause water in the bag to "boil" with oxygen (Plate 22).
4. Immediately upon completing steps two and three with the first of the four selected bags, perform the same steps for the remaining three bags.
5. When the four bags have been measured and recorded for D.O. and pH, and are being aerated, record salinity and water temperature of each bag (Plate 23).
6. Quickly calculate the average D.O. concentration, water temperature, and salinity of the four selected bags.
7. Adjust all the acclimation tanks to the same parameters specified by the average value obtained

Plate 20. Plane unloading is performed rapidly to limit the time the postlarvae are exposed to direct sunlight.

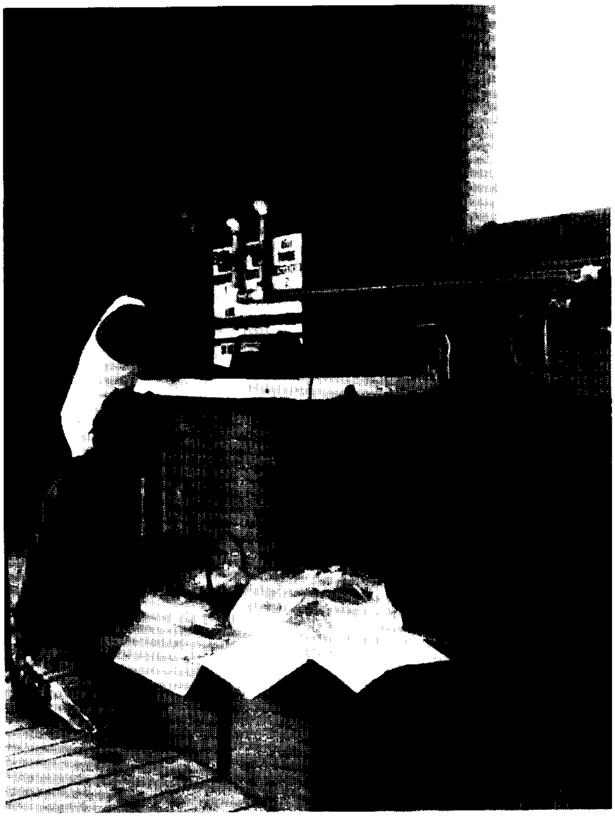


Plate 21. Four sampled bags containing postlarvae are separated and dissolved oxygen concentration and pH are monitored and recorded. This is performed before oxygenating water.

from the four bags. Water temperature is adjusted by introducing the required volume of heated water or bagged ice; D.O. adjustment should be performed by aggressively passing pure oxygen through the station's aeration system. The oxygen concentration in the tanks should be comparable to that in the transport bags upon arrival or no lower than 10 ppm, whichever is achieved in the least amount of time.

8. When equilibrium between bags and acclimation tanks has been reached, stocking should commence.
   NOTE: These procedures should not take more than 20 minutes, and during this time, the remainder of the transport bags should be kept in the shade.
9. It should not be necessary to record parameters for all bags. However, if appreciable mortality, excess debris or adult Artemia are observed, those bags should be examined and evaluated thoroughly.

Stocking Density

Generally each transport bag contains between 40,000 to 70,000 postlarvae and acclimation tanks have a volume of approximately 1,000 liters. The maximum allowable stocking density for each tank is

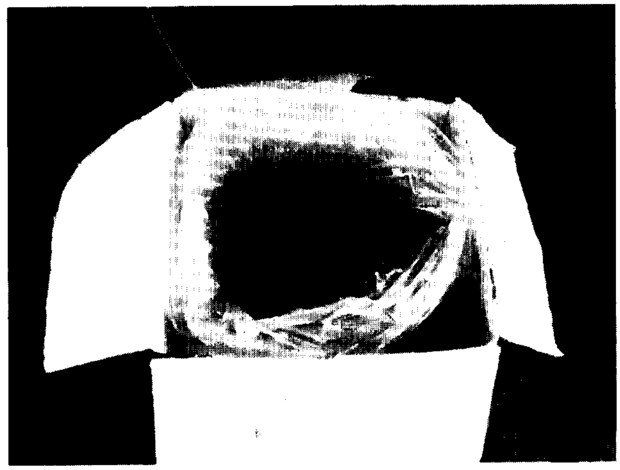


Plate 22. Oxygenating bagged water with postlarvae after recording dissolved oxygen concentration and pH, but before monitoring water temperature and salinity.

Plate 23. Monitoring and recording water temperature and salinity in transport water containing postlarvae. The average then calculated and acclimation tank water is adjusted with the same water parameters of the transport bags.

500 postlarvae per liter, or 500,000 postlarvae per acclimation tank.

If at all possible, it is better to operate at lower densities during the rainy season when acclimation takes more time. Delivery of 1,100,000 postlarvae in 20 bags is common. For this situation, the acclimation station should be set up for a stocking density of 370 postlarvae per liter. For this example, it is assumed that each bag contains an equal number of postlarvae. Therefore of the three acclimation tanks to be used, two will be stocked with seven bags each, and the third with six bags.

Stocking procedures are as follows:

1. Since postlarvae are double bagged with polyethylene bags, remove the outer bag.
2. Reduce the quantity of pure oxygen bubbling through the acclimation tank aeration system to a gentle roll.

Figure 7. Acclimation Control Report

Farm ______________________________ Date ______________________________

______________________________ Supplier ______________________________

Receiving

Time of harvest of PLs ______________________

Water temperature of bags ________________ ˚C

Salinity of water in bags ________________ ppt

Quantity of PLs ______________________ Count of representative utilized yes ☐ no ☐

Stress test results ______________________

Parameters on Arrival at Farm

Time of arrival ______________________

		(individual bags)
O_2 of water in bags ____________	ppm average	(______________________)
pH of water in bags ______________	average	(______________________)
Temperature of water in bags ________	˚C average	(______________________)
Salinity of water in bags __________	ppt average	(______________________)

Parameters at Acclimation Station

Time of stocking tanks ______________________

O_2 of water in tanks ____________ ppm average

pH of water in tanks ______________ average

Temperature of water in tanks ______ ˚C average

Salinity of water in tanks __________ ppt average

Initial Volumetric Counts (optional)

Total PLs ______________________

Live PLs ______________________

Dead PLs ______________________

Percent mortality in transport ______________ %

Final Volumetric Counts (optional)

Total PLs ______________________

Live PLs ______________________

Dead PLs ______________________

Percent mortality in acclimation ______________ %

Microscopic Evaluation of Postlarvae (Examine 20 PL each time)

Qualities	Arrival	Mid-point	Final
Gut fullness			
Mucus on setae			
Opaque tails			
Deformities			
Average			

Acclimation

	Average Parameters					Average Evaluation						
Time	Salinity	Temp	pH	O_2	Activity	Erratic	Opaque	Molts	Gut Fullness	Mortalities	Cannibalism	Observations
Pond												

	Buckets		
	No 1	No 2	Average
Percent Survival post 48 hours:	(__________%	__________%)	__________%

Biologist ________________ ________________ ________

3. Remove the rubber bands that tie the shipment bag and place the bag in a upright position in the tank to be stocked.
4. Grasp the bottom corners of the bag and slowly extract it from the tank while postlarvae slowly swim out onto the surface water of the tank. **NOTE:** At this time, the technical staff should make a general visual evaluation of the condition of the postlarvae (discussed in *Routine acclimation assessment of postlarvae*).
5. Before stocking of the last bag in the tank, a random sample of approximately 20 postlarvae should be taken and a farm biologist should make an, in depth, assessment of larval conditions as described in *Microscopic assessment of larvae*. This assessment should be made no later than five minutes after sample is taken.
6. Once the last bag has been stocked, and the time recorded on the appropriate data sheet, acclimation should begin.

NOTE: While the bags are being emptied into tanks, evaluation of postlarval condition should be concerned primarily with the observation of erratic swimming behavior and presence of mortality (opaque white postlarvae). If the number of dead postlarvae is appreciable (>10 percent), then a volumetric count of the postlarvae in the tanks should be conducted to calculate transport mortality.

Volumetric Counts

It is generally not necessary for the farm to perform counting exercises since a farm representative is present at the hatchery site and participates in the counts. In order to reduce handling and manipulation stress on postlarvae, farm site counts are generally avoided. The exception is if there appears to be excessive mortality during transportation (>10 percent); during stocking or during the acclimation period. In the first case, volumetric counts are performed at the beginning of acclimation (within one hour of stocking tanks) and again at the completion of acclimation. In the second case (if there is no transportation mortality but appreciable mortality occurs during the acclimation procedure), then a volumetric count should be performed at the completion of acclimation. These final volumetric counts are generally performed one hour before completion of acclimation to save time and commence harvesting procedures immediately when acclimation is completed.

Additionally, counts should be made at the farm if a shipment of postlarvae is to be divided between two or more ponds.

Procedures for volumetric counts are as follows:

1. Two people are necessary for counting; each should have a 1-liter plastic "wide mouth" container.
2. The two people should position themselves on opposite sides of the acclimation tanks facing each other and begin mixing tank water.

Plate 24. Counting live and dead postlarvae on a counting frame in the acclimation station. ***Note:*** *while one person counts, his assistant records.*

3. With arms extended downwards, they aggressively mix water with an "upwelling" motion, making sure their hands reach the bottom of the tank. With square tanks, the corners should be included in the mixing.
4. When the water is well agitated each person should sample one liter of water with his respective container.
5. This random sample is then slowly poured through a framed screen of fine mesh and each postlarvae is individually counted (Plate 24).
6. Counts should distinguish between live and dead postlarvae, so the mortality percentage can be calculated.
7. The average count in 1 liter is then multiplied by the total number of liters to find the total number of postlarvae in each tank.
8. These steps are then repeated for each acclimation tank and numbers recorded on the acclimation sheets.

Results of volumetric counts can be used to determine the final number of live postlarvae stocked (in the case of appreciable mortality), and can be used to divert selected tanks to specific ponds.

Feed Schedule

An aggressive feeding regime is necessary to reduce stress and maintain good ambient conditions for the postlarvae during acclimation.

The combined flow-through design, the presence of activated carbon, and 2 ppm of EDTA tend to reduce levels of metabolites in the acclimation system. A feeding regime can be safely incorporated into the acclimation operation. The strategic goal of feeding is to ensure that postlarvae have sufficient metabolizable energy to combat physiological aspects of stress. Postlarvae may be exposed to high levels of stress during transportation and acclimation, however, active feeding may prevent this from reaching critical levels. Since very little is known about nutritional requirements of postlarvae, a broad feeding regime is used to make available the necessary metabolizable energy, and fulfil other requirements. The feed consists of frozen Artemia nauplii, cooked egg yolk (finely ground), and a processed flake diet. The Artemia nauplii in frozen chunks (minimum concentration of 10 nauplii/ml) are fed throughout the acclimation period. The commercial flake diet and cooked egg yolk are alternated hourly; i.e. one hour feeding with egg yolk the second hour with flake.

Feeding during acclimation should be as follows:

1. If volumetric counts are not necessary, feeding should commence immediately after tanks have been stocked and acclimation has begun, but if volumetric counts are necessary at the beginning of acclimation, feeding is postponed until these are completed.
2. The first feeding consists of cooked egg yolk with one yolk per tank containing 500,000 postlarvae. The egg yolk is slowly passed through a 500 micron mesh circular sieve held over the water surface and covering the entire tank surface area. This should be performed slowly to avoid clumping of the egg yolk (Plate 25).
3. At the second feeding, four grams of flake are broadcast over the water surface area and allowed to slowly sink. The flake should be passed through a 500 micron sieve before broadcasting.
4. Steps two and three are alternated hourly for the duration of acclimation.
5. During all feedings, frozen Artemia nauplii are used. Approximately 4 cm^3 of frozen nauplii should be cut and added to each tank (two frozen chunks (4 cm^3) per hour).

   NOTE: The Artemia must be given in the frozen state. Nauplii in melted liquid form are not guaranteed to be good and should not be used. Frozen chunks are allowed to float on the surface, and as they melt nauplli will be slowly released into the water column.

Reservoir Tank Temperature Control

As discussed in Chapter 5 (*Postlarval Transportation*), postlarvae are packed at the hatchery at 22°C for transportation and the farm representative is responsible for maintaining that temperature during the trip to the farm. The technical staff awaiting the arrival of postlarvae are responsible for maintaining water temperatures and salinity at the acclimation station. Since the technical staff are in continual communication via radio this should be easily accomplished.

It is the acclimation strategy to maintain water temperatures relatively cool (25°C) and constant

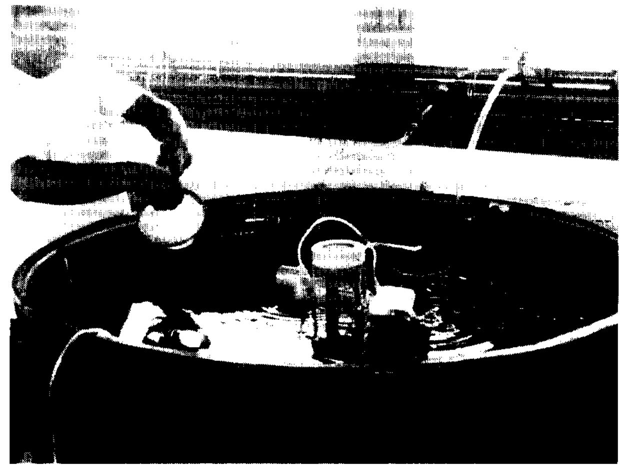


Plate 25. Feeding cooked egg yolk passed through a small mesh sieve.

throughout the operation until the last few hours when it becomes necessary to acclimate to pond water temperatures. Salinity adjustment and water chemistry adjustment are also necessary.

The objective of maintaining a constant 25°C in the acclimation tanks is to reduce aggressive activity in postlarvae and reduce production of metabolites in the relatively small tanks. The temperature is not lowered more than 25°C so as not to inhibit the postlarval feeding response. Although this temperature control is labor intensive, especially during long range acclimations, it satisfies the physiological requirements of postlarvae during acclimation.

Since ambient temperatures are much higher than 25°C and heat exchange factor of the acclimation tank walls is efficiently high, the reservoir tank water must be maintained at approximately 23°C. This is done by continually introducing bagged ice into the reservoir and by carefully monitoring the temperature. The most practical solution is a wall mounted dial thermometer with a cable extension and probe to continually monitor "at a glance."

If the temperature in the reservoir tank is carefully monitored it may not be necessary to introduce bagged ice directly into acclimation tanks while postlarvae are present. All temperature manipulation should be performed indirectly and externally, avoiding actual direct contact with larvae.

A practical technique is to use one of the two 2,000 liter reservoirs at a time. When the first tank empties, bring the second 2,000 liter tank "on-line." While using the second tank, refill the first tank, add 2 ppm of EDTA, and decrease the temperature with bagged ice. By the time the second tank has emptied, the first tank will be ready to go "on-line".

When it is necessary to acclimate the postlarvae to actual pond water temperatures (described in next section), the reservoir tank water can be significantly heated by introducing boiling water prepared earlier while waiting for postlarvae to arrive (*Ecological*

Preparation in Chapter 6). Sufficient hot water is added to reservoir tanks to increase water temperatures 5°C higher than the actual pond water. This will result in using reduced quantities of reservoir water to achieve higher water temperature in acclimation tanks. Once acclimation tanks are at the same water temperature and salinity as the targeted pond, acclimation harvest can begin.

Acclimation Schedule and Monitoring

Acclimation begins immediatly after the last bag has been emptied into the tank and before volumetric counts, if necessary. Since tanks are filled to capacity, the water volume of each tank will remain constant regardless of the fact that water from the reservoir tanks is continually entering the tank. This is a consequence of the flow-through design. Since the water volume remains constant throughout the acclimation process it will have no effect on subsequent postlarval counts.

Although there are many different acclimation strategy schedules, we have traditionally carried out acclimation operations with an intermediate rhythm of change in physical parameters. This issue is quite controversial in aquaculture operations and we suspect that no particular method is conclusively the best. The acclimation schedule described here is designed to maintain minimal physiological stress on postlarvae. Although our method subjects postlarvae to longer periods of time in the acclimation station than other more accelerated methods of acclimation, the flow-through design coupled with the consciencious handling of postlarvae and water quality should offset the time disadvantage in most situations. The additional time and labor invested in acclimation also permit a more in-depth assessment of postlarval behavior and condition (see next section). If the postlarvae are stocked in the pond without proper evaluation, the technical management of the pond becomes complicated since initial survival estimates might be incorrect and the biologist may not accurately know the pond population until it is too late. Water salinity and chemistry are adjusted from hatchery conditions towards nursery conditions throughout the acclimation period, but water temperature remains constant during the initial 75 percent of this period and is only adjusted towards nursery temperature during the last 25 percent. Once the water valves to the acclimation tank are partially opened to allow pond water to enter from the reservoir tank, the salinity of the acclimation tanks should be monitored at fifteen minute intervals in order to accurately calibrate the inflow and make sure that the change in salinity over a set time interval is within the norms of the schedule described in Tables 1 and 2.

The acclimation schedule (starting at 33 ppt and ending at 0 ppt) reflects an overall acclimation period of 17.5 hours. The acclimation temperature remains at a constant 25°C. until approximately the last four hours, at which point the temperature is slowly adjusted up to the pond's water temperature (approximately 29°C) at a rate of 1°C. change per hour.

Table 1. Acclimation schedule for postlarvae six days and older.

Salinity range in ppt	For 1 ppt Change every	Change per Hour
33 —> 25	20 min.	3 ppt/hr.
24 —> 20	20 min.	3 ppt/hr.
19 —> 15	20 min.	3 ppt/hr.
14 —> 10	30 min.	2 ppt/hr.
9 —> 5	60 min.	1 ppt/hr.
4 —> 0	100 min.	0.6 ppt/hr.

Table 2. Acclimation schedule for postlarvae younger than six days.

Salinity range in ppt	For 1 ppt Change every	Change per Hour
33 —> 25	30 min.	2 ppt/hr.
24 —> 20	30 min.	2 ppt/hr.
19 —> 15	30 min.	2 ppt/hr.
14 —> 10	60 min.	1 ppt/hr.
9 —> 5	60 min.	1 ppt/hr.
4 —> 0	120 min.	0.5 ppt/hr.

When younger postlarvae (<PL6) are being acclimated the schedule should be slowed. A more conservative schedule is suggested in order to reduce stress. Younger postlarvae have a less developed immunological response and therefore may be more vulnerable to secondary infections as a result of initial stress. Table 2 represents a more conservative schedule to be utilized with postlarvae less than six days old.

This conservative schedule reflects an overall acclimation time of 24 hours. Salinity and temperature monitoring at 30-minute intervals will ensure that the schedule of change is being adhered to. Monitoring of D.O. and pH should be performed every hour during acclimation. All data collected should be recorded in the acclimation sheets represented in Figure 7.

During the period of acclimation, postlarvae should be graded by the condition assessment that is elaborated in more detail in the next section.

Postlarval Assessment During Acclimation

The manifestations of stress can normally be identified by the direct observation of postlarvae and should be used as a tool in forming acclimation strategies.

The assessment routine during acclimation is divided into two principal categories. First, the assessment of postlarvae at the moment of arrival (before being stocked into the acclimation tanks), at the midpoint of acclimation and at the end of acclimation prior to harvesting. The first category is more meticulous and requires the use of dissecting microscopes for more precise observations. This routine is basically performed by sampling a 1 liter volume of water from the tank (sampling from the bottom, upwards) and carefully examining postlarvae for :

1. Index of gut fullness,
2. Mucus and debris on setae,
3. Opaqueness of swimmerets and tail muscle, and
4. Morphological deformities.

The second category is a routine assessment of postlarvae, every hour during the acclimation period. This routine is basically performed by sampling a 1-liter volume of water in the same manner described above and carefully examinig the postlarvae swimming in the liter for the following:

1. Level of swimming activity,
2. Eratic swimming behavior,
3. Opaqueness of tail muscle,
4. Presence of molts,
5. Index of gut fullness,
6. Presence of mortalities, and
7. Frequency of cannibalism.

Close observation and assessment of postlarvae at the acclimation station will not only help direct changes necessary in acclimation schedules but also establishes a higher level of confidence in postlarvae strength and quality. This is critical for effective crop management.

Since procedures described in this section imply an inherently high level of subjectivity, it is suggested that one key person be given responsibility for this function. This should reduce variation in interpretation. All observations should be rated on the scale of 1 to 3 (described in Chapter 4).

Microscopic assessment of postlarvae

The microscopic examination upon arrival at the farm site should help assess the effects of transportation on postlarvae.

Immediately upon arrival and before actual stocking of acclimation tanks, one person should be responsible for collection of 20 postlarvae from one of the transport bags while the technical staff is examining the parameters of water in the bags. Postlarvae should be evaluated immediatly after the collection of the sample so that the observations reflect the condition of postlarvae in bags and not the stress caused by holding postlarvae in a beaker.

Once the postlarvae have been positioned and oriented for observation on a glass slide, examine each one and record the condition based on the following scale:

1 = Poor, lowest, least.
2 = fair, mid-range, average.
3 = excellent, highest, most.

Index of gut fullness

It is unlikely that the index of gut fullness will be higher than a rating of two since water temperature for and during transport is maintained at approximately 22°C. In any case, a percentage estimate of gut fullness upon arrival will serve as a good guideline for evaluating the intensity of feeding behavior during acclimation.

Mucus and debris on setae

The accumulation of mucus and the later attachment of debris to the setae and antennae as well as other appendages is a strong indicator of stress.

Focus on the setae and antennae by swinging the focus dial back and forth, in order to view the three dimensional effect. Carefully examine the spaces between the setae and antenna hairs for any build-up of debris and record data (1, 2 or 3) on acclimation sheets.

Opaqueness of swimmerets and tail muscle

One of the most obvious signs of stress is change in opaqueness of the tail muscle. Under normal conditions, the tail muscle will be transparent with a few pigmentation spots. When postlarvae are stressed, this tail muscle and also the swimmerets may become opaque and, in extreme cases of stress, may turn completely white. This is a phenomenon that is not completely understood but may be associated with the rechanneling of physiological energy from the tail region to other areas.

The opaqueness of tail muscle occurs quickly after stress is induced, therefore it is crucial that postlarvae be examined soon after the sample has been taken so that the stress caused by the sampling procedure is not reflected in the evaluation.

Morphological deformities

Another factor that makes evaluating the quality of postlarvae necessary is the number of morphological deformities. Although deformities are not directly related to stress, these can be used as an indicator for future survival estimates in the nursery or grow-out pond.

Specimens should be examined for:

1. Complete and well develped rostrum.
2. Well formed (unbent) rostrum.
3. No curvature, or cramped tail.

4. Well formed eyes and eye stalks.
5. Well formed and complete swimmerets, and
6. Overall physical appearence.

The microscopic evaluation of postlarvae, as mentioned above, should be recorded at three predetermined times during acclimation; at arrival, at mid-point and at termination.

Routine acclimation assessment of postlarvae

In addition to microscopic examination there should be constant observation of postlarvae during every hour of acclimation. Although this assessment is general and does not involve the use of the microscope, it should be an important element in decisions to change acclimation schedules.

The objective of this assessment is to maintain visual contact with postlarvae during imposed fluctuations of water quality inherent in acclimation. By a direct and general observation of postlarval behavior, one can make a subjective judgement on their condition. In case stress indicators are observed, the acclimation schedule should be slowed down to give the postlarvae more time to adapt to the changes in their environment.

At hourly intervals during acclimation, the technical staff should sample a one liter volume of water from each acclimation tank with an upward motion. While the postlarvae are swimming in the sample water, they should be subjectively evaluated and properly recorded with the 1 to 3 scale on the acclimation sheets for the following criteria :

1. **Level of swimming activity**
   If postlarvae are stressed for reasons of low D.O. they will generally accumulate on the water surface and will agitate the surface with increased aggressive movements. If this behavior is noted and confirmed by use of a well calibrated oxygen meter, injection of pure oxygen into the water should alleviate the problem. Other symptoms of stress may manifest themselves in an entirely different behavior. A major behavioral indicator of stress is lethargy and diminished swimming activity. When these manifestations are noted, action should be taken to reduce the rate at which change in water parameters is taking place so that postlarvae have more time to adjust physiologically.
2. **Erratic swimming behavior**
   This behavior has been noted in two particular instances: (a) during the attempt to molt, and (b) during a reaction to a toxic contaminant in the water. Molting can be identified by carefully observing the periodic rhythm at which postlarvae will cramp up and then relax. In case a large percentage of the tank's population begins to molt, care should be taken to maintain temperatures cooler than normal (23°C.) to supress cannibalistic activity by the non-molting postlarvae. A major molt in the tank, in itself, may indicate a stressful situation. The rate of water exchange should be diminished along with an increase in feed rations; the latter, along with temperature reduction in the water, is an attempt to discourage cannibalism.
   In the second case, when erratic swimming is not associated with molting activity, it is necessary to monitor any increase in mortality. If mortality index increases with time, the decision to suspend all changes in water parameters for a two hour period should be made. If mortality increases, it is possible that a toxic compound is present in the water. A complete evaluation of pond water in the reservoir tanks should be conducted reviewing all steps taken in acquiring, transporting and all chemical treatment, as well as a review of specific treatments used in tank disinfection, etc.
   Once a mass mortality in a tank begins, there is little one can do if all the postlarvae have been exposed to the same conditions. This illustrates the importance of maintaining a high level of control of the procedures described in Chapter 6.
3. **Opaqueness of tail muscle**
   This symptom is a classical indicator of a physiological reaction to stress. If it is noted at a high frequency, quick action should be taken to slow down the acclimation schedule of change.
4. **Presence of molts**
   Floating exoskeletons on the water surface, either in the 1 liter sample or on the tank's surface, are obvious indicators of molting. Although action to be taken is discussed previously in this section, it should be re-emphasized that there is a need to discourage cannibalistic behavior by decreasing water temperatures and slightly increasing the feed rations to each tank. A slowing of the acclimation water exchange is recommended as a precaution against the possibility of the molt being a direct reaction to stress. A word of caution in case of mass molting in tanks: postlarvae will generally become lethargic and benthic while in their molt. This behavioral pattern can be confused with mass mortality. If it occurs, a bottom sample should be taken from the tank and 10 larvae should be microscopically examined with specific attention paid to any gill movement or heart pumping activity. If both organs are moving rhythmically, then this behavioral pattern may be related to molting. If no organs appear to be active, it would be safe to assume that mass mortality has occurred.
5. **Index of fullness.**
   The observation of feeding activity and high index of fullness in the gut are positive signs indicating that there is little stress imposed on postlarvae. Generally, postlarvae will not feed,

or feeding will be reduced, if they are under a major stress.

When the index of fullness is not high, action should be taken to increase the quantity and frequency of feeding. A low index of fullness and the presence of a high concentration of feed in the water column may indicate a high level of stress. In this situation, feeding should be suspended, to avoid increasing the amount of uneaten feed in the system and the rate of change of water parameters should be reduced.

The index of fullness can be easily distinguished by the white line on the dorsal part of the tail muscle. The gut line coloration reflects the feed source; when cooked egg yolk, the gut line will be white; when Artemia nauplii, the gut line should be orange.

The index of fullness should be represented as a percentage. The length of the tail is classified as 100 percent and an estimate is made of what percentage of that length is full. Since each postlarvae should theoretically have different indices of fullness, a subjective judgement of the average index of fullness should be made.

6. **Presence of mortalities:**
   The occurrence of less than 3 percent mortality during acclimation is acceptable. Under normal circumstances anything >3 percent should put the technical staff on alert. A complete check of tank water quality factors such as D.O., pH, temperature and salinity should be conducted. Furthermore, a reduction in the rate of change of parameters should be initiated. If postlarvae have a low index of fullness, feed should be increased. If the guts appear full, water temperatures should be reduced to 23°C to reduce the animals' metabolic rate. This "buys time" for a thorough investigation into the causes of the mortalities (either chemical or environmental). It also reduces the amount of toxic metabolites pumped into the system by the postlarvae's physiological mechanisms.
7. **Frequency of cannibalism:**
   Generally, cannibalistic behavior is normal among postlarvae receiving insufficient quantities of feed. If there is a high frequency, it may also mean that there is a high index of mortalities. An increase in quantity and frequency of feeding should minimize cannibalism. If dead postlarvae are present, most live postlarvae will prefer them as a feed source to artificial feed, however, increasing feed should discourage aggressive attacks among postlarvae.

Tank-Pond Equilibrium

It is preferable, although not always possible, to stock postlarvae during the cool hours of the night or at sunset. In any case, it is necessary to confirm water parameters of acclimation tanks to verify that an equilibrium has been reached between the pond to be stocked and the acclimation tanks.

The most obvious equilibrium requirements are water temperature and salinity, and secondly, pH. As mentioned in the previous section, reservoir tank water temperatures can be manipulated by the introduction of heated water to the reservoir, which will indirectly increase water temperatures in the acclimation tanks via the flow-through design. This technique is useful and recommended when the pond is being stocked at mid-day.

Many times, the pond water will be 1° to 2°C warmer than the ambient temperatures in the acclimation tanks. In such situations, it becomes necessary to predict what pond water temperatures may be when salinity equilibrium has been met. To manage the elapsed time in acclimation efficiently, the water temperatures should be manipulated with advanced time, so that the equilibrium is achieved within the acclimation schedules discussed previously. Once equilibrium has been confirmed, begin harvest in tanks.

Acclimation Harvest Procedures

Harvesting is probably the most critical phase in acclimation procedures. Acclimation imposes stress on postlarvae, and the mechanical manipulation caused by harvesting, if not performed conscientiously, will have detrimental effects on postlarval survival. To ensure the least amount of stress, harvest procedures should be well planned.

Postlarval transport tanks should be well cleaned and disinfected, prior to their use. Oxygen bottles should be filled and connected to the corresponding air hoses with air stones. The following are the steps to be taken in the harvesting procedure:

1. Fill transport tank with water from the reservoir tanks or from the pond to be stocked. This water should be at the same temperature and salinity as water in acclimation tanks.
2. Perform the final microscopic assessment of postlarvae as described in *Microscopic assessment of larvae*.
3. Close inflow water valves to acclimation tank and maintain aeration.
4. Connect air line hose to harvest bucket, to maintain harvest bucket screen free of debris (Figure 8).
5. Close effluent valve of acclimation tank to be harvested.
6. Unscrew central stand pipe in tank.
7. Partially open effluent valve of acclimation tank and allow to drain into bucket. Confirm that flow rate is controlled, so the harvest bucket does not overflow. Confirm that an ample supply of air is flowing through the harvest bucket.

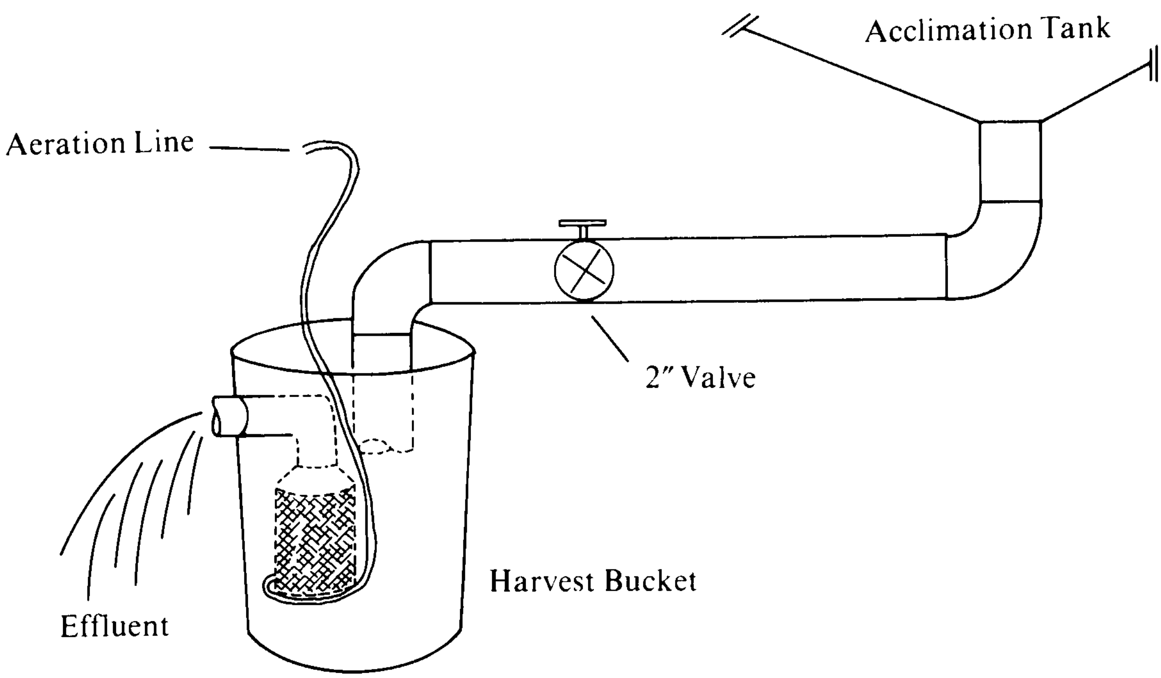


Figure 8. Schematic diagram of acclimation harvest bucket collecting postlarvae drained from acclimation tanks.

8. When 20 percent of the acclimation tanks water has been harvested, close effluent valve and deposit harvested postlarvae in transport tanks.
9. Repeat steps 7 and 8 a minimum of five independent times to complete the harvest of each 1,000-liter acclimation tank. Precaution: If postlarvae are "balling-up" or are noticed to be too concentrated in the harvest bucket, it may be necessary to increase the number of times steps 7 and 8 are repeated to ensure the least amount of stress to postlarvae.
10. Continually wash down the sides of acclimation tanks with the inflow hose to collect postlarvae adhering to the sides. This is especially critical during the end of the harvest for each tank. Also note that flushing should include the effluent pipes and elbows.
11. Repeat steps 2 through 10 for each tank.

Harvesting procedures should take no more than 30 minutes per tank. With the use of several harvesting buckets, more than one acclimation tank may be simultaneously harvested (Plate 26).

The densities of postlarvae in the transport tanks should not exceed 800 postlarvae per liter with continued oxygenation of transport water.

Once densities in transportation tanks have been reached (800 postlarvae per liter) the tanks should be completely filled with water to decrease wave action in the tanks.

The truck or tractor that transports tanks to the pond should not exceed 25 kph, but speed may be much less, depending on dike conditions. One person should accompany the tanks to ensure that they are receiving adequate oxygenation and to regulate the speed of transport.

Pond Stocking Dispersal

When transport tanks are alongside the pond to be stocked, connect the 10-cm (4-inch) steel-coil reinforced rubber hose to the 10-cm (4-inch) gate valve of the transport tank. Walk the hose into the pond to a point with a minimum of 50 cm water depth, and partially submerge the mouth of the hose at the water surface. Partially open the effluent gate valve and monitor postlarval activity at the discharge opening of hose. During the night, it may be necessary to use a hand-held flashlight to observe postlarvae being

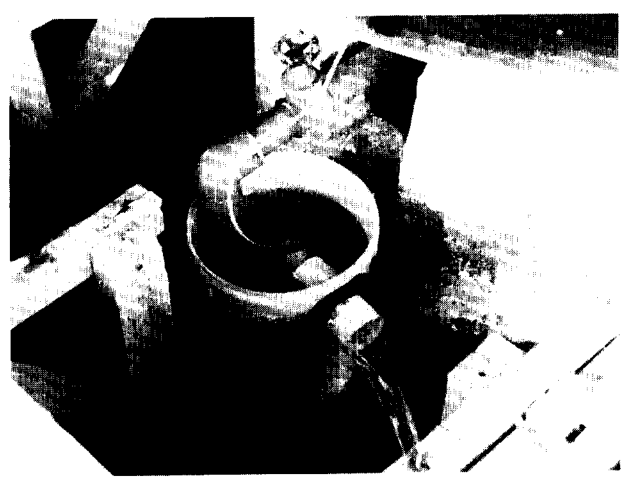


Plate 26. Acclimation tank harvest bucket in operation. Note the flow rate of bucket effluent.

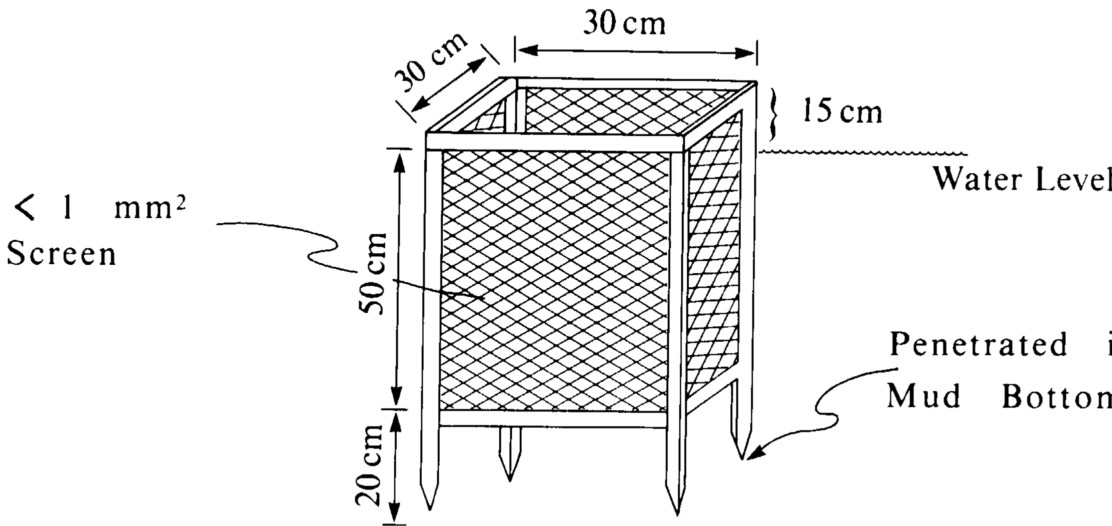


Figure 9. Schematic diagram of pond stocking survival bucket for post 48-hour evaluation.

stocked. If there is excessive turbulence or damage being caused to the postlarvae, slightly reduce the opening of the effluent gate valve at the tank.

When 90 percent of the tank has been drained, start the portable 5-cm (2-inch) pump and flush out the tank to ensure that all postlarvae drain out of the transport tank and connected hose.

Personnel in the pond should not walk around, since postlarvae might settle to the bottom. If more than one transport tank is to be stocked in the pond, additional tanks should be stocked at approximately 50-meter intervals from each other, and always on the upwind side of the pond.

Survival Test Bucket

Before the stocking of the pond has been completed, it is necessary to collect 200 postlarvae and introduce 100 of them into each of two independent survival buckets placed at the side of the pond. This procedure will help evaluate survival of the postlarvae 48 hours after being stocked.

Each survival bucket (Figure 9) should be placed near the edge of the pond and in a minimum of 50 cm water depth. The bucket should be firmly anchored to the mud bottom and retain approximately 15 cm free board over the pond's water surface to prohibit escape of postlarvae. The two buckets should be located within 1 meter of each other. The postlarvae in the buckets should not be fed and should remain undisturbed for 48 hours (Plate 27).

Forty-eight hours after stocking, all postlarvae from the buckets should be removed and counted individually. Live postlarvae should be counted separately from the remains of dead ones. Divide the number of live postlarvae by the number of postlarvae

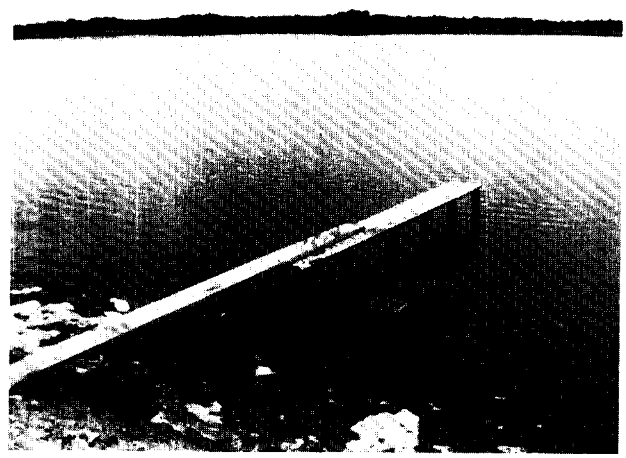


Plate 27. Nursery pond survival buckets in place after nursery stocking of postlarvae. Each survival bucket contains 100 postlarvae.

deposited in the bucket to calculate percent survival. The results of the two buckets should then be averaged.

After postlarvae have been counted, examine buckets for any holes that may have developed during the 48-hours that may have allowed escape of postlarvae. Also examine the seams and corners, since these are places where postlarvae may become trapped or squeezed, causing an increase in mortality not related to postlarval condition.

The 48-hour survival is useful as an indicator of acclimation and stocking stress on postlarvae.

An average percent of survival after 48-hours of 85 percent or higher indicates a successful stocking. Survival test results between 60 percent and 85 percent may indicate that either postlarvae quality was less than optimal or that there was undue stress on postlarvae during the manipulative stages prior to stocking. Survival tests results can then be compared to stress test results at the hatchery to analyze postlarvae quality. Results in the 60 percent to 85 percent range do not always correlate with poor survival in the nursery pond, but should serve to alert personnel to the possibility of poor results.

Survival test results lower than 60 percent after 48-hours strongly suggest problems. These may be a result of poor postlarval quality, which may be directly analyzed by reviewing the results of stress tests. Other problems may be due to inadequate manipulation, prior to stocking. If survival test results are below 60 percent there is considerable probability that nursery pond survival will be lower than optimal. A review of the information pertaining to transportation logistics, acclimation schedules, observations and stocking procedures should be conducted and documented.

The accompanying chart is an example of relatively good test values used as a guide for interpretation of actual field data.

Postlarvae stress test	70-85 percent
Acclimation percent mortality	2-5 percent
Postlarvae 48-hour survival	>85 percent
Final nursery survival	67-75 percent

Chapter 8

Nursery Stocking

Nursery ponds are stocked with postlarvae at a density of between 1,500,000 and 2,000,000 per hectare (150-200 PLs/m2). In case of stocking wild-caught postlarvae, these densities pertain to the sum total of *P. vannamei* and *P. stylirostris*.

Before stocking, it should be confirmed that the nursery has been adequately prepared. The following checklist should be reviewed to ensure that the nursery is ready:

1. Water levels are at a maximum depth for operation.
2. Inflow and effluent weir gates are adequately sealed.
3. Inflow and effluent weir gates have double small mesh screens (0.5 mm).
4. The first 0.5 mm mesh screen in the effluent weir gate should be covered with empty feed bags as an extra precaution against possible escape of postlarvae (Plate 28), and
5. No water is being exchanged.

The record of postlarval stocking in all nursery ponds or direct-stocked growout ponds should be documented using the sheets depicted in Figure 10.

The farm volumetric count is only necessary when wild captured postlarvae are purchased.

Plate 28. Nursery effluent gate adequately sealed with empty feed bags on fine mesh screens. This will reduce the chances of postlarvae escape in a recently stocked nursery.

Feeding Strategy

Feeding on a routine basis should begin soon after stocking has been completed. The commencement of the routine water exchange is generally delayed until one week after feeding has begun. The water exchange

Figure 10. Record of Postlarvae Stocking

Farm ____________________

Pond or Nursery ____________________ with __________ Ha

Stocking Density ____________________ PL/Ha

Date	Supplier	Amount Dispatched	Farm Volumetric Count (optional)	Acclimation Duration (hours)	Acclimation Survival % (optional)	Species Segregation %van %sty	Amount of Commercial PLs	48 hr Survival Performance 48 hours	Quality 1-3 Scale

Total* ______ ______

*This figure represents the number dispatched corrected for by the "species segregation" in the case of hatchery postlarvae with the participation of a farm representative. In the case of wild "natural" postlarvae, this figure represents the "Farm volumetric count" corrected for by the "species segregation."

Biologist ____________________

program will be discussed in the next section.

The optimal elapsed time for stocking a nursery pond is one day, but often this cannot be achieved. Every attempt should be made, however, to limit the elapsed time in stocking to under five days.

A maintenance feed ration application should begin the day following complete nursery stocking. This maintenance application should begin with 10 kg/ha/day for the first seven days and be increased subsequently to 45 kg/ha/day from the eighth day until juveniles attain 0.80 gram size.

The juvenile feed is a relatively high protein/high energy diet, although it does not contain all the essential nutrients required by postlarvae. Essential vitamins and minerals, as well as specific amino acids and fatty acids, will be ingested by postlarvae while grazing on the natural biota of the pond bottom.

The juvenile feed has the following nutritional characteristics:

Pellet size:	3/32" or crumbles
Protein:	35%
Fat:	8%
Fiber:	5%
Ash:	11%
Humidity:	10%
Gross energy:	3,937 Kcal/kg

This feed is capable of promoting growth at a rate of 0.2 g per week in postlarvae stocked at the above stated densities. Since juveniles are transferred out of the nursery ponds and into the growout ponds at a size of 0.6-0.8 g., nursery ponds are typically used for only four to five weeks.

Feed is distributed by casting it from a boat or canoe (Plate 29). The feed boat should traverse the entire surface area of the nursery in a zig-zag pattern. Each lateral dike of the nursery should have four painted stakes separating equidistantly the entire length of the nursery. Using these painted stakes as guides, the feed boat operator can direct the boat from stake to stake across the pond width (Figure 11). Caution should be exercised in limiting the distribution of feed to a minimum of 10 m distant from bordering dikes of the nursery, so that feed is not washed up onto the pond bank by wind. Feed should not be distributed closer than 20 m from effluent weir gates.

Plate 29. Broadcasting shrimp feed in a nursery pond using boats to cover the entire surface area of the nursery.

Juvenile and adult shrimp are characteristically nocturnal feeders. Postlarvae are primarily nocturnal but still retain a slight degree of opportunistic feeding behavior, which results in increased feeding activity. Based on this, nursery ponds should be fed twice per day. Optimal feeding times are during the early morning (0700 hours [7 a.m.]) and late afternoon (1800 hours [6 p.m.]). This feeding schedule is a technical "compromise" since it is difficult to adequately supervise feed application procedures during the night.

Since nursery ponds generally measure between 0.6 and 0.8 hectares (6,000 to 8,000 m^2) in surface area, the twice daily distribution of 20 kg per feeding should be sufficient. This schedule is considered more efficient for nursery ponds because postlarvae are limited in the distance they must travel foraging for food. By distributing feed more often (twice each day), utilization should be more efficient.

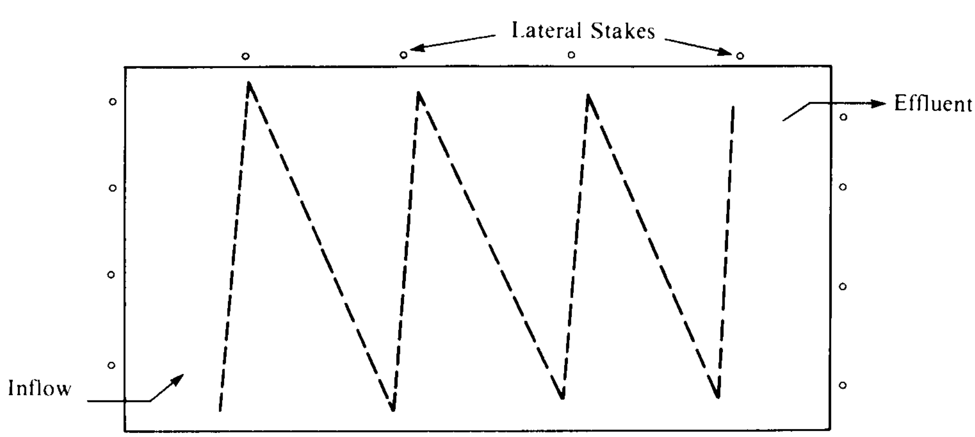


Figure 11. Lateral stakes configuration and feed distribution pattern in a nursery pond.

Occasionally minor formulation changes are made in the diet in accordance with commercial availability of certain raw materials. This may sometimes result in excessive floating of pellets on the water surface. When this occurs, feed should be applied at a greater distance from the downwind dike, so that the pellets have sufficient time to sink. Pellets blown onto the shore result in not only waste, but also decomposition and contamination of pond bottoms.

The occurrence of excessive floating pellets is frequently not directly related to formulation changes, but may be due to irregular surface shape on the ends of the pellet. The irregular surface can retain air when the pellet is initially introduced in the water, and more time may be necessary for the air bubble to be released and the pellet to sink. This problem can usually be solved at the feedmill by adjustments to the cutting knife.

Observations of excessive floating pellets (in excess of 5 percent) should be immediately reported so that a solution can be implemented at the feedmill.

Water Management and Screen Size

The water exchange program in nursery ponds begins seven days after the last stocking of postlarvae. Water exchange is programmed to begin approximately six days after the application of feed.

Seven days after completion of stocking of postlarvae, the entrance weir gates should be regulated to allow 5 cm of water over the control boards. The quantity of water allowed to enter should be regulated according to the hourly pumping capacity of the farm. If a farm has the capacity to pump eight hours per tide with two tides per day, then 5 cm of water should be allowed to enter each nursery for 16 hours per day.

Five centimeters should also be allowed to drain from the nursery at the effluent weir gate. The nursery should maintain its maximum operative level during this routine exchange program. If there are two entrance weir gates in the nursery, then each gate should be regulated to allow 2.5 cm to go over the control boards. This water exchange program is continued during the entire four- to five-week residence time of juveniles in the nursery pond.

Many nursery ponds may have either pumps or PVC tubes for the entry of water. In the latter case, the management of water exchange can be performed at the effluent weir gate, by allowing 5 cm of water to drain over the control boards, and maintaining the operative water level constant. If nursery water levels begin to decrease or increase, this indicates that respectively more or less water should be allowed to enter at the inflow. This can be manipulated either by pumping more or less water into the nursery, or by utilizing more or fewer inflow PVC tubes.

All water, either entering or exiting the nursery, should pass through a 0.5 mm screen to prohibit the entry of predators and the escape of postlarvae. After three weeks of the water exchange program, this 0.5 mm screen may be replaced with the standard 2 mm screens.

The technical staff should be alert for the presence of postlarval mortalities collecting on the effluent weir screens and on the downwind nursery shores. Close inspections in these two areas is necessary for two to three days after stocking of the nursery to assess the condition of postlarval population better. The presence of postlarval mortalities on the effluent weir screens may indicate entrapment resulting from excessive water flow.

The sampling of the area on the effluent side of the first effluent weir screen should be performed twice daily for the first two days after the initiation of the water exchange program to ascertain if there is loss of postlarvae. This sampling is performed with a small mesh (< 1 mm) scissor net. The presence of postlarvae in these samples indicates that the effluent screen is either not sealed correctly or is damaged.

The presence of fecal casts near the effluent weir gates and on the downwind shore of the nursery suggests that the postlarvae are eating well and that survival is acceptable.

Parameter Monitoring

Water quality parameters are monitored twice daily, at two separate stations in each nursery. A parameter monitoring platform is located near the effluent gate and another one is located near the inflow weir gate or entrance pipe. The parameter platform is extended far enough into the nursery to ensure a minimum water depth of 60 cm (Plate 15).

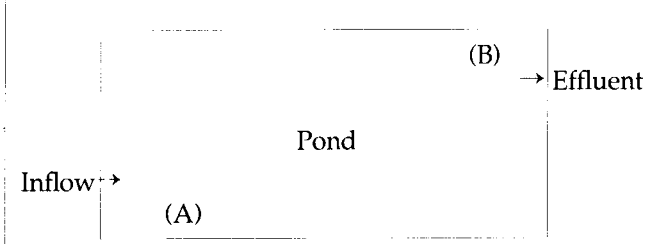
At 0600 hours (6 a.m.), each nursery should be monitored for D.O., pH, temperature and salinity. Again at 1400 hours (2 p.m.), each should be checked for D.O., pH, temperature, transparency and operative water levels. All measurements are recorded twice daily on the Parameter Monitoring Control Sheets (Figure 12).

The route taken to monitor parameters in the nurseries should be changed every day. It may take as much as 10 minutes to monitor parameters in each nursery. If there are 10 nurseries the whole parameter monitoring cycle in the nursery ponds may take nearly two hours to complete. Since the physical parameters monitored at 0600 hours (6 a.m.) are more significant than those measured at 0800 hours (8 a.m.), changing the daily route will allow each nursery to be measured at 0600 hours at least once per week.

Growth Monitoring

Early growth monitoring is essential for efficient organization and for preparation of an optimal schedule for transferring juveniles. It is of primary importance that juveniles be stocked or transferred into growout ponds at the earliest possible time,

Figure 12. Parameter Monitoring Control Sheets



Farm ____________________

Date ____________________

Biologist ____________________

	Morning					**Afternoon**					
Pond	Time	O_2	pH	°C	Sal	Time	O_2	pH	°C	Trans	H_2O Level
A											
B											
A											
B											
A											
B											
A											
B											
A											
B											
A											
B											
A											
B											
A											
B											
A											
B											

paying special attention to average juvenile weights.

The optimum average juvenile transferral weight is between 0.6 and 0.8 g. Juveniles smaller than this may be susceptible to excessive stress, which may decrease their performance in the growout ponds. Juveniles greater than 0.8 g are more difficult to transfer over large distances due to biomass weight in transport tanks. Since the transfer target weight range (0.6-0.8 g) is rather narrow, it becomes necessary to carefully monitor growth early on in the nursery to gauge the transfer date accurately.

It is important to understand that in the juvenile stages the animals' growth percentage relative to body weight is fast. This results in an increase in molting frequency. A difference of one molt cycle may result in the juvenile growing past the optimal transfer target weight.

Weight monitoring begins two weeks after the last postlarvae stocking in the nursery. Every week on the same day, samples are taken beginning at 0630 hours (6:30 a.m.). If more than one nursery pond is to be sampled in the same day, it is imporant that the sampling procedure be conducted no later than 1000 hours (10 a.m.). Since juveniles are nocturnally oriented, sampling should be performed as early as possible in the morning in an attempt to capture a significant number of juveniles (>150 juveniles) while they are still relatively active. If sampling is performed too late (after 1000 hours) juveniles may be docile and capture frequency may be reduced.

Growth sampling technique

The same person should be used constantly to cast the sampling net. This is critical because each person has a distinctive method of casting. If the capture frequency variable can be reduced (by using the same person consistently) then capture data can eventually be analyzed to investigate possible correlation between capture frequency and nursery survival performance.

The cast net sampler, should walk into the nursery to ensure that the cast net samples the area with a minimum water depth of 60 cm.

In a nursery pond there are 16 sampling stations. Each of the four dikes of the nursery has four stakes positioned equidistant from one another along the entire length of the dike. These stakes also serve as guide markers for feed distribution as discussed previously. At each station, the net should be cast into the nursery at a point with a minimum of 60 cm water depth. Juveniles are then collected in a plastic box containing 5 cm of pond water. From the plastic box, juveniles should be transferred into a small plastic bag and the water allowed to drain out. The plastic bag containing juveniles should then be weighed on a triple beam balance and the weight recorded. The weight of the wet but empty plastic bag is then subtracted from the total weight and this value is recorded. Juveniles are then counted out into the plastic box with water. The total weight of juveniles minus the bag weight is divided by the total number of juveniles counted to determine the average weight per juvenile. Juveniles should then be returned to the nursery pond alive.

This procedure is carried out independently at each of the 16 stations. The sum of the four stations along each dike is then summarized on the pond growth sample sheets (Figure 13).

At one of the four stations along each dike, two to four juveniles that are visually judged as the smallest should be weighed and the average minimum weight calculated. Also, at this station, two to four of the largest juveniles should be segregated and weighed to determine the average maximum weight per juvenile. At the end of the nursery sampling there should be a total of four stations with the minimum-maximum weight range as well as the overall average weight per juvenile in the nursery.

If the pond is stocked with wild-caught postlarvae, juveniles captured during sampling should be separated by species while they are in the plastic box with water. Species should be weighed and counted separately and treated independently of each other throughout the sampling procedures. The pond growth sample sheets are adapted for these situations by separating the species into the following categories:

- Total (general)
- *P. vannamei*
- *P. stylirostris*
- Others (which include *P. occidentalis* and *P. californiensis*).

In an effort to standardize capture frequency, all nursery pond cast nets used for growth monitoring should be of the same dimensions and characteristics. Nursery cast nets are designed according to the following technical criteria:

Diameter	6 meters
Mesh size	0.5 cm^2
Pocket skirt	30 cm
Lead weights	6 lbs

Although during the first few weeks of growth monitoring samples, it is expected that many postlarvae will escape through the weave of the cast net, it is still necessary to sample early on to determine an index of survival. If, during the first few weeks, few postlarvae of relatively large size (0.3 g to 0.5 g) are captured, it may be assumed that nursery survival is lower than optimal; on the other hand, if many juveniles of a relatively low average weight (0.2 g) escape, then it may be assumed that survival is good.

All growth data are then graphically presented on the growth curve sheets described in Chapter 7 under *Growth Monitoring*. All visual assessment of juveniles observed during sampling should be performed in the same manner as described in Chapter 7 and recorded on the pond growth sampling sheets.

Pond ______________

Farm ______________
Date ______________
Biologist ______________

Observations

Spring tide ❑ Neap tide ❑
Percent of gut fullness ______
Carapace hard ❑ soft ❑
Fungal Contamination yes ❑ no ❑
Short antennae yes ❑ no ❑
No. dead/week ______
Feed ration on bottom yes ❑ no ❑
Hydrogen sulfide odor yes ❑ no ❑
Presence of benthic algae yes ❑ no ❑
Presence of invertebrates yes ❑ no ❑

Weeks Summary of Parameters

	Min.	Max.
O_2		
pH		
°C		
Sal		
H_20 Trans.		
H_20 Level		
Percent required		
H_20 Color		
Feed bags/day		

Total	**Total P.**			**P. vannamei**					**P. stylirostris**			**P. others**			
Dikes	No. Shrimp	wt.	x	No. shrimp	wt.	x	max.	min.	No. shrimp	wt	x	No. shrimp	wt	x	Observations
Dike A															
Dike B															
Dike C															
Dike D															
Diag. 1															
Diag. 2															
Total															
Prev. week															
Difference															

Figure 13. Pond growth sample sheet.

Chapter 9

Juvenile Transfers

There is a great advantage to stocking production ponds by the method of juvenile transfer as compared to directly stocking postlarvae. The inherent qualities of semi-intensive culture strategies make it difficult to estimate actual population numbers and biomass accurately at any given moment during the culture cycle, but shrimp in the juvenile stages tend to have a better developed immunological response system and are more resistant to stress; as a result, mortality rates are significantly reduced. During the first five weeks after stocking postlarvae, mortality is generally 25 percent to 35 percent of the originally stocked population. The mortality of juveniles by the time they reach a target harvest weight of 23 g, on the other hand, is generally 20 percent to 35 percent over a 25-week culture cycle. Since the mortality curve is obviously not linear over the entire cycle from postlarvae to harvest size, it is advantageous to run the shorter economical risk of the five-week period in the nursery pond rather than the 25-week period of a relatively large production growout pond. The economical implications are not only restricted to the investment of time and production area risks, but also include the equally important management of feed rations during the entire culture cycle.

It is more economically efficient, in terms of production forecasting as well as implementation of more accurate feed and culture management strategies, to use production models such as ponds stocked with a known number of relatively resistant juveniles that reflect a more linear mortality curve over a 25-week period.

Transfer of juveniles into a growout production pond is the final step involved in "locking in" the growout pond into its production forecast for the final harvest. Although the farm maintains a current annual production forecast divided into monthly intervals, the juvenile status at transfer is the determining factor in the re-evaluation of production estimates. For this reason it is essential that correct transfer techniques be implemented so that production projections may maintain their credibility. Once the juveniles are transferred into a growout pond, there is very little that the biologist can do in terms of population analysis and performance evaluations until the pond is harvested. As a result, every effort should be made to compile as much accurate data as possible during the transfer operation in order to be able to make a more precise subjective evaluation of transfer results to support the growout pond's harvest forecast.

Scheduled Transfers

As described in Chapter 8 under *Growth Monitoring*, the target weight for juveniles to be transferred is between 0.6 g to 0.8 g. Although in practice, this weight may be reached within four to five weeks, with postlarvae stocking densities previously mentioned, the governing criteria determining the transfer date is the average weight of juveniles. Since juveniles have a tendency to molt at a higher frequency than adults, it may be necessary to sample the juveniles more than once per week to ensure that they do not exceed the narrow weight range optimal for transferring.

Prior to transferring, the degree of carapace hardness should be determined to guarantee the maximum protection of juveniles from possible physical damage experienced during transfer.

During sampling, the percentage of juveniles with soft carapaces should be calculated. If the percentage of juveniles with soft carapaces exceeds 5 percent, the transfer date should be postponed until this percentage is under 5 percent.

In summary, there are four major factors to be considered in establishing or programming the schedule for transferring juveniles from nursery to growout pond. These are:

1. Average juvenile weight (0.6 g to 0.8 g);
2. Degree of carapace hardness (<5 percent soft shell);
3. Adequate preparation of growout pond; and
4. Coincidence of transfer with the spring tide phases of the moon. Although this is not critical, such transfers are generally completed more efficiently because of increased shrimp activity.

If the farm's biological staff has meticulously prepared and organized the transfer in advance, the juveniles transferred into the growout pond should experience the compensatory growth response phenomena. Although the physiological reason for this phenomena is not completely understood it is thought to be directly related to the positive metabolic effects of the change in environment experienced by the juveniles from one of high densities and reduced available food, to one of relatively low densities with an increase in available food. This compensatory growth may also be related to the elimination of growth inhibiting hormones secreted by the juveniles in a high density situation when the maximum capacity of the nursery pond is approached. The compensatory growth phenomena may last from two to three weeks in the growout pond without the use of pelleted feeds.

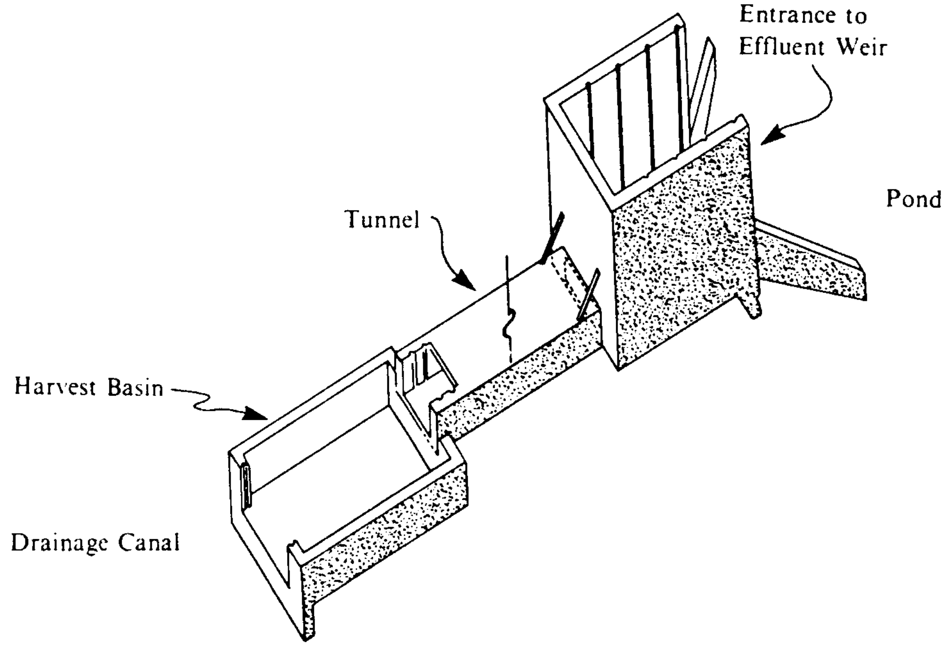


Figure 14. Schematic diagram of nursery pond harvest basin on effluent weir gate.

Transfer Mechanisms

Juveniles are nocturnal animals and have a natural migratory instinct during the spring tides, when the moon phase is either full or new. It is more efficient to take advantage of these inherent qualities and commence the transferring of juveniles during the night, when swimming activity is increased. Night transfers are also more advantageous in terms of maintaining cooler temperatures during the operation.

The gravity harvest method is best, but this may not always be possible in nursery ponds with inadequate drainage capabilities. It then becomes necessary to seine juveniles or capture them by cast netting.

The objective of the transfer mechanism is to harvest, quantify, transport and stock juveniles from the nursery pond to the designated growout pond with the minimal amount of stress. The main areas of possible stress in normal gravity harvest transfers are:

1. The elapsed time juveniles are concentrated in high density.
2. The water current pressure that may cause physical damage to juveniles by pressing them against the harvest box mesh screen.
3. The collection method of juveniles from the harvest box.
4. The elapsed time animals are out of water during the weighing and quantifying of juveniles extracted from the harvest box.
5. The water quality and elapsed time in the transport tanks as well as transport time to the growout pond, and
6. The method of draining water and juveniles from the transport tanks to the growout pond.

In those nursery ponds where the bottom topography does not allow adequate drainage, it is necessary to use seine nets or cast nets. This method may be very damaging to the juveniles as a result of pulling a net along the pond bottom. This method also requires that farm personnel walk in the pond, which results in a high degree of sediment suspension that may foul gills and cause undue stress to the juveniles. In the majority of nurseries where seining becomes necessary it is recommended that the gravity harvest technique be utilized first and that the nursery pond be refilled to repeat the same procedure several times before terminating the transfer operation with the seine net. This method reduces the number of juveniles exposed to the high stress and low efficiency of seine type transfers, and should significantly improve survival rates of transferred juveniles.

In the majority of cases, nursery ponds are designed to be between 0.60 and 0.80 hectares in surface area in square or rectangular shapes. Typical dimensions are 70 m by 120 m with an average depth of 1.4 to 1.6 meters.

The nursery pond bottom topography should have a cross-fall slope of 0.5 to 1 percent for complete drainage capabilities and a minimum water depth at the inflow dike of 0.8 m. Using this type of nursery pond design, night transfers of more than 1,000,000 juveniles can be done in six hours.

Gravity transfer technique

Figure 14 and Plate 30 show a schematic diagram of the pond harvest basin concentrating and capturing juveniles for transfer.

Transfers should be completed by 0600 hours (6 a.m.). This scheduling criteria should be used for two important reasons:

1. The light at dawn facilitates visibility in order to determine if juveniles are burrowing into the

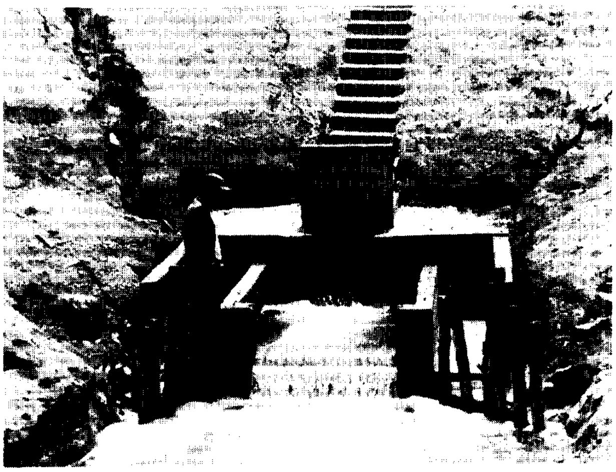


Plate 30. View of nursery pond harvest basin used for capturing and concentrating juveniles.

Plate 31. Sixty percent reduction of nursery pond water level prior to commencing juvenile transfer operation.

Plate 32. Wooden framed, small mesh harvest box structure that stands partially submerged in harvest basin.

mud and are not being efficiently captured, and

2. At dawn, the temperature is still cool enough to finish the transfer, or, if problems arise and completion is postponed, early daylight permits adequate visibility to partially refill the nursery in an effort to control water temperature.

In the majority of nursery transfers that can be completed in six to eight hours, the operation should commence between 2200 hours (10 p.m.) and midnight. If it is estimated to take longer than eight hours, then the schedule should be moved forward (earlier). Transfers should not be initiated before 1800 hours (6 p.m.), unless the weather is rainy or overcast.

Once it has been established that the juveniles are prepared for transfer and the date has been set, water levels in the nursery pond should be lowered by 60 percent, the day before the operation. If the nursery pond's water depth at the effluent weir gate is 1.5 m, it should be reduced to 0.6 m before beginning the transfer (Plate 31).

It is recommended that a screen cleaner be permanently placed on the effluent weir gate to ensure that the screen does not plug and rupture, as well as ensuring that the water pressure against the effluent screens is not so great as to cause physical damage to juveniles in the vicinity of the weir. In the latter case, it will be necessary to drain the nursery at a slower rate or a 6 mm mesh convex net can be temporarily installed just in front of the effluent weir gate to diminish water pressure and crushing of juveniles against exit screens.

The main objective in starting with a 60 percent reduction in nursery pond water depth is to enhance the capture efficiency. With water levels at the maximum operative level, very few juveniles will be captured during the first half of the transfer because they are dispersed throughout the entire water volume. It becomes necessary to reduce the total volume of the nursery and slightly concentrate the juveniles towards the effluent side in order to ensure rapid harvests.

Although juveniles are nocturnal animals, they are photopositive. A strong, battery-powered, halogen lamp with high intensity should be located on top of the effluent weir gate and directed at a 30° angle into the water surface approximately 3 to 4 meters from the entrance area of the effluent weir gate. This light serves to attract juveniles towards the effluent gate where the current will carry them out of the nursery and into the harvest box. The effectiveness of the light increases as the total volume in the nursery is reduced.

Plate 32 shows the harvest box structure that is placed within the harvest basin of the effluent gate. The wooden frame slides into the effluent tunnel slide channels and is sealed. A fine mesh (2 mm) cylindrical tunnel connects the wooden frame to the harvest box, which is lined with 2mm mesh. The

Plate 33. Harvest box structure in location within nursery pond harvest basin.

harvest box is submerged within the harvest basin; the walls of the box have sufficient freeboard to keep the juveniles from jumping out (Plate 33).

The concept of this harvest system takes advantage of the benthic behavior of juveniles. Once the juvenile is in the box, it will find a substrate on which to attach, either horizontally or vertically. When the juvenile is on the bottom of the box or attached to the walls, it is out of the turbulent current of water coming through the box.

When all equipment is in place, the restriction boards in the effluent weir should all be removed. Since the harvest is conducted by surface drainage, the restriction boards hamper the easy movement of water and juveniles.

Enough down boards should be placed on the back end of the harvest basin to ensure adequate water depth, both in the harvest basin and harvest box (Plate 34). Once the nursery begins to drain harvest, the water will spill over the down boards but should not overflow the harvest box.

Juvenile transfer begins by raising the double effluent filter screens and removing sufficient down boards from the weir gate to allow surface drainage. It is of critical importance to manage the quantity of water draining over the effluent down boards properly since too much water will cause excessive turbulance and water pressure, resulting in damaged juveniles. The best results are obtained by limiting the amount of water over the down boards to 20 cm maximum (Plate 35). This should result in efficient drainage and juvenile harvest as well as maintaining a minimal water depth in the effluent gate culvert (tunnel) of 10 cm to 15 cm.

It is necessary to maintain 10 cm to 15 cm of water over the cement floor of the culvert in order to cushion the fall of juveniles, otherwise the juveniles may be physically damaged by the rough surface of the concrete slab.

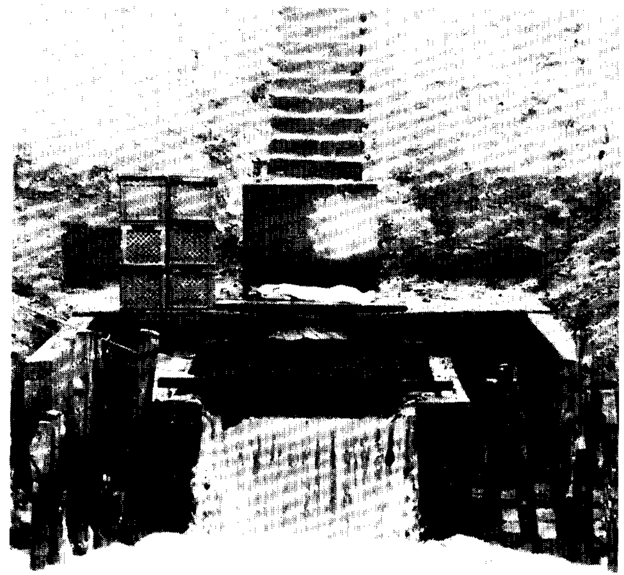


Plate 34. Down boards in place on effluent side of nursery harvest basin to maintain adequate water levels in basin and box.

Plate 35. Approximately 20 cm of water draining over effluent down boards is allowed during transfer operation. The wooden pole and hand show water mark levels.

Plate 36. Dipnets are used to extract juveniles from harvest box and deposit them in plastic box containers.

Plate 37. Water from plastic box containers is allowed to drain while debris and predators are eliminated.

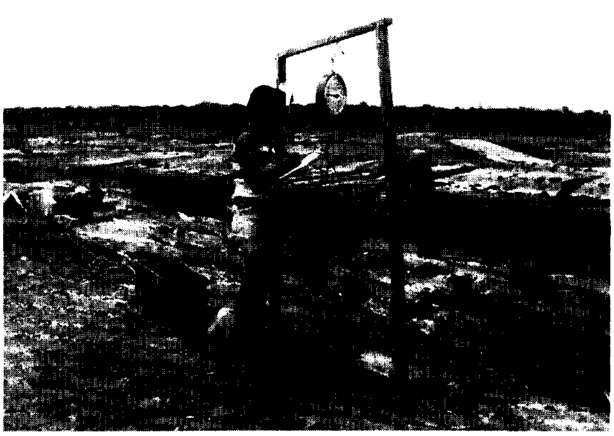


Plate 38. Juveniles in plastic box containers being accurately weighed.

The attraction exerted by the halogen lamp will cause increased activity of shrimp near the effluent gate, depending on the rate of capture. The harvest box containing the juveniles should be harvested every 15 minutes, or when it contains approximately 15 kg of juveniles, whichever comes first.

The juveniles are extracted from the harvest box, using a fine mesh (1 mm) scissor net or dipnet (Plate 36). They are then deposited in the plastic box containers and allowed to drain for approximately 15 seconds (Plate 37) before weighing (Plate 38). The plastic box containers should not be filled with more than 2.5 to 5 kg of juveniles (Plate 39). Care should be taken to avoid their jumping out of the box containers (a cover net with elastic edges may be employed to cover the plastic box as it leaves the harvest box until it is deposited in the hauling tank).

During the 10 to 15 seconds allowed for adequate water drainage from the plastic boxes, all trash and potential predators such as fish and crabs should be manually removed (Plate 40). This allows for accurate weighing of the quantity of juveniles as well as protecting the future shrimp population in the growout pond from predators.

At times, it may become necessary to install one of the two effluent filter screens, in the event that too many juveniles are being harvested in relation to the amount that can be carefully and efficiently handled by farm personnel. It is better to install the filter screen than the down boards, as the back pressure caused by installing down boards may cause the juveniles to retreat into the nursery pond.

During the last phases of the transfer harvest, when the water level in the nursery pond is low, the water current velocity may not be sufficient to drain the juveniles from the nursery. In this case, it becomes necessary to implement a more effective means of attraction strategy. Fresh, clean pond water should be allowed into the draining nursery pond, this fresh water acts as a strong attractant to the remaining juveniles. In order to implement this strategy effectively, it is necessary to insert down boards at the end of the effluent gate culvert and allow water to drain in great quantities from the adjacent nursery pond through the "Y"-shaped dual effluent gates. Since the adjacent nursery pond should have significantly higher water levels, the water will easily drain from the adjacent nursery into the partially harvested one (Plate 41). This fresh water should flush the area near the mouth of the effluent weir and allow sufficient water to cover approximately a 20 m radius with 30 cm water depth. The incoming fresh water should improve the water quality in which the juveniles are concentrated, as well as decrease the density and attract all juveniles in the vicinity to swim toward the effluent gate.

Once the required amount of water has been allowed to enter the nursery, the system should be

Plate 39. 2.5 to 5.0 kg of juveniles per plastic box container. Notice the absence of any excess debris or predators.

Plate 40. Potential predators that have been removed from plastic boxes containing the juveniles.

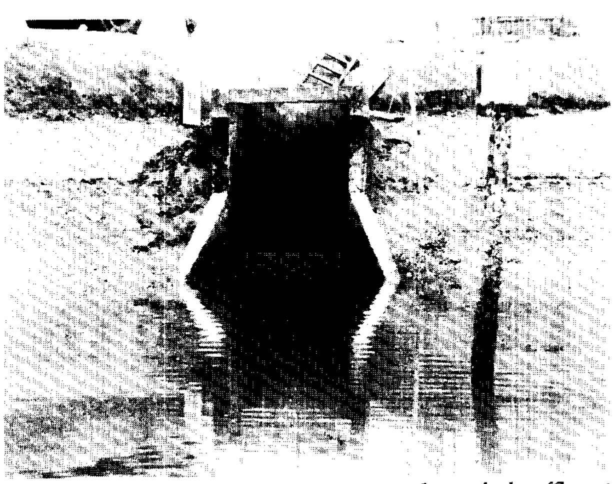


Plate 41. Flushing fresh water in reverse through the effluent weir gate to improve water quality conditions as well as increase water volume during final transfer procedures.

Plate 42. Flushing with fresh water with a 20-cm auxilary pump to attract juveniles and increase water volume during final transfer procedures.

reversed. This is done by damming the effluent flow in the adjacent nursery and raising the filter screen in the effluent of the nursery being transferred. With the increase in volume of water, effluent water current velocity should be significantly increased, which results in a more efficient capture/drainage rate for the juveniles. This operation should be repeated as many times as necessary to ensure that no juveniles are left behind in the drained nursery because of burrowing action or stagnated puddles.

If a filled nursery pond doesn't exist next to the nursery being transferred, it may be necessary to use a 15 cm to 20 cm auxiliary pump to transfer water from the effluent canal into the nursery being transferred (Plate 42). The main objective is to increase the water volume sufficiently to allow effluent current to increase and effectively drain juveniles.

Throughout the entire transfer operation, it is necessary to monitor D.O. and water temperatures

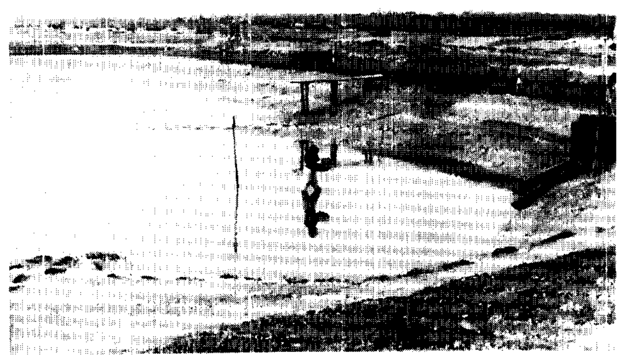


Plate 43. Monitoring D.O. and water temperature at regular intervals during the transfer operation.

every two hours (Plate 43). If D.O. levels drop below 3 ppm or water temperatures surpass 32°C it is necessary to take emergency measures by reversing the drainage process and either letting or pumping fresh clean water into the effluent area. The opening of entrance weir gates or inflow tubes may be necessary to supplement the entry of fresh water into the nursery.

Seine net transfer technique

Complete drainage by gravity through the effluent weir gate is not possible for all nursery ponds. In those nurseries where drainage is a problem, it is necessary to finish the transfer with a seine net. Most of the transfer can be performed by gravity as described in the previous section, thereby causing minimal stress to the majority of the juveniles. The last phase of the transfer will have to be carried out with the seine net and under higher stress conditions. The unit can be refilled to a depth of 30 cm and harvest by gravity (drainage) can be attempted over several consecutive evenings prior to initiation of seining. Feed can also be offered each morning in front of the effluent gate to attract animals towards the weir gate during the two or three days of repeated gravity transfer.

The critical problem in transferring a nursery pond with nets is that a relatively large number of farm personnel is required to pull the net through the nursery (at least six men, depending on the size of the seine). This number of people walking through the pond significantly affects water quality in a negative way as a result of the increase in resuspended bottom sediments.

Seining is generally postponed until juveniles are larger in average weight (2.0 grams). This is because smaller juveniles of 0.60 grams will escape through the mesh of the seine net. Smaller mesh size seines are impractical because they plug easily with the bottom mud, resulting in a mud/juvenile slurry that is detrimental to captured juveniles. In order to reduce the amount of mud inside the seine drag, the mesh size should be no smaller than 0.5 to 1.0 cm square. Juveniles of 2 g average weight will be easily captured and relatively free of bottom mud.

The seine drags should be circular in shape and should be dragged for relatively short distances (app. 50 m). Longer drags are detrimental for the juveniles and result in poor performance of juveniles in growout ponds.

During any seine transfer, it is necessary to flush fresh water through the stagnated areas. This should be done by allowing fresh water to enter through the inflow gates or tubes and letting the lower quality water in the puddle exit through the effluent gate without significantly increasing the water depth in the area being seine-harvested.

After every individual drag of the seine, juveniles should be concentrated at the shore. They should be washed with water from the puddle to eliminate any mud debris and predators such as fish and crabs before transfer into plastic boxes used in the quantification operation.

During the final phase of any transfer, either by gravity harvest or by seine net, the critical factor governing the success of the operation, stresswise, is the quality of water in which the juveniles find themselves in the nursery. As mentioned before, D.O. and water temperatures should be monitored frequently, especially during the last phase. Also of critical importance during low water depth in the nursery is the risk of predation by aquatic birds. It is vital that there be personnel armed with shotguns present at dawn on the nursery banks to discourage bird predation. Predatory birds include the cormorant, heron, egret and common seagull. A cormorant may consume half its body weight per day. If the bird weighs 1.5 kg it could concievably consume almost 0.8 kg of juvenile shrimp. If the juveniles weigh 0.6 g each (1,700 juveniles/kg), one bird could consume almost 1,360 juveniles. As many as 20 birds feasting in one nursery has drastic economic repercussions. This necessitates the implementation of an aggresive predator control strategy during the final stages of any transfer operation.

Juvenile transfer quantifications

When approximately 5 kg of juveniles have been extracted from the harvest box or the seine net, they are deposited in a plastic box, and as mentioned before, the water is allowed to drain for 15 seconds. During this short time, the technical staff should observe the juveniles in the box and extract all debris and predators. Since quantification of juveniles is performed by weight, the excess weight of debris and predators will distort the real weight of juveniles being transferred. In order to manage a growout pond economically and accurately predict production estimates, it is essential that the most accurate juvenile transfer weight measurement be obtained.

When the majority of the water has been allowed to drain out and all debris and predators have been removed, the plastic box containing juveniles should be weighed on a dial balance scale (Plate 38). The weight of the plastic box is subtracted and the net weight of the juveniles is recorded before introducing the juveniles into the transportation containers (described previously).

From every 90 kg of juveniles weighed, the technical staff should take a relatively small sample in order to be able to calculate the number of juveniles per kg (Plate 44).

An example of sample frequency during an average transfer follows:

i.e. —A 0.8 ha. nursery that contains 1,120,000 juveniles weighing an average of 0.80 gms each, will contain a biomass of 896 kg. If weight samples are

Plate 44. Weighing small, random, representative sample of juveniles to determine number of juveniles per kilogram. Sample size approximately 0.25 kilograms,

extracted and calculated for every 90 kg of transferred juveniles then a total of 10 weight samples should be taken during the course of the entire transfer.

Transfer in a properly constructed 0.8 ha nursery pond should take between six to 10 hours.

Juvenile transfers are quantified (1) by species classification and (2) by size classification. Both factors are monitored and calculated from the same random sample.

Culture species segregation

Penaeus vannamei is the predominant commercially cultured species on the Pacific coast of the Americas. *Penaeus stylirostris* is of secondary importance as certain viral pathogens preclude their importance in the commercial sector. *P. occidentalis* and *P. californiensis* do not adapt well to large scale commercial operations and, as a result, do not make up a significant part of commercial production.

Although all four species are found in the natural environment and actively compete for space and available feed, *P. occidentalis* and *P. californiensis* generally disappear from the population when they weigh between 11 and 15 g. This natural selection process is not completely understood, although it is strongly suspected that the competitive environment found in a commercial production pond is more congenial for *P. vannamei* and *P. stylirostris* and, therefore, these are the predominant species harvested in the classification of 26-30 through 36-40 count size. Using culture strategies of lower stocking densities and smaller harvest target sizes, *P. occidentalis* and *P. californiensis* have performed rather well and show commercial feasibility. However, since the majority of commercial operations are designed for higher stocking densities and smaller harvest target size or lower stocking denisites with larger harvest size, these two species are not considered as attractive for commercial production.

Penaeus stylirostris adapts well to commercial pond design and criteria but is hampered by its vulnerability to the IHHN virus. This viral pathogen can completely wipe out the population at the juvenile as well as the postlarval stages in production hatcheries.

Unless *P. stylirostris* utilized in commercial operations can be guaranteed to be virus-free, survival in nursery and growout ponds will be, at best, inconsistent and unpredictable.

There has been limited success in many commercial operations with mixed stocking strategies of 80 percent *P. vannamei* and 20 percent *P. stylirostris*. This strategy is generally employed where there is a relatively short supply of *P. vannamei* and an abundant supply of *P. stylirostris*. In this particular case, the operator assumes the probable risk of losing 20 percent of the *P. stylirostris* forecasted, but is relatively sure of maintaining the majority of the *P. vannamei* population for harvest.

As mentioned above, the majority of commercial facilities choose to produce *P. vannamei* for its commercial adaptability and survival performance. Although *P. vannamei* is specifically vulnerable to the *Baculovirus penaei* (B.P. virus), it can be screened for this virus with wet squash mounts under light microscopy. This results in relatively viral-free *P. vannamei* postlarvae if this screening technique is utilized in commercial hatcheries. IHHN, on the other hand, is somewhat more difficult to screen for.

During the juvenile transfer process, the number of *P. vannamei* juveniles transferred must be calculated. The other secondary species transferred into the growout pond are not considered in the exercise of production forecasting or harvest estimates, but must be considered for overall pond management strategies in terms of culture densities, feed rates and water management.

It is important to understand that *P. vannamei* is the predominant species and the number of *P. vannamei* juveniles transferred will be used as the basis for the production harvest estimates, however, management strategies implemented during the culture cycle may be influenced by the total biomass of all four species of shrimp.

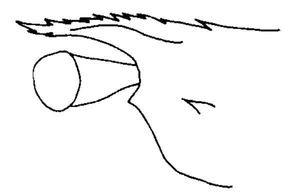
For every 90 kg of juveniles transferred, it is necessary to extract a random sample of approximately 0.25 kg to be classified by species and independently by weight. In theory, for transferral of any nursery that contains juveniles with an average weight of 0.8 grams, a 0.25 kg random sample will contain approximately 310 juveniles that must be segregated by species. Once the juveniles are segregated and counted by individual species, the respective percentage of each species can be calculated.

There are a variety of methods utilized for identifying the different species. Aside from body and antennae coloration, the most practical method is by the rostrum shape and configuration.

I. *Penaeus vannamei*

a. **Rostrum:** The tip of the rostrum projects slightly past the eyes. The dorsal edge of the rostrum presents between 7 and 9 spines. The ventral edge of the rostrum has two spines that are located anterior to the first of the dorsal spines.

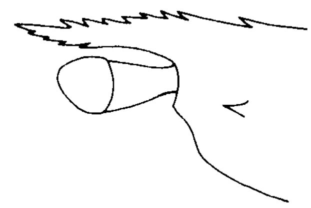
b. **Body coloration:** Predominately white with yellow tones. Generally not highly pigmented. Antennae are dark red.



II. *Penaeus stylirostris*

a **Rostrum:** Is relatively long and curved upwards. The first one-third of its length does not present spines on dorsal edge. Dorsal edge of the rostrum contains between 7 and 9 spines. The ventral edge of rostrum has between 4 and 5 spines.

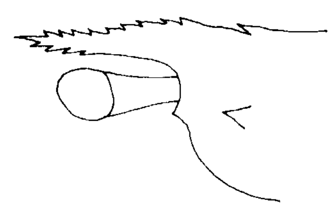
b. **Body coloration:** Predominantly blueish-white with heavy body pigmentation. Antennae vary from greenish to violet.



III. *Penaeus occidentalis*

a. **Rostrum:** Is generally very long and curved upwards. The dorsal edge has 9 to 10 spines that reach almost to the point of the rostrum. The ventral edge has 4 to 5 spines.

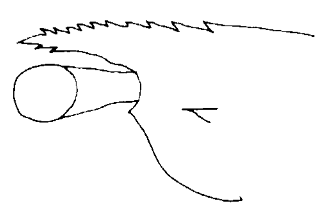
b. **Body coloration:** Generally white with a large amount of pigmentation that is readily observed. Antennae are dark.



IV. *Penaeus californiensis*

a. **Rostrum:** Is relatively short and does not extend past the eyes. The dorsal edge is curved downward and has 9 to 10 spines that almost reach the point of the rostrum. The ventral edge has two spines.

b. **Body coloration:** Generally white with large amount of pigmentation that gives a slight appearance of darker brown lateral bands. Antennae are dark.



Biologist ____________

Farm ____________
Pond ____________
From Nursery ____________

Date	Net Pounds Transferred	Pounds on 49m^2 mortality net	Number of Juveniles Transferred	Species Segregation % van	Species Segregation % sty	Number of Commercial Juveniles	From Nursery	Time Started	Time Finished	24-Hour Transfer Survival

Total ____________

Stocking Density ____________ /Ha

Corresponding Nursery

Performance (Historical):

1. Nursery pond ____________
   P.L. Origin ____________
   No. Stocked ____________ PL
   No. Transferred ____________ Juv
   Nursery Duration ____________ days
   Percent Survival ____________ % Total

2. Nursery pond ____________
   P.L. Origin ____________
   No. Stocked ____________ PL
   No. Transferred ____________ Juv
   Nursery Duration days
   Percent Survival ____________ % Total

3. Nursery pond ____________
   P.L. Origin ____________
   No. Stocked ____________ PL
   No. Transferred ____________ Juv
   Nursery Duration ____________ days
   Percent Survival ____________ % Total

Figure 15. Juvenile transfer stocking sheet.

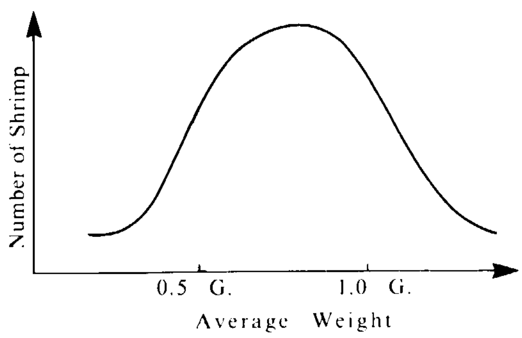


Figure 16. Typical population size distribution for nursery populations stocked with wild-captured postlarvae.

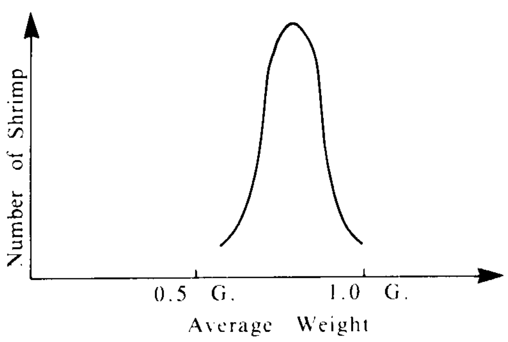


Figure 17. Typical population size distribution for nursery populations stocked with hatchery postlarvae produced from gravid females.

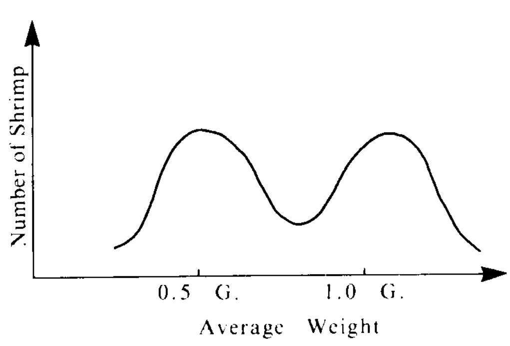


Figure 18. Population size distribution for two distinct populations in the same nursery pond.

A brief outline and key for the general features of each species is on page 48 (adapted from Yoong and Reinoso, 1983).

This guide can be used as a general and relatively accurate key for identification of the various species. As experience is obtained, the process will be easier to perform quickly.

Once the respective percentages have been calculated for each species, the data are recorded on "Juvenile Transfer Stocking" sheets (Figure 15). Note that calculations are performed for approximately every 90 kg of juveniles transferred. This is necessary to maintain accuracy and becomes more critical during the segregation by size stage (next section).

Juvenile size segregation

The size distribution of most populations can be represented by a bell-shaped curve. Although nursery ponds are scheduled for juvenile transfer according to the average weight of juveniles within the nursery, there is generally some size disparity within the population.

Juveniles that originate from wild captured postlarvae generally show a wide range of size disparity as a direct result of the great variability of postlarval ages captured in a natural estuary ecosystem.

Juveniles that originate from hatchery-produced postlarvae of wild-captured gravid females generally demonstrate less size disparity because all of the original postlarvae are of similar age and background.

Both of the above described situations generally reflect a monopolar distribution curve within the population (Figures 16 and 17).

The population size distribution within a nursery pond may become more complicated with a bipolar distribution pattern if the nursery pond has been stocked with two different batches of postlarvae with a wide time separation between the two stockings. This would result in two distinct populations of juveniles in the nursery pond (Figure 18).

There is an interesting phenomenon associated with the growth responses of juveniles from some maturation stock. Although this phenomenon is not always manifested, often the population may segregate itself, a certain percentage of the population remaining small as "runts," while the majority will reflect normal growth responses (Figure 19).

Although the reasons for the bipolar size distribution pattern in the population is not yet understood, it is suspected to be a result of infection with the IHHN virus. IHHN infected *P. vannamei* have been strongly associated with runt-deformity syndrome (RDS), which has been suggested as the putative etiology (Brock, personal communication). The prevalence and severity of IHHN infection is higher in stunted as compared to non-stunted cohorts within these populations. Other etiologic factors that have been suggested to cause RDS include exposure during larviculture to antibiotics and unidentified nutrient deficiency in maturation broodstock, as well as possible genetic defects.

Size disparity patterns within any set population constitute the primary reason why the calculation of the number of juveniles transferred cannot be performed by a straight mathematical formula based on overall average weight. It may not be accurate to assume, for example, that since the average weight of the juveniles in the nursery is 0.80 grams (1,250 juveniles/kg), the transfer of 90 kg of juveniles (1,250 juv/kg x 90 kg) will result in 112,500 juveniles having been transferred. This straight mathematical approach does not take into account the very real and natural population size distributions explained above.

In order for the biologist to arrive at the most accurate data possible in reference to the number of juveniles transferred, the calculation process should be modified to take size disparity within the population into account. This concept will help evaluate the final nursery performance in terms of survival of postlarvae to the juvenile stage as well as serving as a better basis for pond growout production estimates.

To explain the correct mathematical calculation of juvenile transferred, it will be best to show a real-life example and compare the results with those obtained from a straight forward mathematical calculation without considering size variations within population.

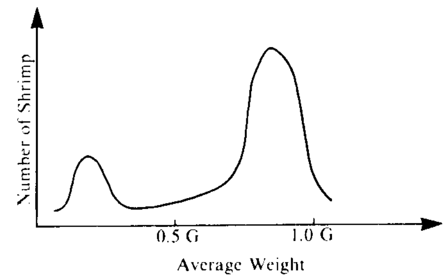


Figure 19. Phenomenal growth differentiation in population distribution of some maturation source postlarvae.

Example:

Suppose a random sample of juveniles is extracted from the transfer harvest box. This sample weighs approximately 0.25 kg (precise net weight on triple beam balance = 240 grams).

Juveniles are then spread out on a clean surface and visually segregated according to size into two or three groups. At a nursery with exaggerated size disparity the juveniles may be segregated into three distinct groups (Plate 45), while at a nursery with minimum size disparity they may be segregated into only two groups. In this example, three distinct groups have been visually segregated and each group has been weighed separately in order to establish the average weight of each juvenile for each individual group, as follows:

	Group weight	Juveniles/group	Average weight/juvenile
Group 1	120 g	800 juveniles	0.15 g/juvenile
Group 2	30 g	40 juveniles	0.75 g/juvenile
Group 3	90 g	35 juveniles	2.57 g/juvenile
Total	**240 grams**	**875 juveniles**	

The percentages of the total sample of each group are as follows :

Group 1 represents 50.0 percent by weight of the total sample (120 g ÷ 240 grams x 100)

Group 2 represents 12.5 percent by weight of the total sample

Group 3 represents 37.5 percent by weight of the total sample

Since group 1 juveniles weigh an average of 0.15 grams there are: 1,000 g/1 kg x 1 juvenile/0.15 g = 6,667 juveniles per kg.

In summary:

Group 1	50.0% x 90 kg x 6,667 =	300,015 juveniles
Group 2	12.5% x 90 kg x 1,333 =	14,996 juveniles
Group 3	37.5% x 90 kg x 389 =	13,129 juveniles
	Total of	328,140 juveniles

transferred in the 90 kg batch represented by the random sample

If, on the other hand, the mathematical calculation did not take into account the size distribution pattern observed in the sample, the result would have been as follows:

240 gram sample ÷ 875 juveniles = an average weight of 0.27 grams/juvenile
1,000 g/kg ÷ 0.27 grams/juvenile =
3,704 juveniles/kg x 90 kg transferred =
333,360 juveniles transferred

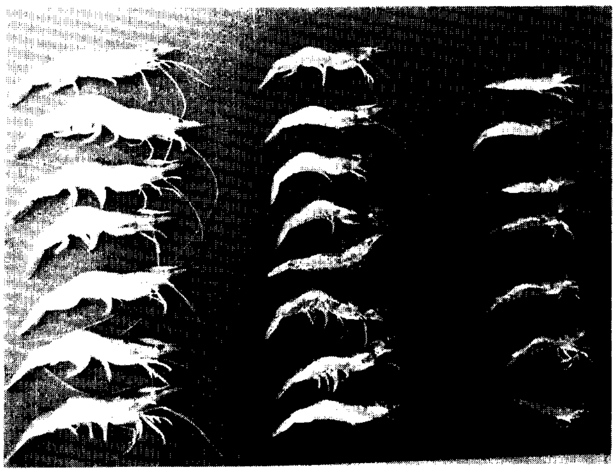


Plate 45. Size disparity segregation of juveniles from random sample. Notice three distinct size groups within sample.

The results of the two distinct methods for calculation clearly express the potential for error within this critical procedure. The calculation incorporating the size distribution concept is the most accurate method for estimating the number of juveniles transferred or stocked into a growout pond. If the second, more simplified method had been used; a stocking error of as much as 1.5 percent more for each 90 kg batch would have resulted. For an entire nursery pond transfer, the 1.5 percent error per batch may represent a 9 percent error. This error could influence management strategies of the particular growout pond causing possible overfeeding or increased water exchange resulting in poor water quality or slower growth rates.

These calculations, incorporating the population size distribution factor, becomes more important when the pattern of juvenile activity is analyzed. In a normal nursery transfer harvest, the larger juveniles are generally captured during the first half of the total transfer time. The smaller juveniles, being less aggressive and exhibiting a diminished migratory behavior, will generally be captured during the latter phase of the nursery harvest. As a result, it is inaccurate to assume an overall average weight for the entire duration of the nursery transfer, since there will be a significant difference in average weight during the first half as compared with the last half during harvest.

The calculations presented in the example should be well documented in the "Transfer Field Work Sheets" shown in Figure 20 and the summarized data should be recorded on the Juvenile Transfer Stocking sheets shown in Figure 15.

Time is a limiting factor for most juvenile transfers. The random samples taken for approximately every 90 kg of juvenile batches harvested during the process sometimes cannot be accurately analyzed at the time of sampling. When this occurs, it may be necessary to take the routine customary random samples for each 90 kg batch and store them individually in plastic bags for analysis when time permits. In this case, it is necessary to keep the juveniles moist with pond water in the bags, or to keep them on ice so that weight will not be lost due to dehydration. The individual bagged samples should also be accurately tagged to correspond with the respective batch that they represent.

Although the juveniles do not necessarily have to be alive for an accurate analysis of the sample, they must accurately represent live specimens in regards to the weight analysis, so high humidity storage is critically important.

Juvenile Transport

There are many ways to transport juveniles to the growout pond safely and with minimal stress. The selection of the method depends on the total distance of transportation and its duration.

The main criteria underlying the selection of the mode of juvenile transportation is to effectively minimize stress. The major physical parameters that can be managed are as follows:

1. Minimizing the time of juvenile holding and transport.
2. Clean holding tank water.
3. Heavy oxygenation of holding tank water.
4. Holding/transport tanks filled to the upper neck with water to minimize wave action within the tank, and
5. Conscientious mechanical handling of the juveniles in terms of biomass weight per liter of water and the minimizing of possible net damage to the juveniles.

If the nursery is conveniently located adjacent to the growout pond destined to receive the juveniles, the transfer process is tremendously simplified and the design and logistics of transportation are greatly facilitated. The entire sequence of steps described in the previous section should be adhered to. This operation is readily performed by transferring the juveniles in the same plastic box with fine mesh (2 mm) lining on the inside. One advantage of using plastic boxes is that the weight of the juveniles contained in each box (approximately 2.5 to 5.0 kg) is distributed over the entire surface area of the box's bottom. If the juveniles were transported in a bag net or other container, the weight of the juveniles would be concentrated in a relatively reduced surface area and physical damage to juveniles as well as undue stress would result.

Since the distance from the adjacent nursery to the growout pond is relatively short (<40 m), the transportation can be performed by personnel on foot. Care should be taken to ensure that the personnel maintain a fast pace during this operation. It is not considered to be detrimental to the juveniles if they

Kilograms of juveniles represented : ____ Kg   Sample No: ______

Group	Group Weight	No. of Shrimp	Average Weight	Percent Population by Weight
1				
2				
3				
TOTAL				

No. of juveniles

Kilograms of juveniles represented : ____ Kg   Sample No: ______

Group	Group Weight	No. of Shrimp	Average Weight	Percent Population by Weight
1				
2				
3				
TOTAL				

No. of juveniles

Kilograms of juveniles represented : ____ Kg   Sample No: ______

Group	Group Weight	No. of Shrimp	Average Weight	Percent Population by Weight
1				
2				
3				
TOTAL				

No. of juveniles

Kilograms of juveniles represented : ____ Kg   Sample No: ______

Group	Group Weight	No. of Shrimp	Average Weight	Percent Population by Weight
1				
2				
3				
TOTAL				

No. of juveniles

Figure 20. Juvenile transfer field work sheets incorporating population size disparity factor.

are kept for less than one minute within the plastic transport boxes during the entire procedure.

One minute is the maximum amount of time that the cephalothorax (which houses the gill cavity complex) can retain water. Care must be taken to cover the top of the plastic box to keep juveniles from jumping out.

On most farms, the nurseries are concentrated in one or more locations. Although this design is generally more labor intensive in reference to juvenile transportation, it is generally easier to manage. With nursery ponds centrally located, one person can be given responsibility for disinfection, preparation, acclimation and nursery stocking of postlarvae. That person's efforts will be concentrated on a relatively small area and his/her time will be more efficiently utilized. Receiving, acclimating and stocking postlarvae can all be performed in one centralized area. If the design and implementation of transportation are carried out conscientiously, the stress imposed on the transported juveniles may be significantly reduced and result in a transportation mortality of less than 2 percent.

Any juvenile that must be transported during more than two minutes should be moved in clean, oxygenated water. Special transport tanks are designed so that physical damage to the juvenile as a result of violent wave action is reduced. These transport tanks can be drained by gravity flow through 10 cm gate valves and be quickly refilled with clean pond water for the subsequent shipment.

During transfers, the most time consuming factor is actually transporting the juveniles over the dikes from the nursery pond to the growout pond. This is the principal bottleneck regardless of whether juveniles are transferred by land over the pond dikes or by boat in the reservoir canals. It is generally more efficient to incorporate the use of two or more transport vehicles during the operation. While one vehicle is transporting the first batch of juveniles, the second vehicle can be loading the second batch. The more vehicles used during the operation, the smoother it will go.

Although there are a multitude of designs for juvenile transport tanks, the one generally used has a capacity of 1,200 liters (1.2 metric tons) of water. The tops of the tanks have a box-type neck that the water level reaches when the tank is full. Wave action will be minimized by this type of neck (Plate 46). Since pond dikes are rarely free of ruts and rough surfaces, the violent wave action within tanks during the transportation must be controlled. By filling the tanks up to the top of the box-type neck, all wave action will be limited to this restricted area where there should be few juveniles. Since juveniles are benthic-oriented, their concentration will be on the bottom and walls of the tanks.

Two tanks can be hauled in each truck (depending on the weight capacity of the vehicle). The tank water should be changed for every shipment of juveniles. The water utilized for the transport tanks should be from the juvenile nursery being transferred (harvested). Since the juveniles being transported will already be stressed, it is desirable that no additional stress be caused by chemical, temperature, or salinity differences that may exist between nursery water and growout pond water.

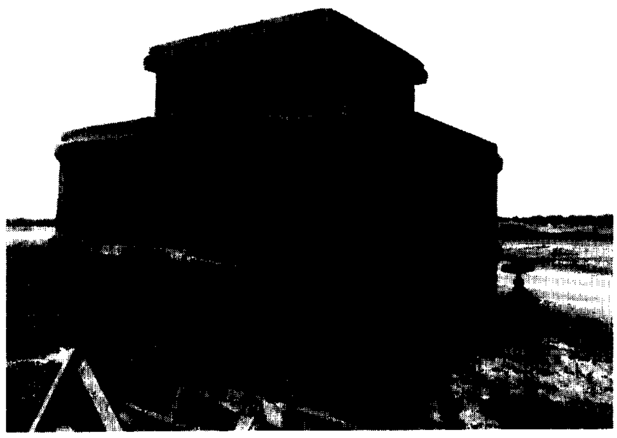


Plate 46. Juvenile transport tank with box-type neck to minimize wave action. Tank is constructed of molded polyester plastic with 1,200-liter capacity.

To reduce the impact of stress to the juveniles imposed by retaining them in the transport tanks until the tanks are transferred, pure oxygen should be continously bubbled through the water. A high concentration of D.O. in the transportation water will help reduce the lactic acid accumulation within the juvenile muscle tissue, which is a direct response to stress. By maintaining D.O. measurements above 7 ppm, the concentrated juveniles should not be detrimentally affected during the holding and transportation periods.

Transportation of juveniles on land, over the dikes or by boat in the reservoir canal should be limited to a maximum of 30 to 45 minutes. Even when transportation time is less, the tanks should be accompanied by one person from the technical staff who ensures that moderate speed is maintained over the pond dikes to control violent wave action. The representative should also closely monitor the amount of pure oxygen bubbling through the system and maintain it at adequate levels. The technical personnel should closely observe the deposition of juveniles within the hauling tank and into the pond, closely monitoring juveniles as water level in the tank is lowered for such characteristics as actively jumping, white tails, lethargic behavior, etc. These should be observed with the assistance of a seal beam light.

The transportation tanks, if filled properly with fresh water from the nursery pond and maintained with high levels of D.O. (>7 ppm), can be loaded with 23 to 32 kg of live juveniles per 1,200 liter tank. This loading density of 26.5 grams of juvenile per liter of transport water is acceptable as well as physically practical. Assuming that the average weight of the juvenile population during the transfer operation is 0.8 grams per juvenile, this would result in a holding capacity per 1,200 liter transport tank of almost 40,000 juveniles or 33 juveniles per liter of water. During an average transfer of one nursery pond over 6-8 hours, this would involve the utilization of 30 tanks during the course of the night. If four tanks are used, transported by two vehicles, each vehicle would make eight loaded trips to the growout pond during the entire transfer.

Since ambient water temperatures are relatively elevated (26° to 29°C) it is critically important that the D.O. levels, transport elapsed time, and clean water all be within optimal levels. If there are variations of these three factors from the norms described above, elevated transport mortality may result either from stress or from physical damage, which in turn may cause cannibalism.

Although the biomass holding capacity and transport densities for live juveniles described above are relatively high, they are considered to be a compromise with the practical logistics involved in transportation. Lower densities for transportation would certainly be more attractive from a technical viewpoint but would undoubtedly cause logistical problems unless many vehicles were used for the operation.

Pond dispersal of juveniles

In order to monitor the success of the transfer operation, there are two mechanisms employed that serve as quality indicators for the operation.

The first of these two indicators is designed to directly monitor the number of juveniles that did not survive the transfer process. This method incorporates the use of a 7m x 7m 1/4 inch mesh net placed on the bottom of the growout pond at least 3 meters from the pond's shoreline (Plate 47).

Juveniles are drained by gravity from the transportation tanks by a 10 cm diameter flexible hose directly over the center of the 49 m^2 net placed on the bottom (Plate 48).

During the course of the day following each previous night's transfer operation, the net should be lifted out of the pond and dead juveniles should be weighed (Plate 49). The gross weight of dead juveniles is then recorded on the Juvenile Transfer Stocking sheets (Figure 15). This weight should be subtracted from the previous night's gross pounds transferred in order to calculate the final net number of juveniles transferred during the previous night.

The theory behind this method assumes that those juveniles that arrive in lethargic or damaged condi-

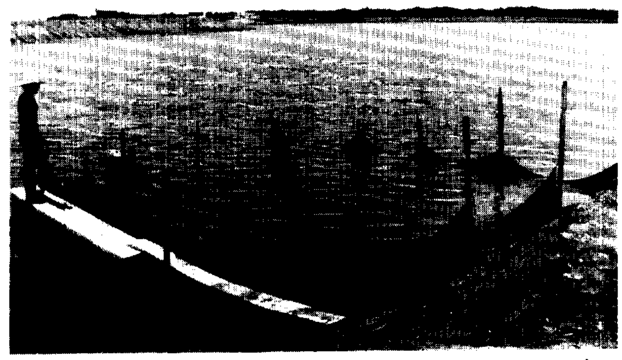


Plate 47. Seven meter by seven meter bottom net to monitor transfer mortality at eight hours post transfer.

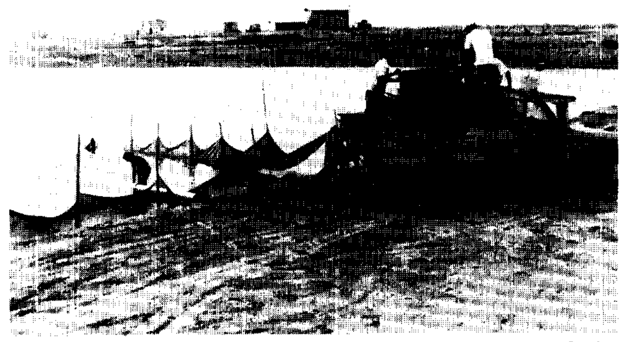


Plate 48. Gravity stocking juveniles from transport tanks by 10 cm hose directly in the center of 7 meter by 7 meter mortality net placed on growout pond bottom.

Plate 49. Collecting previous night's transfer mortality on 7 meter by 7 meter mortality net. The mortality must be quantified and subtracted from gross poundage.

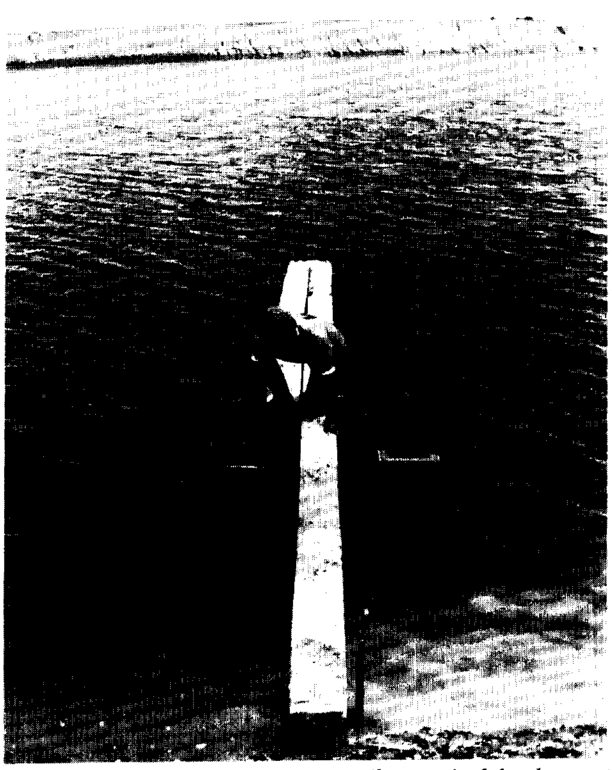


Plate 50. Twenty-four-hour juvenile survival bucket test performed in replicate. Each bucket contains 30 juveniles. Notice hinged tops to prohibit jumping out.

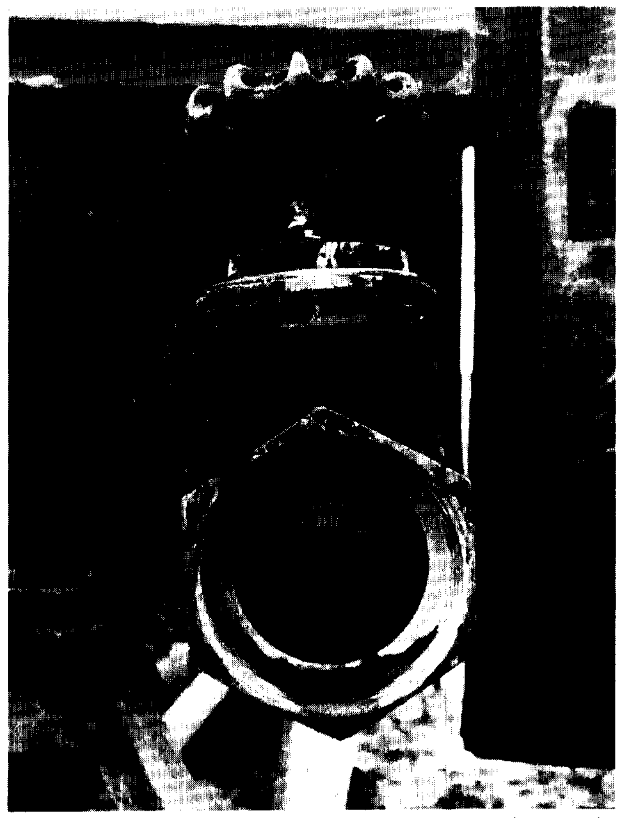


Plate 51. Transport tank discharge gate valve should never be operated in less than half open position. The resistance to flow is significantly increased as the opening is decreased.

tion will remain on the net after being stocked in the growout pond and die before swimming past the 49 m^2 area of the net. Although this may not be the actual case, and some damaged juveniles may swim off into the growout pond to perish outside the nets boundaries, the method serves as an indicator and dead animals can be subtracted from the quantification of the previous night.

The second method used as a quality indicator is the survival bucket test. This method is very similar to the test conducted when stocking a nursery pond with postlarvae described in Chapter 7. It consists of placing 30 juveniles within the enclosure of a survival bucket. This test should be conducted in replicate and each survival bucket should contain 30 juveniles (Plate 50). Twenty-four hours after the previous night's transfer, the buckets should be monitored and all live juveniles should be counted in order to calculate the survival percent for each individual bucket. The average should then be calculated and this value recorded on the "Juvenile Transfer Stocking Sheets" (Figure 15).

The result of survival calculations in this test are not used in the final number of juveniles transferred, as is the case with the 49m^2 net test, which does influence the net quantity of transferred juveniles. The 24-hour survival test should be used strictly as an indicator of the quality of the transfer operation.

Both of these tests should be used as management tools to assess transfer procedures. If the outcome of either shows a significant incidence of transfer mortality (>5 percent) for the previous night's transfer, measures should be taken to correct deficiencies of the operation. If all the transfer requirements are adhered to properly—for example, clean and oxygenated nursery water in filled transport tanks and 23-32 kg of live juveniles per 1,200 liters of water—and there is still high mortality, then it may be necessary to reduce the transport densities by 40 percent (14-18 kg/1,200 liters). It may be possible that juveniles within the nursery pond are subjected to stress due to water quality or a pathogen, in which case the additional stress involved in physical manipulation of transfer may cause elevated mortality. The objective is to reduce the amount of physical stress inherent in any quantified transfer operation. If greater caution is exercised in all phases of the operation, from extracting juveniles in the harvest basin box to dispersal of juveniles within the growout pond, then survival performance for transfers should be significantly improved.

One source of physical damage to the juveniles may be the effluent drainage gate valve at the bottom of the transport tanks. This 10 cm gate valve should never be opened less than half-way. A fully open gate valve offers the least amount of resistance to flow when compared to any other common valve (Mott, 1972).

When discharging juveniles into a growout pond, the gate valve may not be operated at the fully opened position since this may result in too high a discharge velocity and would constitute a potential cause of damage to juveniles. If the gate valve is operated at three-quarters to one-half open (Plate 51), the corresponding resistance to flow is acceptable for juvenile discharge.

When the transport tanks have arrived at the growout pond, a 10 cm flexible hose or rigid PVC pipe should be attached to the 10 cm drainage gate valve on the transport tank. One man should walk the mouth of the flexible hose or pipe into the growout pond and position it on the water surface of the growout pond, exactly in the center of the $49m^2$ netting.

The person controlling the flexible hose should observe the reaction of the juveniles being dispersed into the growout pond. Signs of erratic swimming behavior, opaque coloration in the tail muscle, or morphological damage in juveniles should be reported. Any of these signs strongly indicate the presence of elevated stress. Discharged juveniles should quickly swim away from the discharge flow of water and to the bottom. Since transfers are performed during the night, the person in charge of the discharge hose should use a seal beam light to observe the juveniles' behavior pattern. Prolonged swimming on the surface is another common sign of stress, and comes from disorientation.

Pure oxygen entering transport tank water should only be turned off when the transport tank is completely empty. An extra 210-liter barrel of water on the transport vehicle with a 10-liter bucket should be used to flush out any juveniles remaining on the tank bottom. When the discharge has been completed, the vehicles should return to the nursery and the transport tanks should be refilled with water from the nursery being transferred using a 5-centimeter pump. This water should be relatively free of debris, and, if possible, should be passed through a bag filter (Plate 52). Pure oxygen should then be bubbled through the water while the tanks are being reloaded with live juveniles.

When excessive numbers of juveniles are being harvested and transport tanks cannot keep up, it may be necessary to slow down harvesting by placing a screen in the effluent gate of the nursery as described in the section on *Gravity Transfer Techniques* or replacing an additional 10 cm down board to decrease water flow. This should enable the transport operation to "catch up" with the rate of juvenile capture.

When the survival rate is too low, or abnormality is observed in the juveniles during the course of the transfer operation, it may be necessary to select between six and 10 specimens and preserve them for later analysis. Such abnormalities could be: opaque or cramped tails, erratic swimming, stunting, deformities and abnormal coloration. Also take a general sample of apparently healthy juveniles when the survival rate is low (<50 percent). These specimens should be processed and preserved according to the guidelines described in Chapter 11 (Specimen Processing and Preservation).

To evaluate low juvenile survival rate, a histological study of affected specimens should be performed. For this study to be successful, it is important to use proper preservation techniques and procedures, and specimens selected must be alive at the time they are preserved.

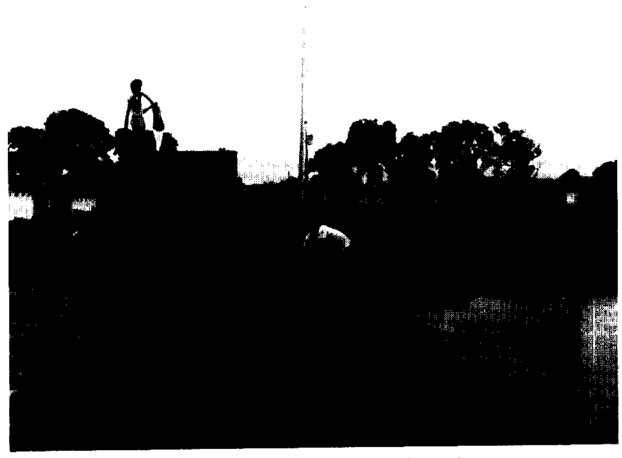


Plate 52. Filling juvenile transport tank with nursery water passed through bag net to eliminate debris.

Chapter 10

Direct Pond Stocking

In some cases, it may be difficult to stock a production growout pond with juveniles from a nursery. When this occurs, postlarvae should be stocked directly into the growout pond. It is less than ideal when the quality of postlarvae is not well known, for the obvious reason that poor survival may result in the partial utilization of a relatively large growout pond.

There are, however, certain advantages to the direct stocking method: First, labor intensity is significantly diminished because the juvenile transfer operation is eliminated; and secondly, mortality resulting from physical manipulation of juveniles during any transfer operation is precluded.

Direct stocking is sometimes an attractive alternative when an accurate estimate of the number of postlarvae to be stocked can be reached. Furthermore, this strategy can be implemented when the farm's technical staff is relatively sure of the quality of the postlarvae being utilized. The failure to predict these two factors may result in inefficient management.

Since the inherent risks involved in direct stocking are generally higher than those in growout ponds stocked with the "hardier" juveniles transferred from nurseries, the postlarval counting procedures and microscopic evaluation described in Chapter 7 (*Volumetric Counts* and *Microscopic assessment of postlarvae*), respectively become extremely critical. The direct stocking alternative is generally opted for only when the farm either has no nursery ponds available or when physical conditions in farm design impede an efficient transfer operation; for example when muddy dikes in the rainy season prevent land transportation. A more conservative approach, such as directly stocking smaller ponds, will minimize the risks and potential for catastrophic results. The failure or poor survival of shrimp in a 20-hectare, directly stocked pond, is much more damaging than the failure in a 6-hectare pond. So if the risk must be taken, it will be necessary to implement a sound strategic plan, deciding which ponds are most appropriate for this alternative.

All previously described procedures in the categories of pond disinfection, preparation, fertilization and weir gate configuration (board and screens) should proceed without variation. Predator control procedures (drying out and chlorination) during pond preparation become more important because postlarvae are more susceptible to predators than are juveniles. Postlarval acclimation and stocking procedures for nursery ponds should be adhered to as described in Chapter 7 and 8, respectively. Directly stocked growout ponds should be managed similarly to stocked nursery ponds, including the preliminary feeding of 20 kg per hectare (described in Chapter 4 [*Preliminary Feeding*] and in Chapter 8) and such monitoring systems as replicate survival bucket testing.

The same "Record of postlarvae stocking" sheets shown in Figure 10 should be used for growout ponds that have been stocked directly with postlarvae.

Screen Size and Water Management

Like a stocked nursery pond, the directly stocked growout pond should have similar filter screens covered and sealed with empty feed bags on all weir gates, both inflow and effluent, for seven days beginning on the last day on which the pond received postlarvae.

During the seven days when the recently stocked growout pond is allowed to remain stagnant, the farm biologist should make periodic inspections along the downwind bank of the pond during the early morning hours before wind activity increases. During these inspections, the biologist should be alert to the presence of decomposing postlarvae as well as molted carapaces and fecal casts. Any observations should be recorded, particularly the presence of decomposing postlarvae since this would be a significant indicator that an extensive mortality has occurred sometime after the stocking of the pond.

The biologist should also make periodic inspections of all weir gates in order to ensure that there is no water leaking into or from the pond. The presence of postlarvae on the effluent side of the filter screen strongly suggests that they are escaping and immediate action should be taken to confirm the proper sealing of the screen.

After the seven-day stagnation period, the empty feed bag seals placed on all filter screens should be removed, and the water exchange program should commence.

As described in Chapter 8 (*Water Management and Screen Size*), a fine mesh filter screen (0.5 mm) should be placed over the 2 mm filter screen for security, in the event that an emergency water exchange is necessary during the seven-day stagnation period. Once the water exchange program begins, this fine mesh (0.5 mm) filter screen should be maintained in place for two weeks. It may not be necessary to keep it in place for three weeks as in the case of nursery ponds. The objective of the 0.5 mm filter screen is to decrease the number of potential predators introduced into the pond (refer to the section on *Weir screen configuration* in Chapter 11).

This technique allows the postlarvae to develop and reach a size at which they will be more efficient in escaping from predators. Generally, in direct-stocked growout ponds, the density of postlarvae per square meter is significantly lower than in nursery ponds, resulting in improved growth.

After the initial two-week water exchange program, this fine mesh (0.5 mm) filter screen should be removed, leaving the screen/board configuration set-up shown in Figure 1 (a 7 mm filter screen used in conjunction with a 2 mm screen). This filter screen configuration should remain in position until the shrimp population has reached a minimum average weight of 4 grams. When the average weight of the ponds shrimp surpasses 4 grams, the 2 mm mesh size filter screen (inflow and effluent) should be replaced with a 7 mm mesh size screen. These screens should remain in place until harvest.

All filter screens, regardless of mesh size, should be adequately sealed with the routine sealant mixture "cebo" of animal lard and chalk as described in Chapter 2 (*Dry season disinfection*). This sealant should be continously maintained and renewed to eliminate escape or unfiltered water entering the pond.

All screens in weir gates should be routinely checked and inspected at weekly intervals to monitor sealant and filter screen conditions. Any screen found to be torn, ruptured, or in poor condition should be immediately repaired or replaced and resealed. Although this operation should be done on a weekly basis, a more frequent inspection is preferable for effluent filter screens since a large rupture in both screens may result in population losses.

The routine water management scheme is described in the following chapter. This schedule is strongly correlated with the total biomass weight in the pond. Since direct-stocked growout ponds contain relatively small biomass during the first two weeks in relation to the total surface area of the pond, water management should be limited to allow only 5 cm of water to inflow over the level boards in each weir gate. To maintain the proper operation level, the amount of water allowed to flow into the pond should be equivalent to the amount of water allowed to drain. If water quality deteriorates during these initial two weeks, a significant increase in water exchange may be necessary. If so, install a fine mesh (0.5 mm) semi-circular filter screen in front of the effluent weir gate to prevent postlarvae from being forced against filter screens during heavy drainage (Plate 53).

In many instances, pond water level may decrease during the initial seven-day stagnation period as a result of seepage through improperly sealed weir boards, normal surface evaporation and pond bottom soil percolation. Water level should then be recuperated by allowing inflow through the entrance weir gates and by restricting drainage from the effluent weir gates. Once this is attained, routine management of 5 cm of water flow over control boards should be maintained. If the growout pond contains two inflow weirs and only one effluent weir gate, the equilibrium must be maintained by allowing 10 cm to drain over the effluent level boards, or in the event the growout pond has only one inflow gate and two effluent gates, 10 cm should be allowed to enter the pond and 5 cm should be allowed to drain from each of the two effluent gates assuming equal weir width throughout.

Plate 53. Semi-circular pre-filter screen installed in front of effluent gate to prevent early postlarvae from being forced against screens during strong drainage.

This water management strategy should continue for a total of two weeks, to counteract the possibility of stratification in the water column. By creating, a slight current of water flowing into the pond and richer water draining from the bottom, the probability of stratification is reduced. This is critical in shrimp ponds since shrimp are characteristically benthic (bottom dewellers). The majority of the shrimp's activities occur in the bottom 10 cm of the water column. Contamination in this reduced area by build-up of metabolites and uneaten, decomposing feed, may cause undue stress in early postlarvae and contribute to low survival rates.

After the initial two week water exchange (three weeks from the last day in which the pond received postlarvae), the 0.5 mm filter screens should be removed from the standard 2 mm screens and the water exchange program should continue according to the water management strategy outlined in Chapter 11 (*Water Management*).

As noted previously, an emergency water exchange may become necessary during the initial seven-day stagnation period. This is the primary reason for the standard 2 mm filter screen overlayed with the fine mesh 0.5 mm filter screen in both inflow and effluent weir gates.

In the untimely event that the water level has significantly decreased for whatever reason, resulting in elevated water temperatures (>32°C) or an excessive algal bloom causing decreases in D.O. content of the water during the night, it may become necessary to initiate water exchange, even though the postlarvae are so small that they may escape or be damaged against the filter screens. Certain algal blooms may prove stressful to postlarvae. Presence of certain species of dinoflagelates and blue green algae might necessitate water exchange during the stagnation period. An intense green coloration or burgandy red (red tide) should be flushed immediately to decrease algal concentration.

There are various strategies for controlling algal blooms and the stimulation of specific algal species within a pond. These are discussed in more detail in Chapter 11 (*Hydrological Parameters*), but they are not recommended for recently stocked postlarvae in a growout pond. The primary strategy in such situations is reduction of the algal concentration by means of increased water exchange. The amount of water allowed to enter and drain in such an exchange should be similar to that previously described (5 cm of water over the level control boards in each of the two inflow and effluent gates).

Reduced Feeding Strategy

Generally, feeding for growout ponds stocked directly with postlarvae can be significantly reduced during the first two to four weeks after stocking. The initial feeding strategy should consist of a maintenance distribution to allow the pond bottom fauna to flourish. A practical feeding regime of 7 kg feed/hectare/day should be carried out for maintenance purposes since the biomass of postlarvae is small in relation to the carrying capacity of the surface area of the growout pond.

Depending on the production tonnage estimated semi-intensive growout ponds should be stocked at a direct density of between 130,000 and 210,000 postlarvae per hectare (13-21 postlarvae/m^2). If the biologist assumes a conservative estimate of 40 percent survival from postlarvae to a target harvest size of 23 g average (26-35 tail count classification size) production targets of 1,200 and 1,950 gross kg/hectare may be achieved. An example calculation follows:

1. $\frac{130{,}000 \text{ postlarvae}}{1 \text{ hectare}} \times 40\% \text{ survival} = \frac{52{,}000 \text{ shrimp}}{1 \text{ hectare}}$

2. $\frac{52{,}000 \text{ shrimp}}{1 \text{ hectare}} \times \frac{23 \text{ grams}}{1 \text{ shrimp}} \times \frac{1 \text{ kg}}{1000 \text{ gm}} = \frac{1{,}196 \text{ kgs}}{1 \text{ hectare}}$

Although this example reflects a relatively high total biomass when the pond is near harvest phase, the following example, in a recently (direct) stocked growout pond, demonstrates the relative insignificance of total biomass. It is difficult to efficiently feed the total biomass over the relatively large area of a growout pond when it has been recently stocked with postlarvae.

The calculation shown below can be used to determine the biomass of the pond at the moment of stocking, if one assumes that the average weight of a 10-day old postlarva recently stocked averages 0.008 grams and the growout pond surface area is 10 hectares.

To feed 10 kg of postlarval biomass effectively in a 10-hectare pond, it is necessary to feed according to area and not in relation to biomass. Most feeding strategies are calculated according to biomass weight and result in higher efficiency. However, initial feeding strategies should be based on area because of the small biomass.

The second reason for a strategy of reduced feeding in directly stocked ponds is related to stocking density. Due to the relatively low stocking densities of 13 to 21 postlarvae per square meter, the stocked postlarvae will have an ample supply of the benthic biota on which to graze. A wide spectrum of food organisms will ensure a more balanced diet from natural sources and will reduce feed cost.

Since feed costs can make up 40 percent of production costs, it becomes an attractive strategy to reduce intensive feeding for as long as possible before weekly growth performance is negatively affected. For these reasons, directly stocked ponds should generally be fed a maintenance ration of 7 kgs/hectare/day until the population has reached an average weight of 2-3 grams.

Once the shrimp population reaches an average weight of 2 to 3 grams, the daily rations should be calculated at weekly intervals. These calculations are based on total shrimp biomass estimated in the pond. The feed ration table in Chapter 11 (*Feed ration tables*) should serve as a guideline to establishing the daily pond ration.

Feed dispersal in growout ponds should begin no earlier than 1600 hours (4 p.m.) and the feed should be spread over the entire pond surface area in a zig-zag pattern similar to that described in Chapter 8 (*Feeding Strategy*). Since feed is a significant cost center in semi- intensive culture operations, it should be managed efficiently. Direct supervision is necessary to ensure proper feed dispersal patterns. It may be difficult to cover the zig-zag pattern in a 10-hectare pond that has a daily ration of 120 kg of feed, however under direct supervision the rate of dispersal can be

1. $\frac{130{,}000 \text{ postlarvae}}{1 \text{ hectare}} \times \frac{10 \text{ hectares}}{1 \text{ pond}} \times \frac{0.008 \text{ gm}}{1 \text{ P.L.}} = \frac{10{,}400 \text{ gm}}{1 \text{ pond}}$

2. $\frac{10{,}400 \text{ grams}}{1 \text{ pond}} \times \frac{1 \text{ kg}}{1000 \text{ gm}} = 10.4 \text{ kg in a 10-hectare pond}$

increased or decreased at need to ensure that the limited amount of feed is uniformly dispersed through the entire pond area. The four wooden stakes, placed equidistantly along each of the four sides of the growout pond, will serve as directional guides for the personnel in the feeding canoe as described in Chapter 8.

Shrimp populations are more active during the late afternoon than mid-morning hours, and since proper feeding techniques are labor intensive, the frequency of feeding growout ponds is limited to once per day. Unlike nursery ponds, which are fed in the early morning and again in the late afternoon, feed application in growout ponds should start at 1600 hours (4 p.m.).

With respect to the proper utilization of feed, care should be taken to limit its dispersal nearer than 10 meters from all bordering dikes and at least 20 meters from all effluent weir gates. This should reduce the loss of feed on the dike slopes as a result of wind and wave action on pellets that sink slowly or may be pulled to the effluent by the current of water being drained.

Feed dispersal should be limited to areas of the pond in which shrimp are found, so sections of the pond with less than a 30-cm water depth should be excluded. The following procedure will provide this control.

1. While the growout pond is being prepared to receive shrimp and is being filled with water, the entrance (inflow) weir gate should be tentatively sealed when the water level in the pond is 30 cm under the standard operating level.
2. Any islands or peninsulas along the shores of the pond that are exposed while the entrance gate is tentatively sealed should be identified.
3. Wooden stakes should be partially sunk into the pond bottom mud at 10-meter intervals all along the peripheral edges of any exposed islands or peninsulas.
4. The wooden stakes should be long enough to be suffiently exposed on the surface once the water level of the pond has reached its operation level.
5. The top point of the wooden stakes should then be sharpened to a point so that it cannot be used as a potential perch for predatory birds.
6. Once all exposed areas have been adequately marked all along the perimeter, the entrance weir gate should be unsealed and the pond allowed to fill to its maximum operation water level.

This operation only has to be performed once since well-placed stakes need minimal maintenance and do not affect harvests. Once the shallow zones have been properly identified and marked, they should be avoided during the zig-zag pattern of feed dispersal. This practice should result in improved feed conversions, particularily in growout ponds with poor bottom topography.

Very little is known about the nutritional requirement of *P. vannamei* and virtually nothing is known of their nutritional requirements in an earthen pond environment. In semi-intensive culture, it is generally assumed that the majority of the essential vitamins and minerals as well as some of the amino acids and polyunsaturated fatty acids are obtained from the live natural biota within the pond.

Artificial pelleted feeds that most adequately support optimal growth performance in early postlarvae through juvenile stages should contain a relatively high content of digestable protein and fat. This supplemental feed should partially support the gross nutritional requirements of shrimp, particularly during the early stages when growth rate is accelerated.

This high protein/fat juvenile pellet, as described in Chapter 8, is produced in a pellet size of 3/32" diameter and as crumbles. The small diameter of the pellet improves the acceptability for the small size shrimp and contains more individual pellets per kilogram, which facilitates better dispersal over the pond's surface.

The pellet size and protein content of feed is generally dictated by the average size of the shrimp in the pond population. Although it would be more advantageous to feed a small pellet with high protein/fat content throughout the entire pond culture duration, this is not always practical. The smaller 3/32" diameter pellets cost more to produce as a result of the diminished production rate at the pellet mill. The protein fraction of pelleted feeds is generally the most expensive component of the diet. The nutritional formulation of any feed should be such that the protein fraction is not used as an energy source. The less expensive nutritional constituents, i.e., fats and carbohydrates, should be included in the diet in sufficient amounts so that the shrimp metabolize these to fulfill their energy requirements and all available dietary protein is metabolized for growth and tissue development. If the pelleted feed does not contain an adequate supply or quality of energy, the shrimp may partially metabolize dietary protein to fulfill their energy requirement; this results in decreased feed efficiency. The following table should be used as a guideline in establishing proper feed formula schedules in relation to average shrimp size.

The gross nutritional profile for the 35 percent protein feed ration is given in Chapter 8 and is similar to that of the crumble ration. The following are the gross proximate analyses for the larger 5/32" diameter pellet ration, which contain less protein/fat.

Pellet diameter	:	5/32"	5/32"
Protein	:	25%	20%
Fat	:	6%	5%
Fiber	:	4%	3%
Ash	:	7%	6%
Humidity	:	10%	10%
Gross Energy	:	3,200 Kcal/kg	2,800 Kcal/kg

Table 3. Feed ration recommendations in relation to average shrimp size.

Approximate Age (days)[a]	Size Range (gms)	Ration Form	Percent Protein	Percent Fat
1 - 21 days	0.008 - 0.30 g	crumbles	35	9
22 - 45 days	0.30 - 4.0 g	3/32" pellet	35	8
46 -129 days	4.0 -18.0 g	5/32" pellet	25	6
130-170 days	18.0 -23.0 g	5/32" pellet	20	5

[a]The approximate age expressed in number of days in the growout pond and how the days correlate with the size range in grams are for the stocking densities of 160,000 postlarvae per hectare (16 Pl's/m^2).

Depending on the average weight of the shrimp population, with the stocking densities described above, these feed ration profiles should be able to support weekly growth performance of between 0.8 grams and 1.2 grams.

Pond Parameter Monitoring

Hydrological parameters in growout ponds should be monitored twice daily. Each pond should have two parameter platforms, one located near the inflow entrance weir gate and the second located near the effluent gate. These platforms should extend sufficiently far into the pond to reach a minimal water depth of 60 cm (Plate 15).

The same methodology for daily monitoring of nursery ponds described in Chapter 8 (*Parameter Monitoring*) should be applied for all growout ponds, including such techniques as changing daily routes to ensure that during the course of the week, all ponds will have been monitored, at least once, in the early morning (0600 hours [6 a.m.]).

Data should be properly recorded on the Hydrological parameter monitoring sheets (Figure 12).

Hydrological parameters should be monitored within the bottom 5 cm of the pond. Measurements recorded on the pond surface are not representative of conditions at the bottom. D.O. and water temperatures are generally not a problem since the oxygen meter polarographic probe and the PVC-encased glass thermometer, can be submerged to the bottom for correct measurements. Salinity and pH measurements present complications since the instruments should not be completely submerged to the bottom, so it is necessary to submerge a self opening and closing plastic bottle to the bottom of the pond to take an appropriate sample.

Stratification gradients have been observed in all types of semi-intensive growout ponds and invalid management decisions can be made if surface water measurements alone are used.

Growth Monitoring

In directly stocked growout ponds, the weekly sampling of the shrimp population for growth should begin two weeks after the last day postlarvae were stocked. Although most of the shrimp at this time will be small and, therefore, not captured by the cast net, it is a prudent strategy to begin early sampling in order to establish a subjective evaluation of the population.

If the shrimp are relatively large (~0.5 grams) during the first sampling (post two weeks), it can be postulated that there has been poor survival and the resultant lower densities have stimulated increased growth. The opposite can also be true since small postlarvae can usually be seen escaping from the cast net on the surface of the pond. Factors such as low frequency of capture and postlarvae escaping through the mesh of the cast net can be tentatively interpreted as indications of good survival rates.

Once growth sampling begins, it should be continued weekly. The same personnel should be employed to sample each pond. Scheduling of sampling should be restricted to the early morning hours between 0630 and 1000 hours. Sampling later than 1000 hours should be discouraged since capture frequency is reduced because shrimp burrow into pond bottoms as water temperature increases.

The sampling pattern explained in Chapter 8 (*Growth sampling technique*) for nursery ponds applies to growout ponds, except that in larger ponds, samples should be taken in the center area also. Sampling canoes should make two diagonal crossings in the growout pond, with four throws of the cast net during each crossing. The animals sampled across one diagonal can be grouped together in the plastic box with 5 cm of water to keep them alive. These grouped samples can then be weighed together to establish the average weight of the shrimp for each independent diagonal. Unlike nursery ponds, which have a total of 16 weighing stations (4 stations for each of the four sides of the pond); growout ponds have a total of 24 weighing stations. Figure 13 (Growth monitoring sheets) includes a space for the weight analysis for each respective diagonal crossing in the growout pond. Unlike the shore-based stations whose samples should be weighed and analyzed individually at

Table 4:. Standardized cast net dimensions for different average weight groups.

Average weight of shrimp	Small 0-0.8 g	Medium 0.9-5.0 g	Large 5.1-23 g
Cast net diameter	6 m	6 m	6 m
Cast net mesh size	0.5 cm^2	1.0 cm^2	1.5 cm^2
Cast net pocket length	30 cm	30 cm	30 cm
Cast net lead weight	6 lbs	8 lbs	10 lbs

each of the four stations on all four sides of the pond; the four samples taken for each diagonal crossing can be weighed in one group.

The stakes placed along each of the four sides of the growout pond at equidistant intervals, which are used as guide markers for proper feed dispersal patterns, should also be used as sampling stations.

The personnel who operate the cast net during the sampling operation should prepare the net for casting while standing outside of the pond on the bank; he/she should then walk into the pond at each sampling station, up to a depth of approximately 40 cm, and immediately make the cast. This technique should be standardized and directly supervised in order to ensure that samples are taken at a 60-cm minimum water depth. The objective of this sampling procedure is to increase the capture frequency, adding validity to the estimated average weight calculated. Since the majority of the shrimp inhabit deeper waters, capture frequency and accuracy of weight calculations will be reduced if samples are taken close to the shoreline with less than 40 cm of water depth. Furthermore, it is important that the person taking the sample prepare himself and his net adequately before physically entering the pond, since shrimp are sensitive to shock-waves produced by a person walking through the pond. If cast net personnel are slow to cast once they are in the pond, the majority of the shrimp will respond to the shock-waves and move to deeper waters. If the total number of shrimp captured in 24 sampling stations is less than 100, then the entire sampling operation should be repeated during the night of the same day. The objective of this repeated operation is to capture more shrimp in the sample so that average weight calculations will be more precise. Night sampling procedures should begin at 2000 hours (8 p.m.).

The reasoning behind such strict procedural controls in sampling techniques is that this operation is one of the few opportunities for the field biologist to be in close contact with the shrimp population. It is essential to achieve as much standardization in the sampling techniques as possible. If the same techniques are consistently implemented and precautions are taken to ensure standardization, then capture frequency may be used as an interpretation tool for making production forecasts, for feeding strategies and for implementation of water management tactics. Although sufficient statistical evidence has not yet been gathered to establish a mathematical formula correlating capture frequency with shrimp densities, it may be assumed that high capture frequency (>400 shrimp captured at 24 sampling stations) generally indicates high survival. Likewise, low capture frequency (<200 shrimp captured in 24 stations) should cause concern, and capture frequencies of less than 100 indicate, almost certainly, low survival rates.

Although capture frequency analyses are directly related to stocking densities, shrimp size (weight) and total pond surface area, if sampling procedures are correctly standardized, each pond can accumulate historical data over two or more culture cycles and be independently evaluated in comparison with past performance.

The dimensions of the cast net should also be standardized in order to use capture frequency as an indicator tool accurately. Table 4 shows the different cast net specifications to be used for the various size (weight) ranges during the entire culture period.

These specifications are designed to be more efficient in capturing shrimp. Larger shrimp are generally stronger and avoid cast net capture more than do smaller sized animals. Thus, a larger mesh size and heavier lead line will allow the cast net to sink more rapidly to the bottom and result in a higher probability of effective capture. Cast nets with diameters larger than 3 meters are more difficult to manage and consistently throw with an open arc.

The same weighing and species segregation procedures described in Chapter 8 (*Growth sampling technique*) should be employed in establishing minimum and maximum average weights. Care should be taken to ensure that the triple beam balance is accurately calibrated at each weighing station, and that the tare weight of the wet plastic bag used to hold the shrimp is accurately weighed and subtracted from the total weight. The results of weekly growth samples should be carefully recorded on the growth monitoring sheets (Figure 13).

The objective of complete coverage of the pond's

Table 5. Live (head-on) weight and corresponding plant size classification.

Live (head-on) weight	Plant Classification (tail)
13.8 - 16.8 gms	41-50 tails/pound
17.2 - 19.1 gms	36-40
19.7 - 22.2 gms	31-35
22.9 - 26.5 gms	26-30
27.5 - 32.8 gms	21-25

surface for growth monitoring is, in essence, to attain the most representative picture of the shrimps' weight. When the average weight of the population reaches 18 grams, the sampling procedure should include segregation according to size. The captured shrimp should be visually segregated according to three sizes; small, medium, and large. They should then be counted and weighed separately in order to establish the average weight for each of the three classifications. The different percentages and their respective weight should be recorded on the growth monitoring sheets.

This modification of the sampling procedure is made in order to establish the optimal harvest date better. At times there may be significant differences in product value from one size classification to another. It is possible to ensure that the farmer will receive the best price for his product by analyzing the various percentages with their respective average weights, and moving actual harvests forward or postponing them. Table 5 represents the various head-on live weight of commercial size shrimp and their approximate corresponding commercial classification by tail count. This table assumes an average 66 percent tail pack-out (34 percent of the live weight corresponds to the head).

If no bipolar population distribution exists, an average weight of 23 grams generally packs out with 60 percent of the population in the 31-35 tails per pound bracket and 40 percent in the 26-30 class with a normal bell curve distribution.

As an example, if the growth monitoring sample results in an estimated size segregation percentage of 70 percent with an average weight of 23 grams and 30 percent with 19.5 grams, it would be prudent to postpone the harvest by one or two weeks in order to allow the 30 percent portion of the population to acquire a minimum of 20-20.5 grams to fall into the 31-35 size and thus receive an increased value for the final product.

Chapter 11

In Progress Pond Management

Strict procedural controls in the management of "in progress" growout ponds is rather difficult, for so much depends upon the special nature of each situation and on the biologist's response to it. However, there are many instances in which catastrophies can be averted by simply maintaining routine culture operations and developing specialized skills for coping with specific situations as the level of experience increases.

Semi-intensive growout ponds are generally stocked at densities of between 40,000 to 150,000 juveniles per hectare (4.0-15.0 juveniles/m^2). Stocking densities are decided by a variety of factors: cash flow, farm water exchange capabilities, production goals (kilograms and size classifications), level of expertise of the management team, and the availability of adequate numbers of postlarvae, the last being of critical importance.

Depending on the juvenile stocking densities in the growout pond, the cycle may last from between 140 to 210 days when the production strategy involves a harvest target size of 26-30 and 31-35 tail count classification. The success or failure of the harvest of the growout pond are direct functions of the management decisions taken on a daily basis throughout the culture cycle.

Careful and strategic planning should be a priority. It should be clear that relatively fragile biological systems in semi-intensive commercial operations are being pushed close to their maximum limits, and therefore, may crash within the course of a few hours if the fragile equilibrium is not correctly managed.

This chapter will elaborate on certain basic guidelines to help the farm biologist maintain a productive equilibrium during the culture cycle. There are seven basic elements that influence daily management decisions during the growout cycle. These are : (1) Routine water management, (2) Weir gate controls, (3) Feeding strategies, (4) Predator control, (5) Hydrological parameter management, (6) Routine growth monitoring, and (7) Assesment of benthic fauna. Fertilization strategies were previously described in Chapter 3 and should be implemented on a routine basis as defined.

Management of in progress growout ponds strongly depends on the production goals of the farm. Strategies discussed here are applicable to the specific stocking densities described above and do not entail major infrastructure investment, such as mechanical aeration equipment, feed dispersal blowers or other relatively sophisticated equipment that may predominate under intensive culture scenarios.

Water Management

Routine water management is defined as the calculated amount of water, by volume, exchanged in the pond on a daily basis. Since all growout ponds should be consistently maintained at their prescribed maximum operative level, any water entering the pond should equal the amount of water exiting the pond. The calculated volume of inflow water over a 24-hour period can then be divided by the calculated total volume of water within the growout pond to establish the percent of volume exchange for that particular pond on that day.

The importance of a well managed water exchange program can not be over-emphasized. In commercial semi-intensive production operations, water is virtually the most important factor in grow- out performance. The objective of a water exchange program is multi-fold, principally: (1) drainage of water that contains metabolites of the resident population as well as other organic build-up, (2) introduction of fresh, relatively clean water with renewed phyto and zooplankton populations, and (3) establishment of a circulation pattern that contributes to water column destratification.

Since the population of shrimp in a pond is restricted in its ability to migrate to areas of improved water quality as it might be able to in the wild, water quality must be maintained in a productive equilibrium. Organic build-up within the pond must be managed in order to ensure a healthy environment for the confined population. As a direct consequence, an economically feasible and practical approach to the above stated requirements is a generous and meticulously managed water exchange scheme.

There are many factors governing the water exchange capacity of the farm and of the ponds at any given time. These factors include (1) number of pumps and their respective flow rate capacity, (2) total number of hours within the day that pumps can operate in relation to tidal variation, (3) size of the entrance and effluent weir gates, and (4) the maximum operative water level of the ponds.

Establishing pond operative level

Shrimp growth is directly affected by, among other factors, water depth. Generally, the deeper the growout pond, the higher growth rate of the shrimp. This phenomena is the basis for maintaining growout ponds at their maximum operative water level.

If the farm's topography is not consistent throughout, the maximum operative water level must be adjusted to each particular pond. The first step is to identify the lowest point of the four dikes of the pond. Once this specific area has been identified, then the maximum operative level can be established at 30 cm below the crown of the lowest dike. The 30 cm of "freeboard" on dikes is established assuming that the dikes are well constructed, of consistent, compacted clay and are wide enough to resist water pressure (Plate 54). This decision must be made in the field and if the dimensions of the dike are not adequate, it may be necessary to allow more "freeboard" for added protection against rupture and resulting losses.

When the maximum operative level for a particular pond has been tentatively established, this level must be cross-referenced with the maximum level of water in the reservoir canal. The reservoir canal water level must be at least 20 cm above the maximum operative water level in the pond so that water will gravity flow into the growout pond. If the maximum operative level in the pond is less than 20 cm below the water level in the reservoir canal, the pond's operative level should be re-established in relation to the maximum water level in the reservoir canal (20 cm below).

Once the maximum operative water level has been established, each of the entrance and effluent weir gates should be marked with triangles that have been painted and nailed to the weir gate walls on the pond side to identify this level (Plate 55). These triangles should have the dimensions shown in Figure 21.

The objective of painted triangles is to readily monitor pond water level. If the water level is below the triangles' bottom apex, the deficiency can be easily measured with a measuring rod and accurately recorded on the water management sheets in the column headed "Water level." If the pond's water level is higher than its prescribed operative level then the bottom apex of the triangle will be submerged. Since direct measurement is difficult if the apex cannot be seen, one measures the distance between where the water level intersects either side of the triangle. The resultant measurement will be how much the water level is above the prescribed operative level of the pond.

When the operative water level has been established and marked on all weir gates, the average pond depth should be calculated. When the pond is at its operative level the average pond depth should be used for all future references to that particular pond. Fifty depth soundings should be made, following a grid pattern five deep and 10 wide (Figure 22).

Once the depth soundings have been made, the average depth can be calculated for each pond, by averaging all 50 soundings. The resultant average pond depth then becomes the official numerical value for the ponds operative level. Daily water levels are recorded on the water management sheets in terms of

Plate 54. Crown of pond dike with 30 centimeters of "freeboard" above water level of pond.

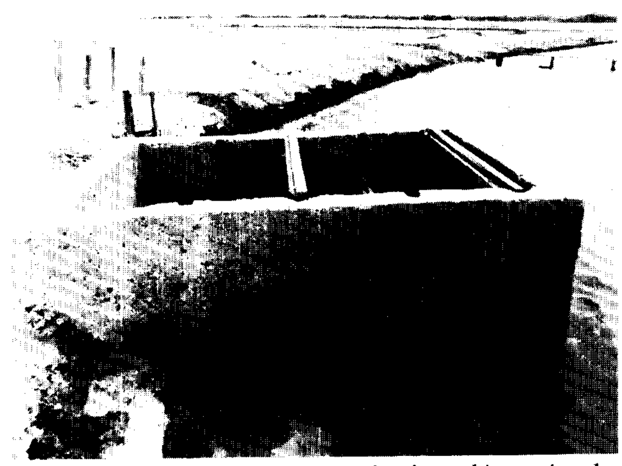


Plate 55. Operative pond water level marking triangles located on entrance weir gate walls on pond side to facilitate managing water levels in ponds.

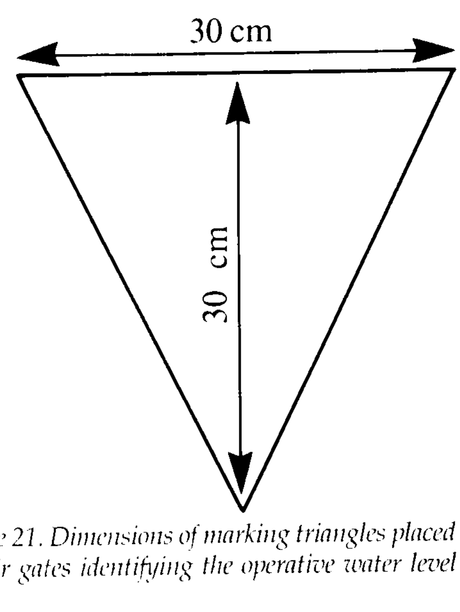


Figure 21. Dimensions of marking triangles placed on walls of weir gates identifying the operative water level for each pond.

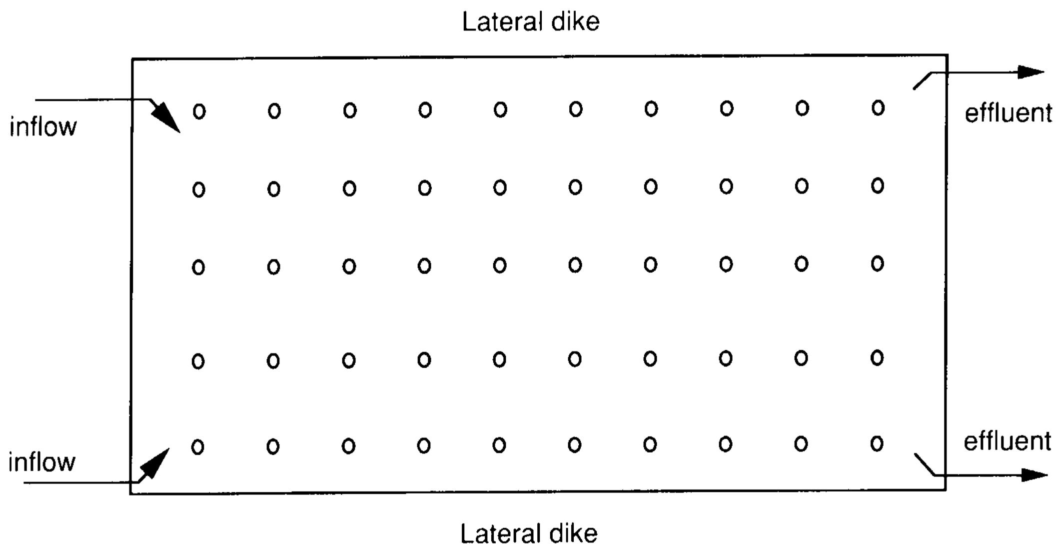


Figure 22. Depth sounding grid pattern in ponds to determine average water depth when at operative level and consequently to calculate water volume of the pond.

this measurement. If a pond's average water depth has been calculated at 180 cm average depth when the water level is tangent with the bottom apex of the triangle, then water levels should be expressed as 180/180 on sheets. When the pond's water level is 10 cm below the bottom apex of the triangle, the data should be expressed as 170/180. Conversely, if the pond's water level covers the triangle's apex and the measurement across the triangle, where the water level intersects the two sides of the triangle is 5 cm, then the daily monitoring data should be expressed as 185/180.

To calculate the percentage of water exchange, by volume, per pond, the pond's total volume of water must be estimated. Although it is not highly accurate, the estimated volume should be sufficiently valid for water management purposes. When the average water depth of a pond is 130 cm, the volume can be calculated as follows, assuming the surface area of the pond, in this instance, to be 9.85 hectares:

1. $\frac{9.85 \text{ hectares}}{\text{pond}} \times \frac{10{,}000 \text{ m}^2}{\text{hectare}} \times \frac{1.30 \text{ meters}}{\text{average depth}} = \frac{128{,}050 \text{ m}^3}{\text{pond}}$
2. $\frac{128{,}050 \text{ m}^3}{\text{pond}} \times \frac{\sim 264 \text{ gallons}}{\text{m}^3} = \frac{33{,}805{,}200 \text{ gallons}}{\text{total volume}}$

This calculation should be performed for all nursery and production ponds on the farm. The sum of all volumes will be the total volume of water for the entire farm.

Determining water exchange capacity

To determine the water exchange capacity for the entire farm, one should calculate the pumping capacity of the farm's pump station. This is a function of the number of pumps, their respective capacities, and the number of hours per day that they operate in respect to tidal fluctuations.

In general, pump station capacities should be designed in accordance with the total water volume of the farm and desired water exchange capabilities. Due to economic restrictions, exchange capabilities rarely exceed 20 percent of the farm volume. A significant capital investment is required for a large inventory of motors, pumps, and their respective maintenance (Plate 56).

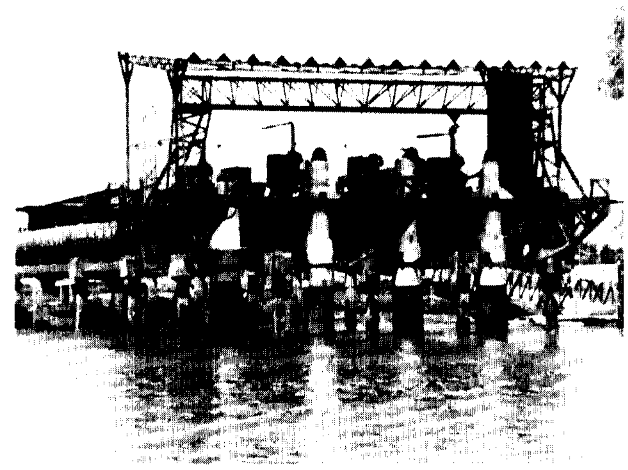


Plate 56. Typical central pump station for commercial farm.

Generally a 13 percent water exchange capacity for the entire farm is adequate for the semi-intensive culture strategies outlined in this manual. There should be a "safety margin" back-up system since pumps become damaged and motors must be repaired. Unless there is a high maintenance turnover in which these extra units will be frequently rotated, it is inefficient to have a large stock of motors because they don't tolerate long periods of storage very well; it is better to have the units installed and operating. Thus, when all units are in operation, water exchange may be more than adequate allowing pumps to operate fewer hours. If one unit must be shut down due to mechanical failure, then the operating times for the remaining units may be increased to maintain adequate exchange.

To calculate the pumping capacity of the farm, the biologist should determine what part of the 24-hour period the tidal fluctuations will permit pump operation. The biologist should also ascertain the flow rate specifications for each of the pumps. Flow rates should be extrapolated from performance curves of the pumps based on mean tidal levels and resulting total dynamic head. For example, assume that the farm has eight axial pumps of which six are 61 cm diameter and two are 51 cm diameter. The performance curve dictates that at a given operating speed (600 rpm) and a pumping head of 2.5 meters, the discharge capacity is 19,000 gallons per minute for the 61 cm pumps and 14,000 gallons per minute for the 51 cm pumps. It has been previously established that the tide allows eight hours of pumping per tide, with two tides per day resulting in a maximum pumping period of 16 hours per day. The pumping capacity per day can be determined as follows:

1. $\frac{16 \text{ hours}}{\text{day}} \times \frac{60 \text{ min.}}{\text{hour}} = \frac{960 \text{ min.}}{\text{day}}$
2. (6) pumps x with capacity of 19,000 gallon / min each
+ (2) pumps x with capacity of 14,000 gallon / min each
142,000 gallons per minute total
3. $\frac{960 \text{ min.}}{\text{day}} \times \frac{142{,}000 \text{ gallons}}{\text{minute}} = \frac{136{,}320{,}000 \text{ gallons}}{\text{day}}$

The total pumping capacity of the pump station would be 136,320,000 gallons per day.

To calculate the water exchange capacity for the farm as a percentage, divide the total pumping station capacity per day by the total volume of water, calculated in the example in the previous section.

Suppose that a farm has a total production area (nursery and production ponds) of 300 hectares. By calculating each individual pond's total water volume at operative levels (as described inthe previous section) the total water volume for the farm would come to 1,014,150,000 gallons. By dividing volume pumping capacity by total volume of the entire farm, the result is a water exchange capacity of 13.4 percent per day.

1. $\frac{136{,}320{,}000 \text{ gallons}}{\text{pumping day}} \div \frac{1{,}014{,}150{,}000 \text{ gallons}}{\text{farm}} \times 100$
2. = 13.4 percent water volume exchange capacity per day for the farm.

When the maximum volume exchange capacity for the farm has been determined, then individual pond requirements can be calculated based on the maximum exchange rate. If all ponds were treated equally in regards to water exchange, then each pond would have an exchange capacity of 13.4 percent per day. This forms a basis for water management procedures on the farm.

Return to the example described in *Establishing pond operative level* in which the total water volume for a particular growout pond was calculated to be 33,805,200 gallons. If daily water exchange capacity of the farm is 13.4 percent and all ponds are managed equally, the amount of water that should be allowed to enter that particular pond would be 13.4 percent x 33,805,200 = 4,530,000 gallons daily. This exercise should be performed for all ponds within the farm and the sum of the ponds' daily requirements should be cross-referenced against the total volume pumping capacity on any given day.

To correctly monitor and calculate, on a daily basis, the amount of water actually entering a particular pond over a 24-hour interval, the physical dimensions of the entrance weir gate(s) should be considered within the mathematical formula. The width of all entrance weir gates should be correctly measured and recorded.

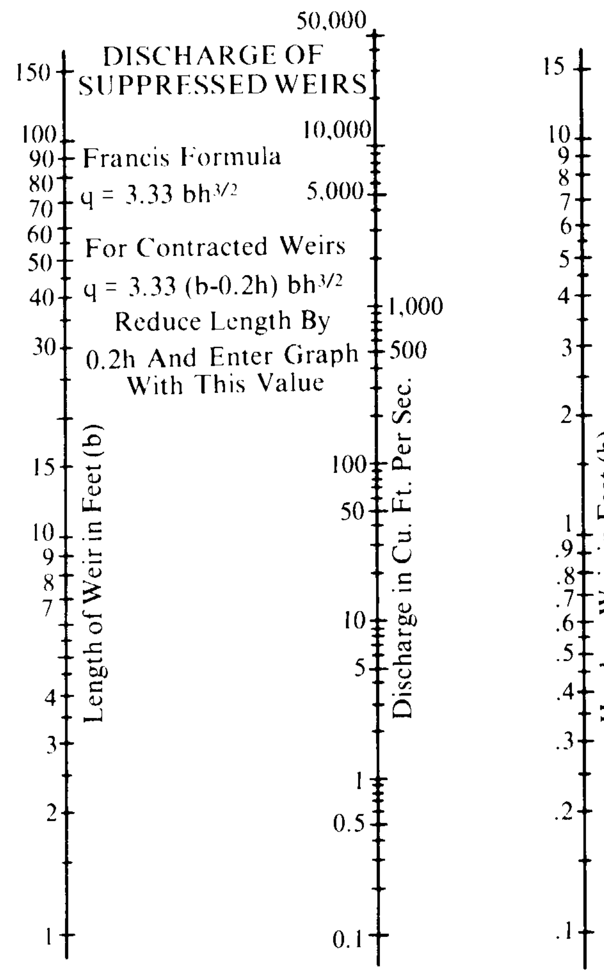


Figure 23. Nomographic solution for rectangular (suppressed) weir discharge flow rates (adapted from Lefax Publishing Co.). Used for estimating water volume entering ponds.

Routine water exchange monitoring

The previous sections have described the preliminary calculations for the establishment of a routine water exchange program. Once the respective volume exchange calculations for each pond have been performed and the physical dimensions (width) of each entrance weir gate recorded, the amount of water volume allowed to enter the pond over a 24-hour period can be roughly estimated by utilizing standard rectangular suppressed weir gate flow measurement nomographs. The nomograph represented in Figure 23 has been extracted from Lefax (Lefax Publishing Co., 2867 E. Allengheny Ave., Philadelphia, PA. 19134, page 11).

Continuing with the same example given earlier, for a farm with 13.4 percent water exchange capacity and a particular pond with a volume of 33,805,000 gallons of water, if the pond requires 4,530,000 gallons to pass through a 1-meter wide entrance weir, the following procedure should be performed to acquire an estimate of water requirement.

The nomograph in Figure 23 is expressed in feet for linear measurements and in cubic feet per second for volumetric measurements. The nomograph reflects three variables of which two are known: (1) length/width of the rectangular suppressed weir (converted to feet) and (2) cubic feet per second required by the pond on a given day. Knowing these two variables, facilitates connecting the two points on each of the two vertical axes with a straight edge, and its intersection on the third axis (extreme right-hand side) will define the required head over the entrance weir down boards:

A. **Variable one**: Length/width of rectangular weir is directly measured in the field. In this particular example, the pond only has one entrance weir gate, which measures 1 meter in length.
   1 meter = 3.28 feet.

B. **Variable two**: Total daily water volume required by the pond is 4,530,000 gallons, which is an approximate calculation.

1. $\frac{60 \text{ sec.}}{\text{min.}} \times \frac{60 \text{ min.}}{\text{hour}} \times \frac{24 \text{ hours}}{\text{day}} = \frac{86{,}400 \text{ sec.}}{\text{day}}$
2. $\frac{7.5 \text{ gallons}}{\text{Ft}^3}$
3. $\frac{4{,}530{,}000 \text{ gal. required}}{\text{day}} \times \frac{1 \text{ day}}{86{,}400 \text{ sec.}} \times \frac{1 \text{ Ft}^3}{7.5 \text{ gal}}$
4. **6.99 ft^3/sec.** of fresh water entering pond over a 24-hour period.

C. **Variable three**: Since variable one (3.28 feet) and variable two (6.99 ft^3/sec.) are known values, connect the two points on the first two respective vertical axis and record the extrapolated value on the third vertical axis. In this example, the first vertical axis should be marked at 3.28 feet. The second vertical axis (in the center) should be marked at 6.99 ft^3/second. Connecting the two marked points with a straight edge results in a 0.72 foot of head of water that must go over the entrance weir down boards.
   0.72 foot = 22 cm

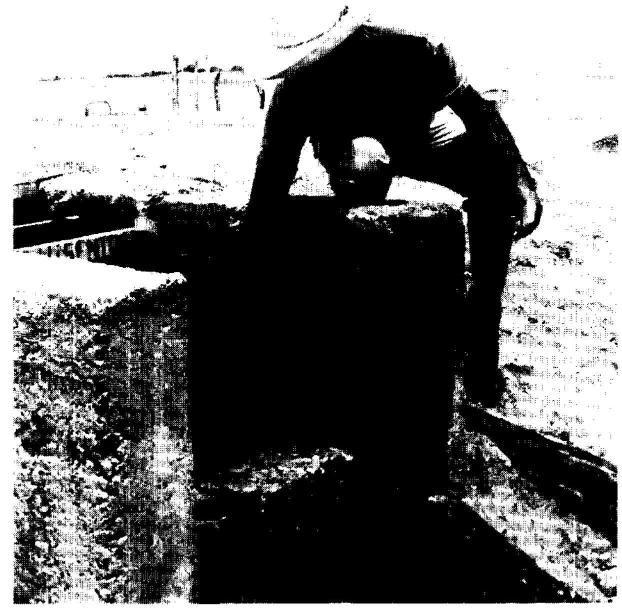


Plate 57. Personnel measuring actual water entering over entrance weir down boards. This exercise is performed in all entrance weirs at two-hour intervals.

D. In conclusion: 22 cm of water going over the entrance weir gate down boards over a 24-hour period results in:
   22 cm x 24 hours = 528 cm of water in a 24-hour period.

This 528 cm of water per day in a particular pond is a reference guide signifying an exchange rate of approximately 13.4 percent per day.

In order to monitor and calculate the actual amount of water entering the pond on a daily basis, one person should be delegated the responsibility of actual measurement of the amount of water going over the entrance weir down boards.

At two-hour intervals, the designated person should measure the amount of water entering the pond over the weirs down boards (Plate 57).

This measurement should be taken between 0600 hours (6 a.m.) and 1800 hours (6 p.m.) every day, (*i.e.* 0600, 0800, 1000, 1200, 1400, 1600 and 1800 hours).

The field monitoring sheets shown in Figure 24 should be used to record the actual centimeters of water entering over each weir at two-hour intervals over a 12-hour period.

Characteristically during a 24-hour period, there are two high tides. Generally, the farm's pumping schedule is limited by the high tide frequency since pumps will operate much more efficiently with the

Farm ____________________

Date ____________________

Head (cm)

Pond	Entrance Weir	0600	0800	1000	1200	1400	1600	1800
	A							
	B							
	A							
	B							
	A							
	B							
	A							
	B							
	A							
	B							
	A							
	B							
	A							
	B							
	A							
	B							
	A							
	B							
	A							
	B							
	A							
	B							

Recording Biologist ____________________

Figure 24. Field monitoring worksheet for daily water management.

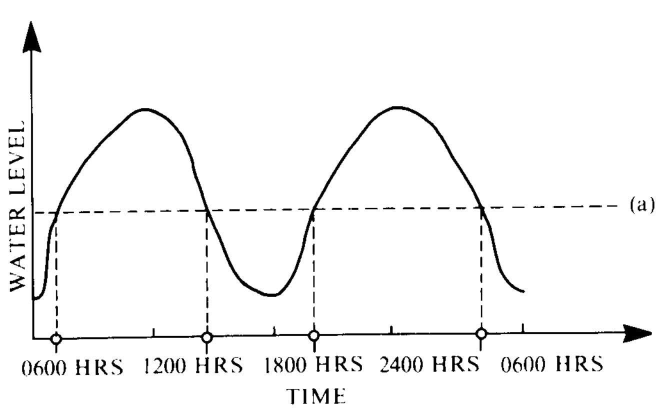


Figure 25. Typical tide cycle over 24-hour period depicting times when pumps are permitted to operate.

Plate 58. Increased flow rate of 61 cm axial pump during high tide when total dynamic head is reduced. Compare same flow with Plate 59.

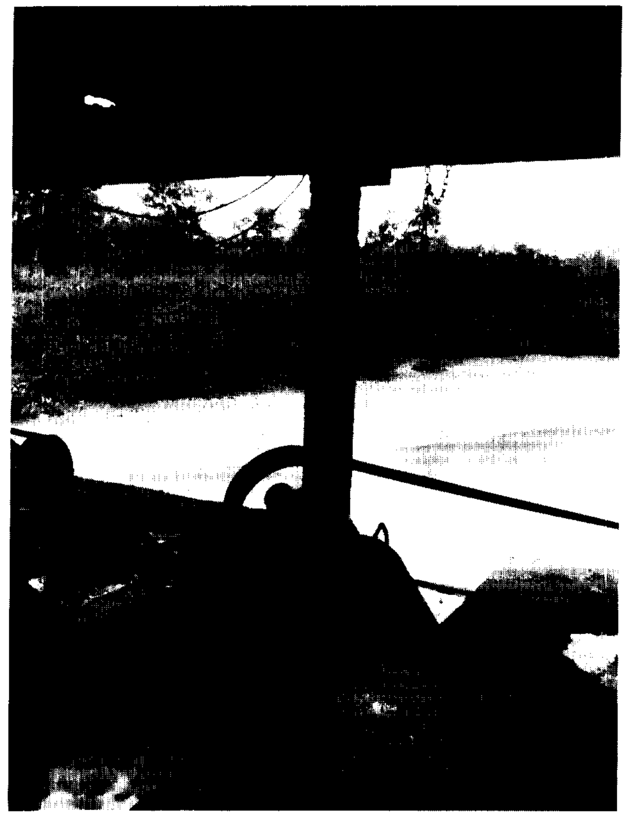


Plate 59. Decreased flow rate of same 61 cm axial pump during low tide when vertical head is increased.

reduced vertical column of the water to be elevated (Plate 58). Pumps operating during low tides generally run with a heavy work load (Plate 59) and if the vertical head distance is significant, a whirlpool will form causing the suction of air and consequent cavitation by the pump (Plate 60). Prolonged cavitation will cause erosion and pitting on the impeller and pump body wear plates, which require periodic and costly maintenance expenditures. To avoid such inefficient pump utilization, the biologist should consult the performance curves for each pump and determine the maximum allowable vertical head that remains within the efficient performance range as well as reduction of cavitation.

Figure 25 defines a hypothetical, but typical tide cycle over a 24-hour period. The horizontal broken line (a) represents the range in which the pumps are permitted to operate (area above line [a]).

In this particular example, the pumps are started at roughly 0700 hours (7 a.m.) and allowed to operate until 1600 hours (4 p.m.), a total elapsed time of 8.5 hours. The same situation exists for the evening tide when the pumps are started at approximately 2030 hours (8:30 p.m.) and turned off at 0500 hours (5 a.m.), which results in an additional 8.5 hours for a total of 17 hours pumping time for each 24-hour period.

Continuing with the same example used above,

Plate 60. Whirlpool effect, at low tide, causing pump cavitation and inefficient operation.

assume the following measured data in a pond with only one entrance weir gate:

Gate	0600	0800	1000	1200	1400	1600	1800
A	12	21	30	37	20	13	6
B	—	—	—	—	—	—	—

At the end of the day, the biologist responsible for correct water management should interpolate the data for the odd hours when measurements were not taken as shown on the next page.

Actual Measurements	0600	0800	1000	1200	1400	1600	1800	even hours
	12	21	30	37	20	13	6	
Interpolated	16.5	25.5	33.5	28.5	16.5	9.5		
Measurements	0700	0900	1100	1300	1500	1700		odd hours

The total should be calculated by adding the measured values to the extrapolated values (0600 hours [6 a.m.] through 1700 hours [5 p.m.] truncate last measured value for 1800 hours [6 p.m.]).

ie :

12+16.5+21+25.5+30+33.5+37+28.5+20+16.5+13+9.5 = 263 cm

The resulting sum of 263 cm represents the water entering the pond over a 12-hour period. Two 12-hour periods in a day represents (2 x 263 cm) 526 cm/ 24-hour period.

It had been previously determined for the pond to have a 13.4 percent exchange rate, it required a total of 528 cm of water entering over a 24-hour period. The 528 cm is thus designated as 100 percent of the water requirement. In order to calculate the percentage of the water actually entering the pond on this given date, the actual value is divided by the required value and multiplied by 100 as follows:

526 actual ÷ 528 required x 100

is: 99.6 percent of the required value.

Since the required value represents 13.4 percent water exchange rate by volume, the actual water volume can be easily determined.

99.6 percent x 13.4 = 13.3 percent actual volume exchange for that day.

The Daily water management summary sheets shown in Figure 26 should be correctly filled out at the end of each day. The total centimeters required for each pond is a constant value once pond volumes and pumping capacities have been accurately determined and while they remain unchanged. As a result, the columns headed by "Requirement" are constant values. In the column headed by "Actual", the value of 526 cm (in this particular example) should be registered. The column headed by "Percent Required" is the value represented by the percentage of the requirement that was calculated to have entered the pond, in this example the value was 99.6 percent.

The remainder of the columns on the Daily water management summary sheets are filled out and should be used for interpretation analysis and decision making. Said decisions should be recorded in the column headed by "Action Taken." The interpretation, analysis and respective guidelines for decision making in reference to daily water management are discussed in more detail in *In-progress pond water allowance*.

The average semi-intensive commercial production pond has two entrance weir gates. In such a case, variable one would be the sum total of linear feet of the length of both rectangular suppressed weirs. Variable two remains unchanged, since the total volume of the pond and the amount of water (ft^3/sec) entering on a daily basis remain constant. Variable three will obviously change as a direct result of any change in variable one.

The following example is for a growout pond with a total volume of 33,805,000 gallons, on a farm with a water exchange pumping capacity of 13.4 percent. The daily amount of water to be allowed into this pond is 4,530,000 gallons, representing 13.4 percent of the pond's total volume. The pond in this particular example has two entrance weir gates, one gate (A) is 1.2 m in length while entrance gate (B) is 1.0 meters in length.

i.e.

A. **Variable one:** Both rectangular weirs are directly measured in the field and summed.
   1.2 meters + 1.0 meters = 2.2 meters = 7.22 feet
B. **Variable two:** Total daily water volume required by the pond is 4,530,000 gallons, which is an approximated calculation (calculation on page 68).
C. **Variable three:** Since variable one (7.22 feet) and variable two (6.99 ft^3/sec) are known values, connect the two points on the first two axis of the nomograph in Figure 23 and record the extrapolated value on the third vertical axis. In this example, the first vertical axis should be marked 7.22 feet. The second (middle) vertical axis should be marked 6.99 ft^3/second. By connecting these two points with a straight edge the extrapolated value results in 0.41 feet of head of water, which must be allowed to enter the pond over the entrance weir down boards.
   0.41 feet = 12.5 cm
D. In conclusion: the 12.5 cm of water entering over the entrance weir gate down boards over a 24-hour period results in:
   12.5 cm x 24 hours = 300 cm of water in a 24-hour period.

Three hundred centimeters of water is significantly less than that obtained in the previous example, which is a direct function of the length (width) of the weir gates. In this example, there is 120 percent more weir length going into a pond with the same volume of water. Notice that the actual required volume of water did not change in variable two as compared with variable two in the previous example.

In the example shown on page 74, assume the measured data in a pond with two entrance weir gates. The respective interpolated data for the odd hours that were not monitored would be that shown in the example.

Date ______________________
Hours Taken ______________________
Number Pumps Working ______________

Spring Tide ❑
Neap Tide ❑

Pond	O_2	Density Per Ha.	Weight Gr.	C.M. Required	C.M. Actual	Percent Required	Water Transp.	Water Level	Action	Pounds Urea	Pounds PO_4	Dead Shrimp

Observations: ______________________

Supervisor ______________________
Administrator ______________________

Figure 26. Daily Water Management Summary Sheets

	Gate	0600	0800	1000	1200	1400	1600	1800
Actual	A	2.0	5.0	12.0	10.0	7.0	5.0	0
Measurement	B	0	6.0	10.0	10.0	5.0	3.0	0

	Gate	0700	0900	1100	1300	1500	1700
Interpolated	A	3.5	8.5	11.0	8.5	6.0	2.5
Measurement	B	3.0	8.0	10.0	7.5	4.0	1.5

The sum total over a 12-hour period should be calculated for each weir gate as was done in the previous example for a pond with only one entrance gate.

ie:

Gate A:2+3.5+5+8.5+12+11+10+8.5+7+6+5+2.5 = 81 cm

Gate B : 0+3+6+8+10+10+10+7.5+5+4+3+1.5 = 68 cm

Since the individual entrance weir lengths (width) were summed in variable one, mathematically this excercise treats the pond has having "one" entrance gate, not two; thus the sums over 12 hours are averaged together (81+68/2) resulting in 74.5 cm. This value represents the sum over 12 hours and must be multiplied by 2 for the 24-hour period value (74.5 x 2 = 149 cm).

The pre-determined total requirement of 300 cm represents 100 percent of the daily requirement. Dividing the measured total for the day by the daily requirement and multiplying by 100 results in the percentage of the water requirement that was actually introduced into the pond on this given day.

149 cm actual ÷ 300 cm required x 100

is 49.7 percent of the required value.

As stated earlier, the required value represents 13.4 percent water exchange rate by volume, the actual water volume can be easily determined

49.7 percent x 13.4 = 6.6 percent actual volume exchange for that day.

The same mathematical concept pertains in the unlikely event that a given pond contains three active entrance weir gates.

Entrance weir gate down boards can be constantly manipulated (installed or removed) to control the amount of water actually entering the pond. Any changes in down boards should be registered in the Daily water management summary sheet's column headed "Action Taken."

In-progress pond water allowance

In the previous three sub-sections, water requirements have been treated as if all ponds were to be treated equally in terms of daily water exchange. In reality this should not be the actual strategy.

Under normal, routine conditions with optimal growth response and no apparent problems in terms of water quality, the water allowances per individual pond should be determined according to the respective biomass carried by the pond during the different stages of the culture cycle. This strategy allows minimal water exchange for ponds recently stocked and carrying less biomass, while ponds that are approaching terminal harvest and carrying increased biomass will have priority and receive significantly more water exchange on a daily basis.

Although every farm has a different daily water exchange capacity, for simplicity's sake, this manual assumes that the daily water exchange capacity is 13.4 percent, representing 100 percent of the requirement. This value then becomes standard and may be used as the valid basis for water exchange percentages for any given day for that particular pond.

The above described management criteria may be used as a general guideline to relate water exchange

Table 6. Minimum water management allowances expressed as percentages of the requirement for different weight ranges and culture densities.

Population Weight range	Culture Density 50-70,000 x ha.	71-85,000 x ha.	86-100,000 x ha.	101-120,000 x ha.
0.6 - 4.0 g	30%[a]	30%	50%	50%
4.1 - 10.0 g	40%	50%	70%	70%
10.1 - 15.0 g	60%	70%	90%	90%
15.1 - 23.0 g	110%	110%	120%	150%

[a]Based on the concept that 100 percent of the requirement is equal to a water volume exchange rate of 13.4 percent per day.

to the standing biomass of a particular pond. At different stages of the culture cycle and at different stocking densities, Table 6 can be used as a management tool for regulation of water allowances for ponds "in progress."

As an example, a particular pond requiring 528 cm of water in a 24-hour period, as in the previous section whose resident population average weight is 7.80 grams at a culture density of 74,000 juveniles per hectare would require 50 percent of the total requirement or:

50 percent x 528 cm required = 264 cm of water.

This requirement accounts for approximately 6.7 percent water exchange volume in the pond for that given day. To regulate water exchange rate, entrance weir gate down boards should be installed or extracted according to need.

Water management exercises described in these sections reflect a very dynamic program. The extraction of one 20 cm down board at one end of the farm will affect all the ponds on the farm by diminishing the amount of water entering the ponds. As a result, monitoring should be performed at daily intervals, and major changes in down boards should be limited so as not to upset established routine equilibrium expressed in Table 6. In the event of emergencies due to deterioration of water quality *all efforts* should be made to direct *priority water* exchange to the particular pond experiencing problems.

In the future, all water management criteria, or measures taken due to particular situations in ponds "in progress" will be defined in terms of water allowance percentage requirements, assuming that 100 percent of the requirement is equal to a 13.4 percent daily water exchange.

Weir Gate Monitoring

Weir gates have two distinct purposes; (1) to exclude predators from the pond, and (2) to keep the resident shrimp population within the pond. Both of these objectives should be achieved while, at the same time, allowing water to freely enter and exit on a continual basis. Therefore, not only should all filter screens be continually kept clean but all weir gates should be routinely monitored to maintain proper operating conditions during the entire culture cycle. This reguires regular daily inspections to confirm that all screen and boards are in their respective and proper sequence.

Filter screens should be meticuously examined at weekly intervals, and repaired or replaced if damaged.

Weir board configuration

Water pressure through weir gates may cause gate boards to shift in position from their standard setting (Figures 1, 2 and 3), resulting in the improper channeling of flow and inefficient exploitation of weir gate design.

At daily intervals, the farms' technical staff should

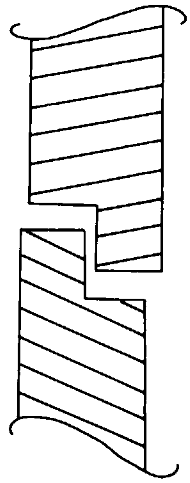


Figure 27. The correct positioning of tongued and grooved gate boards.

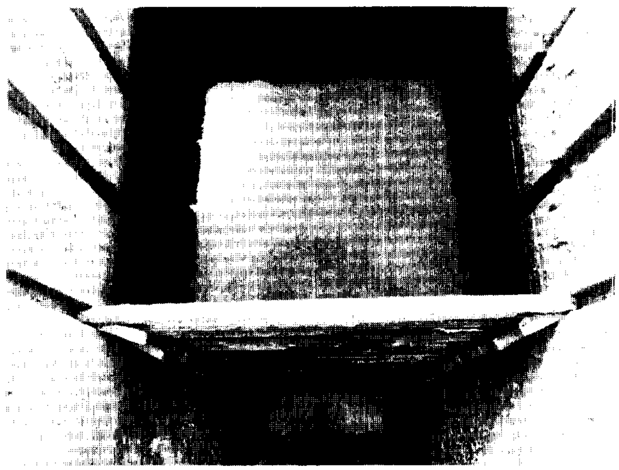


Plate 61. Angle insert wedges applying pressure on weir down boards against concrete slide channels on gate.

Plate 62. Rotten weir gate down board past the point of repair.

Plate 63. Empty feed bags positioned in weir gate slide channels to prevent water from filtering through borders.

Plate 64. Farm filter screen cleaner making his daily rounds.

confirm that the proper board sequence is maintained. Possible alteration of the wedges in boards may cause a shift, allowing water to filter between boards.

Boards should be tongued and grooved so that filtration between them is reduced. Figure 27 depicts proper positioning of tongued and grooved boards.

The chalk and animal lard sealant mixture should be applied between the tongues and grooves to ensure a proper seal. Wedge inserts are important to maintain pressure against the weir gate slide channels (Plate 61). If wedges are accidently dislodged, boards may slightly buckle and break seal, allowing water to pass between them.

Restriction boards should be routinely inspected to ensure that pond water level is below the top edge. The primary objective of restriction boards is to draw water from the bottom. If water is allowed to pass over the top, the configuration will not operate as designed. Precautions should be taken to allow sufficient freeboard over the ponds' operational water level to prevent this. Generally, 20 to 30 cm of freeboard on restriction boards will be adequate.

Weir gate boards should be made from hardwoods, such as mangrove, which is naturally resistent to marine worm infestation and deterioration caused by exposure to salt-water. All boards should be periodically inspected for rotting and broken grooved edges (Plate 62). Boards should be replaced whenever deterioration prevents proper sealing.

All boards that are not being used in the weir gate should be neatly stacked alongside, readily accessible when board changes are necessary.

Weir screen configuration

Weir gate filter screens are key components of entrance and effluent gates. Improper placement or maintenance of filter screens may let predators into the pond or allow the escape of the shrimp.

The technical staff should inspect filter screens daily to ensure that they are snug and in proper position, and that empty feed bags are correctly positioned between the screen's wooden frame and the weir gate's concrete slide channels (Plate 63).

These empty feed bags prevent water from filtering through around the edges of weir gates, and are very effective when pressure is applied by the wedges.

A consciencious effort should be made by the technical staff to supervise and direct farm personnel who have been delegated the responsibility of maintaining the filter screens. Pond filter cleaners should be responsible for a specific number of weir gates, and should have established cleaning routes, never exceeding 1,000 meters "one-way."

Distances greater than 1,000 meters are not recommended, as they do not allow personnel enough time to clean all of their filters well (Plate 64).

The primary objective of pond filter cleaners is to maintain the filter screens, clean and free of debris. Personnel should be instructed to report observations to the technical staff whenever they observe plugged filters inhibiting the flow of water. In this case, routing should be altered to permit more frequent cleaning per station.

Maintenance of clean filter screens during early stages of the pond culture cycle requires more frequent cleaning because finer mesh screens are employed. It may be necessary to increase the number of screen cleaning personnel to maintain unrestricted water flow into ponds with shrimp populations averaging 4.0 grams or less.

All water control management decisions should be assumed by one person, preferably the farm biologist or a responsible person designated by the biologist. No one, without authorization, should be allowed to manipulate or effect changes in boards or filter screens in any weir gate. As was described previously, farm hydraulics are dynamic, and slight changes in one gate may affect the hydraulic balance of the entire farm.

An empty feed bag should be hung near each weir gate (Plate 65), and all dead shrimp found during the course of the day by the screen cleaners should be collected and placed in these bags.

At the end of each day, the technical staff should collect, count, record and discard daily mortalities for each pond. Mortalities for each pond should be recorded on the growth sample monitoring sheets (Figure 13) at week's end. Periodic daily tallies of between 5 and 15 collected mortalities can be considered normal. If the daily count exceeds 15, water parameters should be evaluated and re-confirmed, to ascertain the possibility of significant mortalities.

Feeding Strategy

Pelleted feeds are necessary for proper growth at stocking densities above 6.5 juveniles/m^2.

There is much controversy regarding the percentage of feed actually assimilated by the shrimp population. It is supposed that shrimp ingest the pellets for a relatively short time after the feeding and then they begin to decompose. After decomposition begins, it is assumed that shrimp benefit nutritionally from the bacteria and benthic organisms that break down the pellets into detritus.

As shrimp forage the bottom, they should be able to consume enough nutrients to support productive growth. The 30 to 60 percent of the unconsumed, decomposing pellets estimated to remain on the pond bottom serve as an excellent substrate, which stimulates the growth of bacteria and invertebrates such as copepods, nematodes and protozoa.

Feeding frequency

The majority of well-constructed semi-intensive commercial growout ponds have an average water

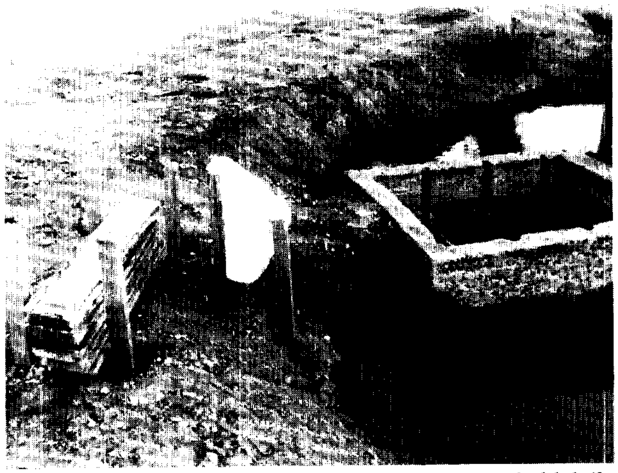


Plate 65. Empty feed bags at effluent weir gates to hold daily mortalities.

depth of 1.0 meter. From a technical viewpoint, the deeper the pond, the better the shrimp survival rate, however, deeper ponds require increased earth movement resulting in increased capital outlay during construction.

Since commercial production ponds are relatively shallow, shrimp activity during the day is significantly reduced. During this time, it appears that the population migrates to deeper areas of the pond and partially burrows into the bottom. Thus, day time feeding results in poor feed utilization efficiency. Feeding during periods of increased activity results in better utilization of the feed with subsequent superior conversion.

Shrimp activity in a pond increases at around 1700 to 1800 hours (5 p.m. to 6 p.m.), and persists until 0600 or 0800 hours (6 a.m. to 8 a.m.). The level of activity can be monitored by observing capture frequency, or water turbidity. During the daylight hours, very few animals will be captured by the cast net; and if the population is actively foraging for food, this activity will result in suspension of benthic sediment and can be observed from the bank. Care should be taken to not confuse this turbidity with that caused by wind and wave action.

Probably the most efficient utilization of feed would be by applying rations at more frequent intervals throughout the night when shrimp activity is highest. In large commercial operations, this strategy is not always practical. Since feed is a major expense item, attempts should be made to rigidly supervise its use. Such supervision is very difficult to accomplish due to limited night visibility.

It is far more practical to feed once per day during late evening hours. Feeding should begin no earlier than 1600 hours (4 p.m.), and, with an adequate number of personnel, should be terminated by 1800 hours (6 p.m.). Evening feeding will ensure that the pellet (with a stability of 6 to 10 hours), remains intact for ingestion by the shrimp until midnight, and it will then be indirectly available as detritus for the remainder of the night when shrimp activity is high.

Feed dispersal

Feed dispersion is extremely important. Pellets should be dispersed uniformly over the entire pond area, minimizing crowding-induced stress.

Different feed dispersal strategies have resulted with variable degrees of success. Aerial feed application results in exceptionally uniform coverage over the entire bottom area of the pond and is probably the best for this specific reason; the limiting factor is the expense. This technique is probably not economically feasible for growout operations of less than 300 to 500 hectares.

Land based feed blower equipment cannot disperse feed over the entire surface area of typical commercial size (250 x 400 m) growout ponds. The same blower apparatus mounted on platform boats may work efficiently but may require many units. Although labor intensive and relatively inefficient, manual feeding from boats which navigate in a zig-zag pattern over the entire surface area of the pond as described in Chapters 8 and 10 is the most commonly used method. There must be a conscientious effort to ensure that the entire bottom area receives feed regardless of the daily dosage of a particular pond.

Feed ration tables

There are a multitude of feed ration tables that can be used to calculate the quantity of feed needed for any given pond. The amount of feed required is generally determined as a percent per day of the average weight of the shrimp population to be fed. A juvenile shrimp will generally be fed a relatively higher percentage of its average body weight per day than a larger animal.

The determination of daily feed rations should not be strictly the result of a pure mathematical formula calculation. The objective of published feed ration tables is to supplement the pond nutrients to support productive and optimal shrimp growth. There are a variety of factors which directly affect the growth performance of a population of shrimp. Other than introduction of a pelleted feed into the pond, such factors as average water temperatures, stocking densities and biomass as well as the primary and secondary biomass carrying capacity (phyto and zooplankton) of the pond will all influence the growth performance of the population. Poor water quality and resulting stress induced from toxins also plays a determining role in the shrimp's ability to actively feed and efficiently convert nutrients into growth.

Since the accurate determination of feed rations is relatively subjective in semi-intensive commercial operations, it should be calculated by experienced personnel. Feed should be used conservatively since it represents a large portion of total production cost and is a potential pond environment pollutant. Poor management practices, such as overfeeding, may result in contamination of pond bottoms. Increased biological oxygen demand (B.O.D.) and low D.O. may result in shrimp temporarily going "off feed." If low levels of D.O. persist, mortalities may occur.

Table 7. Feed ration determination per body weight for postlarvae and juveniles stocked in nursery ponds at 150-200 postlarvae/m^2.

Juvenile Average weight (gm)	Percent of Body Weight fed per Day
0.15 g.	19.00
0.20	17.80
0.25	16.30
0.30	15.00
0.35	13.70
0.40	12.30
0.45	10.90
0.50	9.90
0.55	9.20
0.60	8.60
0.65	8.20
0.70	7.80
0.75	7.50
0.80	7.30
0.85	7.10
0.90	6.90
0.95	6.70

Long term detrimental effects of "overfeeding" will result in build-up of hydrogen sulfide in anaerobic pond sediment. This may cause increased mortality or cause shrimp to go "off feed" for an extended period. The result of poor feed management might also manifest itself during the next crop, causing poor survival rates. Additionally, large areas of the pond bottoms may have to be chemically oxidized to eliminate hydrogen sulfide.

At the other extreme, underfeeding may result in reduced growth rates and increased mortality resulting from stress or secondary infections.

Feed ration tables have been developed based on the results of high-performance operations: (1) for nursery ponds, (2) for growout ponds, and (3) growout production ponds stocked directly with postlarvae (see Tables 7, 8 and 9, respectively).

Effective utilization of these tables depends upon the accuracy of population estimates and body weight calculations since feed ration tables are expressed as a percentage of body weight per day. Tables 10, 11

Table 8. Determination of feed ration per body weight for growout ponds stocked with transferred juveniles at 6.5-9.0 juveniles/ m^2.

Average weight (gms)	Percent of body weight fed per day
1.00 g.	6.00
1.50	5.33
2.00	4.83
2.50	4.50
3.00	4.23
3.50	4.00
4.00	3.80
4.50	3.60
5.00	3.43
5.50	3.30
6.00	3.20
6.50	3.00
7.00	2.93
7.50	2.83
8.00	2.76
8.50	2.70
9.00	2.66
9.50	2.63
10.00	2.57
10.50	2.50
11.00	2.43
11.50	2.40
12.00	2.33
12.50	2.27
13.00	2.23
13.50	2.16
14.00	2.10
14.50	2.06
15.00	2.00
15.50	1.96
16.00	1.93
16.50	1.90
17.00	1.87
17.50	1.83
18.00	1.80
18.50	1.77
19.00	1.73
19.50	1.70
20.00	1.69
20.50	1.66
21.00	1.66
21.50	1.60
22.00	1.59

Table 9. Determination of feed ration per body weight for growout ponds stocked direct at 12.5-18.5 postlarvae/ m^2.

Average Weight (gm)	Percent of Body Weight fed per Day
0.008 g	7 lbs/ha/day
2.0 g	7 lbs/ha/day
2.0 g	5.50 %
2.5	5.00
3.0	4.65
3.5	4.42
4.0	4.22
4.5	4.05
5.0	3.90
5.5	3.75
6.0	3.60
6.5	3.45
7.0	3.27
7.5	3.15
8.0	3.00
8.5	2.90
9.0	2.85
9.5	2.77
10.0	2.75
10.5	2.65
11.0	2.63
11.5	2.60
12.0	2.55
12.5	2.51
13.0	2.50
13.5	2.45
14.0	2.41
14.5	2.40
15.0	2.30
15.5	2.26
16.0	2.25
16.5	2.20
17.0	2.19
17.5	2.15
18.0	2.10
18.5	2.05
19.0	2.00
19.5	1.98
20.0	1.95
20.5	1.90
21.0	1.88
21.5	1.86
22.0	1.80

Table 10. Estimated survivals per age and weight groups in nursery ponds.

Days	Average Weight (gms)	Percent Survival
1	0.01 gms	100 %
7	0.09 gms	80 %
14	0.18 gms	78 %
21	0.35 gms	75 %
28	0.60 gms	73 %
35	0.80 gms	70 %

and 12 express estimated survivals as a function of average weight and time in days.

The calculation of daily feed ration must incorporate data from two tables. For example:

Pond x has been stocked with juveniles at 85,000 juveniles per hectare (8.5 juveniles/m^2). The average weight of the population is 9.50 grams. Since the pond has been stocked with juveniles, one should refer to Tables 8 and 11, and perform the following calculation:

1. $\frac{85{,}000 \text{ juveniles}}{\text{has.}} \times 80.5\% \text{ survival*} = \frac{68{,}425 \text{ juveniles surviving}}{\text{has.}}$
2. $\frac{68{,}425 \text{ juveniles}}{\text{has.}} \times \frac{9.5 \text{ gms}}{\text{juveniles}} \times \frac{1 \text{ kg}}{1{,}000 \text{ g}} = \frac{650 \text{ kg juveniles}}{\text{has.}}$
3. $\frac{650 \text{ kg juveniles}}{\text{has.}} \times \frac{2.63\% \text{ body weight feed**}}{\text{has.-day}} = \frac{17 \text{ kg feed}}{\text{has.-day}}$

*Table 11; average weight of population between 9.00 and 9.93 grams.

**Table 8; ratio of daily feed to body weight when average weight of population is 9.50 grams.

Therefore pond x should receive 17 kg of feed per hectare of surface area every day.

Once the feed ration has been obtained, it is necessary to ascertain if average weekly weight gains are adequate. Gains of between 0.85 and 1.20 grams, are adequate, but if the average weekly weight gains are below 0.70 grams, there is a possibility that the pond is being underfed as a result of better survival or an "overstocking" error, which would lead to an undercalculation of feed rations.

On the other hand, if average weekly weight gains are between 1.3 and 2.0 grams, the staff should be alert to the possibility of "overfeeding" as a result of lower densities than those estimated.

Feed ration calculations should be performed on a weekly basis for all ponds in an attempt to efficiently monitor shrimp growth and feed conversion. Poor feed management may not only affect growth and survival, but also significantly increase production costs. If feed ration calculations are performed bimonthly, the risk of poor management problems is increased.

Table 11. Estimated survivals per age and weight groups in growout ponds stocked with transferred juveniles

Days	Average Weight (gms)	Percent Survival
1	0.80 gms	100
7	1.20	90
14	1.80	89
21	2.70	88
28	3.60	87
35	4.50	86
42	5.40	85
49	6.30	84
56	7.20	83
63	8.10	82
70	9.00	81
77	9.93	80
84	10.90	79
91	11.80	78
98	12.73	77
105	13.67	76
112	14.60	75
119	15.53	74
126	16.46	73
133	17.40	73
140	18.33	73
147	19.26	72
154	20.20	72
161	21.13	71
168	22.10	71
175	23.00	70

When calculating feed rations for juveniles in nursery ponds, Tables 7 and 10 should be utilized. Feed rations for production growout ponds that have been stocked directly are determined from Tables 9 and 12.

Feed characteristics

There are many feed formulas that can be utilized throughout the various phases of a growout cycle. The following general guidelines on their nutritional composition will help to establish their different uses.

The presentation called "crumbles" and the small pellet (3/32") used during early juvenile and juvenile stages permit adequate feed coverage over the entire pond area since there are more individual pieces per kilogram.

Most pelleted feeds for shrimp are relatively expensive and brittle. Bagged feed should be handled with care to minimize "fines" (or dust) formed by breakage and abrasion. Caution should also be exercised not to expose pelleted feed to chemicals or poisons which may be utilized for control of rodent populations.

Feed quality check

When purchasing feed, it should be checked by the technical staff to ensure quality as poor quality feed pellets may result in growth inhibition and deterioration of pond bottoms.

Random samples from all feed entering the feed storage area should be organoleptically evaluated for excessive moisture and the presence of mold. If arriving feed is moist but not contaminated by a greenish-brown mold, it might be assumed that the excess moisture was acquired during transport. In this case, the moist feed should be used immediately. If wet feed is stored, it becomes contaminated by mold and will have to be discarded. Any mold-contaminated feed arriving directly from the feedmill should be returned within 24-hours. Feed pellets with surface mold should not be used in the ponds.

The farm's feed storage facility should employ inventory rotation to ensure "first in-first out."

A vigorous rodent control program should be continuosly practiced in feed storage facilities, but always with caution, to avoid contamination of feed. Maintaining female cats or non-poisonous constrictor snakes in and around feed storage facilities may help diminish rodent population.

Table 12. Estimated survivals per age and weight groups in direct-stocked growout ponds.

Days	Average Weight (gms)	Percent Survival
1	0.01 gms	100.0
7	0.12	90.0
14	0.25	85.0
21	0.50	83.0
28	1.20	80.0
35	2.10	78.5
42	3.02	77.0
49	3.93	75.6
56	4.83	74.2
63	5.75	72.7
70	6.65	71.3
77	7.56	69.8
84	8.47	68.3
91	9.38	66.9
98	10.28	65.4
105	11.20	64.0
112	12.10	62.5
119	13.00	61.0
126	13.92	59.6
133	14.83	58.1
140	15.73	56.7
147	16.64	55.2
154	17.55	53.8
161	18.46	52.3
168	19.37	50.8
175	20.28	49.4
182	21.18	47.9
189	22.10	46.5
196	23.00	45.0

Table 13. Feed characteristics specific for target shrimp weights.

Formulas	Early Juvenile	Juvenile	Growth	Finish
Target size of shrimp (gms)	0-0.35 gms	0.35-4.0 gms	4-18 gms	18-23 gms
Ration format	crumbles.	pellet	pellet	pellet
Ration size (inches)	crumbles	3/32"	5/32"	5/32"
Percent Protein	35	35	25	20
Percent Lipid	8	8	6	5
Percent Fiber	3	3	4	3
Percent Ash	7	7	7	6
Percent Humidity	10	10	10	10
Gross Energy (Kcal/Kg)	3,500	3,500	3,200	2,800

Feed should not be stacked directly on the warehouse floor, but on wooden pallets in organized rows. This permits adequate ventilation which minimizes heat build-up and moisture accumulation.

Random samples should be taken from arriving feed weekly and analyzed for water stability and percent floatation as follows:

1. Drop a random handful of pellets into a 20 liter bucket containing 10 liters of pond water.
2. Roughly estimate the percentage of floating pellets after one minute.
3. At two-hour intervals, evaluate pellet stability until they have disintegrated or have been submerged for six hours.

The pellet stability evaluation should be performed using a 1-10 scale, where 10 represents a hard, intact pellet, and 1 represents total disintegration. After the first two hours the evaluation period can be reduced to every hour. The test is highly subjective, therefore the same person should perform the test.

Four times per year, pellet samples should be sent to independent analytical laboratories for proximate analyses. Results should be compared to with the corresponding values given by the feedmill to confirm that proper standards are being maintained.

The farm should purchase feed from an established feedmill with adequate references. The protein percentage in proximate analysis is measured indirectly and is based on total nitrogen content of the diet. Nitrogen content is multiplied by a conversion factor of 6.25, which results in the estimated crude protein level. It is possible to find "high protein" pellets on the market that contain no actual protein since inclusion of nitrogenous products such as urea can be erroneously interpreted as protein in the proximate analysis. This further stresses the importance of buying feed from reliable sources.

Predator Control

Potential losses due to aquatic bird predation in ponds have been previously discussed in Chapter 9. Farm management policy concerning predator control should be in agreement with local laws and regulations. Here predator control is discussed assuming non-existence of regulations protecting aquatic birds.

There are several types of "humane" equipment commercially available for protection of production ponds from aquatic birds. Pneumatic discharge cannons, light reflectors, scarecrow windmills, etc., all are relatively ineffective after the initial display, for most aquatic birds are adaptive and become readily accustomed to noise or visual stimuli produced by this equipment.

The technique of a stretched wire grid over the ponds surface area may be effective for small ponds and small operations, but is cost prohibitive in large scale semi-intensive operations.

Pre-recorded bird distress calls played on tape and amplified over loud speakers mounted on a truck have had limited success. This technique may be impractical as it requires continual utilization of a farm vehicle that might be more efficiently employed in other activities.

The most effective proven technique against bird predation is deployment of farm personnel armed with shotguns and explosive rockets. For this technique to be effective, farm personnel must continually and agressively pursue flocks of birds from pond to pond.

In larger growout ponds, birds may fly from corner to corner to avoid the noise of shotguns and rockets. In this case, it may be necessary to employ two or more groups of rotating, armed personnel to discharge arms simultaneously in respective corners to displace the birds effectively.

Aquatic predators such as fish and crabs can be effectively controlled by following the pond preparation procedures outlined in Chapter 3. Correct pond preparation will result in very little contamination of the pond by fish and crabs.

Nursery ponds or production growout ponds that have been stocked directly with wild postlarvae generally contain an increased number of predators that have been stocked along with the shrimp. It is extremely difficult, if not impossible, to manually extract the larval stage predators from the wild postlarvae.

At the farm's acclimation station, natural predators can be eliminated by the application of chemicals such as rotenone to the water containing the postlarvae and predators. For this technique to be effective, the exact volume of water must be calculated prior to chemical treatment in order to determine the quantity of rotenone accurately that must be applied to achieve the desired concentration. Rotenone, if used properly, will effectivelly eliminate fish larvae without affecting shrimp postlarvae.

The following is a procedural outline for correct determination of rotenone concentration of 2 ppm:

1. Accurately measure the water volume contained by the transport tank delivering the wild captured postlarvae. Use the following mathematical equation for volume determination:
   a. Rectangular containers:
   $$\frac{\text{Length (cm)} \times \text{width (cm)} \times \text{depth (cm)}}{1000} = \text{liters}$$
   b. Cylindrical containers:
   $$\frac{3.14 \times \text{diameter}^2\ \text{(cm)} \times \text{depth (cm)}}{4 \times 1000} = \text{liters}$$
2. Weigh 0.002 gram of rotenone for every liter of water containing postlarvae. A water volume of 500 liters will require 1.0 gram of rotenone. This dosage will result in a concentration, by weight, of 2 ppm. Although most rotenone is only 5 percent active, this concentration is sufficient for fish larvae elimination.

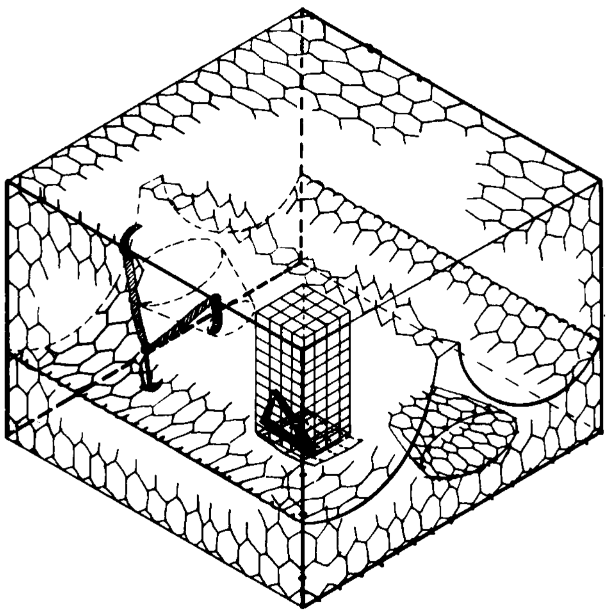


Figure 28. Structural dimensions of typical crab traps for predator control in ponds receiving wild-captured, direct-stocked postlarvae.

3. Once postlarval counts have been performed, the shrimp can be transferred to the acclimation tanks and the acclimation process should be initiated.

Blue crabs are effective predators of shrimp and their elimination is characteristically more difficult. Crabs are attracted to moving water currents that allows them the advantage of food organisms being transported to them. As a result, crabs are generally observed in entrance and effluent weir gates. All personnel who have been assigned to filter cleaning should be instructed to remove blue crabs with dip nets. These crabs will generally attach themselves to the cement walls of the weir gates or directly to the filter screens, awaiting prey. Although this maintenance technique helps diminish damage caused to filter screens at weir gates by blue crabs, it does not significantly reduce the blue crab population in the pond.

In order to help eliminate the blue crab population within the pond, benthic crab traps should be implemented. Figure 28 is a line drawing depicting typical crab traps.

These crab traps should be constructed of saltwater-resistant hardwood slats with an entrance tunnel made of 10 cm PVC pipe approximately 15 cm long. A perforated platic container tied inside the trap is for bait of raw fish scraps. The trap functions on the premise that the crab will enter the trap through the PVC pipe, seeking the bait. Since crabs are benthic, they will attach themselves to a substrate (either trap bottom or walls) and as a result will not escape through the 15 cm long PVC pipe. This crab trap design is successfully employed in all parts of the world by commercial crab fisheries.

Crab traps should be placed in all nursery or production growout ponds directly stocked with wild postlarvae. One trap should be placed for every two hectares of pond surface area, or a minimum of two traps per pond in smaller nursery ponds.

Traps should be equally concentrated around the entrance and effluent weir gates at a radial distance of no more than 15 meters from the weir gate. These traps should be inspected three times per week to harvest crabs and to replace the bait.

The potential risks of predation on the shrimp population in a pond are magnified during operations such as juvenile transfers and pond harvests. It is especially important to increase the number of personnel assigned duties of predator control during these two critical stages, while the shrimp population is vulnerable due to low water levels.

If relatively large numbers of birds are observed flying over one specific pond during the day, it should be cause for alarm. This may indicate that shrimp are swimming on the surface due to low D.O. The D.O. should be checked immediately, and if it is low, then immediate action should be taken to increase the water exchange rate by emergency measures. The use of 15 or 20 cm auxilary pumps may be necessary. Predator control personnel should be stationed along the dikes of the problematic pond to discourage bird predation. The D.O. concentration should be measured at hourly intervals until it is back to satisfactory levels.

Over a period of months, the farms reservoir canal will often acquire a substantial number of fish that have entered the canal in egg or larval stages via the water pumps. These grow rapidly within the protected confines of the canal, and, although they may not be able to enter the ponds as a result of proper weir controls, they may easily reach spawning age. Fish spawning in the reservoir canals pose significant problems as the eggs may pass into the ponds through the mesh of filter screens.

A practical method for controlling endemic fish populations of the reservoir canal is to establish several fish gill net stations along the canal. Gill nets with 8 to 10 cm mesh should be strung across the entire width of the reservoir canal. Lead lines should lie on the contour of the canal bottom and floats should hold the net on the surface. The depth of the gill net should be 1.5 times the depth of the canal. At least one gill net should be located near the pump station (50 meters distant) since fish will be attracted to incoming fresh, oxygenated water. Other gill nets can be placed at strategic locations along the reservoir canal. Nets should be harvested daily and continually mended to ensure that they remain in optimal functioning condition.

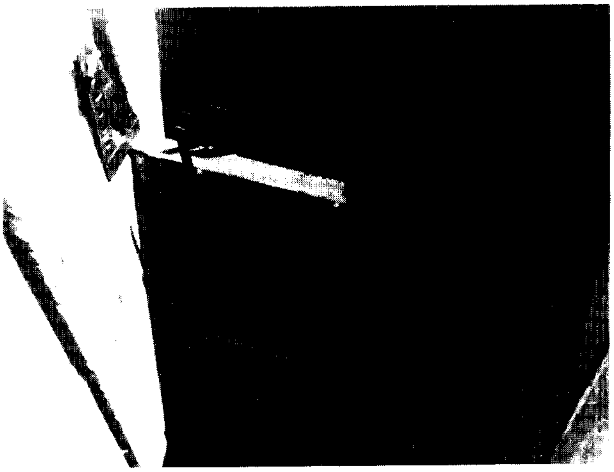


Plate 66. Steel-plated locking mechanisms for effluent down board security against theft.

Theft control

Due to socio-economical conditions surrounding the farm site, human theft may cause significant losses to the farm. The majority of losses due to theft can be prevented by implementing basic security measures.

Well-armed guards should patrol the farms perimeter on a regular basis during the night. Enough guards should be on duty to ensure that any specific area on the farm is patrolled at least every hour.

Patrolling guards should make their rounds in pairs and have a pre-established methods of communicating with the other guards. This should be by either flashlight codes or by radio communication at specific checkpoint stations around the perimeter. Night shift supervisors should ensure that guard duty is effectively being carried out.

If theft activities continue to cause losses, all effluent weir gate boards and filter screens may be locked down during the night with steel plated locking mechanisms and heavy duty paddlocks (Plate 66).

Some farms are more accessible by roads or water routes than others, necessitating increased diligence in the area of farm security. Undoubtedly, with adverse socio/economic conditions so prevalent in third world countries, ponds with an inventory of a product as valuable and as marketable as shrimp run high risks of loss from poaching.

Armed night guards should patrol sectors of the farm where ponds have the larger shrimp, concentrating on protection of strategic areas versus attempting to cover all areas. During harvesting activities, additional guards should be assigned to protect ponds that are more vulnerable to poaching while being drained. As product is being iced down for shipment to processing plant, adequate protection should be provided in areas of pack-out and loading of trucks or boats. Radios should be employed if possible, and if radio communication isn't possible, signals between guards can be used: pre-established flashlight codes, or the firing of a pre-determined number of shots to indicate any problems and sound the alarm.

As routine operations start each morning, personnel entering different areas of the farm to carry out their various duties should always be alert for signs of abnormal activities during the previous night that may indicate poaching, *ie*:

1. slight reductions in water levels of ponds,
2. footprints in or around effluent weir gates,
3. wet dikes, especially on drainage end of ponds,
4. dead shrimp along or near water's edge, or in the vicinity of effluent weir gates or in drainage canals, and
5. deviations from normal arrangement of weir boards or screens.

When evidence of poaching is observed, and if the night guards shift reported no abnormalities in routine, additional personnel should be assigned for several consecutive nights to bolster the security force. It is not uncommon for shrimp farms to sustain armed assaults because of the relatively high value of product. The key to a reliable security program is attention to detail. Night guards should be continually checked to be sure that they are on duty at their assigned positions, and that they are alert, their weapons cleaned and ready with proper ammunition.

It is suggested that guards be frequently rotated from one position of the farm to another, without prior knowledge of assignment, in order to minimize collusion with outsiders interested in theft, or offering bribes to be allowed to steal.

Hydrological Parameters

The single most critical factor governing optimal growth and survival of shrimp is water quality. All activities of the shrimp are affected by the pond's physical conditions, and optimal shrimp production is directly correlated to optimal management of hydrological parameters more than any other factor. Likewise, poor performance, in many cases, can be directly attributed to poor water quality. Consequently, meticulous monitoring of water parameters is a must for good management.

Routine daily monitoring of water parameters is important in determining a management position on water exchange as well as feeding and fertilization strategies for ponds under culture.

There are three primary elements involved in correctly monitoring water quality parameters:

1. Accurate calibration and operation of the relatively sophisticated electronic monitoring equipment;
2. Monitoring of water quality parameters in ponds at critical times during the day to detect possible problems; and

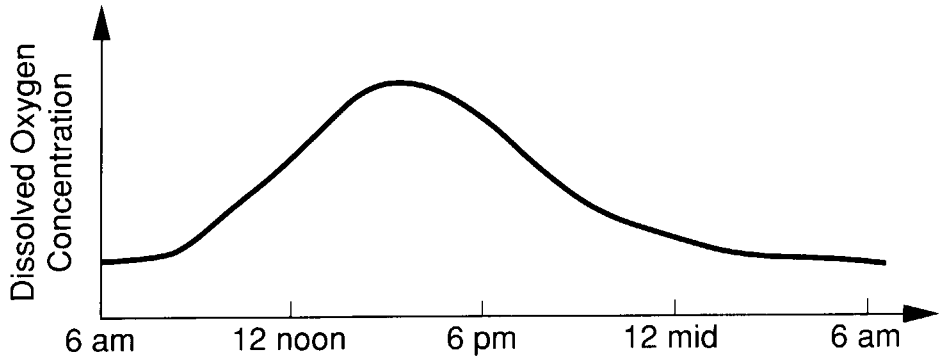


Figure 29. Typical diurnal D.O. concentration in pond water during 24-hour cycle.

3. Monitoring water parameters where the population actually resides on the pond bottom, and not where conditions may be different, such as at mid-water level or on the ponds' surface.

If any of these three areas are neglected, data and interpretation of the same may not be valid or appropriate, and may result in poor management decisions, as well as decreases in satisfactory pond performance.

As previously discussed, hydrological parameters are monitored twice daily at two independent stations in each pond. Morning measurements should be taken between 0600 and 0830 hours (6 and 8:30 a.m.) while afternoon measurements should be made between 1300 and 1530 hours (1 and 3:30 p.m.).

For monitoring to be most effective and interpretation of results to be most accurate, monitoring should be conducted at these critical times during the day. D.O. and pH measurements are of particular importance. D.O. concentrations are typically at their lowest level prior to dawn and at their highest during mid-afternoon between 1300 and 1600 hours (1 and 4 p.m.). (Figure 29).

Pond water pH follows a diel curve similar to that of D.O. concentration and is directly related to the photosynthetic activity of algae in the pond.

During early morning hours, ponds should be monitored for D.O., pH, water temperature, and salinity. During mid-afternoon, they should be checked for D.O., pH, water temperatures, water turbidity (with a secchi disk) and water level of the pond (with painted triangles, using methods detailed in *Establishing pond operative level*). All data should be promptly and precisely recorded on Daily parameter monitoring sheets (see Figure 12).

Instrument calibration and pond sampling

All equipment should be correctly calibrated and periodically re-calibrated to ensure accurate measurements. Equipment that has not been properly calibrated will give distorted readings.

Water temperature should be monitored during early morning hours and again during mid-afternoon hours for minimum and maximum temperatures for the pond during a given day.

Plate 67. Glass/mercury thermometer in PVC case for protection against breakage and temperature compensated refractometer.

Thermometers of the oxygen meter are not utilized since they cannot be calibrated. Water temperatures should be measured with glass/mercury thermometers with a scale range between 0 and 110°C. This thermometer should be encased in a PVC pipe to protect the fragile instrument from breakage (Plate 67). A line is tied to the PVC protective case and the thermometer is allowed to sink to the bottom of the pond and remain there for approximately 30 seconds before removing it and recording bottom water temperatures.

These thermometers should be adjusted/calibrated at weekly intervals to ensure valid measurements. The thermometer should be removed from its PVC protective case and placed in a pot of boiling fresh water. Any deviation from 100°C should be recorded and the corresponding correction factor should be marked with waterproof marker and plastic tape on the thermometer. For example, if after being submerged for one minute in a pot of boiling fresh water, the glass/mercury thermometer registers 99°C, a correction factor should be established as +1°C. (Note: when making this confirmation caution should be taken to avoid direct contact of the mercury bulb of the thermometer with the bottom of the pot, as this may distort the reading. During the remainder of the week, water temperature readings should be adjusted by a factor of "plus one degree." If the actual measurement registers 28°C, the corrected value recorded on data sheets should be 29°C.

Water salinity is monitored once daily during the early morning. Salinity during normal dry seasons will not vary highly, but during tropical rain storms it can drop as much as 3 ppt in one day. Pond salinity measurements should be taken with automatic temperature compensated refractometers. Refractometers should be calibrated daily with clean distilled water and by simultaneously adjusting the small calibration screw on the instrument. After any adjustment, silicone gel should be smeared on the face of the adjustment screw in order to seal it. Water from the bottom of the pond should always be used for salinity measurements as salinity gradients at times exists in growout ponds, especially during the rainy season when less dense rain water floats and doesn't mix with the deeper pond water. Salinity stratification will cause significant errors if surface waters are sampled. Plastic bottles with rubber stoppers should be lowered to the bottom, opened, closed and brought to the surface for salinity measurements. The same water used for monitoring salinity may be used for measuring pH.

Pond water pH should be measured twice daily. Since pH oscillation cycles, over a 24-hour period, are similar to D.O. concentration curves, monitoring during early morning and again in mid-afternoon will reflect the general minimum and maximum limits over 24 hours. Meters for recording pH should be calibrated twice daily, just prior to the monitoring rounds. There are a variety of meters available and calibration procedures differ according to the type of meter used, some meters require calibration with buffer solution of pH 7 and also a slope calibration with a buffer solution of pH 4. Other meters require calibration with one buffer solution that is nearest in unit value to the average pH of the sample. Since pond water generally has a pH range of 6.8 to 8.5, meters that require one single calibration should be calibrated using a buffer solution with a pH value of 7.

Plate 68. Pocket-type pH meter with corresponding, calibrating buffer solutions.

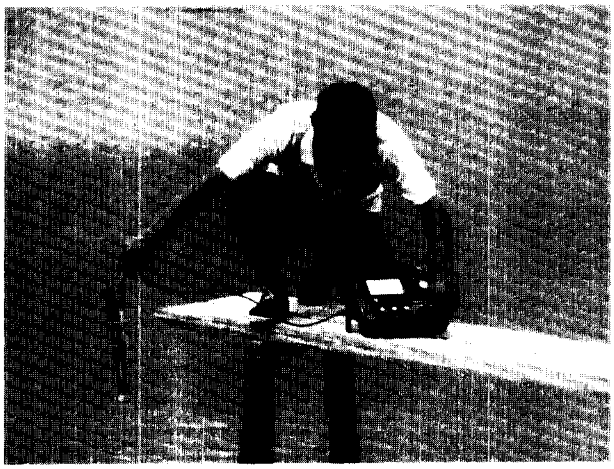


Plate 69. Extension attachment to oxygen probe and cable to ensure bottom sampling.

Pocket/pen type pH meters are reliable for field work. They are light, inexpensive and easy to handle (Plate 68). For proper calibration, the pH probe should be submerged into the buffer solution with pH of 7 and allowed to remain for several minutes for stabilization. By using the small calibration/adjustment screw, the unit can be manually calibrated. The buffer solution should be frequently double checked to ensure a consistent reading as indicated. The solution (buffer 7) generally comes in color yellow. If after a period of time the color fades, the solution should be discarded. The pH 4 buffer solution is red/pink and has similar characteristics. These buffer solutions should be stored in cool, dry, dark places and care should be taken not to contaminate the master bottle. For calibration purposes, a small 50 ml bottle can be filled from the master bottle and used for instrument calibration for four to seven days before discarding and refilling with a fresh solution from the master bottle. Use of this technique will incresase the effectiveness and duration of the buffer solution.

The pH probe should always be stored under humid conditions (100 percent), with a cotton swab saturated with distilled water or buffer solution pH 4 placed in its protective cap. The acidic buffer solution is generally more effective since it limits the growth of mold and bacteria on the glass bulb of the probe that may eventually cause distorted readings. The probe should never be allowed to dry out.

Dissolved oxygen (D.O.) is also monitored twice daily. Although there are a variety of reliable oxygen meters on the market, the Yellow Springs Instrument model 51-B is the easiest to operate in the field.

Calibration procedures should be followed as described in the owners' manual, and the following points should be remembered:

1. The zero and red line calibration checks should be reconconfirmed every 10 readings to ensure that the adjusting dials have not altered.
2. The sea-level calibration should be reconfirmed at every reading. When the meter is not actually monitoring and is being moved from one station to the next, it should be in the "sea-level" calibration mode. Prior to the monitoring of the next station, it will be a straight forward operation to confirm the sea level calibration before changing modes to make a reading.
3. The polarographic probe should be treated with extreme care and kept in a 100 percent humidity environment. The membrane and saturated KCl solution should be changed every 15 days. Daily checks should be conducted to ensure that no air bubbles exist inside the probe cup, under the membrane; if there are any, membrane and solution should be replaced, as air bubbles will distort measurements. Membranes should never be directly touched in the area over the gold circle at the end of the probes.
4. Probe should always be stored with its protective cap (containing a cotton swab saturated with distilled water) in place.

D.O. concentrations should always be measured in the bottom 5 centimeters of the water column. The most effective means of doing this without damaging the polarographic probe by dragging it along the bottom is to attach the probe and cable to a 2-meter long stick. Allow the stick to protrude 5 cm past the end of the probe, taping probe and cable along the length of the stick with electrical insulating tape (Plate 69). When conducting readings, lower stick into the pond until the end touches the pond bottom, then slowly move laterally back and forth. D.O. readings should be made at minimum water depth of 60 centimeters.

Water turbidity is measured in centimeters utilizing the common secchi disk. The vertical handle of the secchi disk is marked off at 5 centimeter intervals and also 2 centimeter intervals. The disk has a 30 centimeter diameter and is painted a sharply contrasting black and white at the four quadrants (Plate 70). By lowering the disk into the water vertically until it cannot be seen and slowly bringing it up while simultaneously twirling it back and forth until it is visible one measures the vertical distance of visibility commonly called turbidity.

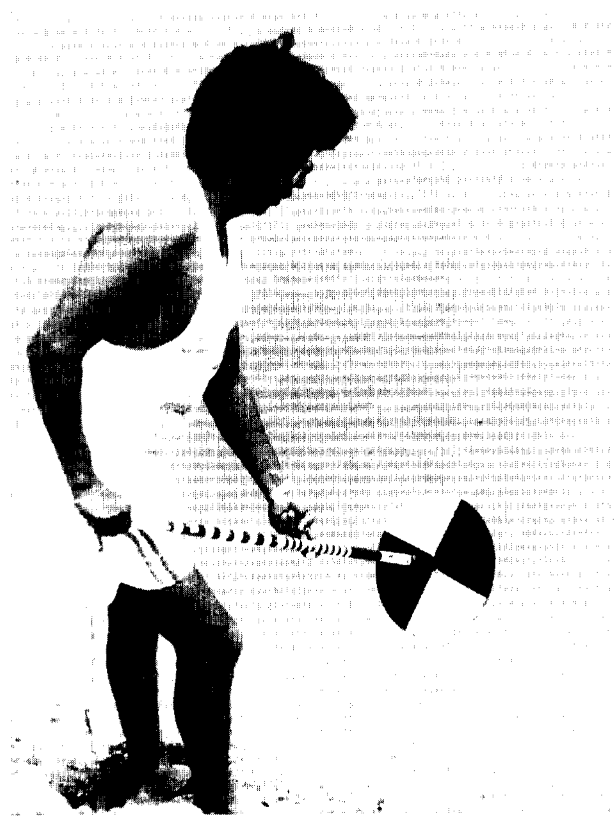


Plate 70. Typical secchi disk for measuring water turbidity in ponds.

Water turbidity is measured once daily during the afternoon to allow the maximum amount of light penetration. This measurement is highly subjective, and, therefore, one person should be designated responsibility for monitoring water transparency data as well as other hydrological parameters. *On-line fertilization routine* in Chapter 3 briefly discusses some of the basic criteria used for turbidity monitoring.

Pond operation level is measured once daily during the afternoon. Detailed procedures are discussed in *Establishing pond operative level*. Data should be recorded on the Parameter monitoring control sheets (Figure 12) as actual level over theoretical operation level.

Hydrological parameter management

In the majority of cases, hydrological parameters can be directly effected by manipulating the rate of daily water volume exchange in ponds. Although management policy for water volume exchange rates on a daily basis was discussed in *In-progress pond water allowance* for the different phases during a culture cycle, these recommendations take on a secondary priority level when a given pond experiences water quality problems.

Ideally, close monitoring of daily water parameters will help anticipate potential problems in ponds. This should be the ultimate goal of the farm biologist, since "stress free" culture cycles result in optimal performance. By closely monitoring the diel cycle of water temperature, pH, and D.O. concentrations, one should be able to anticipate by two days any extreme variations from the norm that might result in critical problems.

Since not all potential problems can be circumvented, real emergency situations must be dealt with by aggressive water management tactics to limit the time frame of poor water quality, thereby limiting possible stress induced on animals under culture.

Depending on the degree of stress, reactions may vary from poor growth to significant mortality.

This section will address procedural steps and follow-through decisions necessary to correct emergency water quality situations.

Pond water temperatures

Although water temperatures are strongly related to ambient atmospheric temperature as well as to wind conditions, they may be significantly influenced by the pond's water level. A hypothetical pond that is operating at significantly lower water levels than capacity is exposing more surface area in relation to its water volume. This results in an increase in water temperatures during sunny days, and a decrease during cooler nights. The high degree of oscillation in water temperatures during the 24-hour cycle may result in unnecessary stress to the shrimp population.

Furthermore, the decrease in water temperatures during the night will make shrimp lethargic and result in a decrease in the feeding efficiency during the time when it should be at its highest point. Average minimum temperature differences of 2°C have been observed in adjacent ponds with a difference of 40 cm in operating levels. Units with depths of 80 cm averaged a minimum of 22°C during windy seasons, while 120 cm units averaged 24°C.

By maintaining pond water levels at their safest maximum operation level less surface area, in relation to water volume, will be exposed, thereby reducing significant temperature oscillation between day and night. The increased average water depth will insulate the bottom pond water and result in relatively stable temperatures (±4°C) over the 24-hour cycle. Subsequently, higher water temperatures during the night will increase shrimp feeding response and activity levels for improved growth performance.

Pond water levels should, therefore, be managed at maximum allowable capacity (operative level). The farm biologist should manipulate the effluent gate down boards to allow the pond water level to adjust in accordance with necessary changes, on a daily basis. Weir gate down boards should be available in various widths such as: 20 cm, 10 cm and 5 cm (Plate 71). By reviewing the data on the "Daily water management summary sheets" shown in Figure 26, the number of boards required to be installed or extracted can be easily deduced. For example, if a given pond shows a registered water level of 140/150, the proper management decision would be to install a 10-cm down board in all effluent weir gates to allow the pond to fill to its maximum operation level, and, once obtained, to drain normally.

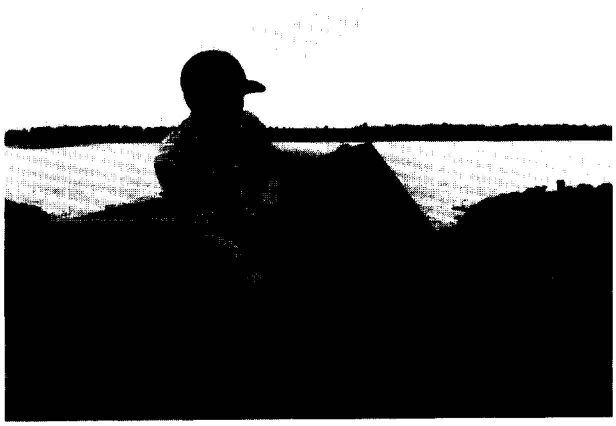


Plate 71. Various sizes of weir gate down boards. Notice varying widths, and tongued and grooved edges.

Pond water temperatures are most important during juvenile transfer operations and terminal harvests. In both cases, water temperatures should not be allowed to exceed 32°C. If temperatures approach the upper limit, fresh water should be allowed to enter the pond.

Pond water salinity

Once the pond is "in progress" or in operative mode with a shrimp population, there is very little one can do to change water salinity. The reduction of the water exchange may result in slowing the rate of salinity reduction but the possible negative consequences outweigh the possible benefits.

There have been attempts at temporarily increasing water salinity in nursery ponds prior to stocking by introducing raw rock salt from evaporated salt ponds. The results have been, at best, inconclusive and there is a significant risk of possible contamination by heavy metals that may kill postlarvae.

There is a general procedure for prolonging the time the pond water maintains its salinity during heavy rainfalls. This procedure, as described in *On-line fertilization routine* in Chapter 3, should be considered prior to stocking the pond, but should never be utilized once the pond is properly stocked.

Pond water transparency and coloration

Water transparency or turbidity is generally related to phytoplankton abundance in the water column. Chapter 3 briefly discusses the specific management criteria used in the interpretation of secchi disk data and its relation to routine pond fertilization. The strategies previously discussed should be used as guidelines for water management.

The normal cycle for a developing algal bloom is shown in Figure 5. Generally, the coloration associated with stage 1 on the curve is a highly transparent light green representing low population density of algae cells. Stage 2 will generally reflect a deeper green color with decreasing water transparency and the initiation of a yellowish hue. Stage 3 is characteristically associated with a dark greenish-yellow coloration, signifying a dense and more aged culture. Stage 4 generally reflects a dark brownish-yellowish hue typical of a mature and dense diatom bloom. In the event of a bloom "crash," where there is significant mortality in the algal culture, a milky white coloration may persist and a high degree of transparency in the water column may occur.

The goal of the technical staff should be to achieve and maintain stage 4 during the majority of the culture cycle. The color cycle expressed in the previous paragraph describes typical progression of color sequence representative of life cycle of diatom algae. Generally the fertilization program is directed at specific enrichment of water based on the nutrient requirement of the diatoms; however, if another group happens to be in majority at a particular time, it may easily bloom and suppress the diatom groups. When this occurs, water coloration may become a deep bright green (like green pea soup) or as in the case of some dinoflagellates, a dark red, burgandy coloration typical of "red tides." Both of these types of blooms may be potentially dangerous and should not be allowed to reach high concentration levels. Particularly the red tide dinoflagellates, if allowed to reach a high density bloom, may produce toxins resulting in shrimp mortalities. In such an event, pond water levels should not be lowered as this may result in the concentration of the toxin-producing algae. When such problems occur, all fertilization, as well as introduction of organic loads such as feed, should be temporarilly suspended. Water exchange should be increased to 150 percent of the total daily requirement and draining should be increased proportionately so the operative water level is not increased.

Pond water pH

The diel oscillation of pond water pH is directly associated with the photosynthetic activity of the phytoplankton population in the pond. During the mid-afternoon, when solar intensity reaches its peak, the algae consume carbon dioxide and produce oxygen. This increases the D.O. concentration and the pH of the water. During the night, algae become "net consumers" of oxygen and carbon dioxide is released, thereby lowering the pH.

The daily oscillation can be used to anticipate algal blooms and potential D.O. concentration deficiencies in ponds before they occur. Typical pond brackish water pH measurements are 7.4 and 8.5 for morning and afternoons, respectively. If the afternoon value significantly increases, this may be interpreted as indicating intense photosynthetic activity with potential oxygen deficiencies during the night when oxygen is consumed by the phytoplankton in the respiration process. As a general rule of thumb, the greater the oscillation or daily extremes, the greater the potential for danger during the night, particularly at pre-dawn hours.

As daily oscillation within a given pond begin to increase, the technical staff should begin comparing values of water turbidity and D.O. concentration. If no abnormalities exist, the staff should be alerted and initiate monitoring of D.O. earlier (0400 hours (4 a.m.) on a daily basis. If D.O. concentrations are observed to be decreasing, an aggressive water volume exchange strategy should be immediately implemented to reduce the risk of oxygen depletion in the pond.

The absence of any daily oscillation in water pH should be directly correlated with high transparency. In such cases, a slight increase in water pH may be enough to stimulate an algal bloom if the fertilization strategy is unsuccessful. In these situations, calcium carbonate may be applied to the pond using the same techniques as described in Chapter 3 (*Fertilization procedures*). The dosage requirement for calcium carbonate should be 40 kg per hectare of water surface area. Allow two to three days for the application to take effect.

Pond water D.O.

The water parameter abnormality that draws the most attention and receives the most immediate reaction from the technical staff is the occurrence of an oxygen deficiency in a pond. There are two major reasons for this deficiency: (1) it may be the result of photosynthetic respiration in a pond exhibiting a high degree of photosynthetic activity, and (2) it may be caused by excessive biological oxygen demand (B.O.D.). Generally, oxygen depletion in a pond does not occur without previous indicators. During periods of intense sunshine, the phytoplankton will produce oxygen and the pond water may reach supersaturated levels, but excess oxygen will be partially released into the atmosphere. During night, the same phytoplankton will consume oxygen and if more oxygen is consumed than was produced during the day, oxygen depletion may follow. The same concept applies to D.O. dynamics in a pond as for the analysis and subsequent interpretation of daily pH oscillations. The further apart the daily recording, the greater the potential for possible problems. Extreme oxygen depletion in a pond almost always results in shrimp mortalities. Every effort should be made to anticipate D.O. depletion and take remedial action. The most effective remedial action consists of increasing the water exchange rate to decrease the algal bloom density in the pond and reduce organic load. The water level should be decreased between 25 and 30 percent and immediately returned to operative water levels by refilling. This may be performed several times if the problem persists. This systematic approach should be used as a prophylactic measure to anticipate and avoid a crisis.

When D.O. concentrations drop below 3.0 ppm, shrimp can sometimes be observed swimming at the surface. More critical depletions ranging from 1.0 to 2.0 ppm generally cause fish mortality. They can be seen floating "belly up" on the ponds' surface or accumulated on the downwind slope of the pond; predatory blue crabs will attempt to migrate. D.O. concentrations below 2.0 ppm generally result in fish, crab and shrimp mortality. The number of dead shrimp found on the shore is generally a small fraction of the probable mortality on the bottom. It is difficult to express the seriousness of oxygen depletion in commercial production. If remedial emergency action is not immediately implemented, an entire pond biomass may be lost in a matter of hours.

All personnel on the farm should be instructed to **immediately report** observations mentioned above to the farm biologist. Personnel assigned to monitor water quality parameters should immediately report low D.O. concentrations(<3.0 ppm). When a D.O. problem is identified filter screen cleaners should immediately mobilize to the specific pond and work only at that pond, effecting a vigorous exchange until the problem is solved — working around the clock if necessary. Two 20-cm down boards should be removed from entrance and effluent weir gates to effect the most immediate and significant water exchange possible. The screen cleaner should be alert so that increased pressure on the filter screen does not rupture it. Water should be drained from the bottom of the pond through the use of restriction boards. Auxillary pumps of 10, 15 or 20 cm should be mobilized to circulate water in the stagnant areas of the pond, or to pump water from an adjacent pond with adequate D.O. levels into the affected pond.

Ponds suffering oxygen depletion or D.O. should be continuously monitored; auxillary pumps should be positioned in areas of known oxygen depletion. Application of feed to ponds sustaining D.O. depletion should be suspended until D.O. is at suitable levels. The technical staff should remain on alert for several days to ensure that the crisis has safely passed.

Growth Monitoring

There are two major objectives for routine weekly sampling of the ponds. Primarily, the average weight of the population is determined to evaluate growth performance, and secondly, but equally as important, this is one of the few times during the course of the week that the farm biologist is in direct contact with the shrimp, and has the opportunity to conduct an objective evaluation of their condition. By conscienciously realizing these two objectives during weekly sampling, the technical staff should be able to achieve a relatively accurate picture of growth and "condition" factors. These evaluations are based on observation of captured shrimp.

Routine weekly growth sampling techniques for the determination of average weight have been described in Chapter 8 and 10. It must be emphasized, however, that the farm technical staff should maintain uniformity and standardization in methodology when taking weekly samples.

A graph depicting weekly growth and daily hydrological parameters can help management find the "best approach" for achieving optimal growth; *ie.* increasing or decreasing feed ration, increasing or decreasing water exchange, increasing or decreasing fertilization, etc.

Figure 30 illustrates the different parameters to be plotted on the weekly growth graph. The horizontal axis (x) represents culture time (days), the vertical axis (y) represents physical parameters that should be plotted at daily intervals. The right- hand vertical axis corresponds to the capture frequency for each growth sample. These values should be represented in bar graph form vertically, and they should be plotted as weekly growth data point entries.

The diagonal line depicts growth of 1 gram per week as a reference for evaluating actual growth during the culture period.

These graphs should be maintained for all ponds "in progress" and should be relied on as management tools for evaluation of pond performance. Poor growth can be readily observed by cross-referencing specific physical parameters. When deflections in growth curves are observed and probable causes attributed to one or more alterations in any of the various physical parameter curves, prompt action should be initiated by the technical staff to correct the problem. For example, if growth slows, and it is noted that daylight D.O. readings have dropped to 2.5 ppm, increased water exchange is warranted.

Routine monitoring assessment of population

There are many visual indicators that can be utilized to approximate the shrimp population.

Management miscalculations, such as insufficient feed ration, insufficient water exchange andexcess fertilization might directly affect desired growth. Certain physiological abnormalities in the shrimp caused by the above or other alterations in the cultured animal's environment, may be observed during the

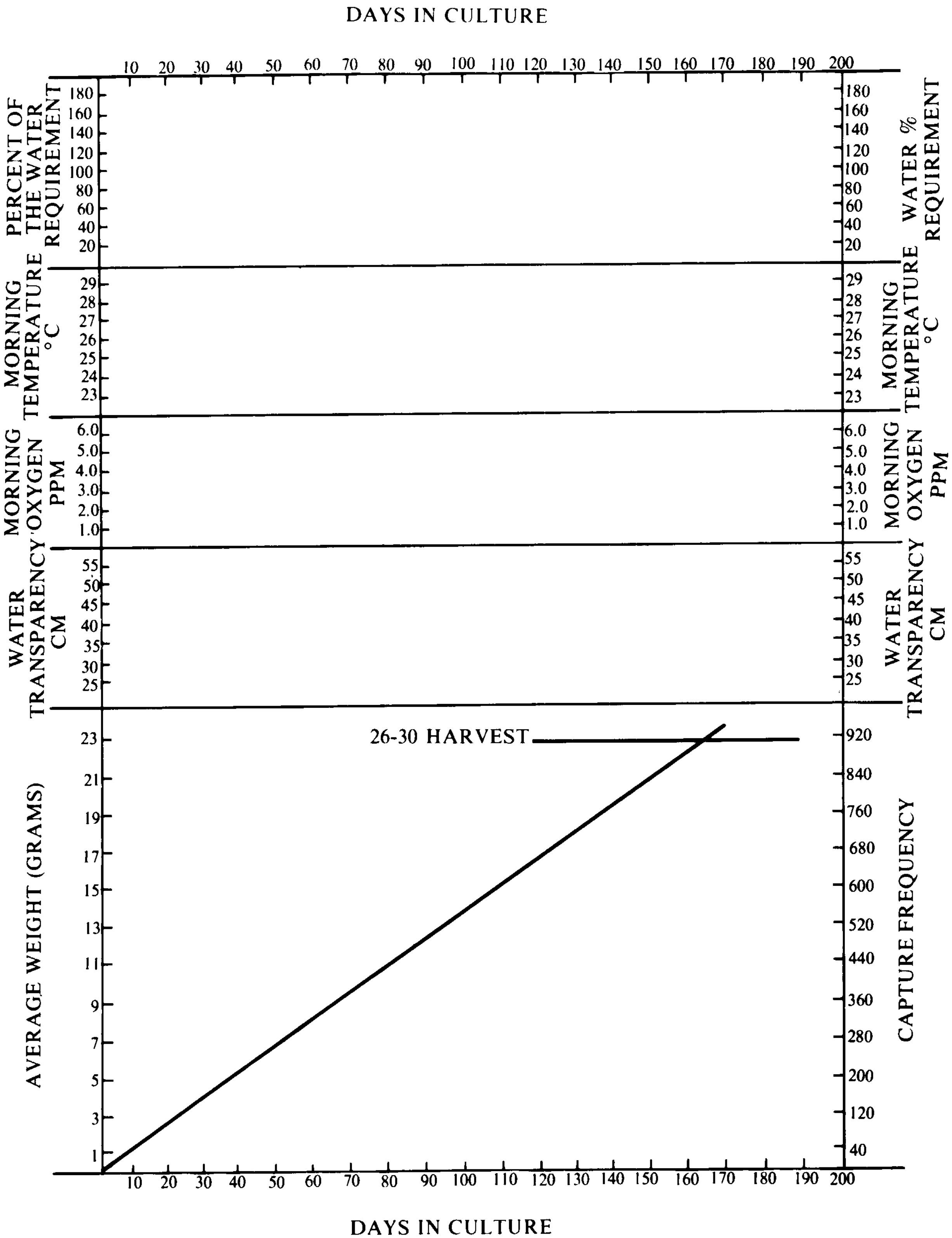


Figure 30. Graphic representation of weekly growth performance and specific physical parameters for "in progress" ponds.

routine weekly sampling. When such observations are accurately analyzed, corrective management procedures can be implemented.

On the same sheets represented in Figure 13, the weekly minimum and maximum values for the different water quality parameters should be recorded. These values should represent the weekly minimum and maximum for each particular water parameter. The final two items — water color and feed ration — should be the values for the specific day when the growth monitoring data was sampled.

Direct observation of a relatively large number of shrimp from a particular pond (>400 animals) is ideal for making a subjective evaluation of its population. Although 400 animals does not constitute a statistically representative sample of the pond population, it is sufficient for establishing general trends in the population. These data should be sufficient to establish a management approach for a particular pond.

While conducting routine weekly growth sampling, captured animals should be grossly evaluated for several physiological characteristics. These characteristics should reflect the general conditions for a majority of the shrimp captured, and not just a select group. The general physiological conditions should be recorded in the observations section of the Growth summary sheets illustrated in Figure 13. The following guidelines should be employed in reference to the observation section on the summary sheets.

Plate 72. Captured specimen representing between 75 and 100 percent gut fullness. Last tail segment is firmly squeezed to compact fecal material in the gut. Notice dark gut on dorsal edge of tail muscle.

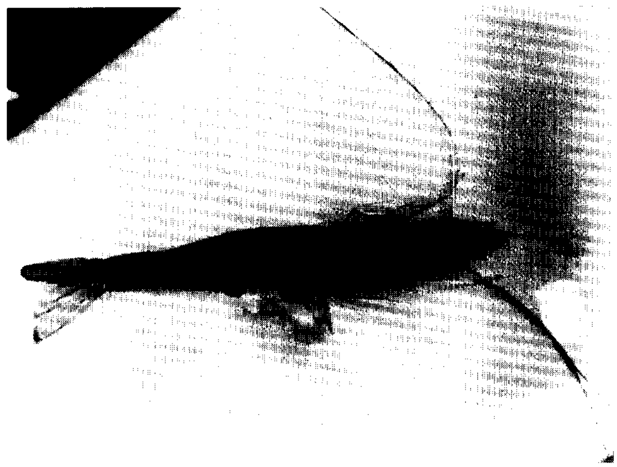


Plate 73. Captured specimen representing 25 to 50 percent gut fullness due to insufficient food availability.

Spring or neap tide

Since capture frequency is strongly influenced by lunar phases, the lunar phase corresponding to each weekly growth sample should be identified. During spring tides (new and full moons) the shrimp population begins experiencing the pull of a migratory instinct and nocturnal activity is significantly increased. Many times an excessive number of shrimp will concentrate at the entrance weir, sometimes such increased activity results in significant mortality along pond shores. Most ponds have specific areas where shrimp tend to accumulate, and during periods of increased migratory activity mortalities may be observed in these areas, especially if the spring tide is strong.

Installation of netting barriers (7 mm mesh) prevents concentration of shrimp in certain pond areas and diminishes surface jumping activity that might result in excessive mortality. Areas that are characteristically dangerous during spring tides are the entrance and effluent weir gates and the shallow pond shores bordered with aquatic grass or weeds, especially on downwind borders. If a particular pond consistently produces excessive mortalities during spring tides at specific locations, precaution should be taken to physically isolate the danger areas with netting material.

Neap tides are characterized by quarter and half moons (either ascending or decending). These tides generally do not stimulate migratory behavior or hyperactivity, but a passive behaviorial response with increased probability of synchronized molting and burrowing activity.

Percent of gut fullness

Gut fullness is an index of the amount of feed being consumed. Captured shrimp should be slightly but firmly pressed on both sides of the sixth abdominal segment, causing the gut contents to compact toward the head region, following which an evaluation of fullness should be made (Plate 72). The percentage value recorded should be a rough estimate of the percentage of fullness for the majority of the shrimp captured. Since these evaluations are subjective, approximate values should be used as opposed to precise determinations. A scale of 75 to 100 percent full, 50 to 75 percent full or 25 to 50 percent full should be employed.

Normal populations will experience active feeding responses resulting in full guts. Digestive tracts containing less than 75 percent fullness may be indicative of reduced feeding responses as a consequence of stress, nonavailability of feed (underfeeding) or sampling during mid-day when feeding activity is diminished. The last interpretation can be excluded by limiting the sampling to early morning (<1000 hours), or late afternoon hours.

Stress as a cause of diminished gut fullness (<75 percent) will generally be accompanied by other physiological symptoms such as opaque tail tissue, excessive red pigmentation on pleopods, or abnormal swimming behavior. A low percentage of gut fullness may also be indicative of insufficient feed, either natural or pelleted (Plate 73).

Shrimp will characteristically graze the bottom consuming benthic filamentous algae, invertebrates, detritus, bacteria, and pelleted feed. If they have insufficient feed then the underfed animals will show partially empty guts and demonstrate slow growth. Possible weight loss as well as softening of exoskeleton texture may result. Underfed animals may be present on the bank and be found trying to escape from the pond during the early morning hours. If a particular pond exhibiting poor growth also reflects low percent gut fullness, with no sign of stress, and the benthic analysis shows low productivity, then these signs may be accurately interpreted as caused by underfeeding.

When a particular population exhibits poor growth, and a nutritional-related problem is suspected, then a more sophisticated evaluation should be conducted.

Shrimp with a healthy intake of food will characteristically store lipid in the hepatopancreas for future energy needs during times of low food availability. The fat is stored as lipid vacuoles which can be readily identified under normal light microscopy at 100 x magnification with wet squash mounts. It is rather difficult to evaluate the relative frequency of the lipid vacuoles subjectively unless the observer has considerable experience. Since this operation is time-consuming, it is generally not performed on a routine basis, but should be done if growth diminishes below acceptable norms. Take samples of five to 10 animals from the pond with diminished growth and take an additional five to 10 animals from any pond reflecting optimal growth (shrimp of basically the same weight) and compare the concentration of lipid vacuoles in the hepatopancreas. The hypothesis is that hepatopancreases containing a high degree of lipid vacuoles generally belong to populations that are feeding aggressively. Populations that do not have sufficient quantities of feed available may not be able to store significant levels of lipids, thus resulting in a relatively low degree of lipid vacuoles accumulated in the hepatopancreas.

Molting

Soft carapace texture is indicative of the post-molt stage. The molt requires that shrimp first shrink by eliminating body fluids (water) from their tissue. The shrinking separates body tissue from the exoskeleton and may be associated with slight weight loss. In the second phase, the body separates from the exoskeleton completely. Sometimes the shrimp will partially consume its discarded exoskeleton. The consumption of calcium and chitin is thought to accelerate the setting and hardening of the new carapace. Once the shrimp has discarded its carapace, it is vulnerable since it lacks its protective exoskeleton. During this phase, shrimp will generally burrow into the mud. The third phase of the molting cycle is associated with an increased amount of water absorption by the body tissue and the formation of the new exoskeleton. This phase is generally associated with a significant, apparent weight gain. Once the shell has hardened, the shrimp will eliminate the excess water absorbed by its body tissue (resuming normal body weight). The exoskeleton completely hardens and the space between the body tissue and the new exoskeleton, which was formed when the shrimp released the excess body fluids, is the space for future growth.

The entire molting process, from body shrinkage to final hardening of the new exoskeleton, occupies a two-day period. The frequency of molting is directly related to growth rates, but generally may occur once every two weeks.

In general, molting eliminates external parasitic problems as well as opportunistic bacterial or carapace fungal infestations. Although these problems are usually correlated with poor water quality, molting permits frequent ridding of various infestations by the shrimp. On the other hand, the molting cycle dangerously exposes the shrimp to cannibalism and predation. If pond sediments contain significant levels of hydrogen sulfide, shrimp that burrow into such conditions have less chance of surviving. If they do survive, growth rates may diminish as a direct result of exposure to toxins.

Soft exoskeletons may also be associated with nutritional deficiencies or lack of sufficient food sources. This case is particularly true if soft carapace conditions persist for extended periods of time. The application of finely ground calcium carbonate ($CaCO_3$) directly over the ponds surface area at 90 kg per hectare (approximately 8.0 ppm concentration) may help harden the exoskeleton.

Small fractions of the population are continually in the molting phase, particularly in ponds that have been stocked over long periods of time and that may actually contain many subpopulations defined by different weights. In such situations it is uncommon to observe sychronized molts by the many populations within the pond.

Juvenile transfers and pond harvest should never

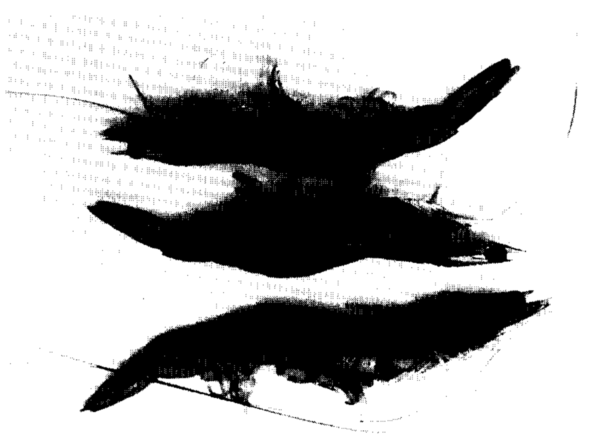


Plate 74. Black spot disease caused by several genera of bacteria, primarily of the Pseudomonas *group. The erosion of the exoskeleton caused by this opportunistic bacteria, as well as the melanization process, causes black spots.*

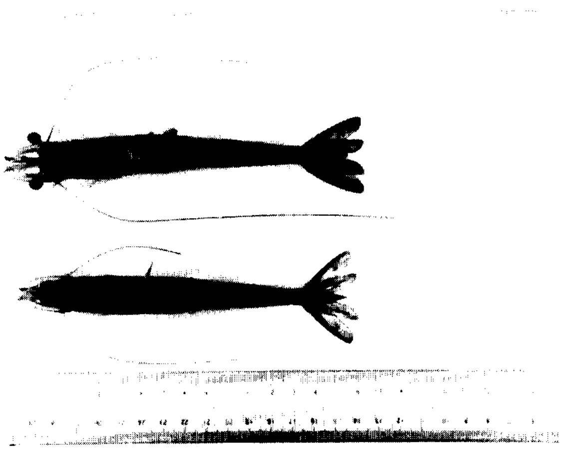


Plate 75. Normal antennae length in specimen on top, while lower specimen exhibits short, cut antennae possibly damaged due to high density conditions.

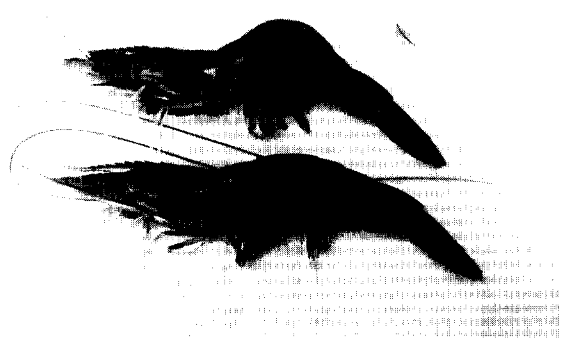


Plate 76. Specimen affected by cramped tail condition (top). Lower specimen is normal.

be initiated when molting is observed at frequencies greater than 5 percent. Lack of the exoskeleton will undoubtedly cause increased mortalities in juveniles transferred or increased broken and damaged shrimp during final harvests. This will result in poor market value of the product.

Fungal infestation

Contamination by common fungal species, such as *Fusarium solani*, is common in semi-intensive production ponds that exhibit poor water quality due to either inadequate water exchange or to excessive organic loading.

General field identification of fungal contamination is straightforward since the fungal infestation generally affects the exoskeleton and can be readily observed. Infestations are usually small "high relief" circular colonies of an off-white to yellow coloration. In advanced stages, in larger animals that molt less often, fungii may penetrate the exoskeleton and cause extensive damage to muscle tissue. Such conditions, if widespread, may significantly affect the market value of the shrimp population.

Small fungal contaminations will generally be shed during molting and, if water exchange is increased and water quality improved, limited damage will be caused.

Chitinous bacterial infestation

Opportunistic bacteria will generally not affect shrimp unless the primary defenses (exoskeleton) have been compromised. If the exoskeleton has become damaged, the opportunistic chitinous bacterial genera, *Pseudomonas*, may cause exoskeletal erosion. This, along with the process of melanization, gives the appearance of black spots (Plate 74).

The frequency of black spot disease characteristically increases during the spring tides when the shrimp population concentrates in certain areas and becomes hyperactive. When shrimp accumulate, lesions or abrasions caused from rostrums penetrating carapaces result. Other causes, such as predator attacks or scraping against the rough edges of concrete weir gates, similarly result in carapace lesions that facilitate infestations of chitinacious bacteria.

Black spots generally disappear or diminish with the following molt. Preventive measures such as limiting access of animals to shallow water by installation of netting barriers, minimizing physical abrasions caused by contact with rostrums, and elimination of predators (blue crabs) also will decrease the frequency of black spots.

Antennae length

Sampled shrimp should be evaluated for normal antennae development and length. Antennae are characteristically fragile organs and are easily damaged or broken when shrimp are concentrated. High frequency of broken antennae is indicative of good survival (Plate 75). This observation should be cross-referenced with capture frequency during weekly sampling.

High capture frequency as well as high frequency of short, broken antennae may indicate good survival and high density. Low capture frequency and high frequency of short antennae may indicate that although population density is not appreciably high, the shrimp may be damaging themselves during the spring tides as a consequence of concentration in restricted or small areas.

Gill coloration

Gill coloration can many times be indicative of gill condition that may also be directly projected to shrimp condition. Normal gill coloration is an off-white with a yellowish hue. Dark brown coloration may be a consequence of the cast net technique that drags the specimen through the mud. As a result, the mud accumulates in the gill cavity and may be inaccurately interpreted.

When the specimens' gills exhibit dark brown or dark greenish coloration (not as a consequence of mud accumulated during sampling), it may indicate a protozoan infestation often accompanied by bacterial infection. Protozoan gill infestations are directly related to water quality. Significant damage to the gills reduces osmoregulatory and gill absorption capacities, which causes animals to become more susceptible to low concentrations of D.O.. Animals with normal gills can survive D.O. concentrations as low as 1.5 to 2.0 ppm, whereas animals with severe protozoan gill infestation are susceptible to mortality at D.O. of 2.0 to 2.5. Slower growth may also be attributed to heavy protozoan gill infestation. A vigorous water exchange program can usually clear up this problem.

Morphological disorders

In large populations it is normal to have morphological disorders; however, if, during the growth monitoring, morphological abnormalities are observed in significant numbers they should be recorded on the "Summary shrimp weight monitoring sheets."

Disorders such as bent rostrums and runting or dwarfism are generally associated with marginal quality shrimp stock. A certain percentage of the population may be affected (< 20 percent) but will not necessarily influence the balance of the shrimp population in the pond.

Cramped tail condition, in which the tail is folded under the thorax and cannot be straightened, is a condition of unknown etiology (Plate 76). This condition has generally been highly correlated with high density and additional stress-causing factors such as acidic pond bottoms (pH < 6.0), low water exchange rate or poor water quality. This condition can generally be stimulated by the stress caused by cast net

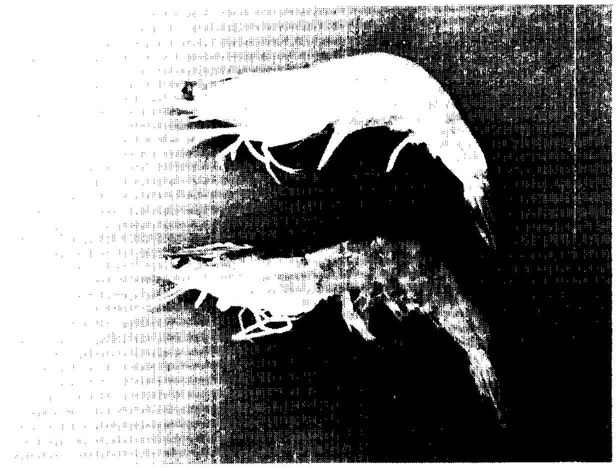


Plate 77. Cotton tail disease associated with distinct white/opaque muscle tissue coloration, of unknown etiology. Lower specimen is normal.

capture, in which a seemingly normal specimen immediately exhibits cramped tail condition upon capture. If the shrimp population is reduced by juvenile transfer (as in the case of nursery ponds) or by partial harvest in production ponds, in most cases this cramped tail syndrome can be alleviated.

Cotton tail disease is another disorder of unknown origin, but is one generally associated with poor water quality (low concentrations of D.O. or elevated concentrations of ammonia) (Plate 77).

For a concise and complete description of abnormalities and diseases in cultivated Penaeid shrimp, refer to Johnson (1989) and Lightner (1988).

Specimen processing and preservation

There are many diseases and disorders whose etiologies remain unknown, but in an effort to identify known diseases and to document poor performance when possible with pathological reports, it is necessary to preserve specimens demonstrating abnormalities, or specimens that appear to be normal, but come from nurseries or ponds with poor survival rates.

If any significant (>10 percent) number of morphological or physiological abnormalities are observed during routine weekly growth sampling, or when nursery survival during transfer, or pond survival during harvest is much lower than anticipated, samples should be taken and specimens preserved.

Bell and Lightner (1988) give an excellent overview of histological examination of cultured shrimp, predominantly *P. stylirostris*. Accurate interpretation of histological sections for disease determination is difficult, and takes many years of study to master. This book, however, covers the importance of proper sampling and preservative procedures so that histopathological analyses will not be jeopardized due to improper preservation and preparation of tissue.

All specimens should be collected while alive and preserved (fixed) immediately; otherwise, stress factors may alter the appearence of histopathological sections of tissue being analyzed. Between six and 10 specimens should be sampled and fixed with Davidson AFA (Bell and Lightner, 1988). One liter of Davidson fixative is made of the following:

a. 330 ml 95 percent ethyl alcohol.
b. 220 ml 100 percent formalin.
c. 115 ml glacial acetic acid.
d. 335 ml distilled water.

Note that this compound should be stored at room temperature.

The procedures described below should be followed explicitly to ensure correct preservation techniques. These procedures are condensed from Bell and Lightner (1988); for more elaborate detail this reference should be reviewed.

1. Select between six and 10 live specimens that exhibit abnormal behavior, discoloration. etc. Specimens must be sampled alive.
2. Maintain specimens in bucket with water and oxygen prior to initiating preservation procedures.
3. Wearing surgical rubber gloves, the fixative should be injected with syringes laterally at points identified in Figure 31.
4. Quantities injected depend on the size of the specimen; about 5 cc of fixative is generally sufficient for shrimp weighing 23 grams.
5. Once injections are complete, the cuticle (carapace) should be cut with scissors along the entire length of a lateral side as shown in Figure 32.
6. Following the injection of fixative and lateral incisions, the specimen should be submerged in the fixative solution for 24-hours.
7. After 24-hours submerged in Davidson fixative, the specimen should be transferred to 50 percent ethyl alcohol. In this alcohol solution, storage at room temperature is indefinite.
8. All samples should be properly marked so that when shipped for histological work-up at diagnostic centers, as much data as possible will be available for accurate disease determination. This minimum amount of information should accompany each sample: Date, farm, pond, average weight of animal, origin of animal (hatchery, wild), days in culture, observations of why sample was taken (list abnormalities or suspicions).

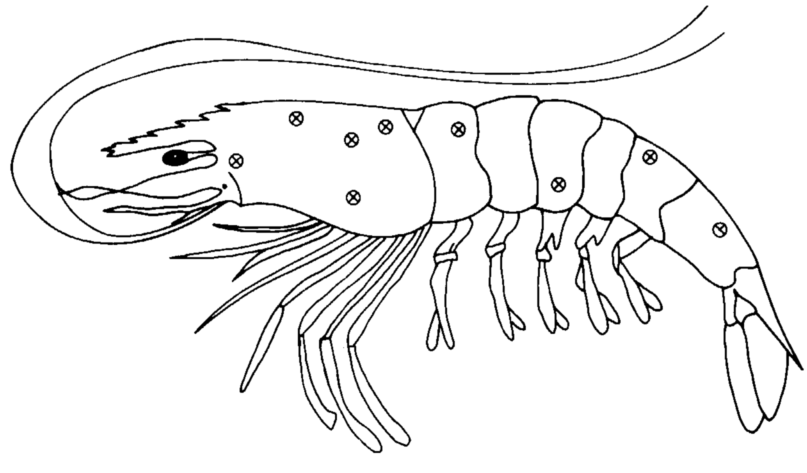


Figure 31. Fixative injection points along lateral side of specimen. The hepatopancreas should receive a generous share of fixative.

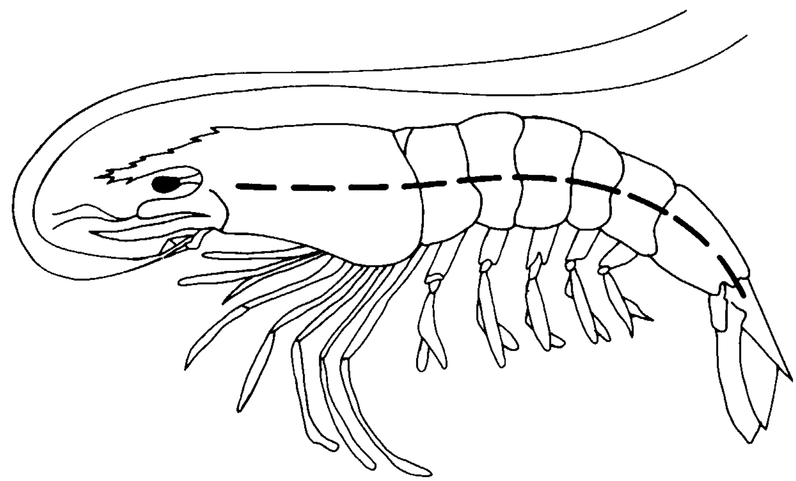


Figure 32. Both lateral sides of carapace should be cut from rostrum to telson, taking care not to cut deeply into underlying tissue.

Bottom Sampling

Analysis of pond bottom can help in assessment of environmental conditions that support the shrimp population. Since shrimp are benthic animals and spend the majority of the time near or on the pond bottom, periodic evaluation of sediment conditions will serve as effective indirect analysis of the environment in which the shrimp are living. The "Summary weight monitoring" sheet lists several factors that should be evaluated during weekly sampling other than average weight determination.

Three benthic samples should be collected from each pond in such a manner that the surface layer remains undisturbed. The sample size should represent approximately 100 cm^2 (Plate 78). These samples can be collected with a common shovel, and do not have to be deep core samples since the analysis is restricted to the surface layer.

Figure 33 illustrates where samples should be collected in a typical nursery or production pond.

Two of the sampling stations should be representative of the deeper areas of the pond adjacent to pond dikes (1 and 3). The third station should be representative of the central, shallower areas of the pond (2).

Benthic fauna and flora

The benthic samples, should be examined under a dissecting microscope and, since these examinations are highly subjective, the evaluation should be restricted to a simple "yes" or "no." The examiner should carefully scan the sample without disturbing the surface layer. The presence or absence of attached filamentous green or blue-green algae should be recorded. If present, the algal layer will generally be very minute and of a greenish-brown color. The presence of benthic alage is beneficial in that it provides a substrate that sustains secondary productivity such as copepods, nematodes and polycheates. To a limited degree, shrimp also benefit from direct consumption of benthic algae. This layer of primary productivity serves as the principal food source for the benthos, and its' presence indicates that the pond is productive. Absence of this algae may be a strong indicator of insufficient food available. When nutrition becomes the limiting factor, the population will graze on benthic algae and virtually clean the pond bottom of living organisms.

Once the examiner has accurately noted the presence or absence of benthic algae, he or she should evaluate the benthic fauna. The examiner should slightly agitate or disturb the surface layer with a needle. Movement in and around the mud sample might be indicative of copepods, nematodes or other fauna. Polycheates are much easier to identify since the colony tubes are visible on the surface of pond bottoms. Any movement observed in the sample as it

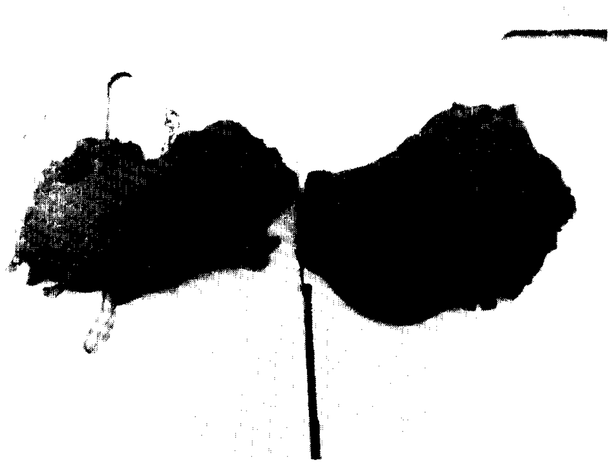


Plate 78. Example of bottom sample collected for evaluation. Notice surface layer is undisturbed.

is being disturbed with a needle indicates the presence of invertebrates, and should be recorded.

Benthic sulfides

Organic material in pond sediments will undergo either aerobic or anaerobic decomposition. Optimal decomposition of organics should take place under aerobic conditions in the presence of oxygen. Under such conditions ammonia will be produced when proteinaceous material is decomposed. Ideally, ammonia concentrations will be oxidized by nitrifying bacteria found in aerobic sediments, and nitrates will be liberated.

When pond sediments are anaerobic (lacking oxygen), the decomposition of organics results in the production and eventual build-up of hydrogen sulfide. High levels of sulfides may cause shrimp to go

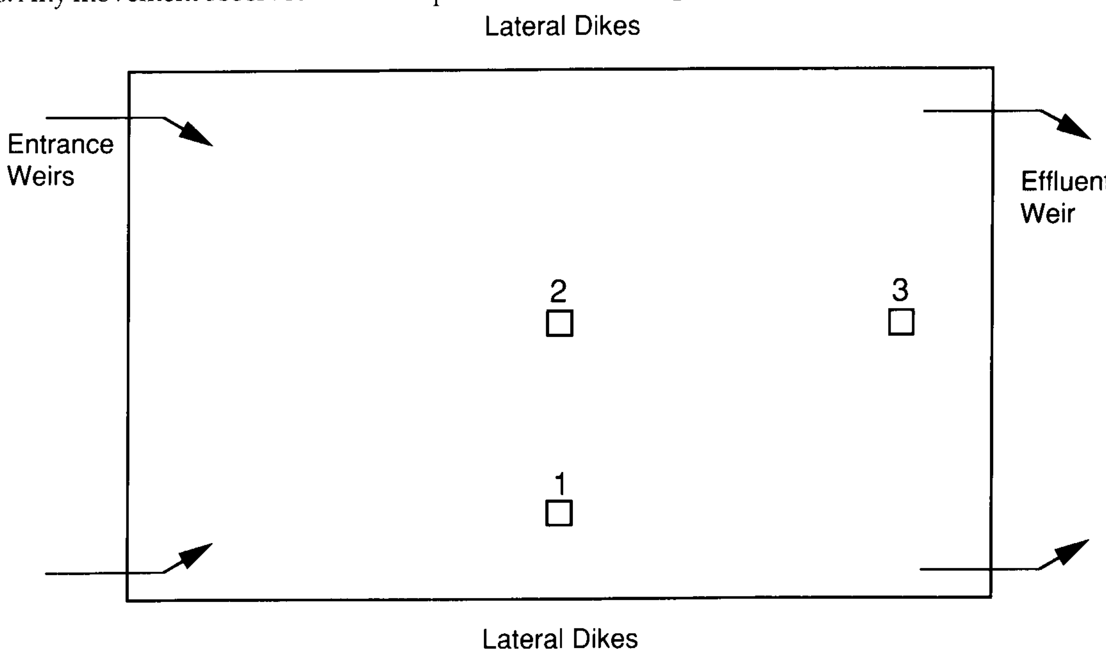


Figure 33. Locations for benthic sampling station in typical ponds.

off feed and often result in increased mortalities. The prevention of sulfide build-ups in pond bottoms should be a major objective, although this may be difficult in larger production ponds. There are a variety of ways to oxidize and eliminate hydrogen sulfide from pond bottoms. Many of these methods are cost prohibitive for most commercial-size operations and will not be discussed here.

The three benthic samples collected should be organoleptically examined for the presence of hydrogen sulfide odor. A slight odor will be present, but it does not necessarily indicate that the pseudo-equilibrium has been broken. The identification of the odor is important since it can be correlated with phytoplankton crashes or overfeeding. A strong hydrogen sulfide (rotten egg) odor of large areas of the pond will generally require the suspension of feeding and the increased water exchange rates for five to seven days.

Frequently, the presence of significant hydrogen sulfide is restricted to small areas. These areas are often near effluent weir gates and downwind corners of the pond that collect floating organics. A major source of floating organics is benthic algae. When the majority of an algal colony dies, the "anchors" weaken and the living portion of the colony produces sufficient oxygen to float the mat to the surface. At the surface, the wind transports it to the downwind side of the pond. When the entire colony has died, it sinks to the bottom, and hydrogen sulfide can then be produced if conditions are anaerobic. Contaminated areas can be located by introducing a long stick into the mud and observing large, sulfide bubbles rising to the surface.

These restricted areas with heavy sulfide contamination should be physically removed or chemically treated during the culture cycle because if they are not neutralized, growth performance and feed conversion may suffer. If the highly contaminated area is along the downwind shoreline, the water level might be reduced by 20 centimeters, allowing some of the shore to be exposed. By manually removing the mud, much of the contamination may be eliminated.

There are times when large quantities of contaminated sulfide sludge will accumulate in front of the effluent weir gate at a distance of approximately 10 meters. In such cases, the most effective manner of elimination is to remove three effluent down boards, place a person to clean the filter screens continuously and dispatch laborers to resuspend the bottom sediment manually. The strong current created by increased draining will flush sulfides from the pond.

Both techniques described represent physical elimination, which is generally safer and most cost effective. However, if hydrogen sulfide contamination is present over an extended surface area, chemical decontamination may be necessary. In this case, iron oxide ore can be applied over the affected area at a dosage of 2 kg per square meter. The ore will react chemically with hydrogen sulfide, leaving neutral ferrous sulfide. The ideal strategy is to monitor the presence of sulfides at bi-weekly intervals and try to limit their build-ups.

Presence of excess feed

Benthic samples should also be examined for presence of excess feed. Excess feed can manifest itself in two forms: (1) floating, decomposed feed, approximately 48 hours old; and (2) uneaten or disintegrated pellets on pond bottoms, in which case feed rations should be cut back by 50 percent and slowly increased every two days while closely monitoring for excess. If excess pellets are again observed, daily rations should be reduced by 10 percent per day.

The presence of excess feed should be closely monitored as it indicates poor management techniques and may result in significant financial losses through poor feed conversions. Any observations relating to excessive feed should be immediately reported, and corrective measures implemented.

Chapter 12

Final Product Harvest

Prior to establishing the pond harvest date, confirmation on estimated size classifications of the population as well as an overall evaluation of carapace hardness should be performed. After the harvest date has been determined (preferably during the week of spring tides) the packing house should be advised at least three days prior to deliveries.

The ice requirement is one weight unit of shaved ice per one weight unit of harvested product. Since most harvests are accomplished at night, ice can be ordered to arrive during the late afternoon prior to commencing harvests. A harvest should not be initiated unless the ice is physically present. Without ice, the product will spoil.

Two days prior to harvest, the pond operative water level should be gradually lowered. Harvesting procedures normally begin with a water level of approximately 30 percent of the established operative level. Fluctuating water levels occasionally induces molting, therefore, reduction of water levels for harvest should be extended over two days.

As water levels are reduced, water temperatures and D.O. concentration should be monitored more frequently (six times per day). Extra caution should be realized in predator control (birds) and also in assignment of day/night watchmen, positioned to prevent poaching, since the product is especially vulnerable as water levels are decreased.

Gravity harvest bag nets should be securely fastened to the effluent side weir gate culvert (Plate 79). These bag nets should be examined prior to use to ensure that they are in good repair.

The bag net is usually constructed of 7 mm^2 seine net material approximately 8 meters long and 1.5 to 2.0 meters in diameter. It should be securely fastened to wood posts.

Attraction lights should then be positioned. These lights are identical to the lamps described in Chapter 11 (*Weir board configuration*). As in transfer operations, these lamps greatly increase harvest efficiency.

Gravity harvests should begin no earlier than 1700 hours (5 p.m.). Effluent gate restriction boards and filter screens should be removed. Enough down boards (40 cm) should be extracted to allow a significant drainage current at the harvest gate.

Initial emptying of the harvest bag net should be performed after the first 15 to 30 minutes, as the harvest bag will generally fill with mud and debris that have accumulated near the effluent gate. Once the gate has been flushed clean of debris, the bag net should be emptied when it contains approximately 700 gross kilograms or after 1.5 hours, whichever comes first. Exceeding these limits may result in product damage due to pressure buildup within the bag.

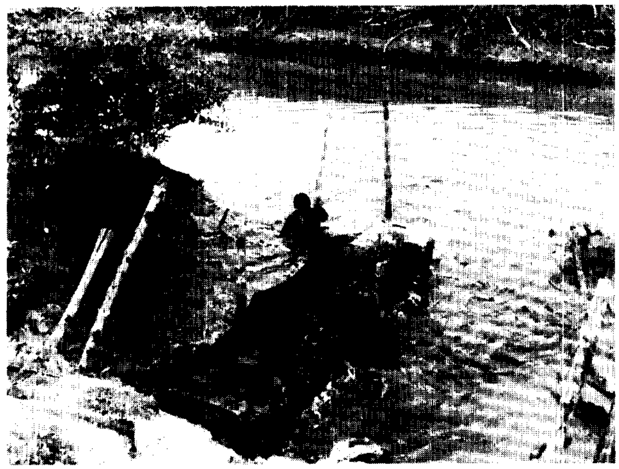


Plate 79. Harvest bag nets of 7 mm^2 netting firmly attached to effluent culvert.

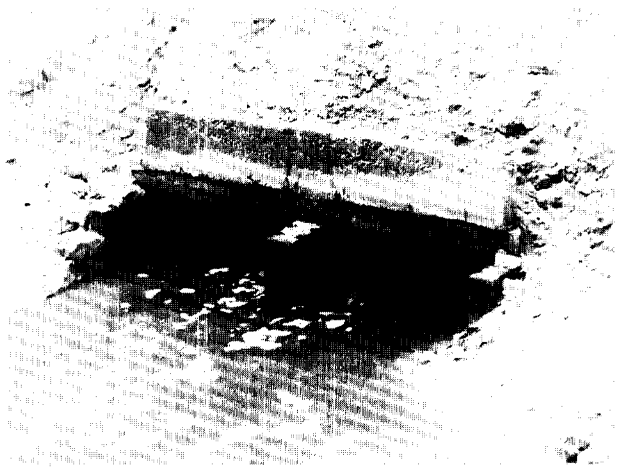


Plate 80. Effluent gate with divided culvert greatly facilitates harvesting procedures by eliminating the temporary suspension of harvest in order to empty bag.

The ideal effluent gate harvest tunnel allows the option of harvesting from either of the two sides. This allows a two-bag harvest. When one is full and ready to empty, the mouth of the net can be closed and the adjacent bag can be opened (Plate 80). In this way, harvest can continue without interruptions. The other alternative is the single culvert set up where only one bag net can be attached at a time (Plate 81), and harvesting must be temporarily suspended while the bag net is emptied. The disadvantage of this procedure is when effluent gate down boards and filter screens

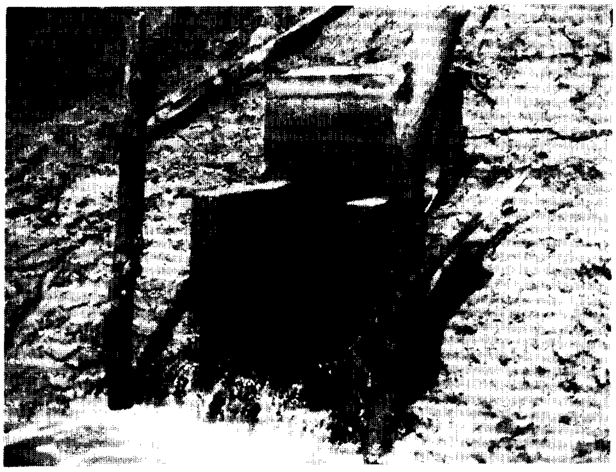


Plate 81. Effluent gate with simple culvert necessitates stopping harvest procedures when emptying bag net.

Plate 82. Weighing and recording cleaned product prior to icing and loading in truck.

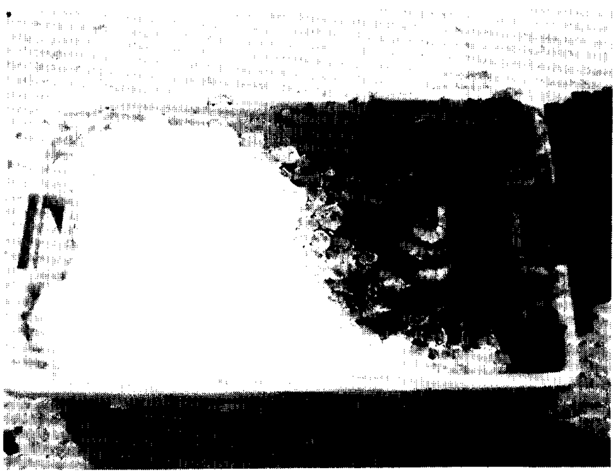


Plate 83. Product placed in transport boxes and iced. Notice top ice layer of approximately 10 cm.

are replaced in the weir to reduce the water current and allow personnel to extract the harvested product from the net manually, the backpressure may disperse the population toward the center of the pond, thereby reducing harvest efficiency.

In many cases, commercial ponds will contain two effluent weir gates that can be harvested simultaneously. While one is being emptied, the other continues harvesting and vice-versa.

While harvest bag nets are being emptied, shrimp should be separated from mud, sticks, fish, crabs and other debris, and washed. Washing will help remove mud and bacteria that may have accumulated in the head region and gill cavity. The presence of excess mud and bacteria will accelerate decomposition and may result in quality loss.

Prior to icing, each container of shrimp should be weighed and accurately recorded (Plate 82). Prior to icing, the product can be dipped in an ice water slurry containing chlorine at 10 ppm for 20 seconds. This not only checks bacterial development but pre-chills the product prior to icing.

The harvested product should be iced in the containers used for shrimp delivery. Each container should receive approximately 10 cm of shaved ice on the bottom, then 23 kg of shrimp, and, finally, another layer of shaved ice approximately 10 to 15 cm thick should be applied over the surface before storing (Plate 83).

At the end of each night (before 0800 hours [8 a.m.]), the total tonnage should be determined. This information will be dispatched with the sealed container truck, along with the respective bill of lading.

The farm biologist should always compare the results of packing plant product classification (tail count per pound) with analyses performed at the farm of specific samples taken during the harvest operation. To ensure minimum discrepancies during product reception and processing at the plant, a trusted representative from the farm should be present during this reception and processing.

When a production pond has been completely harvested, a Pond performance data sheet (Figure 34) should be completed. These data sheets greatly facilitate the maintenance of yearly pond records and summarizes important data pertaining to each culture cycle.

Partial Harvests

Sometimes it may be advisable to harvest certain ponds with exceptionally low growth performance (<.60 g/week) partially. This is especially true when the reduced growth rate is attributed to possible over-stocking. Partial harvests are also beneficial in cases of cash flow deficiencies. In either case, partial harvests should be conducted in the same manner as complete harvests. The only modification is the suspension of the operation when the required tonnage

Shrimp farm ______________________________

Pond ______________ with ______ hectares

A. Stocking

Date of stocking ______________

Type of stocking ______________ in __________ days

Average weight at transfer __________ g

Number stocked ______________

Culture density ______________

Cost of Postlarvae ______________

B. Harvest

Date of harvest ______________

Difference from estimated __________

Type of harvest ______________

Last sample average weight __________

Number harvested ______________

Haravest density ______________

Gross pounds harvested __________ Estimated gross pounds ______________

Gross pounds/hectare ______________

Sales revenue ______________

C. Feeding

Date and average weight at start ________

Feed consumed ______________

Conversion factor ______________:1.00 Estimated conversion factor __________

Cost of feed ______________

D. General

Percent Survival ______________ Estimated percent survival ______________

Culture duration (cycle) __________ Estimated culture duration ______________

Average overall weekly growth ________

E. Economics

Sales Revenue ______________

Feed cost ______________

Postlarvae cost ______________

Indirect cost ______________

Gross Profit ______________

Harvest Analysis

U-15 ______________ %

16-20 ______________ %

21-25 ______________ %

26-30 ______________ %

31-35 ______________ %

36-40 ______________ %

41-50 ______________ %

51-60 ______________ %

61-70 ______________ %

71-80 ______________ %

Others ______________ %

Figure 34. Pond performance data sheet.

has been harvested.

In the majority of cases, a partial harvest of 30 to 50 percent of the total population results in an accelerated growth response for the population remaining in the pond.

Partial harvests of 50 percent at 36-40 and 41-50 tail count size and completion five weeks later at 21-25 and 26-30 classification may be a very profitable strategy if ponds are slightly overstocked (>12 juveniles per m^2).

Harvests for European Markets

A portion of the European market requires its product with the head attached. Whole product presentation constitutes a potential source of quality control problems since the majority of organs and digestive enzymes are found in the cephalothorax region. These organs are the first to decompose and freezing will not substantially prolong prevention of deterioration in quality. Consequently, heads-on product designated for European export must be handled and treated under different conditions to ensure high quality.

Shrimp harvested for this particular market (heads-on) must be harvested live just as in juvenile transfer operations. Harvest bag nets should be emptied every 15 to 20 minutes so the pressure build-up within the harvest bag does not kill animals being harvested.

Live shrimp should be quickly weighed and then submerged in a chilled ice slurry fresh water solution (5°C) containing 5.0 ppm sodium metabisulfite for seven minutes before icing and packing for transport. The sodium metabisulfite solution should be maintained at a 5.0 ppm concentration by adding 1.0 ppm for every 450 kg of product processed. The shrimp must be alive to be able to absorb the chemical into their organs and tissues. After the seven-minute dip, shrimp should be treated as any other product, with careful and quick handling to ensure the highest quality standards.

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About the Author

The author, Jose R. Villalon, born in Havana, Cuba, in 1956, moved at an early age with his family to the state of Arkansas in the United States. He completed his formal education with a Master of Science degree from the University of Washington in Seattle. While at the College of Fisheries in the early 1980s, Villalon studied under the direction of prominent fish nutritionist Dr. John E. Halver and the food engineer Dr. George M. Pigott before devoting himself to the aquaculture private sector. One of his first assignments in the industry was the successful development of an aquaculture feedmill capable of producing dry-compressed and semi-moist pellets as well as flake diets. Villalon later joined a well-known company in the industry and worked his way up through the ranks after proving himself on numerous commercial shrimp farms in the tropics. For the past eight years he has been directly responsible for producing more than 4,000 metric tons of marine shrimp. His strong educational background, bilingual fluency, writing skills and practical farm experience helped move Villalon to the forefront of the company and the aquaculture field. Encouraged by colleagues to publish his experiences, Villalon documented "real world" practical procedures used in the pond culture of marine shrimp. In April 1991 he was elected to the Board of Directors of the World Aquaculture Society, becoming one of the youngest board members to serve this prestigious organization.

Those of us in the aquaculture field have particular appreciation for any publication that will help expand the technical literature available to shrimp farmers and researchers to further their efforts to establish viability on a global scale.

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