AQUACULTURE EXTENSION MANUAL NO. 35 NOVEMBER 2002

Best Management Practices for Mangrove-Friendly Shrimp Farming

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Foreword

Shrimp farming has been perceived to be destructive to mangroves, to produce substances potentially harmful to mangrove ecosystems, and to send excessive organic load to downstream riverine and marine ecosystems during harvest and regular water change. It is important, therefore, to come up with more sustainable and environment-friendly practices for existing aquaculture systems in mangrove areas.

As early as 1998, the Southeast Asian Fisheries Development Center (SEAFDEC) in collaboration with the Association of Southeast Asian Nations (ASEAN) launched a Mangrove-Friendly Aquaculture Program that later gave more focus on shrimp culture. Thus, the Mangrove-friendly Shrimp Culture Project was initiated. The Philippine-based SEAFDEC Aquaculture Department (SEAFDEC/AQD) has been designated as the lead department for technology development and verification, and Thailand the ASEAN lead country for promoting the technology within the Southeast Asian region. The project was funded through the Government of Japan Trust Fund with counterpart funds from governments of member countries where demonstration activities were conducted.

Towards this end, the Project has already obtained encouraging and consistent results in demonstration and privately owned commercial pond facilities using systems where pond discharge has been minimized while maintaining high production and profitability levels. This manual is a compilation of the two recent state-of-the-art series manuals entitled Environment-friendly Schemes in Shrimp Farming and Closed-recirculating Shrimp Farming System by the same authors.

It is with great pleasure that we now present one of the fruits of our collaboration. It is hoped that this manual will guide shrimp farmers throughout the ASEAN region in producing shrimps sustainably.

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Chief, SEAFDEC Aquaculture Department

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Best Management Practices for Mangrove-Friendly Shrimp Farming

Introduction

The negative effects of intensive shrimp farming can now be addressed by the development of the low-discharge and the zero-discharge or closed-recirculation systems. These systems are alternatives to the prevalent open-cycle production system that requires high water exchange. These systems address the problems of massive shrimp production by lessening if not preventing the introduction of disease carriers into the ponds.

To date, the majority of progressive shrimp farmers in Thailand and the Philippines use the low-discharge system also referred to as reduced water exchange system. The use of recirculation systems for intensive shrimp production has been verified and demonstrated by SEAFDEC/AQD in the Philippines and has been used in Thailand for quite sometime already. The recirculation system became popular following the outbreak of luminous bacteria (lumbac) and white spot syndrome virus (WSSV) as shrimp growers tried to free themselves from water-borne and external sources of bacteria and viruses.

The experience and insights gained from successful verification and demonstration of environment-friendly intensive shrimp farming at SEAFDEC/AQD's Dumangas Brackishwater Station in Iloilo, Philippines and at the Marine Shrimp Research and Development Institute of Thailand's Department of Fisheries are detailed in this manual.

Description of the improved pond systems

The low-discharge and the closed-recirculation systems are basically similar as the farm is divided into a number of separate units, i.e., reservoir ponds, grow-out ponds, and sedimentation (also called treatment, tail or settling) ponds (Fig. 1). The difference is that in the former system, a small amount of the water is discharged from the grow-out pond and released to the sea after passing through the treatment pond. In the latter, the effluent of the grow-out pond is reused or recycled after passing through the treatment pond. In the closed-recirculation system, water is fully recirculated by pumping it twice, first from the reservoir to the grow-out pond and second from the sedimentation pond to the grow-out pond. In the low discharge system, water is pumped only once, i.e., from the head reservoir to the grow-out pond.

The low-discharge and closed-recirculation systems include prevention of diseases and removal or reduction of organic wastes, harmful bacteria, and other pollutants from fouled water. These systems are environment-friendly because they integrate reservoirs, sedimentation ponds, crop rotation, probiotics, life support systems, biomanipulators, biofilters, and sludge collectors.

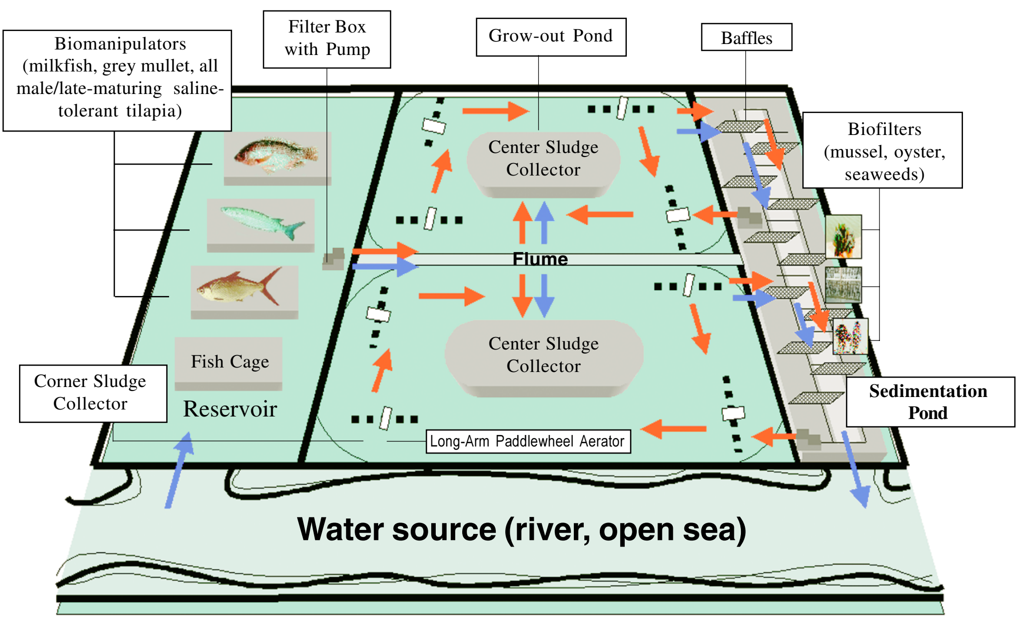

Fig. 1. Pond lay-out of a low-discharge/recirculating shrimp farm in AQD's Brackishwater Station, Philippines. Blue arrows indicate low-discharge system. Red arrows indicate closed-recirculation system.

Basic components of the improved pond systems

1. Grow-out ponds

Generally, grow-out ponds cover about 50% - 75% of the total pond facility of intensive shrimp farms (Fig. 1). They come in different configurations but the most common is either square or rectangular, each 0.5 - 1.0 ha in area. Grow-out ponds may have earthen, concrete or plastic-lined dikes. The shrimps are grown from fry to marketable size at stocking densities of 20 - 60 fry/m^2. The dikes, gates, and canal systems are designed and constructed to hold a minimum water depth of 100 cm; a 150 cm water depth is ideal.

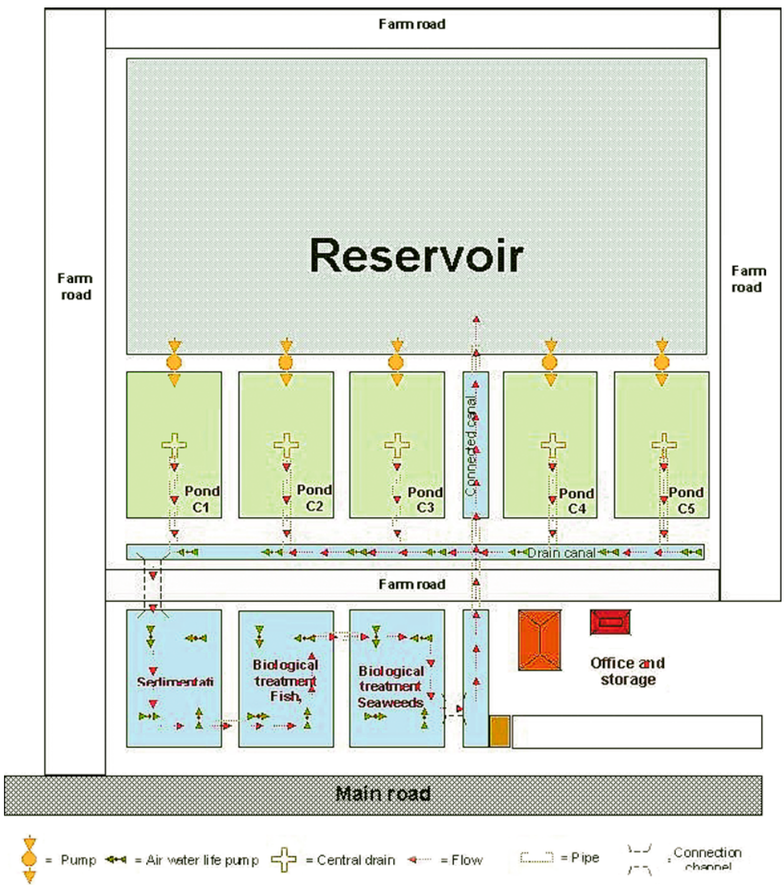

Fig. 2. Design of a recirculating shrimp farm at DOF's Research Institute, Songkhla, Thailand.

Model shrimp farms in the Philippines and Thailand recommend small, easy to manage grow-out ponds, 0.25 - 1.0 ha in area, with reservoir ponds, 0.08 - 1.0 ha. in area. Pond compartments must have independent water supply and drain canals to facilitate water management. This double gate system may be made of wood, concrete or PVC standpipes.

Catwalks are installed at strategic points in the pond to facilitate the monitoring of stocks and feed consumption. These may be made of bamboo, wood or concrete.

Feeding trays (0.75 - 1m^2) are installed about 4 - 8 in a 0.5 - 1.0 ha pond. The trays are used to monitor feed consumption of the shrimps.

2. Reservoir pond with biomanipulators and greenwater

The reservoir pond should be at least 25% of the area of the grow-out pond (Figs. 1 and 3). All incoming water is temporarily stored in this compartment for at least one week before it is used in the grow-out ponds. If only one pond is available for use as reservoir, it is better to subdivide it into two compartments that can be used alternately. It is in the reservoir pond where the desired salinity of the water is controlled or adjusted. Reservoirs also help reduce if not totally eliminate other crustacean hosts and carriers of pathogens. The water pumped into the grow-out pond passes through a filter box to prevent the entry of extraneous species.

Fig. 3. Reservoir pond.

The reservoir is stocked with biomanipulators: all-male tilapia, milkfish or mullet. Biomanipulators have been found to help condition the water and produce green water. Biomanipulators are stocked at a recommended rate of 5,000 - 10,000 fish/ha or an equivalent standing biomass of
1.5 to 2.5 tons/ha.

3. Settling pond with baffles and biofilters

The settling pond (also called sedimentation, tail reservoir or treatment pond) is used to hold the effluent water from the grow-out pond so that dissolved nutrients and suspended solids may be minimized before releasing them back to the water source (Figs. 1 and 4). The main drain canal, which may also serve as the settling pond, should be wide and deep to have efficient drainage. The pond should have a control gate to prevent effluents from flowing out until most of the suspended solids have settled.

Fig. 4. Settling pond.

Water from the grow-out pond is treated through a baffle system installed in the settling pond. Baffles made of plastic sheets or fine mesh nets enhance mechanical filtration and sedimentation as water passes through in zigzag fashion (Fig. 5). The water slows down and suspended solids settle before reaching the filter box.

Fig. 5. Baffles in the settling pond.

To minimize the concentration of dissolved nutrients in the effluent water, biological filters such as oysters, mussels, and seaweeds (*Gracilaria spp.*, and filamentous green algae) are hanged in the settling pond (Fig. 6).

Fig. 6. Biofilters-oysters, Gracilaria and green mussel.

A filter box fitted with a 2 hp submersible pump is installed at the end of the pond for water circulation. The pump is operated for 6 to 12 hours a day about 3 times a week depending on the water quality.

4. Sludge collectors

a. Center sludge collector

This is a double walled net enclosure (10 m x 10 m x 1.5 m) installed at the middle of the grow-out pond occupying about 5% of its area
(Fig. 7). The circular water flow aided by the long-arm paddlewheel collects the uneaten feeds, feces and other sediments at the center of the ponds. The net separates the shrimps from the sludge.

The sludge collector has an inner coarse mesh net (5 mm) and an outer fine mesh net (1 mm) embedded about 50 cm deep into the pond bottom and supported by a bamboo frame. The outer fine mesh net is removed after 60 days when the shrimps have become juveniles - big enough not to get inside the sludge collector. Tilapia, milkfish, or mullet are stocked in the sludge collector to feed on the accumulated wastes.

Fig. 7. Center sludge collector in a grow-out pond.

b. Corner sludge collector

Sludge collectors made of the same materials are likewise installed in all corners of the pond (Fig. 8). These corners are considered dead spots where sludge accumulates. Biomanipulators are also stocked in the corner sludge collector to feed on accumulated wastes.

Fig. 8. Corner sludge collector.

5. Power supply

An intensive shrimp farm's power source should have the capacity to supply the electricity needed to operate the lights, paddlewheels, electric-pumps, blowers, and other equipment necessary at all times. Generally, a 3-phase system is preferred to minimize power consumption. A standby generator (Fig. 9) should also be available to operate the paddlewheels and pumps during power interruptions.

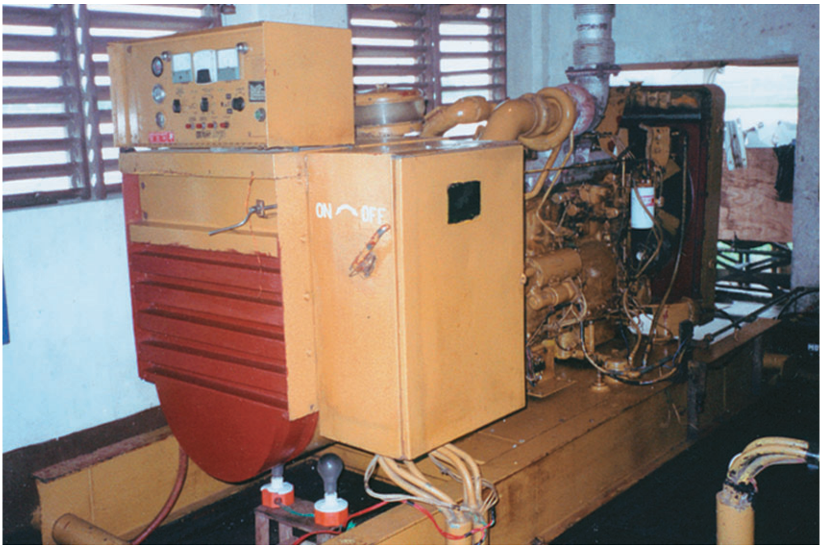

Fig. 9. Standby generator.

6. Aeration systems

Mechanical aeration (fuel or electric-driven) of the pond water is important and is already a common facility in intensive shrimp farming. It improves shrimp production efficiency by keeping dissolved oxygen at optimum levels. Efficient water circulation prevents stratification and lessens the accumulation of nitrogenous compounds in spots where sludge accumulates. Aeration also keeps organic particles suspended in the water column and creates heterotrophic microbial communities that purify the water and mineralizes dissolved organic matter.

Fig. 10. Long-arm paddlewheel aerator. Inset shows the diesel engine (8hp) and electric motor (1hp), connected to a speed reducer designed to operate long arm paddlewheel with 10 to 15 empellers.

The use of long-arm paddlewheels (Fig. 10 and 11) is recommended in intensive shrimp farms with square or rectangular compartments 0.5 - 1.0 ha in area. Long-arm paddlewheels can cover a wider surface area and can adequately aerate and circulate the water in the grow-out ponds. When properly positioned, the paddlewheels create a circular water current that brings the organic sludge to the center of the pond bottom, leaving the peripheral areas clean for the shrimp to dwell on and feed.

It is important that farmers consider aerator efficiency, reliability, and ease of maintenance when purchasing an aeration equipment. A paddlewheel aerator with 10-15 empellers can be operated efficiently using a fabricated speed reducer having a ratio of 1:40 connected to a mechanical diesel engine (8hp) or an electric motor (1hp).

Fig. 11. Types of aerators commonly used in shrimp farms in Thailand and now being used in the Philippines.

The bottom aeration system (Fig. 12) is also recommended as an alternative to paddlewheels in intensive shrimp farms. It increases the dissolved oxygen concentration in the pond bottom and the entire water column. The system consists of PVC pipes (10 mm diameter) perforated with a row of tiny downward-facing holes and evenly laid out on the entire pond bottom at 2-10 m intervals. The pipes are connected to a 2 hp ring blower.

Fig. 12. Bottom aeration system with center sludge collector.

7. Water pumps

When the reservoir pond cannot be filled with water from a nearby source by tidal action, it is necessary to use electricity or fuel-driven water pumps (Fig. 13), whichever is available and cost effective. Water pumps come in various specifications and are essential components of intensive shrimp farms.

Fig. 13. Electrical water pump and diesel-powered water pump.

8. Filter boxes

Filter boxes installed in the reservoir pond are an improvement over the usual filter nets or bags. With locally available materials, the filter box is easy to fabricate and operate. The box is made of plywood, perforated at the sides and bottom and filled with layers of sand, fine gravel or ground-up oyster shells (Fig. 14). A submersible pump is set inside the highest portion of the filter bed that draws water out into the grow-out pond. When properly installed, the filter box effectively eliminates unwanted species of fish and crustaceans that may be carriers of shrimp diseases. In the closed recirculation system, another filter box with an independent pumping system is installed in the sedimentation pond to recycle the treated water back to the grow-out pond.

Fig. 14. Filter boxes.

9. Monitoring equipment

It is important to be equipped with basic tools of the trade (Fig. 15) such as a refractometer (to measure the salinity), a thermometer (to measure water temperature), a secchi disk (to measure transparency), a pH meter, and a dissolved oxygen (DO) meter. These monitoring equipment are necessary so that water quality in the pond can be maintained at optimum levels.

Fig. 15. Water quality monitoring kit.

Pond Preparation

At the start of every cropping season, the ponds must be properly prepared in order to establish optimum pond conditions necessary for the growth and survival of the shrimp post larvae or juveniles that will be stocked. Because shrimps are bottom dwellers, it is necessary to remove the layer of black soil, sludge or debris that has accumulated on the pond bottom during the previous cropping. It is also important to remove competitors and disease carriers, improve soil pH, and propagate natural food organisms in the pond. These conditions are achieved through drying, scraping and tilling of pond bottom, lime and fertilizer application and water preparation.

Shrimp ponds must have a sandy or silt-clay type of soil with the following characteristics:

pH	-	7.0 - 8.5
Organic Matter (OM)	-	< 3 %
Iron	-	< 400 ppm (mg/l)
Color	-	Brown

Procedures

1. Drain the pond totally, and level the pond bottom. If necessary, dig a peripheral and/or central canal that slopes slightly towards the drain gate to facilitate draining and drying of the pond (Fig. 16).

Fig. 16. Central canal in grow-out pond.

2. Dry the pond until the bottom cracks (Fig. 17). This will hasten oxidation, release obnoxious gases, and kill unwanted species.

Fig. 17. Dried pond bottom.

3. Scrape off sludge from the pond bottom. Dispose it where it will not be washed back into the shrimp pond during heavy rains (Fig. 18).

Fig. 18. Scraping sludge from the grow-out pond bottom.

4. Flush the pond by filling it with 30 cm deep water for 24 hours and then draining it completely.

5. Apply either agricultural lime ($CaCO_3$) at 2 tons/ha or hydrated lime Ca $(OH)_2$ at 0.5 - 1 ton/ha to neutralize acidity of the pond bottom soil.

6. Till the pond bottom to mix the lime thoroughly with the topsoil and to further oxidize the upper 10 - 20 cm layer of the pond bottom.

7. Compact the pond bottom with a manual compactor or a roller. Compaction can also be achieved by using the pressure exerted by the water column. This is done by raising the water level to the maximum and holding it for at least one week. The water is then drained and the pond bottom is dried thereafter. This is less laborious but requires a longer time.

8. Install a two-walled sludge collector at the center and the corners of each grow-out pond. Remove the outer fine mesh net 60 days after stocking of the shrimp postlarvae when these have grown larger.

9. Install a substrate made of fine mesh nylon screens (0.5 cm mesh size) like tennis nets across the pond bottom (Fig. 19) to increase the surface area by about 35 - 50% and for attachment of natural food organisms. Position the nets towards the drainpipe to the settling pond. The nets should be about 25 cm above the pond bottom.

Fig. 19. Natural food substrates installed in grow-out ponds.

Water Preparation

Water from the reservoir is pumped into the grow-out pond and fertlized to achieve a desirable plankton bloom under aerated condition. This is done at least 3-5 days before stocking.

Procedure:

1. Install 4 units of electric or fuel-driven paddlewheel aerators per hectare. Use paddlewheels with a minimum of 4 impellers/unit. Position them 5 m from the dike and about 40 m from each other to create a circular current.

2. Fill the grow-out pond with filtered water from the reservoir by gravity or by pumping.

3. When the water depth is about 30 cm, apply tea seed powder to kill predators and competitors at 50 kg/ha during sunny days or 100 kg/ha during cloudy days. Remove dead animals and fill the pond with water from the reservoir pond to at least 100 cm deep.

4. Apply dried chicken or cow manure at the rate of 300 kg/ha together with urea (45-0-0) at 18 kg/ha by the 'tea bag' method. To make a 'tea bag', fill a perforated sack (such as feed sack) with 25 kg of dried manure mixed with 2 kg urea. Close and tie the sack securely then submerge it while suspended from a bamboo pole (Fig. 20). Install the 'tea bags' in strategic points, preferably in front of each paddlewheel. 'Tea bags' gradually release nutrients to the pond water, resulting to a brownish green hue in about 5 days. This color indicates a good combination of zoo and phytoplankton in the water. Remove the 'tea bags' as soon as a stable plankton bloom is obtained.

Fig. 20. 'Tea bag' of manure and urea.

5. If plankton does not bloom, replace 20 - 30% of the pond water and apply urea again at 10 - 15 kg/ha. If an adjacent pond has a good phytoplankton bloom, use water from this pond to replenish and inoculate the other pond.

   Experience in Thailand showed that one week after applying tea seed cake at 25 kg/rai (=156 kg/ha), water transparency increased by more than 10 cm. If transparency is less than 80 cm within 3 days, it is no longer necessary to add fertilizer because the nutrients in the water are enough for plankton growth. When the desired water color is not obtained, inorganic fertilizers are added to accelerate phytoplankton growth. The fertilizers to be used and their application rates are:

Urea (40-0-0)	:	2.0 kg/rai (=12.90 kg/ha)
Phosphate fertilizer	:	1.5 kg/rai (= 9.40 kg/ha)

6. Stock the net cages inside the sludge collector with tilapia, milkfish, or mullet to a standing biomass of at least 2,000 kg/ha to produce adequate green water.

   Water having the following physico-chemical characteristics is recommended for stocking:

DO	-	> 4 ppm
Ammonia	-	< 0.1 ppm
Salinity	-	25 - 30 ppt
pH	-	7.5 - 8.5
Temperature	-	28 - 32 °C
Alkalinity	-	above 80 ppm
Transparency	-	35 - 45 cm
Water color	-	Brownish green

Stocking and Acclimation

Shrimps are most vulnerable during the post larva or fry stage. Even with the best pond preparation, the fry may die during stocking if they are not healthy, if the stocking time is not ideal, or if the quality of the transport water is very different from the pond water. The stocking density should be 20 - 60 fry/m^2.

When buying fry, make sure that they are of good quality (Fig. 21) with the following characteristics:

a. Swim against the current when the basin water is stirred and react to tapping and to passing shadows

b. Swim horizontally and not vertically as if gasping for breath

c. Have straight bodies

d. Have uniform sizes

e. Measure at least 12 mm in length at PL_{18} stage

f. Have clear abdominal muscles

g. Have full gut

h. Have a gut to muscle ratio of 1:4

i. Certified free of monodon baculovirus and white spot virus by a diagnostic laboratory with Polymerase Chain Reaction (PCR).

Fig. 21. Good quality shrimp fry.

Schedule the stocking early in the morning when the temperature is 27 - 28ºC. Prepare the basins, pails, and scoops prior to the arrival of the fry. Install two survival nets (1 x 1 m) in every pond that will be stocked with fry.

Procedure for acclimation

1. Allow the unopened plastic bags containing the fry to float in the pond (Fig. 22) where they are to be stocked for 30 - 60 min.

2. Select 2 - 3 plastic bags for counting and pour the contents of each bag into a basin. Count the fry in each basin and compute the average of three counts.

3. Check the temperature, salinity, and pH of the transport water every 15 min. As a guide, allow 15 minutes of acclimation time for every 1°C, 1 ppt and 0.1 unit difference in temperature, salinity and pH respectively.

4. Open the rest of the plastic bags and gradually add or splash pond water into the bags.

5. Continue adding pond water slowly until the salinity, temperature and pH of the water inside the transport bags and the pond are the same.

6. Stock 100 fry in each survival net.

7. Allow the rest of the fry to swim out of the bags.

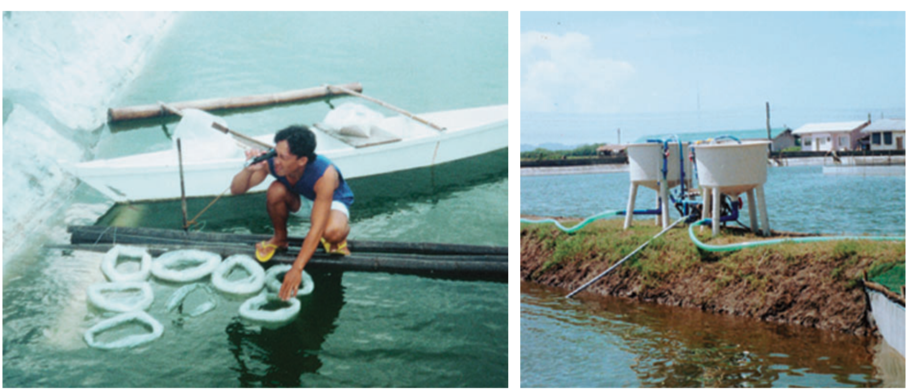

Fig. 22. Acclimation of newly arrived shrimp fry in plastic transport bags and in fiberglass tanks.

Always use the widest difference as the basis for determining acclimation time. If the temperature difference is 2°C but the salinity difference is 4 ppt and the pH difference is 0.1 unit the total acclimation time shall be: 15 x 4 = 60 minutes.

Do not extend acclimation time beyond 2 hours because this will stress the fry. This means that if the pond salinity is more than 8 ppt different from the hatchery salinity, it is necessary to pre-acclimate the fry at the hatchery prior to packing and transport. Request the source hatchery to acclimate prior to transport the fry in water with the same salinity as the pond water where it will be stocked.

Check one survival net after 15 days and the second after 30 days. Compute the average of the two counts and use it to estimate the shrimp survival in the pond.

Feeding Management

Since feeds constitute about 40 - 50% of the total production cost in an intensive shrimp culture operation, the use of good quality feeds (stable with high protein content) is recommended. In order to develop an efficient feeding management scheme for the operation, the total number of shrimps in the pond, growth rate, and feed conversion ratio (FCR) must be monitored every week (Fig. 23).

Fig. 23. Monitoring feed consumption and broadcasting feeds.

During the first month of operation, a 'blind feeding scheme' is used. On the day after stocking, the shrimps are fed at the rate of 1 - 2 kg/100,000 shrimps. Feeding thereafter is adjusted daily as shown in Table 1. Feeds are broadcasted (Fig. 23) throughout the pond following the schedule in Table 2.

Table 1. Daily feed adjustments for the first 30 days of operation.

DOC	Increase/Day/100,000 Fry	Survival Estimate (%)
01-07	150 Grams-250 Grams	100.00
08-15	250 Grams-350 Grams	80.00
16-22	350 Grams-450 Grams	70.00
23-30	500 Grams	60.00

Table 2. Feeding Schedule for 1 production cycle.

ABW	Feed Type	Freq	Feeding Time & Ration					Monitoring Time (hrs)*
			6AM(%)	10AM(%)	2PM(%)	6PM(%)	10PM(%)	
0.01-0.70	PL	2X	50				50	4.0
0.70-2.00	Starter	3X	40		40		20	4.0
2.00-4.00	Starter	4X	30	20		30	20	3.0
4.00-5.00	Mixed	5X	30	20		30	20	2.5
5.00-8.00	Grower 1	5X	25	10	10	35	20	2.5
8.00-10.00	Mixed	5X	25	10	10	35	20	2.5
10.00-18.00	Grower 2	5X	25	10	10	35	20	2.0
18.00-20.00	Mixed	5X	25	10	10	35	20	2.0
22.0-up	Finisher	5X	25	10	10	35	20	1.0

* *after feeding.*

After 30 days, the daily feed ration may be adjusted in two ways:

1. By feeding based on demand, or

2. By projecting the ideal feed consumption based on estimated values for survival rate, average daily weight gain, ABW, and percent feeding rate.

Adjusting the daily feed ration based on demand

Demand feeding involves the actual monitoring of feed consumption in feeding trays installed in strategic points of the grow-out pond. The number of trays to be installed is based on the pond area (Table 3). Based on the average body weights (ABW) that are computed from the weight measurements from shrimps caught in the feeding trays taken every 7 days, percentage of the feed ration (Table 4) can be computed. The feeds are placed in the feeding trays every time the shrimps are fed. Feed consumption in all trays is monitored several hours after the feeds are placed (Tables 2 and 6). The number of feeding trays where feeds were totally consumed is divided by the total number of feeding trays. Based on these data, the feeding ration is adjusted following Table 5.

Table 3. Number of feeding trays to be installed in shrimp grow-out ponds based on pond area.

Pond Area (ha)	No. of Feeding Trays
0.5	4
0.6 – 0.7	5
0.8 – 1.0	8 - 10

Table 4. Percentage of feed ration to be placed in feeding trays based on pond area and ABW range.

Area (Ha)	ABW (gms)		
	1.0 – 10.0	11.0 - 20.0	21.0 - UP
0.4 - 0.6	0.50	1.00	1.25
0.7 - 0.8	0.40	0.80	1.00
0.9 - 1.5	0.30	0.60	0.75
1.6 - UP	0.25	0.50	0.70

Table 5. Feed ration adjustment based on feed consumption in feeding trays.

Feeding Tray Monitoring	Feed Adjustment
8/8	+15%
7/8	+10%
6/8	+5%
5/8	maintain
4/8	maintain
3/8	maintain
2/8	-5%

**Assumptions:*

1. *no. of feeding trays: 8*
2. *size of feeding tray: 0.5 x 0.5m - 0.7 x 0.7 m*
3. *less than 10% left considered consumed*
4. *more than 10% left considered excess*

Adjusting the daily feed ration based on ideal feed projections

This method is best explained by the following sample problem: Project the daily feed ration from 30 - 37 DOC of a pond initially stocked with 100,000 postlarvae. At 30 days of culture the stock had a 90% survival rate, average body weight (ABW) of 2 g and 0.15 g average daily weight gain.

Assumptions:

Initial stock in the pond	-	100,000 postlarvae
Survival rate	-	90%
Average body weight (ABW)	-	2 g
at 30 Days of Culture (DOC)	Average daily weight gain -	0.15 g

Formula:

$$\text{Ideal Daily Feed Ration} = \text{Stock} \times \text{Survival rate} \times \frac{\text{ABW}}{1000} \times \text{Feeding Rate}$$

The projected daily feed rations is shown in Table 8. The feeding rates are based on Table 6 while the estimated daily growth is shown in Table 7.

Table 6. Feeding rates and monitoring time at given ABW.

ABW (g)	Feed rate (%)	Monitor Time (hrs) *
2	6.0	3.0
5	5.0	2.5
10	4.0	2.5
15	3.0	2.0
20	2.5	1.0
25	2.5	1.0
30	2.0	1.0
35	2.0	1.0

* *after feeding.*

Table 7. Estimated daily growth at given ABW ranges.

ABW (g)	Estimated growth (g/day)
2.0 - 5.0	0.1 - 0.2
5.0 - 10.0	0.2 - 0.25
10.0 - 15.0	0.25 - 0.3
15.0 - 20.0	0.3 - .035
20.0 - 25.0	0.35 - 0.38
25.0 - 30.0	0.38 - 0.4
30.0 – UP	0.4 - .045

Table 8. Projected daily feed ration from 30 - 37 DOC of shrimps based on assumed daily weight gain, ABW, and feeding rate.

DOC	ABW (g)	Feeding Rate (%)	Ideal feed/day (kg)
30	2.00	7.29	13.12
31	2.15	7.13	13.80
32	2.30	6.79	14.05
33	2.45	6.63	14.62
34	2.60	6.46	15.12
35	2.75	6.29	15.57
36	2.90	6.20	16.18
37	3.05	6.10	16.74

** 0.05% daily decrease in feeding rate from 30 - 37 DOC based on Table 6.*

Factors affecting feeding

1. *Temperature*. Maintain water temperature at 26 - 33°C. At temperatures below 25°C and above 34°C the shrimps do not feed well.

2. *Dissolved Oxygen.* Maintain the DO level above 4 ppm. Feeding is reduced when DO level drops below 4 ppm.

3. *Diseases.* Shrimps infected with diseases either do not feed well or stop feeding.

4. *Moulting*. Moulting is the normal process by which shrimps grow. When mass moulting occurs, reduce feeding by 25%. Resume normal feeding after 2 - 3 days.

5. *Phytoplankton die-off.* Pond conditions resulting from phytoplankton die off is very stressful for the shrimps. They do not feed when the water is clear. Increased ammonia in the water results in loss of appetite in shrimps.

Monitoring and Record Keeping

Monitor regularly the water quality and shrimp feeding, growth and survival. Keep good records as basis for water management and other treatments to maintain optimum pond conditions for shrimp growth.

1. Monitor the water depth, transparency, temperature, salinity and pH twice daily, at 0600 - 0700H and at 1400 - 1500H (Fig. 24).

Fig. 24. Monitoring the water quality.

2. Monitor the luminous bacteria count once every two days (Fig. 25). Collect water samples using clean and sterile bottles. Bring the samples immediately to the nearest diagnostic laboratory for analysis.

3. Monitor feed consumption by installing 4 - 8 feeding trays (each about 1 m^2) in a 0.5 - 1.0 ha pond.

4. Using the same feeding trays, monitor the condition of the shrimps based on their physical appearance. Physical defects may be signs of stress or may cause stress and eventual mortality.

Fig. 25. Quantifying the luminous bacteria present in the water.

5. Monitor the length and average body weight (ABW) of the shrimps to determine whether they are growing and if there is a need to adjust the daily feeding rate.

6. Keep a record of all the parameters being monitored (Fig. 26). This is essential in troubleshooting problems that will be encountered and will serve as reference for future croppings.

Fig. 26. Sampling and record keeping.

Monitoring growth

Starting on the second month, take samples of shrimps from the feeding trays for length and weight measurements at weekly intervals. Use a cast net to collect the shrimp samples monthly after stocking. Measure the length and weight of 50 - 100 shrimps and compute the average body weight.

Estimating the stock

The number of surviving shrimps in the pond each day may be estimated from the total daily feed consumption and the average percentage of feed consumed per day. Using the daily survival estimate, the average weekly survival rate may be calculated.

Another way of estimating the stock in the pond is by counting the number of shrimps caught by cast net from 10 randomly chosen spots in the pond. The surviving stock is estimated based on the area covered by the cast net, the total area of the pond and the average number of shrimps caught by cast net 10 times.

Estimating feed conversion ratio (FCR)

Calculate the FCR weekly using the estimated number of shrimps, the ABW of the shrimps, and the total feed consumption for the week. If the FCR exceeds 1.5, observe closely the feed consumption in the feeding trays and follow the recommended adjustments in the feeding ration (please refer to Table 3 under Feeding Management). This will keep the FCR difference within a reasonable range from 1.5.

Monitoring water quality in the grow-out, reservoir and sedimentation pond for the closed-recirculation system

Water quality parameters (including soil) should be monitored regularly before, during, and after every cropping. Monitoring should include the farm's water source and the area where the pond effluents are discharged to prevent the degradation of the surrounding natural waters. Both physico-chemical and biological parameters must be analyzed including nutrient, plankton, bacterial and viral profile of the water.

Water quality in the grow-out pond

Water samples for analysis should be taken from the surface and bottom of the grow-out pond.

Transparency, salinity, atmospheric conditions, water and air temperature are monitored daily at 3 PM while pH and dissolved oxygen are monitored twice daily at 6 AM and at 3 PM. Alkalinity, ammonia and nitrite are monitored every Monday, Wednesday and Friday at 3 PM. The 24-hour monitoring of the DO and temperature of the water is done once a week.

Coliforms, fecal coliforms, heavy metals and insecticides in the grow-out pond and the natural water are monitored once a month.

Water quality in the reservoir and settling pond

Just like in the grow-out pond, water samples for analysis should be taken from the surface and bottom of the ponds.

The pH, DO, temperature, salinity, ammonia, nitrite, and transparency of the water are monitored daily at 3 PM.

Every time water is pumped from the reservoir or settling pond to the grow-out pond, the water should first be analyzed for alkalinity, ammonia, nitrite, nitrate, phosphate, *chlorophyll a*, suspended solids, BOD, *Vibrio spp.* and total bacteria.

Following are the optimum levels of various water physico-chemical and biological parameters that should be maintained in the different compartments of the closed-recirculation system.

Grow-out pond:

Parameter	Level
Dissolved oxygen	> 3.5 ppm
Total ammonia	< 0.1 ppm
Nitrite	< 0.2 ppm
Transparency	30 – 40 cm
pH	7.8 – 8.5
Alkalinity	> 80 ppm
Biological oxygen demand (BOD)	< 0.2 ppm
Total bacteria and *Vibrio* sp.	< 10^2 cfu/ml

Reservoir and Treatment pond:

Parameter	Level
Dissolved oxygen	> 3.5 ppm
Total ammonia	< 0.1 ppm
Nitrite	< 0.2 ppm
pH	7.8 – 8.5
Alkalinity	> 80 ppm
Total suspended solids in the water	< 20 ppm
Total bacteria and *Vibrio* sp.	10^3 – 10^4 cfu/ml

Water Management

Successful intensive shrimp farming operations require good feeding and water management to maintain good water quality. Inputs of large quantities of high quality feed cause rapid changes in pond water quality. Uneaten feeds and metabolic wastes add inorganic nutrients and organic matter to the water and the pond bottom. The abundance of bacteria in ponds may be related to the amount of organic wastes derived from shrimp feeds. Under aerobic conditions, microbial decomposition of organic matter produces organic and inorganic compounds, such as phosphates (PO_4), nitrite-nitrates (NO_2^--NO_3^-) and carbon dioxide (CO_2). Under anaerobic conditions, ammonia (NH_3) and hydrogen sulfide (H_2S) are produced.

Water from a nearby source should be aged in the reservoir pond before it is pumped to the grow-out pond. Suspended solids settle while good bacteria and beneficial plankton proliferate. The reservoir should be stocked with fish that effectively serve as biomanipulators producing 'green water', which suppresses the growth of harmful bacteria.

Water quality maintenance

1. Water depth should not be less than 1 m; 1.5 m is ideal. Deeper water provides a more stable environment for the shrimps.

Fig. 27. A shrimp pond with good plankton bloom.

2. The color of the water should either be brownish green, golden brown or light green. These colors indicate good plankton profile (Fig. 27). Bluish green to dark green should be avoided.

3. Transparency in the grow-out ponds must be 40 - 60 cm for the first 60 days of culture (DOC) and 35 - 45 cm from day 60 until harvest. Keep transparency within the optimum range. A good plankton bloom shades the water column, prevents the growth of benthic algae, and stabilizes water temperature.

4. Maintain dissolved oxygen at concentrations greater than 4 ppm. Operate paddlewheel aerators when DO falls below 4 ppm. DO directly affects the feeding, metabolism, health and survival of shrimps.

5. Maintain water pH at 7.5 - 8.5. When pH is lower or greater than the ideal values, change the water and apply dolomitic or agricultural lime at 150 - 300 kg/ha. A pH fluctuation greater than 0.5/day is detrimental to shrimps.

6. Maintain water salinity at 15 - 25 ppt. When luminous bacteria proliferate, reduce water salinity by 3.2 ppt/month to 10 to 15 ppt until harvest. This will reduce the luminous bacteria population to a less harmful level.

7. Keep water temperature at 28 - 32°C. Water temperature is stable in ponds with deeper water.

8. Ammonia should be less than 0.1 ppm and nitrite less than 0.2 ppm. When ammonia and nitrite increase, increase the DO by aeration and water change.

9. Hydrogen sulfide should be less than 0.02 ppm. Hydrogen sulfide does not occur in well-oxygenated water.

10. Alkalinity must be greater than 80 ppm.

11. Total suspended solids must be less than 20 ppm.

12. *Vibrio* bacteria count should be less than 10^2 cfu (colony forming units) in the grow-out pond and less than 10^3 - 10^4 cfu in the settling pond.

Use of 'green water'

A good plankton bloom is indispensable to successful shrimp farming. Plankton in the pond is composed of microscopic plants (phytoplankton) and animals (zooplankton). The quality and quantity of phytoplankton present gives the water a distinctive color that varies from green, yellow-green, brownish green to brown, hence the term 'green water'.

'Green water' is beneficial to the shrimps because it reduces light intensity at the bottom where they stay most of the time. The lower light intensity is less stressful to the shrimps and enhances feeding. It also prevents the growth of benthic algae. Phytoplankton also helps oxygenate the water during the day and stabilizes water temperature.

Use of probiotics

Probiotics for bioaugmentation may be applied in both grow-out and reservoir ponds to reduce toxic gases in the sediment and water and enhance the growth of beneficial bacteria. Probiotics come in powder, liquid or pellet forms. Follow the recommended application rate indicated on the label. Use only good quality probiotics known to work in the saline environment.

Monitor the bacterial count twice a week. Change 20 - 30% of the water if the luminous bacteria count exceeds 10^2 cfu even if the water color and transparency are optimum. Apply probiotics in both the grow-out and the reservoir ponds once a week after water change to help maintain water quality and the population of beneficial bacteria in the pond.

Common problems and emergency measures

Water quality should be properly monitored in order to implement procedures that would prevent adverse effects on the cultured shrimps. Following are the problems commonly encountered during operations and the recommended measures that must be undertaken to solve them:

1. When excessive or rapid phytoplankton blooms occur, change 20 - 30% of the water.

2. When the water suddenly becomes clear due to the collapse of the phytoplankton population, partially drain the pond and replenish with water from the reservoir or from an adjacent pond with a good phytoplankton bloom. Apply urea at 18 kg/ha and install 8 'tea bags', each with 30 kg chicken manure, to restore the color and transparency of the water to the optimum level. Phytoplankton die-off usually occurs when their bloom is not properly maintained.

3. Manually remove floating masses of benthic and filamentous algae. Be careful not to include shrimp juveniles.

4. When unwanted or predatory fish are observed in the grow-out pond, temporarily transfer the fish stock used as biomanipulators in the sludge collectors to net cages set in an adjacent pond. Lower the water depth to 60 - 80 cm depending on the number of shrimps in the pond. Apply tea seed powder (100 - 150 kg/ha during sunny days and 200 - 300 kg/ha when skies are overcast). Keep all paddle wheels operating during tea seed application. After 2 - 3 days, return the biomanipulators to the sludge collectors.

5. In case the water pH and alkalinity are lower than the optimum level, add carbonated lime at 4 kg/rai (=25 kg/ha) daily until the pH returns to its optimum level.

6. When ammonia and nitrite levels are high, increase aeration to increase DO above 4 ppm. Reduce the feeding rate by 10% - 40% if necessary.

Water treatment in the settling pond

1. Increase aeration when DO is lower than 3.5 ppm.

2. Apply lime when pH or alkalinity is lower than the optimum level.

3. Clean or change the sandbags when they are clogged. During the cleaning of the sandbags, recirculate the water into the settling pond.

4. When ammonia and nitrite increase, increase the aeration in the grow-out pond.

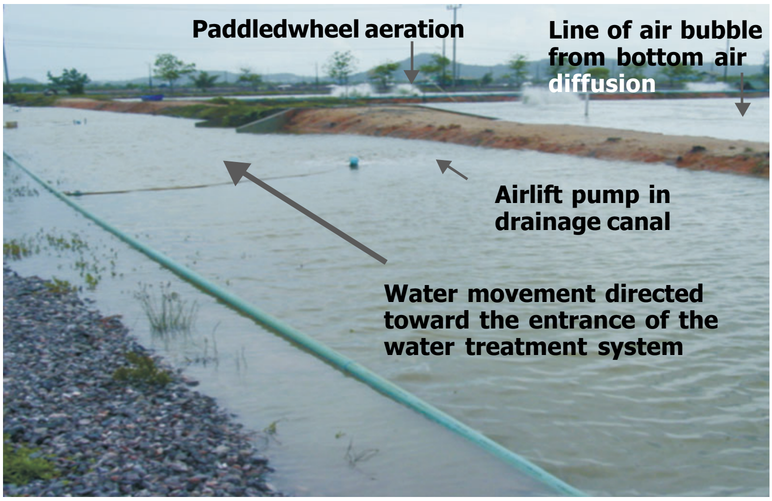

Fig. 28. Pond aeration and the circulation system in the drainage canal.

5. In case total bacteria and *Vibrio* spp. counts are too high, increase the aeration in the settling pond and change the sand bags as necessary.

Fig. 29. Treatment pond for small scale water recycle pond using integrated physical and biological technology.

6. Increase aeration when the settling pond has high BOD.

7. Increase water circulation if fish or seaweeds die in the settling pond.

Aeration

Aeration creates a homogeneous pond environment in terms of temperature, salinity, DO, and phytoplankton distribution. It releases into the atmosphere toxic gases produced in the pond. Aeration also hastens the effect of organic and inorganic fertilizers on phytoplankton bloom, and the effect of tea seed and other inputs.

The paddlewheels are operated according to the following schedule:

Days of Culture (DOC)	6:00 AM to 6:00 PM	6:00 PM to 6:00 AM
Pre-stocking	100%	100%
1-20	1 – 2 units	2 units
21-40	2 units	4 units
41-60	2 units *	4 units
61 to harvest	4 units **	4 units **

*Increase paddlewheel operation during daytime under the following conditions:

a. Overcast skies;
b. Rainy days;
c. When phytoplankton dies-off;
d. Feeding drops below normal level; and
e. Shrimps show signs of disease

**Except during feeding.

Schedule of water transfer for the closed-recirculation system

The schedule of water transfer depends on the water quality that is determined only by regular monitoring.

In the closed-recirculation system, the following water transfer schedule is recommended:

1st	month	:	5% transfer once every 15 days
2nd	month	:	5% transfer once every 10 days
3rd	month	:	5 - 10% transfer once every 7 days
4th	month	:	5 - 10% transfer once every 5 days

In the closed-recirculation system, water transfer starts when water is drained from the grow-out pond to the settling pond. After passing through the settling pond, the treated water is pumped back to the grow-out pond through a filter box. A paddlewheel aerator is operated at the outflow to release toxic gases. Pumping is continued until the desired water level is obtained in the grow-out pond.

However, in the low-discharge system, only a percentage of the water from the grow-out pond (usually the water in the lower layer or near the pond bottom) passes through the settling pond. The suspended solids and organic matter in the water are allowed to settle in the treatment pond before the water is finally released outside the farm.

Fig. 30. Water management.

Harvest

Harvest of the stock depends on market demand. It is important for growers to monitor the prevailing price of shrimps in the market before the final decision to harvest is made. Exporters usually dictate the size and volume to be harvested. Controlling the production cost is the concern of the grower.

1. Check the soft shell count of the stock (% newly molted shrimps) 2 - 3 days before the scheduled harvest (Fig. 31). The soft-shell count should not be more than 2% of the total biomass to be harvested. Harvest should be done three days after moulting.

Fig. 31. Checking the quality of the stock using a cast net.

2. To harvest, drain the grow-out pond 2 - 3 hours after high tide. Collect the shrimps in a harvest net (bag net) positioned at the gate (Fig. 28). The rest of the shrimps are handpicked after the pond is totally drained.

Fig. 32. Harvesting shrimps with a bag net.

3. Soak harvested shrimps immediately in the chilling tanks where the water temperature is kept at 0°C with crushed ice (Fig. 33). Soaking the shrimps in very cold water instantly kills them, delays rigor mortis, and preserves freshness.

Fig. 33. Chilling and sorting of harvested shrimps.

4. Immediately sort, weigh, and pack the shrimps with ice in styropore (Fig. 34) or insulated fiberglass boxes for transport. The shrimps are packed in layers alternating with ice from bottom to top. Normally, it is the buyer that sorts, weighs and packs the shrimps.

Fig. 34. Packing the shrimps in styropore boxes.

Management of Effluents

Untreated effluents of intensive shrimp ponds are loaded with suspended organic matter and dissolved nutrients from shrimp feces, uneaten feeds, and dead plankton. When discharged directly into the surrounding natural waters, the effluents may have deleterious effects especially on a heavily degraded mangrove area. To minimize these negative effects, pond effluents must be checked to ensure that its organic load and dissolved nutrients are within acceptable limits before it is released to the surrounding natural waters.

Analyze the BOD, suspended solids and *chlorophyll a* concentration of pond effluents. If the concentrations are less than that of the natural waters and the BOD is less than 10 ppm, the water in the treatment pond may be released directly to the surrounding natural waters.

Verification runs conducted in Dumangas Brackishwater Station, Dumangas, Iloilo, Philippines (Figs. 35 - 38) revealed that treatment of grow-out pond effluents in settling ponds with baffles and biofilters effectively reduces the amount of dissolved nutrients like phosphate (PO_4^{3}), sulfide (H_2S), and ammonia (NH_3). In the closed-recirculation system, treated effluents having nutrients at optimum levels were mostly recycled for use in the grow-out pond . In the low-discharge system, treated effluents were released directly to the surrounding water.

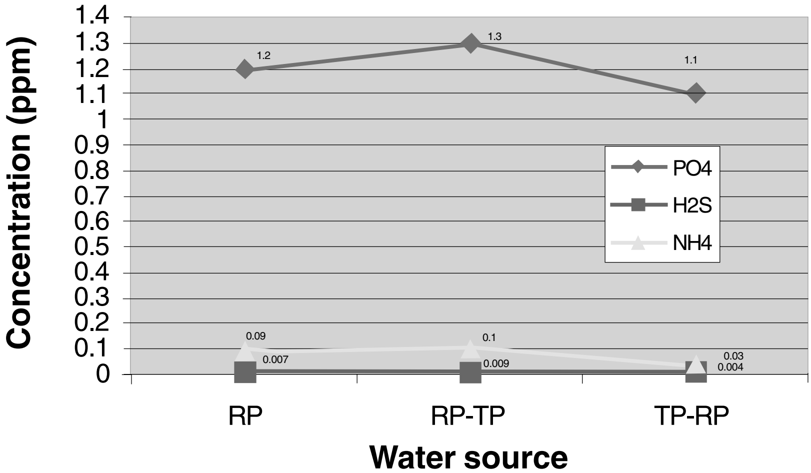

Fig. 35. Phosphate, sulfide, and ammonia levels in shrimp pond effluents before and after treatment in the settling pond of a closed recirculation system at the SEAFDEC/AQD Dumangas Brackishwater Station in 2000. Legend: RP=water inside rearing pond; RP-TP= water drained from RP to treatment pond; TP-RP=water coming out from treatment pond back to rearing pond.

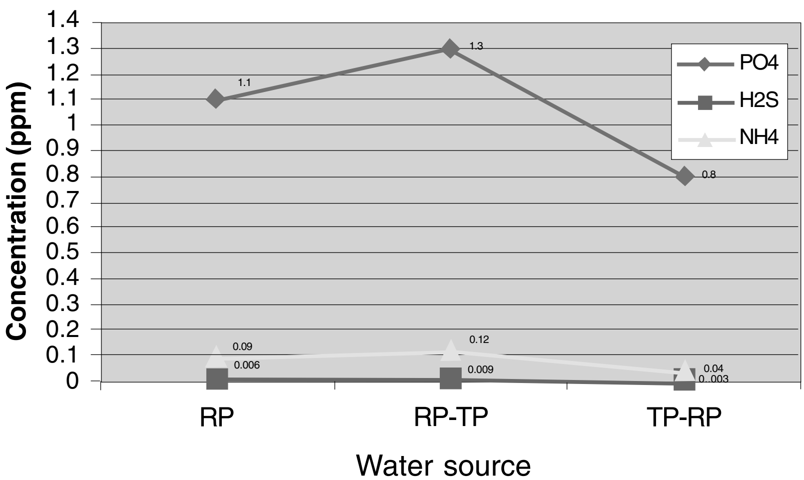

Fig. 36. Phosphate, sulfide, and ammonia levels in shrimp pond effluents before and after treatment in the settling pond of a closed recirculation system at the SEAFDEC/AQD Dumangas Brackishwater Station in 2001. Legend: RP=water inside rearing pond; RP-TP= water drained from RP to treatment pond; TP-RP=water coming out from treatment pond back to rearing pond.

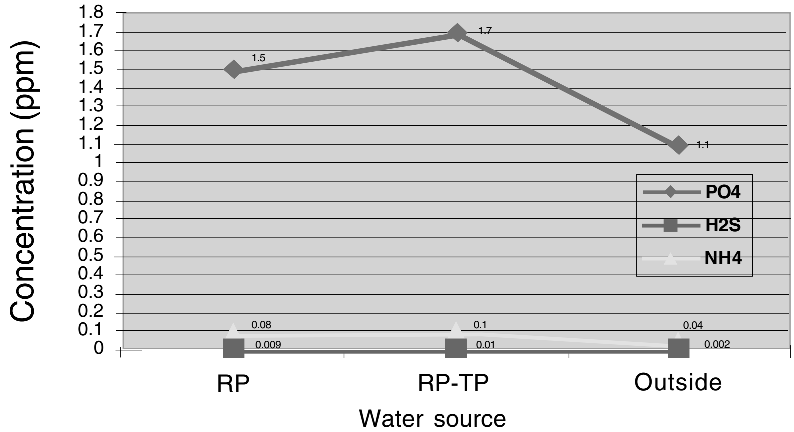

Fig. 37. Phosphate, sulfide, and ammonia levels in shrimp pond effluents before and after treatment in the settling pond of a partial-recirculation system at the SEAFDEC/AQD Dumangas Brackishwater Station in 2000. Legend: RP=water inside rearing pond; RP-TP= water drained from RP to treatment pond; Outside=water coming out from treatment pond to surrounding water.

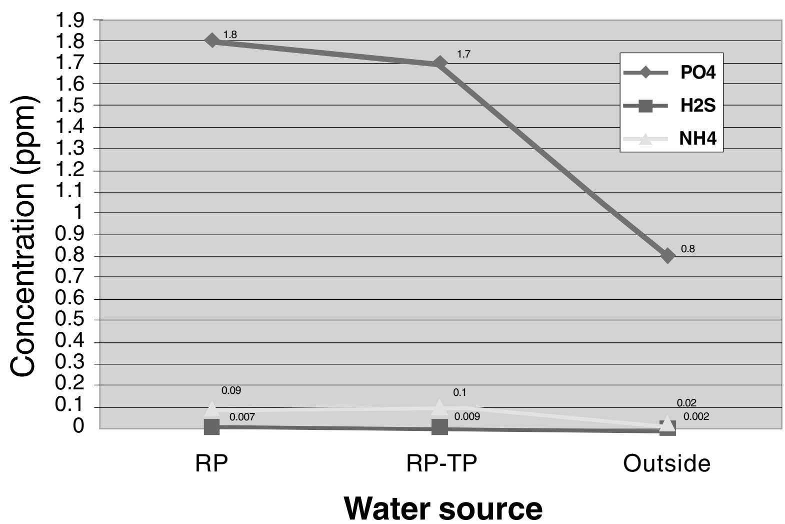

Fig. 38. Phosphate, sulfide, and ammonia levels in shrimp pond effluents before and after treatment in the settling pond of a low discharge system at the SEAFDEC/AQD Dumangas Brackishwater Station in 2001. Legend: RP=water inside rearing pond; RP-TP= water drained from RP to treatment pond; Outside=water coming out from treatment pond to surrounding water.

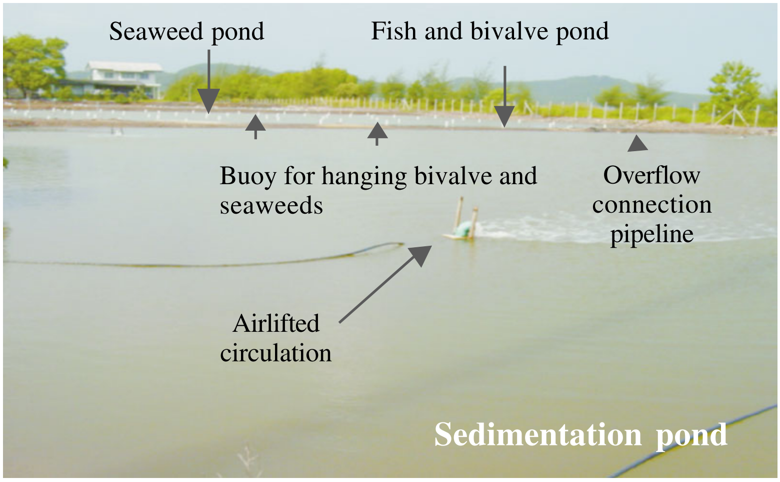

Fig. 39. Effluent treatment system integrated with physical and biological technology.

Costs and Returns

Intensive shrimp farming is a business. Its primary objective is maximum profit both in the short and in the long run. The protocol described in the preceding sections distinctly differs from the farming system used by shrimp farmers in the late 1980's, which resulted to the almost total collapse of the shrimp farming industry. It has effectively minimized if not solved the luminous bacteria problem that has plagued shrimp farms not only in the Philippines but also in Southeast Asia.

Despite added costs, employing these improved intensive shrimp farming systems will not only ensure higher survival and production but profits as well. Table 10 shows the cost and return data obtained from verification runs conducted at the Dumangas Brackishwater Station of
SEAFDEC/AQD from June to October 2000. Table 11 is the cost and return analysis of a production run undertaken in a private shrimp farm (Siochi Farm, Nasugbu, Batangas), using the same system from June-September 2002. Both runs had shown consistently high return on investments ranging from 34 - 39% (Table 10) and 91 - 122% (Table 11) after 140 - 160 days and 115 - 117 days of culture respectively. The harvested shrimps were the market-preferred sizes of 25 - 32 grams.

Table 10. Cost and return data of the low-discharge and environment-friendly method of intensive shrimp farming, Dumangas Brackishwater Station, SEAFDEC/AQD.

Pond no.	**9**	**11**	**13**
Area (m²)	8,786	8,782	9,027
Total stock (pcs)	219,650	219,550	69,835
Date harvested	Sept. 19, 2000	October 9, 2000	October 10, 2000
Stocking density (pcs/m²)	25	25	40
DOC at harvest	139	159	144
ABW (g)	25.5	27	25
Biomass (kg)	4,465	5,379	5,626
Survival rate (%)	79.7	90.7	61.0
Ave. price per kg (PhP)	308.00	273.87	277.77
Gross sales (PhP)	**1,375,474.00**	**1,473,170.00**	**1,562,705.65**
Expenses			
Fry	57,109.00	57,109.00	96,157.00
Feeds	324,729.50	374,729.50	407,205.00
Salaries/wages/OT	80,500.00	80,500.00	113,605.30
Pond preparation	14,277.00	14,277.00	17,515.84
Lime	7,500.00	7,500.00	10,000.00
Biomanipulators	3,000.00	3,000.00	6,000.00
Probiotics	14,025.00	14,025.00	16,500.00
Power/lights/water	138,187.60	188,187.60	190,433.88
Fuel/lubricants	12,963.00	12,963.33	3,647.79
Sludge collector/cages	10,339.44	10,339.44	14,850.00
Feeding bridge/tray	10,000.00	10,000.00	10,000.00
Laboratory analysis	2,500.00	2,500.00	2,500.00
Depreciation	68,419.75	68,419.75	68,419.75
R&M ponds/dikes/equip	49,091.07	49,091.07	51,300.00
Communications	1,580.76	1,580.76	1,470.64
Transport & travel	9,420.58	9,420.58	663.50
Total expenses (PhP)	**803,643.03**	**903,643.03**	**1,010,268.70**
Net profit (PhP)	**571,830.97**	**569,526.97**	**552,436.95**
Investment requirement (PhP)	1,452,250.00	1,561,348.28	1,667,973.95
Return on investment (%)	39.4	36.6	34.3
Payback period (cropping)	3	3	3

Table 11. Cost and return data of the low-discharge and environment-friendly method of intensive shrimp farming, Siochi Farm, Nasugbu, Batangas (Private Farm)

Pond no.	**1**	**2**	**3**
Area (m²)	3,000	3,000	4,000
Total stock (pcs)	75,000	75,000	100,000
Date harvested	Sept. 25, 2002	Sept. 26, 2002	Sept. 27, 2002
Stocking density (pcs/m²)	25	25	25
DOC at harvest	117	116	115
ABW (g)	28	32	31
Biomass (kg)	1,855	1,971	2,025
Survival rate (%)	88.3	81.6	64.3
Ave. price per kg (PhP)	360.00	380.90	377.30
Gross sales (PhP)	**670,312.70**	**753,266.60**	**767,382.75**
Expenses			
Fry	22,050.00	22,050.00	28,100.00
Feeds	108,772.50	108,772.50	145,030.00
Salaries/wages/OT	25,000.00	25,000.00	25,000.00
Pond preparation	4,879.00	4,879.00	6,879.00
Lime	2,700.00	2,700.00	3,200.00
Biomanipulators	1,100.00	1,100.00	1,100.00
Probiotics			
Power/lights/water	40,371.80	40,371.80	40,371.80
Fuel/lubricants	5,628.20	5,628.20	5,628.20
Sludge collector/cages	2,400.00	2,400.00	2,400.00
Feeding bridge/tray	3,500.00	3,500.00	3,500.00
Laboratory analysis	2,500.00	2,500.00	2,500.00
Depreciation	10,600.00	10,600.00	12,670.00
R&M ponds/dikes/equip	14,260.00	14,260.00	14,260.00
Communications	680.00	680.00	680.00
Transport & travel	432.00	432.00	432.00
Total expenses (PhP)	**244,873.50**	**244,873.50**	**291,751.00**
Net profit (PhP)	**425,439.20**	**508,393.10**	**475,631.75**
Investment requirement (PhP)	416,291.13	416,291.13	521,196.50
Return on investment (%)	102.2	122.1	91.2
Payback period (cropping)	1	1	1

References

Boyd, C. E. 1989. Water quality management and aeration in shrimp farming. Fish. and Allied Aqua. Dept. Series No.2, Alabama Agricultural Experiment Station, Auburn University, Alabama, February 1989.

Boyd, C. E. 1998. Regional review of Environmental issues and aquaculture sustainability. Report on a regional study and workshop on aquaculture sustainability and the environment. Bangkok, Thailand: Asian Development Bank and Network of Aquaculture Centers in Asia-Pacific. p. 222-235.

Boyd, C. E. 2000. Water use in aquaculture. Global Aqua. Advocate. 3(3):12-13.

Chanratchakool, P., J.F. Turnbull, S. Funge-Smith, and C. Limsuan. 1995. Health Management in Shrimp Ponds (2nd ed.). Aquatic Animal Health Institute. Bangkok, Thailand.

Parado-Estepa, F. D. 1988. Selection, transport and acclimation of prawn fry. In: Technical Considerations for the Management and Operations of Intensive Prawn Farms. Chiu, Y.N., L.M. Santos and R.O. Juliano (eds.). U.P. Aqua. Soc., Iloilo City, Phil. p. 81-85.

Chiu, Y.N. 1988. Prawn nutrition and feeding. In: Technical Considerations for the Management and Operations of Intensive Prawn Farms. Chiu, Y.N., L.M. Santos and R.O. Juliano (eds.). U.P. Aqua. Soc., Iloilo City, Phil. p. 86-101.

Chiu, Y.N. 1988. Water quality management for intensive prawn ponds. In Chiu, Y.N., L.M. Santos and R.O. Juliano (eds.). Technical Considerations for the Management and Operations of Intensive Prawn Farms. U.P. Aqua. Soc., Iloilo City, Phil. p. 102-128.

Graindorge, V.A. 2000. Diseases management protocols and semi-intensive shrimp farming in Ecuador. Global Aqua. Advocate. 3(2):17-19.

Hopkins, S. J. and J. D. Holloway. 1997. Collection, handling and utilization of sludge deposits from intensive shrimp ponds. Paper presented at the Annual Meeting of the World Aqua. Society. Feb. 1997.

Miget, R. 1999. Closed-cycle shrimp farming research project in Texas. Global Aqua. Advocate. 2(2):8.

Platon, R. R. 1996. Shrimp Aquaculture: The Philippine Experience. Country Report for the ACIAR/NACA/DOF Workshop on Key Researchable Issues in Sustainable Shrimp Culture, Oct. 28-Nov. 14, 1996, Songkhla, Thailand.

Prabhu, N.M., A.R. Nazar, S. Rajagopal, and A. S. Khan. 1999. Use of probiotics in water quality management during shrimp culture, CAS in Marine Biology, Annamalai University Parangipettai 608 502 India J-Aquacult-Trop 1999. 14(3):227-236.

Tookwinas, S. 2000. Biotechnology for Intensive Marine Shrimp Farming. Aqua. Asia. 5(2):44.

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About SEAFDEC

The Southeast Asian Fisheries Development Center (SEAFDEC) is a regional treaty organization established in December 1967 to promote fisheries development in the region. Its member countries are Japan, Malaysia, the Philippines, Singapore, Thailand, Brunei Darussalam, the Socialist Republic of Vietnam, Myanmar, Indonesia, Cambodia and Lao PDR.

Representing the member countries is the Council of Directors, the policy-making body of SEAFDEC. The Chief administrator of SEAFDEC is the Secretary-General whose office, the Secretariat, is based in Bangkok, Thailand.

Created to develop fishery potentials in the region in response to the global food crises, SEAFDEC undertakes research on appropriate fishery technologies, trains fisheries and aquaculture technicians, and disseminates fisheries and aquaculture information. Four departments have been established to pursue the objectives of SEAFDEC.

- The Training Department (TD) in Samut Prakan, Thailand, established in 1967 for marine capture fisheries training
- The Marine Fisheries Research Department (MFRD) in Singapore, established in 1967 for fishery post-harvest technology
- The Aquaculture Department (AQD) in Tigbauan, Iloilo, Philippines, established in July 1973 for aquaculture research and development.
- The Marine Fishery Resources Development and Management Department (MFRDMD) in Kuala Terengganu, Malaysia, established in 1992 for the development and management of the marine fishery resources in the exclusive economic zones (EEZs) of SEAFDEC Member Countries.

About ASEAN

The Association of Southeast Asian Nations is a regional organization formed in 1967. Its member nations are: Brunei Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam.

The member nations of ASEAN cooperate to promote growth and stability in the region. The organization's policies are formulated by the countries' foreign ministers at annual meetings. Projects are recommended to the ministers by committees dealing with economic affairs, culture, science and social development.

The ASEAN Secretariat is located in Jakarta, Indonesia. It is the central administrative organ of ASEAN headed by a Secretary-General.

The Secretariat has four bureaus taking care of trade, investments, industry, tourism and infrastructures; economic and functional cooperation; finance and program coordination and external relations.

The Secretariat has about 40 professional staff members openly recruited from member countries.