Good Management Practices for Shrimp Farming in Costa Rica

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Introduction

This manual of good management practices was written specifically for shrimp farming in Costa Rica by three students from the Worcester Polytechnic Institute (WPI), located in Massachusetts in the United States of America. This manual was prepared in conjunction with and with the help of the Instituto Costariccense de Pesca y Acuicultura (INCOPESCA).

This manual was written as the main deliverable of a project with the primary goal of improving the efficiency and sanitation of Costa Rican shrimp farming. Additionally, the practices recommended in this manual emphasize minimal environmental impact, which farmers and the Costa Rican government both expressed concern for. The long-term goal of this project was that, with training and assistance, farmers would be able to eventually increase the exportation of cultivated shrimp in Costa Rica.

These good management practices (GMPs) have been recommended after much research conducted concerning best management practices (BMPs) recommended for shrimp farming in other Latin American nations such as Mexico, Nicaragua, and Honduras. Additionally, Costa Rican farmers in the Gulf of Nicoya region were interviewed about their current practices and any common problems. Therefore, these GMPs were compiled by applying the previously recommended BMPs to the Costa Rican shrimp farming situation. Note that this is a manual of GMPs as opposed to BMPs because there is still room for improvement and development of the Costa Rican shrimp farming industry.

This manual was created using information compiled from BMP manuals and reports in addition to the information gathered from interviews of Costa Rican shrimp farmers, as stated above. To assure credit is given to all sources, a references page of these manuals and reports is shown at the end of this document.

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Table of Contents

List of Tables

1 Pond Preparation

Preparing the pond before its use is a very important aspect of the whole process of shrimp farming. A clean and substance free environment helps the growth of healthy shrimp. The preparation of the pond includes drainage, drying, cleaning or disinfecting and liming. As we are trying to create a more innocuous product, the cleaning and disinfecting of surroundings of the pond is also important in this stage.

1.1 Soil Preparation

1.1.1 Pond Drying/Liming

Drying the ponds after harvest can help the success of the next crop. The exposure to the sun will oxidize most living material in the soil and reduce the acidity. Ponds should be designed on a slope with the drying process in mind to facilitate the removal of water.

Drying procedure:

1. Drain all water from the pond after all shrimp have been harvested

   Note: Ponds should be designed with an incline to allow for better drainage without having to use pumps.

2. Seal off all entrances to prevent water from entering

3. Clean pond of shrimp/fish remains or trash

   Note: Birds and other predators should never be allowed to feed on dead shrimp or fish because they can spread disease.

4. Burn or bury the shrimp/fish remains

   Note: If shrimp/fish are buried, they should be buried far away from the ponds and covered with layers of lime (about 1 kg/m^2).

5. Apply agricultural lime (calcium carbonate) to the damp ground to adjust the pH of the soil (normally too acidic) and oxidize the organic material. If the pond can not be fully drained, use hydrated or burnt lime for more effect.

Table 1-1Amount of Calcium Carbonate that should be added to regulate soil pH[1].

pH (Soil)	Calcium Carbonate ($CaCO_3$) Kg/ha
> 6	< 1000
5-6	< 2000
< 5	< 3000

6. When soil is slightly dry, turn the soil by plowing or raking.

7. Allow pond to dry for about 14 days, or until there are cracks about 5-10 cm deep, as shown in **Figure 1-1** below.

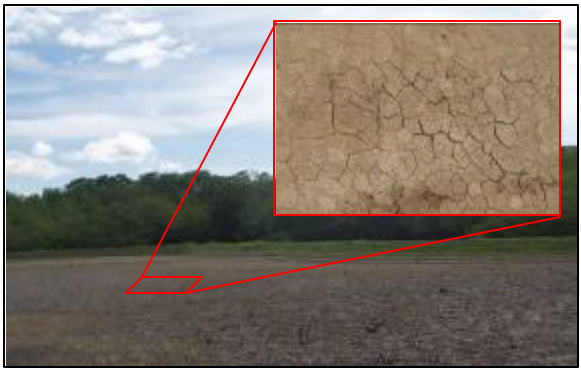


Figure 1-1 Example of a drying pond.

8. While the pond is drying, equipment, gates, channels and pumps should be sanitized with chlorine or another disinfectant. Special care should be taken after a disease outbreak as to not spread it to the next harvest.

9. Barnacles, mussels, and algae should be removed from the ponds, gates, and channels.

1.2 Water Preparation

1.2.1 Water Source

Water inlet locations should be chosen carefully to have the correct levels of salinity, temperature, dissolved oxygen, and turbidity. Normally, water is pumped from estuaries and mangrove forests. Care should be taken to reduce the damage to the forests when building a pumping station.

The water brought into the ponds should be clean and absent of any foreign materials or chemicals. To prevent this:

- Do not place the inlet near or downstream of agricultural farms that apply pesticides, herbicides, or other chemicals.
- Do not place the inlet downstream of other shrimp farms to reduce the chance disease transmission.
- Do not place the inlet near or downstream of industrial areas with pollution in the water.
- Place the inlet near the edge of a mangrove forest to reduce the amount of trees removed.
- Use coarse mesh nets at the inlet to filter out large debris.

Figure 1-2 Example of netting used to keep debris out of the inlet.

Figure 1-3 Example of an inlet close to the edge of a mangrove forest.

1.2.2 Water Conditions

The condition of the water first entering the ponds should be within acceptable ranges for shrimp growth, so that the least amount of treatment is needed. These ranges are shown in **Table 1-2**.

Table 1-2 Acceptable ranges for inlet water.

Conditions	Acceptable Range
Dissolved Oxygen	> 5 mg/L
Temperature	28-34
pH	6-9
Salinity	20-25 ppt

The water should always be checked for foreign materials like heavy metals, pesticides, herbicides, or other chemicals that could affect the shrimp or the human consumer. The new water should also be checked for red tide before adding it to ponds. These precautions will improve the survival of the shrimp and the safety for anyone consuming the final product.

1.2.3 Pond Filling

Filling the ponds should be done slowly and in a controlled manner to help promote the growth of algae and phytoplankton. The shrimp will be able to feed on this growth and reduce the amount of feed needed.

1. Fill reservoirs.

2. Allow water to flow into the ponds through a 500 micrometer screen until most of the pond is filled to 10-30 cm.

3. Close the pond and fertilize the water with approximately 10kg/ha of fertilizer, then allow water to stand for 2-3 days until the water becomes a dark brownish color.

4. Continue to fill the pond to about 50-70 cm and close inlet gates again.

5. Use approximately 15kg/ha of fertilizer on the water then allow to stand for another 2-3 days

Note: If the water has not turned a dark brown by the third day, add calcium carbonate to the water. The higher pH helps the algae bloom.

6. When the color turns to a dark brown again, fill the pond to its full capacity, about 80-140 cm deep.

7. Fertilize once more with about 25kg/ha and let the water stand for another 5 days or until the Secchi disk reading is about 25-35 cm.

Note: If the Secchi disk readings do not improve after 5 days, it is recommended to reduce the water level 10 cm and fertilize with about 8kg/ha.

2 Postlarvae

2.1 Sources

There are many different sources for postlarvae (PL) available to Costa Rican farmers. Costa Rican farmers have stated that they purchase PL from local laboratories or from laboratories in other countries such as Guatemala, Colombia, or Nicaragua. Sometimes PL can arrive on the farm already damaged, diseased, or deformed. Therefore, no matter the location of the laboratory, it is important that the quality of both the laboratory and PL are verified.

> **Note:** It is recommended to purchase enough PL to stock pond with 10-20 PL/m^2. A biologist can be consulted for exact stocking density.

Farmers should purchase their PL from laboratories that:

- ☑ Have strict biosecure growing conditions
- ☑ Have strict control over the access of people, animals, and vehicles to the facility
- ☑ Disinfect all equipment
- ☑ Use high-quality, clean ocean water
- ☑ Sell specific pathogen free (SPF) or specific pathogen resistant (SPR) certified PL that are less susceptible to disease
- ☑ Provide certificates guaranteeing that PL are free of disease
- ☑ Show records of antibiotics and other chemicals used on PL during the process

Biologist should inspect PL for:

- Infections of the hepatopancreas
- Intestinal infections
- Deformities
- Necrosis
- Baculovirus penaei (BP)
- Reactions to stressful conditions
- PCR test analysis
- Any other common diseases

Figure 2-1 L. vannamei postlarva. http://www.recherche.fr/encyclopedie/Crevette

2.2 Acclimation

Acclimation can help reduce the mortality rate when the PL are being transfered from a nursery to the ponds. A biologist should be consulted during this time to over see the postlarvae's adjustment to pond water conditions.

Before Postlarvae Arrive:

- ☑ The tanks and equipment must be cleaned with chlorine and allowed to dry until the chorine is completely evaporated.
- ☑ Make sure tanks are in shaded area

Figure 2-2 Tanks used for acclimating PL.

Postlarvae Acclimation Process:

1. Fill a reservoir tank with water from the pond filtered with 500 micrometer netting.

2. Measure the temperature, salinity and dissolved oxygen levels of PL bags and record. Pump more oxygen into the bags if necessary.

3. Adjust pond water in reservoir tank to average salinity and temperature used to transport the PL. Add ice to the water to bring down the temperature if necessary.

4. Pump oxygen into the acclimation tanks above the saturation level to counteract ammonia levels. Dissolved oxygen in the acclimation tanks should never fall below 6 mg/L.

5. Empty contents of PL bags into empty acclimation tanks.

6. Count and record the number of the postlarvae and the mortality rate using the volumetric counting method shown in **Table 2-1** below.

Table 2-1 Method for volumetric counting of PL[2].

Volumetric Counting	
1.	Mix up the acclimation tank with a wide mouth container. Reach the corners of the tank and mix well
2.	Sample 1 liter of water
3.	Pour evenly over a fine mesh screen (0.5mm)
4.	Count the living and dead postlarvae
5.	Use percentage of dead to live postlarvae to find the average survival rate
6.	Multiply the number of living larvae by the number of liters in the tank to find the approximate number of postlarvae stocked

7. Start slowly adding pond water from the reservoir tank by continuous flow.

> **Note:** Volume within the acclimation tanks should be kept constant by also pumping out water the water from the acclimation tanks at the same time pond water is being added.

8. Carefully monitor and record:
- Salinity (every half hour)
- Temperature (every half hour)
- Dissolved oxygen (every half hour)
- pH (every hour)
- Mortalities
- Stress levels, especially noting:
  - Cannibalism
  - Empty intestines
  - Erratic swimming
  - White coloring

> **Note:** PL can be fed egg yolks or Artemia nauplii (brine shrimp) or commercial feed flakes during acclimation.

9. After the water in acclimation tanks has been gradually adjusted to conditions similar to those of the pond, stock the PL by evenly distributing them over the area of the pond.

> **Note:** Stock PL during the night or very early morning when the temperature is low.

10. Monitor the survival rates of the PL samples in the pond for about 48 hours.

Note: PL can be stocked in netted off sections of the pond to monitor survival and growth rates more easily. Make sure the area in the pond where the PL are stocked is free of predators and has sufficient algae levels.

Figure 2-3 Example of a netted off PL enclosure in a pond.

3 Monitoring Water Conditions

Shrimp depend on the quality of the water throughout their adult phase. Measurements of pH, dissolved oxygen, turbidity, temperature, salinity, and water levels should be taken and carefully recorded and analyzed. They should be measured twice a day; once in the morning from 6-7am, and once at in the afternoon from 1-3pm. The times should be consistent from day to day and should be recorded at each measuring. These readings are important because the shrimp can be very easily affected by changes in water conditions.

Monitoring and controlling the water can greatly affect the amount of stress on the shrimp, and if done well can reduce the amount of water used in the ponds. If less water cycled through the ponds, then less energy is needed to pump the water and there are fewer effluents released into the environment. The following table outlines the advantages and disadvantages of water exchange, and solutions to decrease the amount of water exchanged.

Table 3-1 Advantages and disadvantages to water exchange[3]

Water Exchange		
Advantages	**Disadvantages**	**Solution Options**
• Can be used to help treat problems with: o Dissolved oxygen o Temperature o pH o Salinity o Turbidity • Can be used to help clean out waste on bottom of pond • Drain off excess rain water	• Exiting water has high concentrations of: o Suspended solids o Nutrients o Organic material • Increases likelihood of wild shrimp, predators, or pathogens entering the ponds • Increases likelihood of cultured shrimp escaping • Last 10-15% of discharged water during harvest contains high concentrations of water pollutants • Constantly lose fertilizer and natural productivity of tanks • Cause unnatural enrichment of the estuary waters and may cause algae blooms	• Lower stocking densities • Lower rationing of food • Lower the use of fertilizers and feed • Reduce the frequency of water exchange • Filter the effluent water • Let out last 10-15% of discharged water at a slower rate • Water treated with chemicals should remain in pond long enough for chemicals to biodegrade • Recycling and recirculation of water between ponds and reservoirs to purify the water

3.1 Dissolved Oxygen

Measurement:

- Dissolved oxygen is measured by digital meters which can give a quick and accurate reading. Although some sensors may be expensive, it will save money in the long run by allowing quick response to a potentially damaging situation.

- **How to operate an oxygenmeter[4]:**
  - The probe should be placed deep in the pond, about 10 cm from the bottom, in order to keep the mud and sediment away from the tip.
  - It is normally attached to a PVC pipe or stick for submersion.
  - The readings should be taken at least 4-5 meters from the coast near the entrance and exit gates
  - Dissolved oxygen should be measured in the same spot every day to stay consistent.

Figure 3-1 Dissolved oxygen meter.

- Additionally, it is important that the dissolved oxygen be measured everyday in the morning and afternoon because of the large fluctuations. The levels can change quickly and a good and detailed record can allow you to anticipate the changes.

Table 3-2 Acceptable range of dissolved oxygen.

Mortality	Optimum
< 2-3 mg/L	> 5 mg/L
Testing Times	
6-7 AM	2-4PM

! Warning !

Dissolved oxygen levels can change very quickly and, if not acted upon, may cause mass mortalities.

Causes:

- The dissolved oxygen will fluctuate from day to night because of the algae and phytoplankton in the water. During the day, they create the oxygen in the water, but consume it during the night. Another cause of low levels in the water can be caused by the shrimp's activity. Normally, the shrimp become more active at night when the temperature is more acceptable, and when the dissolved oxygen is lower, which can cause oxygen level problems.

- Rain can help increase the amount of oxygen by agitating the pond surface.

Effects:

The shrimp depend on oxygen like all other living things, and when the levels get too low, they can start to become lethargic or even start dying. Some effects of different dissolved oxygen levels are shown in **Table 3-3**.

Table 3-3 Effects of different dissolved oxygen (DO) levels on farmed shrimp[5].

Concentration of Dissolved Oxygen (DO)	Effect
Less than 1 or 2 mg/L	Mortal if exposure last more than a few hours.
2—5 mg/L	Growth will be slow if the time of low oxygen is prolonged.
5—15 mg/L (saturation)	Best condition for adequate growth.
>15 mg/L (over saturation)	Can be harmful if the conditions exist throughout the whole pond. Generally there is no problem.

Solutions:

- **Aeration:**
  When the dissolved oxygen starts to drop to about 2-2.5 mg/L or below, aeration should begin immediately and should continue until the level reaches at least 4 mg/L. Aeration can be done in many ways, and is usually needed more often at night. Most ponds use electric paddle wheels shown in **Figure 3-2**. Another method, normally used for emergencies, is a large aerator attached to a tractor, shown in **Figure 3-3** and **Figure 3-4**.

Figure 3-3 Example of a floating aerator.

Figure 3-2 Example of a tractor aerator.

Figure 3-4 Example of a tractor aerator.

- **Forced Air System:**
  A more expensive, but more effective system is using forced air. Pipes with holes or porous hoses are laid on the pond bed, and air is pumped through to give an even distribution of oxygen. The volume of oxygen dissolved by the water is greater because of the larger surface area.
- **Water Exchange:**
  If it absolutely necessary, water can be exchanged, adding more water from the estuary and letting out water from the pond through the outlet gets. However, water exchange harms the surrounding environment and causes valuable feed and fertilizer to be lost from the pond (see **Table 3-1** for more detail concerning water exchange). Therefore, this method should be avoided unless it is an emergency situation and oxygen levels cannot be brought up using other methods.

3.2 Temperature

Measurement:

- Temperature can be measured very simply with a thermometer, either glass or digital. Some probes can be left in the ponds for easy inspection.

- The temperature fluctuates from day to night, so it should be measured twice a day, once in the morning and once in the afternoon, when the readings will be at their extremes (see **Table 3-4**). Rain can also largely affect the temperature of a pond, so it is recommended to take a measurement after a large storm.

Table 3-4 Acceptable temperature ranges

Extreme Range	Optimum
<20°C, >40°C	25°C-35°C
Testing Times	
6-7 AM	1-3PM

Causes:

The temperature of a pond is largely dependent on the temperature of the surrounding air and inlet water. Because of this, the water's temperature will fluctuate from day to night. Additionally, high winds tend too cool the ponds.

If water cycling does occur, the inlet water may change the temperature of the stagnant water in the pond.

Effects:

- **Behavior:**
  The shrimp are very susceptible to temperature changes and it can affect their feeding and movement habits. When the water temperature becomes too extreme during the day or at night, the shrimp become lethargic and their eating slows. They will also start to burrow into the bottom of the pond to find better temperatures. Normally the temperatures at night are more comfortable for the shrimp, so they are generally more active then.

- **Disease:**
  Extreme temperatures also put a lot of stress on the shrimp and cause them to become susceptible to disease. An example of this is NHP. Many NHP out breaks occurred when the water was above normal. Not only do the shrimp become more lethargic and eat less, but the bacteria can grow better in the warmer temperature.

- **Dissolved Oxygen:**
  Warmer water also holds less dissolved oxygen. Although there is more oxygen produced by the phytoplankton and algae at higher temperatures, aeration will be less effective because the saturation level of oxygen in the water is lower. During the night, the water can hold more oxygen since the temperature is lower, so it will be more receptive to aeration.

Solutions:

If the temperature is fluctuating too much from day to night, water can be added to the ponds. Deeper water increases the stability of pond temperature. The water in the estuary or inlet may be cooler than the stagnant pond water. Therefore, cycling the water may help reduce the temperature.

3.3 Turbidity

Measurement:

- Turbidity, the cloudiness or visibility depth of the water, is very simple to measure. A Secchi disk can be used to get a numerical value, and is very easy to use and construct. The Secchi disk is painted with alternating colors, about 20cm across, and the reading and construction is very simple. The turbidity measurement is the depth at which the disk cannot be seen through the pond water.

Table 3-5 Acceptable range of turbidity[6]

Secchi Disk
30-45 cm
Testing Times
12-2PM

- This method is subjective, and therefore should be done by the same person each time to keep the reading consistent. The Secchi disk requires consistent lighting, so the turbidity should be measured at the same time in the afternoon every day.

Figure 3-5 Secchi disk.

Figure 3-6 Another example of a Secchi disk.

Causes:

The turbidity level of the water is normally directly corresponds with algae and plankton, which the shrimp feed on. When there are more algae and plankton in the water, the turbidity is greater, and vice versa. Additionally, mud and sediment can contribute to turbidity readings, particularly when there is a lot of wind, rain, or mechanical aeration.

Effects:

- The shrimp can use the algae and plankton as a natural food source. Good turbidity levels can help reduce the need for commercial feed and help save money. Therefore, if turbidity levels are too low, plankton and algae levels are too low, and shrimp will consume more commercial food.

- If the algae or plankton begin to bloom out of control, there can be some damaging effects. The algae create oxygen during the day, but at night, become large consumers of oxygen. This can deplete the dissolved oxygen supply and cause mortality in the cultivated shrimp.

Solutions:

- **Turbidity too high (too clear):**
  The ponds should be fertilized to induce the growth of the plankton and algae. Use the table in **Section 6: Fertilizer** which relates the Secchi disk reading to amount of fertilizer to use. If the turbidity of the reservoir or inlet water is lower, this may be added if desperately needed.

- **Turbidity too low (too cloudy):**
  Reduce the amount of fertilizer used in the pond. Dissolved oxygen should carefully be monitored and aeration should be used during the night. Cycling the water out of the pond may also be used if desperately needed.

3.4 Salinity

Measurement:

Dissolved salt can be measured in many ways. From least expensive to most expensive are:

- Hydrometers
- Refractometers, and
- Current meters

Refractometers and current meters will give a reading in parts per thousand (ppt or g/L), and the hydrometer will give specific gravity. To find salinity from a hydrometer, use the chart in **Appendix A** relating specific gravity and temperature to salinity. Salinity should be measured at least once a day, but can be measured as little as once a week.

> **Note:** Salinity should be measured after large rainfalls, because large amounts of fresh water can alter the salt content in the ponds.

Figure 3-7 Left: Hydrometers. Middle: Refractometer. Right: Current Meter.
http://www.southwest.com.au/~jfuller/liquids/hydrometers.htm

Table 3-6 Acceptable Salinity Ranges

Extreme	Optimum
<10, >35ppt	20-25 ppt
Optimal Testing Times	
6-7 AM	

Causes:

This level normally does not change very much, but some causes for fluctuation are:

- Large rain falls that can add enough fresh water to the ponds that can lower the salinity.
- High temperatures that can cause large amounts of water to evaporate, leaving behind the salt and increasing the salinity of the ponds.
- The inlet water with a different salinity content than the water in the ponds.

Effects:

Pacific white shrimp can survive in a large range of salinity, and can even survive in water with a salinity approaching zero. Having the salinity outside the optimal range can add to the total stress of the shrimp and weaken their ability to fight disease. The shrimp are sensitive to large and rapid changes in the salinity. It is important to monitor salinity often during the postlarval acclimation period when the salinity is changing the most.

Solutions:

If the salinity is either too high or too low, water can be cycled into the pond from the estuary. However, the cycling of water may wash out many nutrients and bring in other foreign material that could damage the ponds.

Note: Efforts to change the salinity of a pond are only necessary if the salinity is extremely high or extremely low, since L. vannamei are so adaptive.

3.5 pH and Alkalinity

Measurement:

The pH and alkalinity can be easily measured by the use of litmus strips. These are cheap and quick color changing strips which are reliable and disposable. More expensive systems also exist, which can give a highly accurate digital reading very quickly.

Note: Digital meters have to be calibrated using standard pH solutions with the same average salinity of the ponds.

Figure 3-8 Left: Litmus strips and Alkaline paper. Right: Digital pH meter

Table 3-7 Acceptable pH and Alkaline strips[7].

pH Levels	Alkalinity Levels
6-9	20-50 mg/L
Testing Times	
6-7 AM	1-3PM

Causes:

The pH will fluctuate from day to night, and is generally lower at night and higher during the day. This is caused by the carbon dioxide released by the phytoplankton at night, which lowers the pH. Other pH changes can be caused by the fresh water of rain and dissolved chemicals or materials in the inlet water.

Effects:

Pacific white shrimp can handle a large range of pH, but are more sensitive to lower pH. Some effects of the pH on L. vannamei are shown in the following table:

Table 3-8 Effects of pH on shrimp[8]

Effect	pH
Mortality	4
No Reproduction	4-5
Slowed Growth	4-6
Best Growth	6-9
Slowed Growth	9-11
Mortality	11

Solutions:

The pH can be compensated for by using calcium carbonate (agricultural lime). This will increase the alkalinity, or ability of the water to buffer the changes in pH. It should be added until the alkalinity is at least 20 mg/L.

3.6 Growth Rates

Measurement:

Growth rate is measured by finding the average weight of the shrimp compared to the previous week. This is also a good indicator of the shrimp's stress levels.

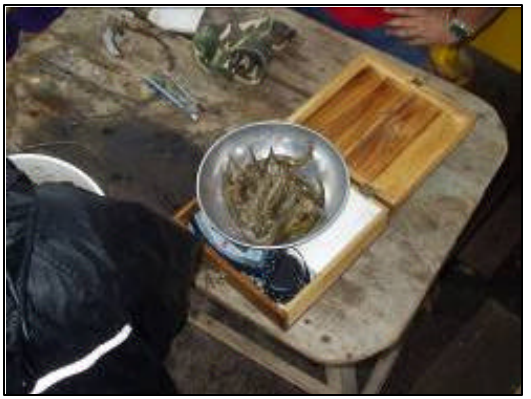


Figure 3-9 A biologist weighing of shrimp to find the average growth rate.

The growth rate should be measured once a week. It is usually done by the biologist, so the shrimp can also be inspected for other diseases, gut fullness, deformations and any other signs of stress. Normally, about 400 shrimp from each pond are weighed and average weight calculated. Growth rates should be carefully recorded and analyzed from week to week, and actions taken accordingly.

See **Table 3-9** on the following page for more information concerning proper growth rates.

Table 3-9 This table indicates average growth rate for healthy shrimp and reasons for growth rate problems[9].

Weekly Weight Gain	Evaluation
< 0.70g	Shrimp are not growing enough. Pond conditions should be closely monitored to see if there are any causes of stress. Possibility of shrimp being underfed. Possibility of higher stocking density than estimated
0.85—1.2g	Optimal average weight gain and growth rate.
1.3—2.0g	Possibility that stocking density is less than estimated. Shrimp may be overfed.

4 Feed and Feed Plan

Feed is one of the most expensive materials needed to maintain shrimp, so feed management is very important. The most common feed used is the pelleted feed, common brands being Aguilar y Solis, Nicolita, and Diamasa. A biologist should be consulted before choosing the brand and protein grade of feed, as there may be many aspects like climate, water quality, and shrimp species that will have to be taken into account. The feeding plan should also be reviewed with the biologist.

Some tips for feeding:

? **Feed Quality**
Many farmers have expressed problems with the quality of feed when it arrives on the farm. Sometimes the feed is already moldy or damp when it is delivered and cannot be used, or is not the protein content requested. Therefore, the quality of feed should be checked as soon as it arrives on the farms. Make sure the company that the feed is being purchased from provides certificates of quality or warranties. Otherwise, even if the feed is defective, farmers might not be able to return it and will lose money.

- **Protein Content**
The feed used with the postlarvae should contain about 35% protein. When the shrimp grow to about 5g, the protein may be reduced to 20-25% without any adverse effects. The feed is cheaper when it contains lower protein.

- **Low Dissolved Oxygen**
The shrimp should not be feed when the dissolved oxygen drops below 2.5 mg/L. They will be become lethargic and stop eating, so feeding would be a waste of food.

- **Feed Trays**
One of the most efficient ways to apply food is by using feeding trays. The commercial feed is placed on the feeding trays, which are then lowered into the water, during feeding periods at least twice a day. See **Table 4-1** for more information concerning feed trays.

Note: A biologist should be consulted in order to determine the exact amount of feed to apply per hectare during grow-out.

Table 4-1 Feed tray construction and use

	Feed Trays
	**Materials:** • Netting • String • Rubber Tubing/Thin PVC Pipe (filled with sand) • Plastic Bottle and Cap (**optional:** fill with sand to regulate the speed of descent to prevent loss of feed)
	**Use:** • Tie trays to posts spaced evenly; about 20 per hectare • Feed twice a day; in the morning (6-7am) and in the evening (3-5pm) • The trays are left in the water for about 2-3 hours or until feed is gone **Note:** Amount of feed left on trays can give an estimate of feeding efficiency.

- **Storage**

  Proper storage of feed is very important to preserve the feed and make sure it is fresh and safe for use. **Table 4-2** on the following page discusses good and poor feed, fertilizer, and chemical storage.

Table 4-2 Good vs. poor feed storage[10].

Good Feed, Fertilizer, and Chemical Storage	Poor Feed, Fertilizer, and Chemical Storage
	
• Completely inside a shed or building • Sheltered from sun, rain, and extreme temperatures • No accumulation of moisture • Good air circulation • Bags raised up from the ground on wooden pallets • Containers left closed or tightly sealed after opened • One bag used completely before opening another bag • Not exposed to mold, insects, animals, or other pests • Medicated feed properly marked and stored separately from regular feed • New feed stored separately from old feed • Feed stored away from pesticides, herbicides, and other chemicals	• Under only a small overhang or completely outside • Exposed to sun, rain, and extreme temperatures • Accumulation of moisture and humidity near containers • Poor air circulation • Bags/containers in direct contact with the ground • Containers left open and susceptible to mold • Multiple bags open at any given time • Exposed to mold, insects, animals, or other pests • Medicated feed not properly labeled and stored in with the regular reed • New feed and old feed stored together • Feed stored near pesticides, herbicides, or other chemicals

! Warning !

Never feed shrimp moldy feed! It causes toxins to build up in the shrimp and can kill them

5 Fertilizer

Fertilizer is used to enhance the phytoplankton and algae levels in the pond, which shrimp naturally feed on. Having higher levels of these microorganisms can reduce the amount of commercial feed needed in most cases. This not only lowers the cost of operating the farm, but also reduces the amount of nutrients released from the farm. Certain brands of fertilizer, such as Plancton, are specifically designed to increase the levels of diatoms in the water which the plankton consume. The shrimp then feed on these plankton, and the growth of harmful types of algae is not fostered. See **Table 5-1** for more details concerning which types of fertilizer that may be used.

Table 5-1 Different fertilizers recommended and not recommended for use[11].

Recommended for use	Not recommended for use
• Commercial plankton and algae fertilizer • Cooking flower from rice or soy • Grass clippings (no pesticides or herbicides)	• Fertilizer that contains ammonium (urea) • Organic fertilizers with animal origins

To Use:

- Decide how much fertilizer to use according to **Table 5-2** and the recommendations of a biologist
- If using granular fertilizer, dissolve in water for 4-6 hours according to fertilizer instructions
- Spread evenly over the pond

Table 5-2 Relationship between Secchi disk reading and amount of fertilizer that should be added[12].

Secchi Disk Reading (cm)	Recommended Amount of Fertilizer (kg/hectare)
20	0
25	2.5
30	5.0
35	7.5
40	10.0

Responsible Use:

The over use of fertilizer may be detrimental to the ponds. The rampant growth of algae can cause dissolved oxygen levels to fluctuate to dangerous levels at night. The release of the fertilizer into the wild also may cause similar problems in the mangrove forests, killing many fish or other animals. Therefore, it is very important to responsibly use fertilizer in controlled quantities.

6 Harvesting

After about seven months of hard work, all of the farmers' and farm employees' efforts culminate in the harvesting of the shrimp. Therefore, it is very important that the harvesting procedure is well-planned in detail and in advance. Additionally, it is very important that the harvest is performed in a sanitary manner so that the product quality is fit for consumers.

When to Harvest

Most Costa Rican farmers choose to have only one grow-out cycle in hopes of preventing outbreaks of White Spot Syndrome Virus, which can be onset by the stressful water conditions that occur during the dry season. Therefore, many farmers only harvest once per year between the months of August and November, depending on the size of the shrimp.

> **Note:** Shrimp should be harvested at night when they are more active and conditions are less stressful. Additionally, a light can be used at night to attract the shrimp to the harvesting areas.

However, if the shrimp are being sold for the international market and need to be larger sizes to fit certain requirements, harvesting in installments is recommended. To harvest in installments, farmers have certain size ranges during which they harvest only a portion of the shrimp. The main harvest is still conducted at the end of the grow-out cycle.

> **Note:** Most farmers choose to harvest their shrimp in the following size ranges: 12-14g, 20-25g, 30-38g. However, these sizes can be adjusted depending on the farm.

Table 6-1 Benefits of harvesting in installments.

Benefits of Harvesting in Installments
• Stocking density is decreased as shrimp grow • Decreased stress levels • Shrimp are less susceptible to disease and generally healthier • Increased growth rates • Total survival rates are increased • Final harvest size can be larger, so shrimp can be sold at a better price

Harvest Preparation

It is very important to prepare thoroughly for the harvest so it can run as smoothly as possible, so farmers should:

☑ Send samples of the shrimp to a laboratory to be tested for:
- Heavy metals
- Chemical residues
- Bacterial infections such as salmonella or E. coli
- Other diseases or infections
- Any other hazardous materials

☑ Contact the processing plant at least three days before the harvest to arrange transport

☑ If the processing plant can not supply ice, contact the nearest ice factory about 3 days before the harvest

Note: The amount of ice ordered should be approximately equal to the total weight of shrimp being harvested.

Harvest Procedure

For the whole harvesting process to be as efficient as possible, it is important to follow a pre-determined procedure. Additionally, it is very important that the harvest is conducted in a clean and sanitary manner. Below outlines the recommended harvesting procedure.

1. Clean and disinfect all equipment and instruments to be used during harvesting with chlorine or another disinfectant.

> **Note:** It is very important that all employees are wearing clean clothes, rubber boots, are in good-health, and practice good hygiene during harvesting.

2. Clean all exit gates of debris.

3. Place lights near the harvest area to attract the shrimp.

4. Place harvesting net over the outlet pipe of the pond in the harvesting area.

5. Place an empty harvesting bag over the open end of the net.

> **Note:** Make sure harvesting bags are clean and do not have residues of any feed or chemicals.

6. Remove the filters from the exit gates and allow water to flow out of the pipes.

7. Let the bag fill.

> **Note:** It is important that the bags are not over-filled. When bags are over-filled the pressure can become too great and the shrimp can become damaged.

8. Remove full bag and replace with an empty bag and repeat process.

9. Remove any trash, crabs, fish, or other debris from the full harvesting bag.

Figure 6-1 Example of trash, crabs, fish, and other debris found while harvesting. Photograph provided by Ana Eugénia Robles.

10. Determine the weight of the bag of shrimp.

11. Place the shrimp directly into water with ice to kill them immediately by thermal shock.

12. Place the shrimp on ice in the transporting bins.

13. Treat shrimp with sodium sulfate or sodium meta-bisulfate to keep them clean and remove black spots. See **Table 7-2** for other treatments that can be used during harvesting to improve the appearance and quality of the shrimp.

14. Transport shrimp to the processing facility or customer as soon as possible so they do not spoil.

Table 6-2 Considerations for quality when harvesting shrimp[13].

Quality Considerations	Defects	Preventive Measures
Appearance	Black Spots	Appropriate use of sulfite or Everfresh
	Maltreatment and damage	Appropriate handling and placement on ice
	Discoloration due to heat	On time placement of the product on ice
	Hanging heads (shrimp with heads)	Appropriate handling of product only on ice
	Red heads	Stop feeding 48 hrs before the harvest
	Soft shells (shrimp with heads or tails (shell-on))	Harvest done at the appropriate time based on periodical checkups
	Yellowish coloring	Appropriate use of sulfite
	Pricked and sandy shells	Appropriate use of sulfite
	Shrimp with milky appearance	Extract from the harvest
	Mixed species	Separation of species at the plant
Smell/taste	Decomposition	Immediate placement of the product on ice
	Chlorine	Use appropriate concentration and exposure time
	Petrochemical odor	Prevent the contamination due to oil, diesel, etc.
	Alcohol or soil odor, and sour head	Make a taste test before harvest
Texture	Soft or spongy texture	Appropriate ration of ice and shrimp as well as appropriate timing of its placement on ice
Defects due to the process	Low weight	Routine checkups on appropriate specifications.
	Inexact count	
	Uniformity	
	Dehydration	Glazed and appropriate packing
	Strange materials	Appropriate extraction

7 Sanitary Procedures

The quality of harvested shrimp depends greatly on the surroundings of the farms and ponds. For the product to be fit for human consumption, it is important that farmers practice the following sanitary procedures:

- ***Maintain Roads and Retaining Walls Surrounding Ponds***
- ***Animal Control***
- ***Clean and Disinfect Equipment***
- ***Promote Good Employee Hygiene***

7.1 Maintain Roads and Retaining Walls Surrounding Ponds

It is important that the roads and retaining walls surrounding the ponds are well maintained.

Problems:

If the roads and walls are eroding into the ponds, they can affect the quality of the water by:

- Washing chemicals into the water
- Spreading disease from contaminated ground or soil
- Increasing the amount of suspended solids
- Increasing the turbidity or cloudiness of the water

All of these factors can make conditions more stressful for shrimp, which makes them more susceptible to disease. Also, erosion of roads and walls can spread disease if cars or visitors transport infections from another ponds or farms.

Solutions:

General road and retaining wall maintenance is necessary, and the following options can help reduce erosion and the spread of disease as a result of it:

- **Maintain vegetation around ponds**
  If vegetation is allowed to grow in a controlled manner around the edges of the ponds, the roots of the plants will help prevent the erosion of the soil. Vegetation can also prevent pollution and microbacteria from washing into the ponds.

> **Note:** Mangroves can be planted around the perimeter of ponds to help prevent soil erosion. This is an environmentally responsible option to combat erosion.

Figure 7-1 An example of mangroves used to prevent erosion along roads and retaining walls[14].

- **Construct a vehicle and visitor disinfecting station**

  - It is important that vehicle tires on trucks, cars, and tractors be washed and disinfected when they enter the farms.

  - Visitors' shoes should also be disinfected because they could transport diseases between farms.

  - The disinfection station should be constructed of cement and vehicles and shoes can be cleaned with chlorine or another disinfectant. **Figure 7-2** shows an example of a vehicle washing station on a shrimp farm.

Figure 7-2 An example of a vehicle washing station on a shrimp farm[15].

Note: It is important that chlorine or the disinfectant used is not allowed to wash into water, especially pond water, or leach into the soil. This can be prevented by using an angled-in cement platform for the disinfecting station as shown above.

7.2 Animal Control

Animals, both wild and domestic, are one of the main methods of disease transmission. The following section outlines common problems and recommended solutions to control a variety of different animals found around shrimp farms.

- ***Predators***

  Predators such as birds, crocodiles, and certain mammals that feed on the shrimp can create many problems on shrimp farms. However, there are a number of simple solutions to combat predators.

  Problems:

  - Consume the shrimp and decrease the amount of product available for harvest.
  - Spread diseases between ponds and farms.

- Contaminate ponds with bacteria such as salmonella and E. coli, which can infect humans who consume the shrimp.

Figure 7-3 Example of birds feeding on dead, diseased shrimp. Photograph provided by Ana Eugénia Robles.

Note: Birds should never be allowed to feed on diseased shrimp, as this can spread disease between ponds and farms. Instead, diseased shrimp should be burned or buried.

Solutions:

- Construct bird nets over ponds
- Intense noise systems to scare away birds and other animals
- Fences around ponds
- Careful watch of farm property

Figure 7-4 Example of bird nets used on a shrimp farm[16].

- ***Wild Shrimp and Fish***

  Escape of wild shrimp and fish into grow-out ponds is often a major problem on farms. The following section outlines problems and solutions for wild shrimp and fish invasion in ponds.

  Problems:
  - Consume cultivated shrimp
  - Consume food intended for cultivated shrimp
  - Spread diseases from wild populations

  Solutions:
  - Netting placed in estuary before water is pumped into pond
  - Multiple nets placed at inlet gates to ponds with between 500 and 1000 micrometer sized holes

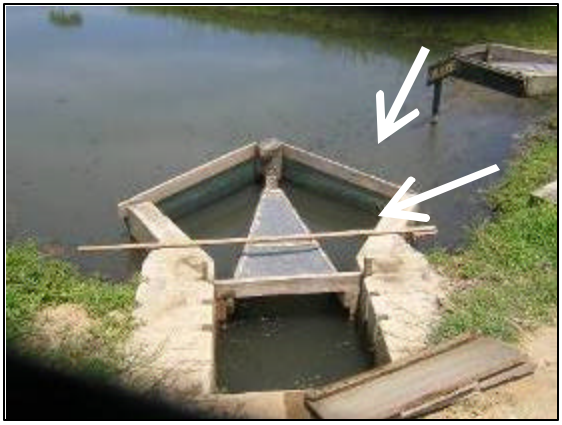


Figure 7-5 Double filtration system with multiple nets located at an inlet gate.

- ***Pests***

  Pests include insects, lizards, and rodents, such as rats and mice, all of which can be found on farms if measures are not taken to remove them. The following section outlines problems and solutions for pest control.

  Problems:
  - Host diseases that can be spread to the ponds and shrimp.
  - Contaminate ponds with salmonella and E. coli.
  - Consume and contaminate feed and other chemicals.

Solutions:

- Eliminate the attraction to feed and hiding areas
- Storage areas should be free of garbage, waste, water puddles, high grasses, and vegetation.
- Feed and chemical storage area should be cleaned regularly and garbage and spills picked up immediately.
- Feed should be protected and stored in a safe way as discussed in **Section 4: Feed and Feed Plan**.

- ***Domestic Animals***

  Domestic animals such as cows and other livestock, cats, and dogs, can all provide a threat to the health of ponds. Therefore, it is important to adhere to certain precautions.

Problems:

- Defecate in or near ponds.
- Transport diseases between ponds and farms.
- Contaminate ponds with salmonella or E. coli.

Solutions:

- Construct fences around the ponds to keep domestic animals away from the water
- Domestic animals should be kept completely off shrimp farm property if possible

7.3 Clean and Disinfect Equipment

Frequent cleaning and disinfection of farm equipment and instruments is vital to maintain good health in cultivated shrimp. Insufficient sanitation of equipment can create many problems in ponds, but there are a number of simple solutions and disinfection methods.

Problems:

- Leaky equipment can contaminate pond and estuary water
- Insufficiently disinfected equipment can spread disease between ponds
- Shared equipment (such as tractors) can spread disease between farms

Solutions:

To prevent the problems listed above and many others that could result from contaminated equipment it is necessary to:

- Make sure the farm has all the equipment it needs and that the equipment is well maintained. If necessary, a mechanic should be consulted.

- Use an approved disinfectant for the activity such as:[17]
  - Chlorine (calcium hypochlorite or sodium hypochlorite at 5.25% or bleach)
  - Formaldehyde gas
  - Iodine
  - Products that contain "Amonio cuaternario" ex: Tynsen
  - Lime (hydrated or burnt)
  - UV light from the sun
  - Concentrated acid
  - Detergents used for pre-washing with some grade of disinfectant
  - See **Table 7-1** for more detail concerning disinfectants

- If a farm has to borrow any equipment from another farm, the equipment should be disinfected between uses.

- Equipment and instruments should be disinfected between different ponds and after a disease outbreak.

Table 7-1 Equipment disinfectant options[18].

Characteristics	Vapor	Chlorine	Iodophors	Surface Active Agents	Anionic Acids
Effective against: bacteria, Gram-positive	Excellent	Good	Good	Good	Good
Gram negative: (E. coli, Salmonella)	Excellent	Good	Good	Poor	Good
Spore	Good	Good	Poor		Regular
Bacteriophage	Excellent	Good	Good		Poor
Properties					
Corrosive	No	Yes	Light	No	Light
Affected by hard water	No	No	Light	Some	Light
Irritating for the skin	Yes	Yes	Yes	No	Yes
Affected by organic material	No	Majority	Partially	Minimal	Partially
Incompatible with	Sensitive material	phenyls, Amines, Soft Metals	Silver, starch	Anionic humidifying agents, Soap	Detergents, alkynes, cationic surface active agents
Stability in solution		It is lost rapidly	It is lost slowly	Stable	Stable
Stability in hot solution (greater than 66°C)		Unstable	Use under 45°C	Stable	Stable
¿Leaves active residue?	No	No	Yes	Yes	Yes
Tests to detect active chemical residue	Not necessary	Simple	Simple	Simple	Hard
Maximum levels allowed by FDA	No limit	200ppm	25ppm	25ppm	
Efficient at neutral pH	Yes	Yes	No	No	No

7.4 Promote Good Employee Hygiene

In order to produce a high-quality product, it is important that farmers promote good employee hygiene. If the shrimp are contaminated or infected in any way, the consumer could be affected. Therefore, it is important to understand problems resulting from poor hygiene and solutions to improve employee hygiene.

Problems:

- Employees can contaminate ponds with diseases such as:
  - Salmonella
  - E. coli
  - Forms of hepatitis
  - Digestive infections
  - Other illnesses

- Employees can spread infection between ponds and between farms

Solutions:

- **Proper Construction of Bathrooms**

  - Bathrooms should be far away from any ponds or feed and the water should not drain into the estuary or any source of water for the ponds.

  - Waste can also be burned.

- **Proper Clothing and Equipment**

  - Personnel in charge of handling shrimp during harvesting should always wash their hands and wear clean clothing

  - Use waterproof gloves while handling shrimp and disinfect after each use

  - Farms should have a first aid kit with necessary medication

- Protective equipment (such as boots, gloves, or masks) should be available for employees using dangerous chemicals

- **Proper Personal Hygiene**

  - Employees should always wash hands after using the bathroom, especially before handling the feed or the shrimp.

  - If a worker is sick with a digestive sickness, he or she should not return to work until he is completely healthy.

  - Workers should be aware of and follow good hygiene and health practices and be conscious of the repercussions of not following them.

  - Avoid actions such as smoking, coughing, or sneezing near ponds.

  - No spitting or urinating into or in close proximity to the ponds, except in a bathroom, constructed as outlined above.

8 Disease Management

Disease management is very important to the success of a shrimp farm. Recently, many disease outbreaks have occurred on Costa Rican shrimp farms. An outbreak on a farm can cause the survival rate of the shrimp to plummet from the desirable 60-70% to 40% or below. This can result in a major loss in revenue for a farm that has supplied the ponds with feed and other expensive chemicals and devoted countless hours to cultivation. Therefore, it is very important to understand:

- ***Causes***
- ***Detection***
- ***Treatment***
- ***Prevention***

8.1 Causes

Diseases have been shown to be caused by any number of factors that can occur on a farm every day, especially:

- **Lack of Sufficient Sanitation**
  It is very important that farms follow as many sanitary procedures described in **Section 7: Sanitary Procedures** as possible to prevent the spread of disease.

  - Farmers should always disinfect equipment and farming instruments after use.
  - Special care should be taken when the equipment is used in multiple ponds, so cross-contamination between the ponds does not occur.
  - Contamination between different farms is also a problem, so farmers should be careful to disinfect any shared equipment and visitors' shoes and cars.
  - Also, farmers should promote good worker hygiene in order to keep their product safe for human consumption.

- **Lack of Sufficient Animal Control**
  Proper animal control is vital if a farm wishes to avoid disease. Not only are predatory animals such as birds, fish, and crocodiles a threat,

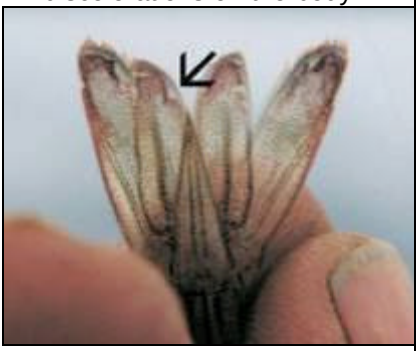
but domestic animals such as cows, dogs, and cats can spread infection to the ponds. It is very important that all of these animals be kept away from the ponds using fences, netting, sound devices, or careful watch of the ponds. Details concerning animal control are discussed in **Section 7: Sanitary Procedures**.

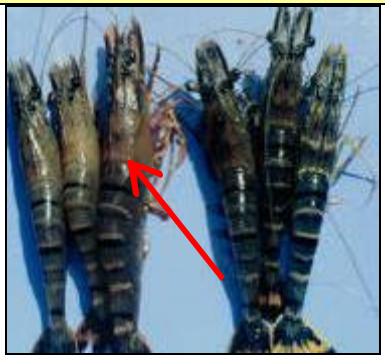
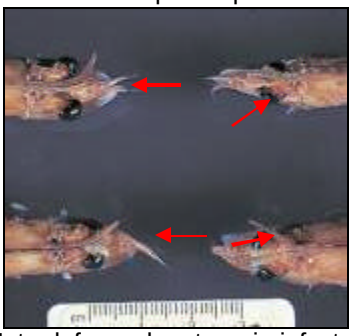
- **Lack of Sufficient Feed and Chemical Storage**
  Proper storage of feed and other chemicals is very important to the health of shrimp on a farm. It is important that the feed is stored apart from other chemicals to prevent contamination. Both feed and other chemicals could be kept in clean, dry areas to prevent mold or corrosion. See **Table 4-2** in **Section 4: Feed and Feed Plan** for storage specifications.

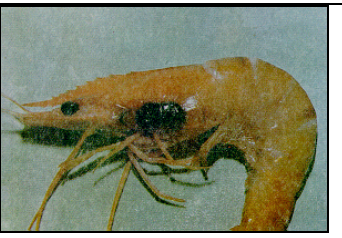
8.2 Detection

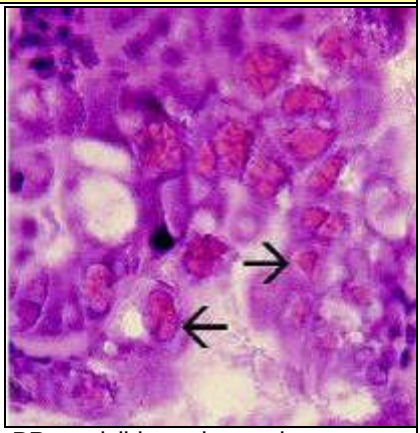
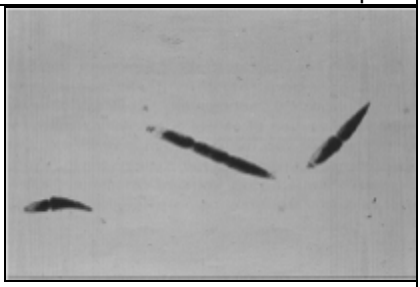
In order to appropriately treat and prevent diseases, it is important that farmers know how to detect disease in the shrimp. The following table (**Table 8-1**) describes symptoms and shows examples of diseases common to Costa Rica and Latin America. However, if the disease cannot be identified, it is important to contact a biologist for help.

Table 8-1 Detection of diseases found in cultivated shrimp[19].

Name of Disease	Type of Pathogen	Symptoms	Examples
Taura Syndrome Virus (TSV)	Virus	• Lesions or discolorations in a buckshot formation on the cuticle, gills, or appendages • Pale red body surface and appendages • Tail fin and pleiopods particularly red	 Note the dark spots and discolorations on the body.  Note distinctive red tail fin.
White Spot Syndrome Virus (WSSV)	Virus	• Loose shell • White calcium deposits embedded in shell • White spots 0.5-2.0 mm in diameter • Darkened red or pink body surfaces or appendages • Heavy surface and gill fouling by external parasites • White mid-gut line	 Note the extreme discoloration of the body and white spots on the shell

Name of Disease	Type of Pathogen	Symptoms	Examples
Yellow Head Virus (YHV)	Virus	• Yellow head • General bleaching and discoloring of body and appendages	 Note the yellow heads on the infected shrimp on the left. The shrimp on the right are not infected.
Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV)	Virus	• Often results in Runt Deformity Syndrome (RDS) • Growth defects • Malformed cuticles • Rostrum deformations	 Note deformed tail in infected shrimp on top.  Note deformed rostrum in infected shrimp.

Name of Disease	Type of Pathogen	Symptoms	Examples
Infectious Myonecrosis Virus (IMNV)	Virus	• Discolorations in the striations of the muscles • Focal to extensive white necrotic areas on abdomen • Muscles may also become reddened	 Notice focal to extensive to white necrotic areas on abdomen.
Necrotizing Hepatopancreatitis (NHP)	Bacteria	• Reduced feed intake • Empty gut • Anorexia • Lethargy • Discoloration and atrophy of the hepatopancreas • Soft shells • Flaccid bodies • Black gills	 Note the discoloration of the hepatopancreas in infected shrimp on the bottom and empty gut.
Vibriosis[20]	Bacteria	• Lethargy • Gathering in shallow water • Loss of appetite • Darkening or reddening of body • Black spots • Yellow/red/brown colorization of gills • Diffuse white patches in abdominal muscles • Luminescence • Necrosis of internal organs • Swollen hindgut	 Note the discoloration of the body and necrosis of internal organs.  Note the luminescence that can be caused by certain strains.

Name of Disease	Type of Pathogen	Symptoms	Examples
Baculovirus Panaei (BP)	Virus	• Decrease in growth rates • Decrease in feeding rates • Gill and body surface fouling • Difficult to visibly diagnose • Might want to seek assistance from a biologist to diagnose using a microscope	 BP as visible under a microscope.
Gregarina	Protozoa	• Yellow discoloration of top of stomach • Destruction of stomach and intestinal lining • Decrease in growth rates • Large numbers of bivalvos mollusks that host the protozoa	  Examples of gregarinas as seen under a microsope.

8.3 Treatment

Immediate treatment for most diseases is often very limited, but there are still some options, such as:

- **Medicated Feed**
  Certain brands of medicated feed can be purchased to fight diseases. However, the medicated feed is more expensive than regular feed, and should only be used in extreme cases. Also, medicated feed is often not effective against certain viruses.

- **Treat Ponds with Lime**
  Ponds can be routinely treated with hydrated lime (CaOH) or agricultural lime, also known as calcium carbonate ($CaCO_3$). Hydrated lime is slightly stronger than agricultural lime, which is merely ground up limestone. The shrimp ingest the lime and it increases the naturally neutral pH of their digestive systems. This helps fight off any infections in the stomach or intestine, which makes the shrimp less vulnerable to more serious diseases such as WSSV.

- **Removal of Infected Shrimp**
  If possible, infected shrimp should be promptly removed from the pond so they do not infect any healthy shrimp in the pond. An early harvest might be necessary to separate the healthy shrimp from diseased shrimp if the infection is severe.

- **Quarantine pond**
  It is important that farmers keep quarantine conditions between ponds, particularly if there is an outbreak of disease. Instruments and equipment should not be used between ponds without thorough disinfection with chemicals such as chlorine. Additionally, animals should not be allowed to feed on dead or dying shrimp because they could spread disease from the infected pond to any healthy ponds.

- **Drain Pond and Treat with Lime**
  Finally, after any infection, the pond should be fully drained and dried and the bottom treated with lime. If possible, the bottom should be

treated with hydrated lime (CaOH) or burnt lime (CaO) which are both stronger disinfectants than agricultural lime ($CaCO_3$).

8.4 Prevention

Since many pathogens are present in the water at all times, and since immediate treatment is often not available, prevention is the most important way to fight disease. Farmers should:

- **Sanitize all equipment between and during growing seasons** (See **Section 7: Sanitary Procedures** for more detail)

- **Use animal control such as:**
  - Bird nets
  - Sound devices
  - Fences around ponds to prevent entrance of livestock and other domestic animals
  - Small enough netting at inlet and outlet gates to prevent wild shrimp and fish from entering
  - See **Section 7: Sanitary Procedures** for more detail

- **Properly store feed and chemicals** (See **Section 4: Feed and Feed Plan** for more details)

- **Purchase specific pathogen free (SPF) or specific pathogen resistant (SPR) certified PL from licensed laboratories**

- **Have only one growing cycle:** Many Costa Rican farmers have chosen to grow-out only during the rainy season. They don't farm during the dry season because water conditions can vary greatly. This stresses the shrimp and makes them more vulnerable to disease.

- **Maintain good water quality to reduce stressful conditions** (See **Section 3: Monitoring Water Conditions** for more information)

Appendix A

Table A-1 Salinity (ppt) as a function of temperature and specific gravity[21].

	Temperature of Water (° C)																
Observed Reading	25	25.5	26	26.5	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5	32	32.5	33
0.998			1.4	1.5	1.6	1.9	2	2.1	2.4	2.5	2.8	2.9	3.2	3.3	3.6	3.7	
0.999	2.1	2.3	2.5	2.7	2.8	3.1	3.2	3.3	3.6	3.7	3.8	4.1	4.2	4.5	4.7	4.9	5.1
1	3.4	3.7	3.8	4	4.2	4.4	4.5	4.7	4.9	5	5.3	5.4	5.7	5.8	6.1	6.2	6.4
1.001	4.7	4.9	5.1	5.3	5.5	5.7	5.8	6.1	6.2	6.4	6.4	6.7	6.8	7.1	7.2	7.5	7.7
1.002	6.2	6.3	6.4	6.7	6.8	7	7.2	7.4	7.6	7.7	7.9	8.1	8.3	8.5	8.8	8.9	9.2
1.003	7.5	7.6	7.9	8	8.1	8.4	8.5	8.7	8.9	9	9.3	9.4	9.7	9.8	10.1	10.4	10.5
1.004	8.8	9	9.2	9.3	9.6	9.7	9.8	10.1	10.2	10.5	10.6	10.9	11	11.3	11.4	11.7	11.8
1.005	10.2	10.4	10.5	10.6	10.9	11	11.3	11.4	11.5	11.8	11.9	12.2	12.3	12.6	12.8	13	13.2
1.006	11.5	11.7	11.8	12	12.2	12.3	12.6	12.7	13	13.1	13.3	13.5	13.7	13.9	14.1	14.4	14.5
1.007	12.8	13	13.2	13.3	13.5	13.7	13.9	14.1	14.3	14.4	14.7	14.9	15	15.3	15.4	15.7	16
1.008	14.1	14.3	14.5	14.7	14.9	15	15.2	15.4	15.6	15.8	16	16.2	16.5	16.6	16.9	17	17.3
1.009	15.4	15.7	15.8	16	16.2	16.3	16.6	16.7	17	17.1	17.4	17.5	17.8	17.9	18.2	18.4	18.6
1.01	16.9	17	17.1	17.4	17.5	17.8	17.9	18	18.3	18.4	18.7	18.8	19.1	19.3	19.5	19.7	20
1.011	18.2	18.3	18.6	18.7	18.8	19.1	19.2	19.5	19.6	19.9	20	20.3	20.4	20.6	20.9	21	21.3
1.012	19.5	19.6	19.9	20	20.3	20.4	20.6	20.8	20.9	21.2	21.4	21.6	21.8	21.9	22.2	22.5	22.6
1.013	20.8	21	21.2	21.3	21.6	21.7	21.9	22.1	22.3	22.5	22.7	22.9	23.1	23.4	23.5	23.8	24
1.014	22.2	22.3	22.5	22.7	22.9	23.1	23.3	23.5	23.6	23.9	24	24.3	24.4	24.7	24.9	25.1	25.3
1.015	23.5	23.6	23.8	24	24.2	24.4	24.6	24.8	24.9	25.2	25.3	25.6	25.9	26	26.2	26.5	26.6
1.016	24.8	24.9	25.2	25.3	25.6	25.7	26	26.1	26.4	26.5	26.8	26.9	27.2	27.4	27.6	27.8	28.1
1.017	26.1	26.4	26.5	26.6	26.9	27	27.3	27.4	27.7	27.8	28.1	28.3	28.5	28.7	29	29.1	29.4
1.018	27.4	27.7	27.8	28.1	28.2	28.5	28.6	28.9	29	29.2	29.4	29.6	29.8	30	30.3	30.5	30.7
1.019	28.9	29	29.1	29.4	29.5	29.8	29.9	30.2	30.3	30.5	30.8	30.9	31.2	31.3	31.6	31.9	32.1
1.02	30.2	30.3	30.5	30.7	30.9	31.1	31.3	31.5	31.7	31.9	32.1	32.2	32.5	32.8	32.9	33.2	33.4
1.021	31.5	31.6	31.9	32	32.2	32.4	32.6	32.8	33	33.3	33.4	33.7	33.8	34.1	34.3	34.6	34.7
1.022	32.8	33	33.2	33.3	33.5	33.8	33.9	34.2	34.3	34.6	34.7	35	35.2	35.4	35.6	35.9	36.1
1.023	34.1	34.3	34.5	34.7	34.8	35.1	35.2	35.5	35.8	35.9	36.1	36.3	36.5	36.8	36.9	37.2	37.5
1.024	35.5	35.6	35.8	36	36.3	36.4	37.1	37.3	37.6	37.8	38	38.2	38.5	38.7	39	39.2	39.4
1.025	36.8	36.9	37.2	37.3	37.6	37.7	38.5	38.7	38.9	39.1	39.4	39.6	39.8	40.1	40.3	40.6	40.8
1.026	38.1	38.2	38.5	38.6	38.9	39	39.8	40	40.2	40.5	40.7	40.9	41.2	41.4	41.6	41.9	42.1
1.027	39.8	40	40.2	40.5	40.7	40.9	41.1	41.3	41.6	41.8	42	42.2	42.5	42.7	43	43.2	43.5
1.028	41.2	41.4	41.6	41.8	42	42.2	42.4	42.7	42.9	43.1	43.3	43.6	43.8	44	44.3	44.5	44.8
1.029	42.5	42.7	42.9	43.1	43.3	43.5	43.8	44	44.2	44.4	44.7	44.9	45.1	45.4	45.6	45.9	46.1
1.03	43.8	44	44.2	44.4	44.6	44.8	45.1	45.3	45.5	45.8	46	46.2	46.5	46.7	46.9	47.2	47.4
1.031	45.1	45.3	45.5	45.7	45.9	46.2	46.4	46.6	46.9	47.1	47.3	47.6	47.8	48	48.3	48.5	48.8
1.032	46.4	46.6	46.8	47	47.3	47.5	47.7	47.9	48.2	48.4	48.6	48.9	49.1	49.4	49.6	49.9	50.1
1.033	47.7	47.9	48.1	48.4	48.6	48.8	49	49.3	49.5	49.7	50	50.2	50.4	50.7	50.9	51.2	51.4
1.034	49	49.2	49.5	49.7	49.9	50.1	50.3	50.6	50.8	51	51.3	51.5	51.8	52	52.2	52.5	52.8
1.035	50.3	50.6	50.8	51	51.2	51.4	51.6	51.9	52.1	52.4	52.6	52.8	53.1	53.3	53.6	53.8	54.1

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