

# **JIFSAN Good Aquacultural Practices Program**

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## **Growout Pond and Water Quality Management**



By Andrew Lazur

## Growout Pond and Water Quality Management

Proper pond and water quality management is essential to successful and quality shrimp production. Maintaining a good culture environment through use of proper management practices will reduce the risk of disease and increase production, shrimp quality, and marketability. Only one chemical, formalin, used to treat certain protozoan parasites, is approved for shrimp production by U.S. Food and Drug Administration (FDA). Therefore, it is essential to implement and follow good aquaculture management practices to ensure shrimp quality.

### Grow-out Pond Site Selection

Proper site selection is an important consideration in shrimp culture and can reduce occurrence of water quality problems, aid in shrimp health and quality, and reduce treatment costs.

#### Factors of Good Site Selection

- Soil type
- Proximity to quality source water
- Available infrastructure
- Relation to other farms and effluent
- Proper elevation
- Outside wetland/mangrove areas

#### Site Selection–Soil Type

Pond water quality is a direct result of source water and the type and chemical characteristics of soil. Clay content is important to hold water, but mineral content can impact water pH, hardness and alkalinity, which affect plankton productivity. High organic matter in soils will increase oxygen demand as bacteria break down organic matter. In addition, the breakdown of organic matter can increase ammonia concentrations, which is toxic



to shrimp. Acid sulfate soils can leach out acid and pyrites that significantly reduce water pH and can also be toxic to shrimp. Soil type must be properly identified before construction.

- Soil type has direct impact on water quality
- Soil pH should be 6-8.5
- Water pH, alkalinity and hardness are a direct result of soil type
- Organic content of soil will influence oxygen demand and oxidation of shrimp wastes



Locating pond in wetlands and mangrove areas increases pond and water quality management problems and negatively impacts important natural environments. In addition, construction in these areas may require farms to develop restoration sites.

- Acid sulfate soils should be avoided or require special construction and management guidelines

### Site Selection—Source Water

High organic loading of source water will increase nutrient and bacterial levels, thereby increasing need for aeration and leading to increased ammonia concentrations. This elevated organic matter and associated ammonia in source water can reduce daily pond feeding rates. Filtration at the intake pump, using a series of varying screen or mesh sizes, is essential to eliminate predators. However, high organic matter in the source water can clog screens quickly. Using a large surface area for all mesh sizes will reduce the frequency of



Pumping locations in source water waterways should be separated from pond effluent sites and have limited exposure to animal wastes. Filtering the water is essential to reduce predators.

- cleaning, which is a regular maintenance activity while pumping water. Locating the intake pump as far as possible from sources of nutrients such as pond discharge sites will reduce the inflow of nutrients, and organic matter, and degrade water quality. Ponds should be located in areas above tidal influence to reduce the incidence of high organic soils, reduce flooding risk, and allow draining of ponds during all ranges of tides—an important consideration in maintaining shrimp quality during harvest. Ponds should be located in areas where no animal (human or livestock) wastes can enter ponds or source water.
- Pond water quality is directly affected by source water.
- Organic load of source water impacts bacteria populations and oxygen demand.
- Nutrient rich source water contributes to nitrogen and phosphorus content and ammonia concentrations of pond water.
- Filtration can reduce predators.
- Intake and effluent canals should be separated.
- Locate ponds above tidal zone.
- Prevent contact with animal and human wastes.

### Site Selection—Infrastructure

- Access to needed infrastructure such as ice and other supplies can reduce costs and assist in product handling. All-weather roads are important to maintain timely and quality product control.
- Proximity of site to electric or fuel utilities offers efficient pumping and aeration capabilities.
- Availability of ice for prompt packing of shrimp and roads to facilitate access to markets.

### Site Selection—Relationship to Other Farms

- To minimize intake of high concentration of organics and nutrients, pumping locations should have maximum separation from neighboring ponds or other farm discharges. Pumping should be scheduled when other discharge is not occurring and when pesticides levels are lowest (based on testing during various rainfall amounts). Using source water that has been in contact with other ponds or farms increases the risk of disease.



Diseases should be prevented at all costs, because many diseases like viruses are untreatable. Options for treating source water are very limited and discussed in the next section.

- Source water intake should be located to maximize distance from discharge from other farms.
- Timing inflow pumping based on rainfall and neighboring farm discharges is important.
- Likewise, farm effluent must be treated and discharged away from farm intake.
- Utilize intensive settling/treatment ponds and reuse water.

### Source Water Quality–Measurement

The basic water quality parameters of source water that are important in maintaining shrimp health include oxygen, salinity, temperature, pH, nitrogen compounds, and pesticides. These should all be checked at different times: oxygen and temperature are measured at least twice daily to determine the influence of photosynthesis on concentrations. Salinity and pH are measured daily, and nitrate,

**Table 1. Maximum concentrations of pesticides and heavy metals for cultured shrimp.**

Chemical	Concentration (mg/L)
Aldrin/Dieldrin	0.3
Chlordane	0.3
Chlordecone (Kepone)	0.3
DDT, DDE, TDE	5.0
Diquat	3.0
Heptachlor	0.3
Mirex	0.1
PCB's	2.0
2,4-D	1.0
Heavy Metals	
Arsenic	76
Cadmium	3
Chromium	12
Lead	1.5
Nickel	70
Methyl Mercury	1

- ammonia and nitrite can be measured 2-3 times per week. Pesticides (those known to be used in watershed) should be tested periodically and at different rainfall levels to determine the effect of runoff on concentrations. See Table 1 for a list of maximum concentration of pesticides and heavy metals allowed by FDA.
- Testing equipment includes field chemical titration kits and electronic dissolved oxygen meters. This testing equipment is relatively low cost and simple to use. In addition to monitoring, it is important to establish management actions to be taken in the event water quality drops below acceptable levels (these optimal water quality concentrations are listed in Table 2.) Recording the results of all water quality testing is essential to review and understand the relationships of water quality parameters, causes of fluctuations in concentrations, and to anticipate when a water quality problem may occur in the future. In addition, referring to water quality records will help you understand how management actions influence water and shrimp quality.
- Key water quality parameters are dissolved oxygen, pH, salinity, nitrate, ammonia, nitrite, BOD, and hydrogen sulfide. Monitor oxygen, and temperature twice daily, and salinity and pH once daily. Also check during periods of high rainfall as increased water flow will influence water quality and may increase pesticides, sediment, and organic loading. Measure other parameters several times over a month period to know ranges. Know what pesticides are being used in the watershed and when, understand their toxicity, and test water periodically for those compounds. Necessary equipment is a chemical test kit and a DO meter. Develop a protocol for acceptable source quality and pumping schedule. Keep thorough records—they are valuable in health management, and in meeting permit requirements include: 1m<sup>2</sup>/40 LPM of flow. Maximizing length of settling system will provide for greater settling time.

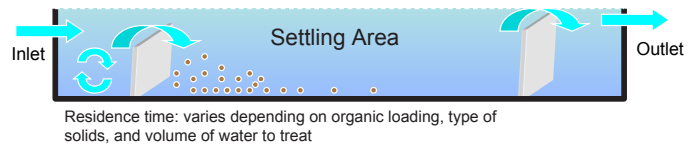
### Source Water–Treatment Options

- Treating source water before use in production ponds with a settling pond is the most cost-effective treatment method. The settling pond will provide time for organics and other suspended solids (which account for much of the

nitrogen and bacterial loading) to settle to pond bottom and not enter the production pond. The volume and size of the settling pond is based on production pond pumping requirements and time needed for settling. Settling solids or sedimentation is effective for particles 100 microns (1/10 of window screen) or larger and the area of settling is based on:  $\text{Area} = \text{Flow rate} / \text{settling velocity}$ . Typical settling area recommendations include: 1m<sup>2</sup>/40 LPM of flow. Maximizing length of settling system is recommended.

Incorporating aquatic plants along the shoreline or floating in settling basin can assist in nutrient and solids reduction. Settling pond maintenance includes preventing erosion of levees, ensuring no animal waste is allowed to enter pond, and draining pond to remove solids when water depth is reduced by 25 percent.

## Settling Pond Considerations



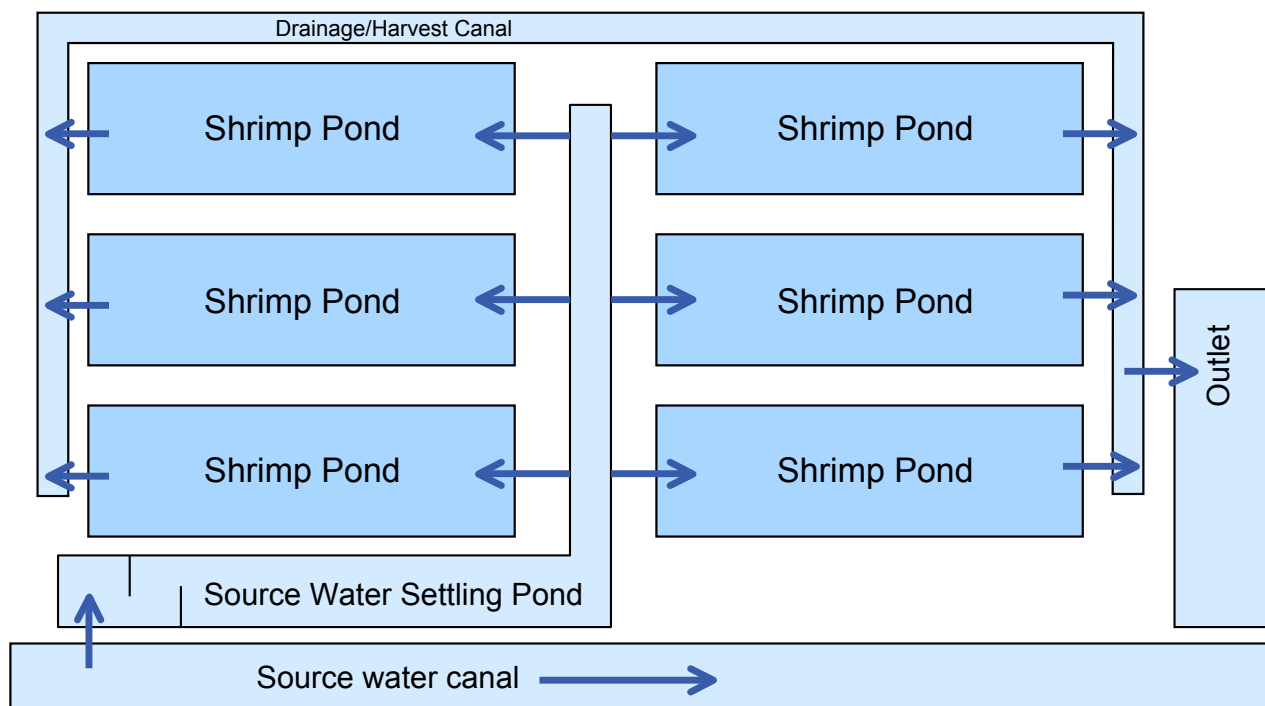
## Settling Pond Considerations

- A settling pond is the most cost-effective tool for treating source water. It provides for settling of organic (nutrient and bacterial) loading. The design of a settling pond influences effectiveness.
- Volume and residence time affect the size of the pond. Earthen baffles or planted rafts allow for aquatic plant nutrient uptake. Access for equipment is needed for periodic solids removal.
- Residence time in a settling pond varies depending on organic loading, type of solids, and volume of water to treat.

## Farm Settling Pond Example

An example of a farm plan with both source water and effluent settling ponds is shown below. The source water settling pond supplies a canal with direct feeds into the production ponds. For existing farms a section or whole production pond can be converted into a settling pond. Important objectives are to provide for ample residence time in a wide area to slow water velocity. It is also important to design or modify the pond to provide access for equipment to remove solids periodically.

## Farm Settling Pond Example



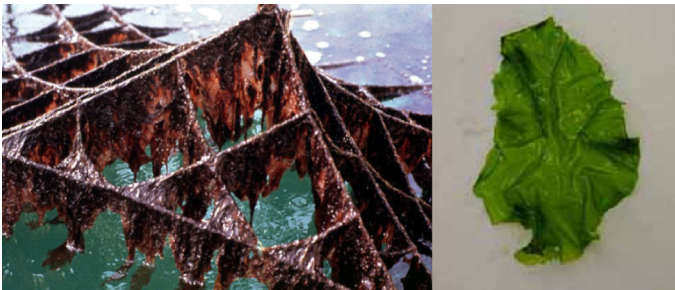
## Settling Pond Treatment Options



Constructed Wetlands



Integrated Shellfish Culture



Seaweed Culture



Rafted Floating Plant Filters

## Settling Pond Treatment Options

Integrating aquatic plants or shellfish in either the source water or pond effluent settling pond can provide solids and nutrient and BOD reduction, thereby increasing oxygen. In addition, these products can be sold, potentially diversifying farm income. Plant species such as mangroves or marsh grasses can be planted for restoration purposes.

### Summary of Site Selection and Source Water Management Practices

- Know what pesticides are used in the area and test source water.
- New ponds should be located in areas of good soils and source watertested before construction.
- Test source water for pH, nitrogen compounds, salinity, and pesticides during dry and rainy periods to know fluctuations.
- Test pond water daily for oxygen, temperature, pH and salinity and weekly for ammonia,

nitrite, and nitrate. Alkalinity should be tested monthly.

- Record all water testing data and refer back to records if any problem arises.
- Maximize distance of pump intakes from any neighboring farm discharge and fill ponds during periods of lowest pollutant levels.
- Treat source water in a settling pond prior to filling growout ponds.

### Pond Water Quality Management

**Goal:** To provide a good quality environment, thereby reducing shrimp stress and promoting shrimp health and quality.

Shrimp are normally exposed to naturally occurring disease-causing organisms in pond waters. The immune system of healthy shrimp can normally defend against infection. However, once shrimp are exposed to environmental stressors such as poor water quality or nutrition, their



immune function is reduced and disease can occur. Since poor water quality is the leading cause of disease, the most important management goal in shrimp production is to maintain a good water quality environment.

### Important water quality parameters

- Dissolved oxygen
- pH
- Ammonia
- Temperature
- Alkalinity/
- Hardness
- Hydrogen sulfide
- Phosphorus
- Salinity
- Biological oxygen demand
- Turbidity

**Table 2. Water quality criteria.**

Parameter	Optimal Concentration
Temperature	26-30°C
Salinity	15-32 ppt
Dissolved Oxygen	>4.0 mg/l
pH	7.0-8.5
Ammonia (NH <sub>3</sub> )	< 0.15 mg/l
Nitrite (NO <sub>2</sub> )	< 4.5 mg/l
Hydrogen Sulfide	< 0.1 mg/l

### Dissolved Oxygen

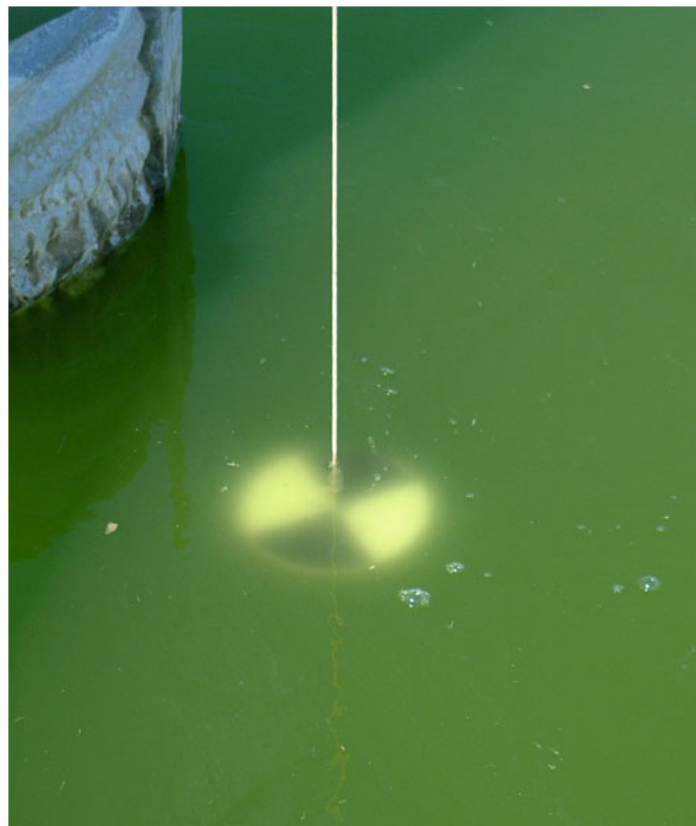
Dissolved oxygen is one of several important water quality parameters that a producer will monitor daily. Maintaining good dissolved oxygen concentrations is essential for successful production. Ponds have a dynamic oxygen cycle fluctuating throughout the day based on phytoplankton photosynthesis and respiration. The highest oxygen levels are observed in late afternoon due to the buildup of oxygen during the day due to photosynthesis (the natural production of oxygen by green plants). Electronic oxygen

meters or chemical water test kits can be used to measure oxygen concentrations.

- Critical for all life.
- Dependent on water temperature for saturation.
- 200,000 mg/l air versus 5 -14 mg/l water.
- Supersaturation may occur in high nutrient ponds.
- Rises during daylight; falls during night.
- Highest at sunset; lowest at sunrise.
- Measured with test kits and meters.

### Oxygen Sources

Oxygen can enter pond water by several means. Photosynthesis by phytoplankton is by far the greatest source of oxygen. This phytoplankton or microscopic algae also tends to be the greatest consumer of oxygen. Managing for a balance of photosynthesis and respiration is an important daily task for farmers. A secchi disk is a simple



A secchi disk is a simple device used to measure the density of phytoplankton population (bloom). The depth at which the disk is no longer visible is the secchi disk value. Values of 6-9 cm indicates a moderate bloom. Values of 4 cm or less indicate a heavy bloom and extreme daily oxygen fluctuations would be expected. Increased aeration is necessary.

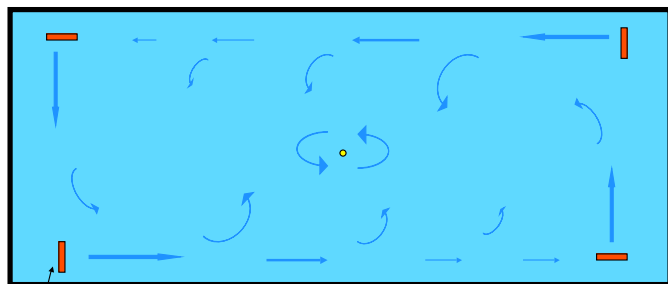
tool used to monitor the algae bloom population. Other sources of oxygen are diffusion or transfer of oxygen from the air into the water surface. Wave action or mechanical aeration can increase oxygen diffusion rates.

- Photosynthesis by aquatic plants and phytoplankton.
- Direct diffusion from the atmosphere.
- Wind and wave action.
- Mechanical aeration.
- Inflow of “new” water.

## Aeration: Types and Uses

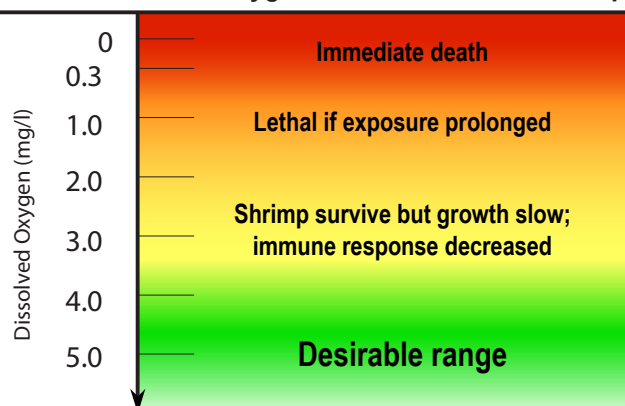
Several types of aerators are used for shrimp farming. The objective of aeration is to force diffusion of oxygen from the air into the water. Paddlewheel aerators accomplish this by breaking water into small droplets and increasing exposure to air using paddles. Aspirator aerators force air into the water via a venturi and a propeller. Another important goal of aeration is to circulate aerated water throughout the pond.

### Pond Aeration: Placement



Paddlewheel Aerator

### Effects of Dissolved Oxygen Concentration on Shrimp



## Pond Aeration: Placement

Paddlewheel aerators are the most effective in oxygen production and also create beneficial current providing for good water circulation throughout the pond. Placement of aerators in the corners allow for solids accumulation in center of pond, which can be removed if a center drain is used or will facilitate solids removal during pond drying time. Depending on size of pond, additional aerators can be placed at middle of pond length providing for additional oxygenation and circulation. Typically 10-20 hp/ha is used with high shrimp stocking densities and feeding rates.

## Major Causes of Oxygen Depletion

Low dissolved oxygen can be caused by many factors. The most common is overenrichment (excessive feeding or inflow of nutrients) of ponds, which causes heavy phytoplankton blooms resulting in high respiration or consumption of oxygen. Phytoplankton can die off quickly causing a rapid decomposition of algae by increased bacteria concentrations that consume more oxygen. Hot weather naturally will result in lower oxygen concentrations because warmer water holds less oxygen. A turnover can occur if the cooler and more dense deeper water of ponds (which often also have lower oxygen concentrations) is suddenly mixed to the surface due to a heavy rain or strong winds.

- Introduction of organic wastes.
- Excessive algae blooms and high respiration.
- Plankton die-off.
- Runoff from the watershed.
- Long periods of hot weather.
- Turnover of stratified ponds.
- Overstocking and excessive feeding rates.

## Dissolved Oxygen Measurement

Oxygen can be easily measured with an electronic meter or chemical test kits. Though relatively expensive (\$1,000 U.S.), a handheld oxygen meter can measure temperature and salinity and requires much less time than chemical test kits. Since oxygen fluctuates during the day, it is important to measure twice per day (early morning and afternoon) to know the influence of



photosynthesis in oxygen production. This will also help to plan when and how much mechanical aeration to apply. Be consistent in monitoring times to compare days and trends. Also record all water quality measurements.

## Temperature

Temperature is an important water quality variable because it will affect shrimp metabolism and feeding rates, directly impact biota respiration (oxygen consumption) rates, influence the solubility of oxygen, and affect the degree of ammonia toxicity. Warmer water holds less oxygen than cooler waters as is shown by the difference in oxygen concentrations for the three temperatures. Water temperatures above 32° for prolonged periods can stress shrimp and reduce growth.

- Inverse relationship with DO saturation.
- Impacts pond biota metabolism and oxygen uptake.
- Oxygen solubility in salt water at sea level:
  - 12° C = 11.3 mg/l
  - 22° C = 8.9 mg/l
  - 32° C = 7.3 mg/l
- Easily measured with thermometers.

## pH

pH is the measure of hydrogen ion (acidity) concentration. All living organisms have optimal ranges of pH where growth is best. Soil and water pH is easily tested and low pH is regulated by the addition of limestone. Since pH fluctuates naturally during the day, be consistent in the time of measurement to be able to better compare changes in pH from day to day.

Simple hand-held meters or chemical test kits are available to monitor pH.

- Measure of acid/base relationship.
- 7 is neutral; below is acidic; above is basic.
- Shrimp tolerate 6.5–8.5.
- Wide swings not recommended.
- Increases during daylight; decreases at night due to respiration and increasing carbon dioxide levels.
- Buffered by available carbonates.

- Measured with test kits or meters.

## Daily Fluctuation in pH of Pond Water

The consumption of carbon dioxide causes pH to naturally fluctuate during the day. It is generally lowest at sunrise (due to accumulation of carbon dioxide during the night) and highest at afternoon when algae consumption of carbon dioxide is at its greatest. Waters of moderate alkalinity are more buffered and the degree of pH fluctuation is lower.

## Alkalinity

Alkalinity is an important water quality parameter. It is a measure of the carbonate bases,  $\text{CO}_3$ , which can affect the potential for primary productivity and also the water pH. Values of 50-100 mg/l are considered moderate and are recommended. Addition of limestone can increase the concentration of carbonates and alkalinity. Alkalinity in ponds needs to be measured once a month.

- Measure of available carbonates.
- Buffers water.
- Prevents wide swings in pH.
- Easily measured with test kits.
- Increased by addition of limestone (dolomite).

## Liming Ponds

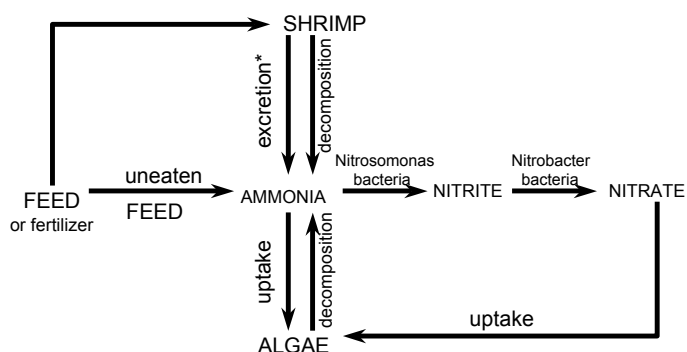
Addition of limestone, particularly dolomite, can increase alkalinity and water pH. It can also increase availability of nutrients to phytoplankton. Application is most easily accomplished when pond is drained and the limestone spread over the entire pond bottom. The rate to use depends on soil pH. Soil pH of 5 generally requires 6 tons/hectare.

- Common application rate:
  - 2-4 tons limestone/surface hectare
- When to apply limestone:
  - During pond drying time
- Takes several weeks to months for the full benefit of lime to be noted.
- Spread as well as possible over soil when applying.
- Is ineffective when applying to ponds with high flow rates.

## Pond Nitrogen Cycle

Nitrogen compounds are in constant cycling, being produced, converted and consumed, in a pond environment. Feed is the primary source of nitrogen as it is comprised of proteins from key ingredients such as fish, bone, or soybean meal. These proteins are utilized by the shrimp and ammonia is given off as a waste. Beneficial bacteria convert the toxic ammonia to nitrite (also toxic), which is further converted to nitrate, a process called nitrification. Nitrate is generally not toxic in pond environments. Nitrate can be used by plants/phytoplankton and to a lesser extent can be converted to nitrogen gas in the anaerobic portions of soil. Managing ammonia in ponds is most often accomplished by maintaining a healthy phytoplankton bloom.

### Pond Nitrogen Cycle



## Total Ammonia Nitrogen (TAN)

Ammonia is present in two forms, ionized ( $\text{NH}_4^+$ ) which is nontoxic, and the toxic form, un-ionized ( $\text{NH}_3$ ). The concentration of these depends on water temperature and pH. The higher the water temperature and pH, the greater the concentration of the toxic form. The summation of both the ionized and un-ionized forms is termed total ammonia nitrogen or TAN. The relationship of temperature and pH is important to understand because chemical test kits measure TAN. The concentration of toxic ammonia,  $\text{NH}_3$ , must be determined by the temperature and water pH.

- Composed of toxic (un-ionized) ammonia ( $\text{NH}_3$ ) AND non-toxic (ionized) ammonia ( $\text{NH}_4^+$ ).

- As pH and/or temperature increases, the proportion of TAN that is in the toxic form ( $\text{NH}_3$ ) increases.
- Total ammonia nitrogen, NOT un-ionized or ionized ammonia, is tested by water quality kits. The un-ionized and ionized components must be calculated.

## Toxic Ammonia ( $\text{NH}_3$ )

Ammonia in ponds comes from feed and nutrients entering with the water. If feed is uneaten, then more ammonia is present than if it is consumed by shrimp. For every kilogram of feed fed, about 30 grams of ammonia will be excreted by shrimp into the pond. Un-ionized ammonia is very toxic to shrimp and causes gill damage and reduced growth at low concentrations. Ammonia can be a problem anytime during the culture cycle and must be monitored once or twice per week.

Low concentrations of ammonia can damage gills and reduce growth or cause mortality. Preventing accumulation of toxic ammonia requires diligence in monitoring both ammonia and phytoplankton (which take up ammonia as a food source) and responding quickly by reducing or stopping feeding, fertilizing to stimulate more phytoplankton or exchanging water.

- Where does it come from?
  - ✓ Major waste product from shrimp
  - ✓ Uneaten feed
- What is the problem?
  - ✓ Stress
  - ✓ Gill damage
  - ✓ Poor growth
- When does it occur?
  - ✓ Most likely in summer when feeding levels, water temperature, and pH are high and when algae population is low
- What is the optimum concentration?
  - ✓ 0 mg/L
- What is a problem concentration?
  - ✓ Damage at  $>0.015$  mg/L
  - ✓ Death at  $>2.0$  mg/L

- What are the treatments?
  - ✓ PREVENTION!!!
  - ✓ Decrease feeding rates
  - ✓ Maintain healthy algae bloom
  - ✓ Exchange water

## Nitrite (NO<sub>2</sub>)

Nitrite is another nitrogen compound that results from feed and can be toxic to shrimp. Nitrite is an intermediate product of the conversion of ammonia to nitrate by bacterial action. Even at relatively low concentrations (~5 mg/l), nitrite can disrupt the oxygen transport within cells and circulatory system. Since the conversion of nitrite to nitrate is accomplished by certain bacteria, environmental conditions that affect bacterial growth and metabolism can impact the rate of conversion and therefore the concentration of nitrite. Change in water temperature is an example.

Nitrite is stressful to shrimp at low concentrations. Maintaining healthy algal blooms will encourage ammonia uptake which reduces the loading for bacteria to convert ammonia to nitrite to nitrate. In extreme nitrite concentrations, water can be exchanged into the pond.

- Where does it come from?
  - ✓ Product of nitrification process (ammonia breakdown).
- What is the problem?
  - ✓ Reduced oxygen transport
- When does it occur?
  - ✓ Usually when the bacterial composition in the pond is disrupted.
- What is a desirable concentration?
  - ✓ 0 mg/L
- What is a problem concentration?
  - ✓ > 4.5 mg/L
- What are the treatments?
  - ✓ PREVENTION!
  - ✓ Often mitigated with high chloride levels
  - ✓ Flush system with new water

## Hydrogen Sulfide (H<sub>2</sub>S)

Hydrogen sulfide is a by product of the breakdown of organic matter, usually under anaerobic conditions. Soils with moderate to high organic concentrations that have anaerobic conditions can be a significant source of hydrogen sulfide, which is toxic to shrimp even at low concentrations. If an eggy odor is noticed when sediment is disturbed, it is an indication of anaerobic conditions and the presence of hydrogen sulfide. Drying and tilling pond bottoms, as well as maintaining thorough aeration of ponds are effective tools in reducing hydrogen sulfide.

- What is it?
  - ✓ Colorless, toxic gas with odor similar to rotten eggs
- Where does it come from?
  - ✓ Present in soils with anaerobic conditions
- What is the problem?
  - ✓ Toxic to shrimp—interferes with respiration
- What is a desirable concentration?
  - ✓ 0 mg/L
- What is a problem concentration?
  - ✓ “If you can smell it, it’s a problem.”
- What are the treatments?
  - ✓ Aeration
  - ✓ Soil tilling and drying
- Toxicity varies with changing pH and temperature
  - ✓ pH ↓, H<sub>2</sub>S toxicity ↑
  - ✓ More H<sub>2</sub>S is in un-ionized form at lower pH
  - ✓ Temperature ↑, H<sub>2</sub>S toxicity ↑

## Growout Pond Management

This section will describe important pond design, water quality and shrimp health management practices improving the quality of the culture environment and the shrimp produced.

## Pond Design Criteria

Locating shrimp ponds in low elevations, such as mangrove swamps, has created many environmental and shrimp production problems.



## Sample Water Quality Data Sheet

Pond No. \_\_\_\_\_

Date	Time	Temp	Secchi	Alk	pH	TAN	NH <sub>3</sub>	NO <sub>2</sub>	Notes

Daily recording of water quality parameters is an important tool in understanding the relationships between parameters and effects on shrimp feeding and growth. Disease is often a result of poor water quality and maintaining good records will enable farmers to better take corrective action and note changes.

Ponds should be located more inland with the pond bottom elevation being 1-2 meters above highest tides. A rectangular-shaped pond is cheaper to construct, and also reduces wind erosion damage to levees if pond length is perpendicular to prevailing winds. A levee slope of 1.5:1 to 2:1 minimum is recommended to reduce erosion. This means that for every meter in elevation the levee is 1.5 – 2 meters in width. To maintain moderate water temperatures, it is best to have water depths of at least 0.8 meters, preferably 1-1.6 meters in depth. If the selected site has acid sulfate soils, which result in low pH and reduced shrimp growth, do not disturb soil with equipment or cover with top soil. Planting levees with a grass cover can reduce erosion and increase pond turbidity.

- Ponds located at least 1-2 meters above highest tide elevation will be easier to manage, have less environmental impact and often have better soil type.
- Rectangular shaped ponds aid in aeration and experience less wind erosion (length perpendicular to prevailing wind).

- Levee slopes of 1.5:1 at minimum and those cored to prevent seepage last longer and are easier to manage.
- Pond water depth of 0.8 meter minimum to 1.6 meter is recommended.
- Save and reuse top soil; plant levees with native grasses.
- Limit disturbance of acid sulfate soils or treat and cover with top soil.

### Pond Design

- The top width of the levees will be affected by height and slope, but at a minimum, they should be wide enough to accommodate harvest equipment. Pond bottom should be clean of debris and flat, with a gentle slope to the drain to facilitate easy draining and shrimp harvest.
- The pond discharge should be at least 0.3 meter higher in elevation than the drainage canal water level to allow for harvest equipment to be attached and for the pond drain structure to be easily maintained. The harvest structure should be carefully constructed and durable and designed

to facilitate quick harvest of shrimp allowing for minimum time between harvest and icing. This will greatly improve shrimp quality.

- Wide top width allows for harvest/transport equipment.
- Bottom even and sloped to drainage system facilitates harvesting and provide access for equipment.
- Placing the drainage system at least 0.3 m above canal water level will aid in harvest.
- Discharge/harvest control gate should be durable and efficient which helps to reduce harvest time.

### Pond Management–Preparation

Proper preparation of the pond soil prior to flooding and stocking shrimp can improve water quality, reduce incidence of disease, and can help to increase production and quality of shrimp. Basic practices to achieve this include drying the pond between shrimp crops. Exposing the pond bottom soil to the sun and air enhances the oxidation or breakdown of organic matter and reduces pathogens. Tilling aids in aerating soils that may have anaerobic areas where organic matter and hydrogen sulfide (toxic to shrimp) accumulate. The exception to tilling is when acid sulfate soils are present. In this case, toxic iron pyrites can be released and significant reduction in pH is possible.

Treating the soil with the addition of hydrated or slaked lime is helpful in reducing potential pathogens—1,000-2,000 kg/hectare is an effective rate. Addition of limestone (different from hydrated lime) is an effective practice to increase water alkalinity and increase pH. A rule of thumb is to use 6 ton/ha when soil pH is 5 and 3 tons/ha at pH of 6. Soil pH's of 7 and higher generally do not need limestone, unless alkalinity is lower than 50 mg/L.

- Drying pond—oxidizes organic matter/reduces hydrogen sulfide and pathogens.
- Tilling soil can aid in oxidation, however, it is not recommended for acid sulfate soils due to release of pyrites and reduction of pH
- Sterilizing pond soil/pooled water—use of hydrated or slaked lime applied to pond

bottom can reduce microbial count (acts by rapid increase in pH).

- Increasing soil pH—addition of limestone - dolomite can reduce soil acidity, increase alkalinity, and buffer pH (applications of 3 tons/ha at pH 5, 1.5 tons at pH 6).
- Prevent erosion of acid sulfate soils—treat soil, cover with top soil, and plant cover crop.

### Fertilizers

Fertilizers are used to increase primary productivity or natural foods in ponds. These can be natural or synthetic substances—plankton and other natural food organisms—added to the aquaculture pond to increase primary productivity.

#### Types:

- Organic
  - Example: composted animal manures
- Inorganic
  - Urea, ammonium phosphate
    - † Typical rate of 20-30 kg N/ha and 1-2 kg P/ha

### Organic Fertilizers

Organic fertilizers are derived from plant material or animals. They are obtained by the conversion of animal manure, post harvest material, or organic waste into compost.

Raw materials commonly used for the production of organic fertilizers include:

- Animal manure
- Post-harvest material
- Organic waste
- Biosolids/sludge (human waste)

### Hazards Associated with Animal Manure

Human and animal fecal materials are important sources of microbiological contamination of aquaculture fishery products. Organisms linked to these sources include *Salmonella* spp. and other pathogenic bacteria. Animal manure and solid biological waste may provide safe, effective fertilizer when properly treated. If the treatment is inadequate, or if no treatment is used, the risk of

contamination of aquaculture fishery products is extremely high.

- When fecal material is used for fertilizer without proper treatment, there is danger of contamination of aquaculture fishery products with pathogenic bacteria.
- These bacteria can cause gastrointestinal and other illnesses in humans.
- Survival of viruses and protozoa in composted manure has not been clearly determined.

### Treatments to Reduce Risks

To convert organic waste into safe fertilizers (compost), practices should be followed to reduce the presence of pathogenic bacteria. Composting is a natural biological process by which organic material is broken down and decomposed. It is carried out by bacteria and fungi, which ferment the organic material and reduce it to a stable humus. Microbial analysis of compost may be performed to determine if the procedure was effective in eliminating pathogenic bacteria such as *Salmonella* spp. Active treatments such as pasteurization, drying with heat, anaerobic digestion, stabilization with alkaloids, aerobic digestion, or a combination of these may be applied to speed the composting process.

- Artificially induce the environment conversion of waste to compost.
- Compost piles are turned frequently or other aeration is provided to maintain adequate oxygen (aerobic) conditions.
- Temperature and moisture levels in the pile are monitored and supplements are added as necessary.
- Composting is a natural, biological process by which organic material is broken down and decomposed.
- Because the fermentation process generates heat, it can reduce/eliminate biological hazards in organic matter.

### Hazards Associated with Manure Treatment and Storage Location

Manure should be confined for treatment.

- The location for storage and treatment of animal manure should be away from the aquaculture production site.
- Barriers or some type of physical containment should be used as part of the manure storage areas to prevent contamination of culture areas or fishery products by pathogens spread by rain, underground water sources, or wind from the stored manure.
- Contamination of ground water supplies can be minimized if animal manure is stored on a cement floor or in special holes lined with clay.
- Manure piles should be covered with plastic or other materials and/or stored under a shed since rainfall on manure piles can result in runoff containing pathogenic bacteria that can contaminate fields, equipment, etc.
- The minimum distance from the manure storage facility to the aquaculture site depends on many factors such as the configuration of the aquaculture site, land slope, and existing barriers to contain water.
- Treated manure should be kept covered and away from waste and garbage to prevent recontamination by birds or rodents.

### Untreated Animal Manure

- Untreated manure is a potential source of pathogenic organisms and therefore should not be used.
- The use of untreated animal manure (without composting) presents a greater risk of contamination compared with treated manure and should NOT be used.

### Basics of Shrimp Feeding

Feeding management is one of the most important factors in good production of shrimp. Attention to the type of feed, feeding rate, and shrimp consumption can reduce costs by reducing feed waste, reduce water quality problems from over enrichment of ponds, and ensure good shrimp growth and health.

- Feed is the number one cost of shrimp production.
- Feed is very important contributing factor to reduced water quality.



- Know the nutritional requirements of shrimp species and size.
- Feed the proper form and size.
- Observe shrimp feeding behavior.
- Keep good records.

## Pond Feeding Management

Selecting and using the proper feed quality, including protein level, and proper feed storage is essential to maximize shrimp growth and aids in shrimp health.

- Use feeds of proper nutritional value: 35-40% protein depending on shrimp size.
- Ensure feed has proper vitamin A and C, and astaxanthin content for increased immunocompetence.
- Vitamin and feed quality is reduced in high temperatures and humidity.
- Feed shelf life is limited.
- Select feeds with good water stability.
- Extruded feeds increase digestibility, reduce antinutritional compounds and microorganisms.

## Pond Feeding Management Practices

Following recommended good feeding management practices is essential to maximize efficient feed utilization by shrimp, maximize shrimp growth, and reduce feed waste. Feed quality can be reduced if stored improperly. Heat and high humidity can reduce the vitamin content of feeds and cause mold, which can introduce toxins. Keeping feed cool and dry is important to maintain feed quality. Be sure to buy feed that has been recently produced and only store a quantity that can be used in a few weeks or 2 months maximum. Distributing feed over a large area of the pond, several times per day, is important to ensure that all shrimp have access to feed for proper growth and ability to maintain good health. Wide feed distribution with multiple feedings also helps the breakdown of organic wastes by beneficial bacteria and reduces spikes in water quality problems such as ammonia. Daily observation of feed consumption by use of feeding trays is a valuable

tool in managing water quality and assessing the health of shrimp.

Recording feed rate and shrimp feeding behavior carefully is one of the most important management tools that farmers have to know how their shrimp are performing. If shrimp are not feeding well, it may be an indication of some stress or disease. If shrimp are not feeding well or mortality is observed, feeding rate should be reduced or stopped to prevent feed waste and its negative impact on water quality.

- Store feed in a cool, dry location and prevent rodent exposure.
- Do not use old and moldy feed.
  - ◻ 1-2 month maximum shelf life.
- Use proper size feed for shrimp sizes.
- Distribute feed over large area of pond.
- Feed multiple times per day.
- Use feeding tray to monitor feeding response and determine proper feeding rate/reduce waste.
- Record daily feeding rate and behavior.
- Monitor shrimp growth and adjust feeding rate accordingly.
- Reduce or stop feeding rate if water quality parameters fall below good range.
- Promote natural food productivity.
- Use proper larvae stocking densities.



Since shrimp feed on bottom, feeding trays are an important tool to know how much shrimp are eating. Feeding should be monitored daily. If uneaten feed is observed, reduce feeding rate, check water quality to be sure no problems exist, and monitor shrimp health.

## Pond Pest Control

Reducing pests can increase production and reduce disease occurrence. Pests that affect shrimp quality are those that can transmit disease such as wading birds, which can carry organisms on legs and feathers, and rodents, which can contaminate

feed. The use of barriers such as netting along pond banks can reduce use of ponds by birds and animals. Pyrotechnics, such as propane-powered cannon or handheld scaring devices can be an effective tool in reducing bird predation. These should be used consistently and varied to keep birds from getting accustomed to the noise.

- Common pests: fish, birds and mammals.
  - Potential source of disease and predation
- Prevention is best approach.
  - Multiple screening for fish on water supply intake (0.3 mm); piscicides (saponin or tea seed cake at 1.5 ppm; Rotenone at 0.5-1.0 ppm)
  - Pyrotechnics or scare devices to prevent birds
  - Fencing to prevent mammal use and influx of waste
  - Dry and rodent-proof building for feed storage

## Effluent Management

Managing discharge or effluent from shrimp ponds is important to reduce pollution of receiving waters that are reused for shrimp production. Minimizing poor quality water will reduce disease outbreaks, which can spread to other ponds or farms. Allowing solids to settle in a settling pond will greatly reduce organic loading and improve water quality. Effluent should be analyzed regularly to determine the effectiveness of treatment and determine if additional effluent management is required. If necessary, ponds with known virus or bacterial outbreaks can be treated in a settling

- pond with hydrated lime or chlorine and using additional storage time prior to release.
- Discharge pond water slowly to allow settling and prevent erosion.
- Treat effluent with a settling pond: 3-day minimum residence time—reduces organics, TSS, BOD, and nutrients.
- Monitor quality regularly.
- Quarantine infected pond water and sterilize.
  - 25-30 mg/l chlorine

## Effluent Quality Recommendations

The following table presents recommended effluent concentrations of several important water quality parameters to minimize environmental impact and pollution of receiving waters used by shrimp farms as source water.

## Pond Water Management Practices

Basic pond management principles are designed to maintain good water quality and reduce incidence of disease. It is important to develop a plan of action to be taken when a water quality measurement approaches being outside the desirable range and stressful concentrations. This is why monitoring regularly and recording data is important—it will aid in anticipation of needed action. An example of a protocol would be to not pump and exchange water when neighbors are discharging, or reducing feeding rate when ammonia concentrations rise quickly. Though water exchange has been used as a management tool to improve water quality, it also increases risk of disease as the source water may be temporarily

## Effluent Quality Recommendations

Variable	Value	Notes
Dissolved Oxygen (mg/l)	4 or more	
pH	6.0 – 9.5	
Total Ammonia Nitrogen (mg/l)	5.0/3.0 or less	Initial/At time of harvest
Total Suspended Solids (mg/l)	100/50 or less	Initial/At time of harvest
Biological Oxygen Demand – 5 day (mg/l)	50/30 or less	Initial/At time of harvest
Phosphorus (mg/l)	0.5 or less	

of lower quality than the shrimp ponds due to pesticides or sediment, etc. Minimizing water exchange and maximizing aeration are good management practices. Water reuse can be a good tool providing the water is treated by settling and aeration prior to reuse. In some cases, water can be treated with hydrated lime to reduce pathogen load. Using native aquatic plants or shellfish in settling ponds can aid in reducing nutrients and improve water quality.

- Use individual settling ponds for inflow and effluent.
- Develop quality protocols for water exchange.
- Minimize water exchange, maximize quality.
- Reuse water.
- Integrate plant or bivalve culture in settling ponds to reduce nutrients/organics.
  - Ex: seaweed culture

## Shrimp Health Management Practices

These are some important management practices directly concerning shrimp health. Besides maintaining a high quality environment, using quality feed and good feeding practices, these health practices will significantly reduce the potential for disease and should be followed strictly.

If a disease outbreak occurs, the water in the infected pond should be quarantined and treated before reuse or being discharged. All equipment that has been in contact with the infected pond should be treated. Nets and other small equipment can be sterilized using a variety of chemicals following guidelines on the product label. Harvest equipment can also be sterilized with chemicals or exposed to the sun for several days. If a disease outbreak occurs, have the disease diagnosed by a qualified laboratory. Knowing what disease organism is the cause will provide farmers with the most effective response.

- Ensure stocking of good quality post larvae.
  - Do not use wild caught larvae
- Properly acclimate post larvae to pond temperature and pH.
- Focus on reducing stress and prevention.

- Monitor and record shrimp health daily.
- Remove and properly dispose of dead shrimp.
- Maintain biosecurity.
  - farm to farm, pond to pond
- Quarantine infected ponds/treat effluent.
- Treat all harvest and transport equipment.
- Proper identification of disease.
- Follow recommended pond preparation practices.
- Use proper shrimp stocking densities.

## Shrimp Health and Quality Management Practices

It is important to note that, only one chemical is permitted by the FDA for treating shrimp ponds and that compound, formalin as Parasite-S or Formalin-F, is only permitted for the treatment of the protozoan parasites *Bodo*, *Epistylis*, and *Zoothamnium*. No compound is allowed by FDA for bacterial or viral infections. This limited option for treatment means that prevention of disease by following the recommended practices in this manual is essential to maintain good shrimp health.

- Zero use of banned chemicals.
- Follow label recommendations of all chemicals.
- Properly train farm workers in safe and responsible chemical use.
- Harvest and handle shrimp in a sanitary manner.
- Harvest in cooler time of day.
- Ice shrimp immediately using clean ice and water upon harvest to reduce core temperature.

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