An Assessment of the Environmental Impact
Of Alabama Channel Catfish Farming

Claude E. Boyd, Gregory N. Whitis, and Julio F. Queiroz
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama 36849

Channel catfish farming and other types of aquaculture have grown rapidly in the past few decades, and it finally has become an activity large enough to attract the attention of environmentalists. As a result, the United States Environmental Protection Agency has been coerced by environmental interests to enforce the Clean Water Act in the aquaculture sector. The nature of the regulations and the timing of their implementation are uncertain. However, it is virtually certain that aquaculture pond effluents will be subjected to permitting within the next few years. The Alabama Catfish Producers Association intends to be proactive and become involved in the process through which regulations will be formed. Thus, they provided funding to Auburn University to conduct an environmental assessment of channel catfish farming in Alabama. This study focused on catfish farms in Bibb, Dallas, Greene, Hale, Marengo, Perry, and Tuscaloosa Counties in West Central Alabama where most of the catfish production of the state is realized.

There are about 25,000 acres of ponds with 10.7% of the area for fry and fingerlings and 89.3% for food fish. Most production is from watershed ponds filled by rainfall and runoff, but water levels in many of these ponds are maintained in dry weather with well water. There are some embankment ponds supplied by well water. In 1997, the production of food fish was near 90,000,000 pounds, so the average, annual production per acre was about 3,600 pounds.

Because ponds are filled and maintained primarily with runoff, the water supply is seasonal and water conservation measures must be used. Farmers attempt to store as much runoff in ponds as possible so that water levels can be maintained during summer and fall when there is little runoff. Fish are harvested by seining without drawdown of water levels. However, after about 5 or 6 years, it is necessary to partially drain ponds and renovate fish stocks. After about 15 years, ponds may be completely drained to renovate the embankments and bottoms. Thus, in a 15-year period, about two pond volumes of water are intentionally discharged from ponds, but storm overflow occurs after winter and spring rains.

Although the Alabama industry does not rely heavily on groundwater, as does catfish farming in other southern states, it does use an estimated 23,000,000 gallons of groundwater per day from wells. Seepage from ponds more than replaces the amount of groundwater withdrawn for use in ponds. Thus, Alabama catfish farming does not deplete groundwater supplies on a long-term basis.

Catfish ponds in Alabama serve the dual purpose of fish production and flood control. The large area of ponds retains runoff after heavy rains and releases it gradually. Flooding by larger streams in the area has greatly diminished since catfish farming became a major activity. Overflow from ponds occurs primarily during cool months when fish in ponds are not being fed.
at high rates and when pond water quality is generally good. Also, pond overflow occurs at the
time that stream flow is high. The timing of overflow from ponds greatly reduces the potential
for stream pollution by effluents from ponds.

When ponds are partially drained for harvest, the first 75 to 80% of pond volume released
tends to have the same composition as pond water. Only the last 20 to 25% of pond volume
released during complete draining of ponds tends to increase in concentration of potential
pollutants relative to pond water. Total suspended solids and total phosphorus are the only water
quality variables consistently higher in concentration than typical concentration limits for water
quality variables in effluent permits for other industries in the southern United States. Total
phosphorus in pond effluents is usually associated with suspended solids, and the main sources
of total suspended solids are erosion of denuded areas on watersheds, embankments, pond
bottoms, and discharge ditches. Concentrations of nitrogen and dissolved phosphorus in
effluents are not high, but effluent loads (weights of pollutants in effluents) of these two
variables are greater than those for runoff from typical row crops in Alabama. Because of annual
draining for harvest, fry and fingerling production ponds have much greater effluent loads of
potential pollutants than do food fish production ponds. Watershed ponds that discharge
following heavy rains also have greater pollution loads than do embankment ponds that seldom
discharge water naturally.

There is little use of medicated feeds in catfish ponds. Sodium chloride is frequently
applied to control nitrite toxicity, and copper sulfate is often applied to kill blue-green algae
responsible for off-flavor in fish. There is no evidence that sodium chloride applications of 50 to
80 mg/L to ponds will lead to salinization of streams. Copper sulfate may be applied at 0.75
mg/L to ponds 3 or 4 times per year. Copper from copper sulfate quickly precipitates from water
and is not present at toxic concentrations in effluents.

Hydrated lime may be applied to ponds 3 or 4 times per year at 50 to 100 kg/ha for algal
control and other purposes. This amount of lime will not increase pond water pH enough to
cause pH above 8.5 or 9.0 in pond effluent. Pond fertilizers such as triple superphosphate,
diammonium phosphate, urea, and 10-34-0 (% N - % P₂O₅ - % K₂O) liquid fertilizer are applied
at 5 to 10 pounds N and P₂O₅/acre 2 or 3 times per year in fingerling and fry ponds. Farmers
may sometimes apply fertilizer to production ponds which do not develop plankton blooms. The
majority of nitrogen and phosphorus in pond effluents originates from feed inputs rather than
fertilization.

Seven streams were sampled upstream from any influence of catfish pond effluents and
downstream of catfish farm outfalls at monthly intervals for 14 months. The pH was slightly
greater downstream of catfish farms than above, but average pH was between 7.1 and 8.2 at all
sampling locations. Dissolved oxygen concentrations were essentially the same upstream and
downstream of catfish farms, and all average concentrations exceeded 5 mg/L. Specific
conductance values tended to be elevated downstream of catfish farms during drier months, but
specific conductance never exceeded 600 microSiemens/cm and was within an acceptable range
for freshwater aquatic life. The average 5-day biochemical oxygen demand was generally
similar between upstream and downstream sites, but there were occasions when the biochemical
oxygen demand was greater upstream from catfish farm outfalls than downstream from them. In
fall 1997, total ammonia nitrogen tended to be higher below farms than above, but the opposite
was true in June 1998. Except for a single sampling date in September 1997, there was little
difference in average nitrate-nitrogen and total nitrogen concentrations between upstream and
downstream sites. There were no clear trends of difference in either soluble reactive phosphorus

2
or total phosphorus between sites upstream and downstream of catfish farms. Total suspended solids tended to be greater downstream of catfish farms in March and April 1998, but concentrations were higher above catfish farms than below them in June and July 1998, and similar trends were observed in turbidity values.

The small streams into which Alabama catfish farms discharge drain mostly cropland, pastures, and woods, and they do not have especially high quality water. Upstream of catfish farms, 5-day biochemical oxygen demand values usually are above 5 mg/L and concentrations of total suspended solids are often above 50 mg/L after rains.

There were almost an equal number of cases where water quality variables are higher above catfish farms than below. Furthermore, there were not cases where extremely high concentrations of variables (or very low dissolved oxygen concentrations) were noted downstream of farms. The findings suggest that catfish farm effluents are not having adverse impacts on stream water quality.

A few other observations were made that are of environmental interest. When ponds are drained, dried, and renovated, sediment removed from bottoms is used to repair embankments and not disposed of outside of ponds. Electricity used for pumping water and mechanical aeration was estimated as only 0.41 kilowatt-hours per pound of production. Each ton of fishmeal used in feeds yields about 10 tons of dressed catfish.

Better Management Practices

Evaluation of the environmental status of channel catfish farming in Alabama revealed generally good production practices and absence of widespread, negative environmental impacts. It is not possible to operate channel catfish ponds with current technology and not have effluent. Farmers must discharge water occasionally to renovate fish stocks and repair ponds, and overflow occurs after rainstorms. Water reuse could reduce the amount of discharge when ponds must be drawn down, but this practice would be expensive because farmers would need to purchase and operate pumps to transfer water. On a few farms there is space to construct settling basins, or natural wetlands are available for treating effluents. However, on most farms, an existing pond would have to be used as a settling basin. Renovation of the farm infrastructure to permit the use of existing ponds as settling basins also would be expensive and pumping costs would be incurred.

The catfish industry in Alabama releases little water other than storm overflow, and the major water quality concern is high concentrations of total suspended solids. Because the source of these solids is primarily erosion, it would be possible to greatly reduce total suspended solids concentrations through erosion control techniques.

The use of standard NPDES (National Pollution Discharge Elimination System) permits with the requirement of water quality monitoring to verify compliance would be very difficult and expensive because of the large number of outfalls associated with catfish farming. We feel that the installation of management practices to prevent environmental effects could be an alternative to NPDES permits and an effective means of environmental management for the Alabama catfish industry.

A list of better management practices that could make farm operations more efficient and provide environmental protection will be provided. Some farmers are already using many of these practices, but wide-spread adoption of good management procedures is desirable.
(1) Establish grass cover on denuded areas of pond watersheds to minimize erosion.

(2) Grass cover should be provided on the interior and exterior of pond embankments to minimize erosion.

(3) Divert excess flow of large watershed away from ponds to minimize total suspended solid inputs to ponds.

(4) Use reasonable stocking and feeding rates to reduce nutrient and organic matter inputs and water quality deterioration.

(5) Do not feed more than the fish will eat to reduce feed input.

(6) Do not use fertilizer unless necessary to promote plankton blooms to reduce nutrient inputs.

(7) Use well water conservatively.

(8) Do not install deep-water discharge structures in ponds because surface waters usually are of higher quality than deeper water.

(9) Maintain at least 7.5 to 10 cm of depth below overflow intakes in embankment ponds to conserve rain and runoff in warm months and minimize overflow.

(10) Position mechanical aerators to minimize erosion of pond bottoms and embankments, but use adequate aeration to prevent low dissolved oxygen concentrations.

(11) Do not discharge water during final seining, and when ponds are completely drained, release the final water as slowly as possible to minimize discharge of potential pollutants.

(12) Do not leave ponds empty in winter, and shut valves when ponds are empty to prevent discharge of suspended solids after rains.

(13) Close pond valves when renovating inside earthwork to prevent discharge of suspended solids after rains.

(14) Use sediment removed from pond to repair earthwork rather than disposing of it outside of ponds to reduce erosion potential on farm.

(15) Extend drainpipes beyond the toes of the embankments to prevent erosion of the embankment by discharge.

(16) Construct ditches to minimize erosion and establish grass cover on them.

(17) Use concrete structures or rip-rap to protect areas impacted by rapidly flowing discharge from erosion.
(18) Extend pipes that discharge directly into streams to prevent bank erosion.

(19) Where possible, release pond effluents into natural wetlands to take advantage of natural water treatment.

(20) Store materials such as fertilizers, lime, salt, and other pond amendments so that they are not washed into streams by rainfall.
Inland Shrimp Farming and the Environment

Claude E. Boyd

There is considerable interest in inland farming of marine shrimp in areas where slightly saline water is available and even in some freshwater areas (Jory 1999). There are two ways of obtaining saline waters for inland shrimp ponds. In some areas, there are aquifers containing naturally saline water, and ponds can be filled from wells developed in saline-water aquifers. Where saline water is not available naturally, brine solutions from coastal salt farms or solid salt may be transported to the ponds and mixed with freshwater to provide enough salinity for shrimp production. In some cases, shrimp production has been done in freshwater without adding salt.

There is little historical documentation of inland shrimp farming, but some reliable information is available. In 1989, I visited a site near Mahasarakham in northeast Thailand where salty ground water was being used by a few farmers to produce Penaeus monodon. This practice never became established in the area. In the mid 1990s, shrimp farmers in central Thailand began to mix brine solution and irrigation water in inland ponds to culture shrimp. This became a major activity, and a 1997 survey (Musig and Boonnom 1998) reported about 11,500 ha of inland shrimp farms in central Thailand. In the summer of 1998, in response to concerns about salinization of soil and irrigation water, the Thai government banned inland shrimp farming. There has been considerable controversy over the ban, and the Thai government is now attempting to find a way to resolve the controversy and still allow inland shrimp farming.

Inland shrimp farming projects also have been installed in the United States in Arizona (Jory 1999) and in Florida (Scarpa 1998). The project in Arizona relies on ground water from wells that has a salinity of 1 to 2 ppt. The effort in Florida is based on culturing shrimp in
recirculating freshwater (0.4 to 0.5 ppt salinity). In 1999 and 2000, some catfish farmers in west-central Alabama begin to experiment with shrimp culture in ponds filled with ground water from wells that contained 2 to 6 ppt salinity. The effort has been fairly successful and is expected to continue and to expand. During 2000 in Ecuador, several pilot projects where brine solution or salt was used to increase the salinity of freshwater ponds were successful in producing shrimp. There also are areas in Ecuador with saline underground water suitable for using in shrimp culture. Thus, inland shrimp farming is expected to become a viable activity in Ecuador. There are many other areas in the world where inland shrimp farming could be conducted, and this type of shrimp culture could become an important addition to world shrimp supplies.

Because the inland culture of shrimp in the United States is not a large activity, there has been little notice of it by environmental groups. However, it is interesting that some channel catfish farmers in west-central Alabama have been culturing catfish in waters of 2 to 6 ppt salinity for years. This water is highly prized by catfish farmers, because it has considerable therapeutic value to fish, and disease problems are much less than in normal freshwater water used for catfish farming. It is not known how much catfish farming is conducted in saline water, but it is certain that several hundred hectares of ponds are used for this purpose. An environmental impact assessment of channel catfish farming in Alabama (Boyd et al. 2000) did not reveal any negative impacts of catfish culture in saline water. However, it should be noted that all culture in saline water has been conducted in embankment ponds that only overflow after heavy rainfall, ponds are constructed in heavy clay soils where seepage is low, sediment is not removed from ponds, and ponds are not drained more than two times in 15 years for fish harvest because harvest is done by seining (Boyd et al. 2000).
The United States Environmental Protection Agency currently is conducting a rule-making procedure for aquaculture effluents. The initial rule is due in June 2002, and the final rule will be published in June 2004 (Federal Register 2000). Effluents from inland shrimp farms will be considered under the EPA rules. It is assumed that most inland shrimp farms in the USA will reuse water to conserve salinity. However, there will be environmental concerns about inland shrimp farming related to salinization of surface water, ground water, and soils. The issue of inland shrimp farming and the environment deserves careful attention to assure that this type of shrimp culture develops in an environmentally-responsible manner. The following discussion will focus on the situation in Alabama, but the comments are applicable in most other areas.

The saline ground water available for inland shrimp farming in Alabama occurs in the west-central part of the state in Greene, Hale, Marengo, and Tuscaloosa Counties. The aquifers are at depths of 60 to 120 m. Wells yielding 750 to 3,500 L/min usually can be developed. The land available for inland shrimp farming usually is located in the Black Belt Prairie and is gently to moderately rolling, former pastureland. Soils normally have a high content of sticky, expandable clay.

The saline ground water normally has a salinity of 1.5 to 6 ppt. Typical concentration ranges of major constituents and pH are provided in Table 1. Sodium and chloride make up the majority of the concentration of major ions in the water. The saline ground water is much lower in salinity than normal seawater that has an average salinity of 34.5 ppt. However, the proportions of calcium and bicarbonate are much higher in the saline ground water than in seawater, but the opposite is true for magnesium and sulfate (Table 2). A high proportion of calcium and bicarbonate is considered desirable in aquaculture pond waters (Boyd and Tucker 1998), and a low proportion of sulfate also is desirable because sulfate is the source of hydrogen
sulfide in anaerobic pond soils. The significance of a low proportion of magnesium is not known, but pilot studies have shown that shrimp grow well in the saline ground water in Alabama.

The suitability of irrigation water from the standpoint of salt concentration often is expressed in terms of total dissolved solids and sodium adsorption ratio (Boyd 2000). The sodium adsorption ratio (SAR) is calculated as follows:

$$\text{SAR} = \frac{(Na)}{1/2 \sqrt{(Ca) + (Mg)}}$$

where \(Na = \) sodium concentration (meq/L)  
\(Ca = \) calcium concentration (meq/L)  
\(Mg = \) magnesium concentration (meq/L)

The SAR for saline ground water in Alabama ranges from 20-40, and total dissolved solids from 1,500 to 6,000 mg/L. The usual influence of SAR and total dissolved solids on plants (Boyd 2000) is summarized in Table 3. Thus, the saline ground water used for inland shrimp farming in Alabama could be expected to harm most plants. It also could cause salinization of surface water or soil if discharged from ponds into natural habitats. Inland shrimp farming in Alabama, and presumably in many other places, should be done in water recirculating systems without discharge of effluents. The exception would be where salinity in pond water is so low that total dissolved solids and SAR of effluent would not lead to soil or water salinization or harm plants (Table 3).
Inland shrimp farming can be conducted without causing adverse environmental effects if certain precautions are followed as follows:

1. Production should be done only in ponds where discharge can be prevented after rainstorms. The most suitable ponds would be embankment ponds with adequate freeboard to retain rainfall without overflow. Alternatively, ponds could be allowed to discharge but the effluent held in a detention basin without overflow located nearby and on the farm.

2. Ponds should not seep so that water infiltrates into freshwater aquifers, streams, or non-saline soils. Soils for pond construction should have an adequate particle size distribution to allow for the construction on watertight embankments and bottoms. Proper compaction techniques should be used to further reduce the infiltration potential of bottoms and embankments (McCarty 1998). Anti-seep devices should be installed around pipes extending through embankments. Where soils will not resist infiltration, clay liners or plastic membranes could be used to prevent infiltration (Yoo and Boyd 1994).

3. Water should be reused and not discharged into natural habitats. Ponds must be drained for harvest, so a reservoir must be provided for holding this water for reuse. The same reservoir can be used to detain overflow from ponds after heavy storms. The reservoir should be large enough to provide 6 or 8 days retention time before water is reused. This will allow for purification of the water by natural processes. Water exchange between production ponds and treatment reservoirs may be done when water quality problems occur in ponds. It is
anticipated that culture ponds will be aerated mechanically. Installation of mechanical aerators in the reservoir would enhance water purification during retention.

(4) It is a common practice to remove sediment from intensive shrimp production ponds between crops. This sediment contains salt, and if disposed of outside of inland shrimp ponds, leaching of spoil piles by rainfall could lead to soil and water salinization (Boyd et al. 1994). Pond bottoms should be dried between crops, and sediment used to reshape the insides of embankments. When sediment must be removed from ponds, it should be stored in a basin where rainwater contacting it can be retained without overflow.

(5) A vegetative barrier should be provided around inland shrimp farms. The continued health of this vegetation would be an indication that salt intrusion is not occurring into the area around the farm. Piezometer tubes should be installed around inland shrimp farms and salinity of ground water measured on a regular schedule to assure that ground water salinization is not occurring. Soil salinity in areas surrounding inland shrimp farms also should be monitored. If the monitoring program suggests that salinization is occurring, practices would need to be improved to prevent it.

(6) Soils in the bottoms of abandoned ponds and surrounding area could be treated with calcium sulfate (gypsum) for reclamation. Gypsum treatment is a common practice for reclaiming saline soils.
Inland shrimp farming has several advantages:

- Allows diversification of land use for food production.
- Shrimp farming can be done outside the coastal zone where possibilities for negative environmental impacts are less.
- Disease problems in shrimp culture can be greatly reduced.
- Inland shrimp farming tends to be more intensive than coastal shrimp farming, so there is more efficient use of land and water resources.
- Logistics often are simpler because transport of supplies and products can be by truck instead of boat as is sometimes the case in traditional shrimp farming.
- The water supply is not shared and there can be better control over water use.

The disadvantage of inland shrimp farming is related almost entirely to the possibility of salinization. However, use of the practices suggested above should allow inland shrimp farms to operate in a responsible manner in freshwater areas with non-saline soils.
Table 1. Typical concentration ranges of water quality variables in salty ground water in west-central Alabama.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7-8 standard units</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>1,500-6,000 mg/L</td>
</tr>
<tr>
<td>Chloride</td>
<td>500-3,000 mg/L</td>
</tr>
<tr>
<td>Sodium</td>
<td>200-1,500 mg/L</td>
</tr>
<tr>
<td>Calcium</td>
<td>50-185 mg/L</td>
</tr>
<tr>
<td>Magnesium</td>
<td>10-40 mg/L</td>
</tr>
<tr>
<td>Potassium</td>
<td>5-15 mg/L</td>
</tr>
<tr>
<td>Sulfate</td>
<td>5-20 mg/L</td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>85-300 mg/L</td>
</tr>
</tbody>
</table>
Table 2. Comparisons of proportions of individual ions in salty ground water in Alabama and seawater.

<table>
<thead>
<tr>
<th>Ion</th>
<th>Milliequivalents (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Salty ground water in Alabama</td>
</tr>
<tr>
<td>Cl</td>
<td>38.5</td>
</tr>
<tr>
<td>Na</td>
<td>34</td>
</tr>
<tr>
<td>Ca</td>
<td>12</td>
</tr>
<tr>
<td>HCO₃</td>
<td>10.5</td>
</tr>
<tr>
<td>Mg</td>
<td>2</td>
</tr>
<tr>
<td>K</td>
<td>2</td>
</tr>
<tr>
<td>SO₄</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 3. General standards for total dissolved solids (TDS) and sodium adsorption ratio (SAR) in irrigation water.

<table>
<thead>
<tr>
<th>Salt tolerance of plants</th>
<th>TDS (mg/L)</th>
<th>SAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>All species, no detrimental effects</td>
<td>500</td>
<td>2-7</td>
</tr>
<tr>
<td>Sensitive species</td>
<td>500-1,000</td>
<td>8-17</td>
</tr>
<tr>
<td>Adverse effects on many common species</td>
<td>1,000-2,000</td>
<td>18-45</td>
</tr>
<tr>
<td>Use on tolerant species on permeable soils only</td>
<td>2,000-5,000</td>
<td>46-100</td>
</tr>
</tbody>
</table>
Literature Cited


Environmental Codes of Practice in Aquaculture

Claude E. Boyd
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama 36849

I am pleased about being asked to write a regular column for the new GAA magazine, and I hope to provide some useful information on aquacultural production in each issue. In this respect, environmental issues are very important to the future of aquaculture, and GAA was formed largely in response to criticisms of negative environment impacts from shrimp farming and other types of aquaculture. Thus, it seems appropriate for the first column to be about aquaculture and the environment.

Aquaculture is important to world food production. The harvest of fish and other aquatic organisms from natural waters apparently has reached its upper limit, but the demand for fishery products is still growing. The difference between catch fisheries production and the demand must be supplied by aquaculture, or there will be a shortage of fisheries products and a sharp rise in their price. Aquaculture has responded to this challenge, and it has increased world production of many species and represents about 20% of world fisheries production. However, the aquaculture industry’s image and future may be greatly diminished unless it deals effectively with environmental issues and concerns that have recently arisen.

The aquaculture industry should formulate an environmental agenda with the following objectives:

- Assess production systems to identify the major environmental impacts,
- Develop and implement better environmental management procedures,
- Foster public relations programs to explain the methods of aquaculture, the importance of aquaculture to society, and aquaculture’s dedication to the environment,
- Become more active in the political arena—the environmentalists are very involved politically,
- Get involved with environmental management agencies in order to influence the nature of future regulations – the environmentalists certainly are,
- Provide better environmental education for producers.

I have limited knowledge and experience in public relations, political lobbying, managing associations, or extension programs, so I will limit my discussion to technical issues.

The negative impacts of aquaculture, and especially those of shrimp farming, have been outlined many times in the past. The most important concerns are mangrove and other wetland alteration by aquaculture projects, water pollution, wasteful use of fish meal, uncontrolled use of antibiotics, drugs, and other chemicals, excessive water use, salinization of freshwater, changes in land use patterns, introduction of exotic species, and social conflicts. These negative impacts usually result from poor planning or bad management, and they are not routine consequences of aquaculture. Nevertheless, these bad examples have tarnished the image to the entire industry and threaten to cause even more damage. A positive and proactive approach is the logical means of countering the bad publicity and protecting the image of aquaculture.
Better management practices should be adopted to reduce the possible adverse impacts of aquaculture and to demonstrate the industry's commitment to environmental stewardship. The GAA publication, "Codes of Practice for Responsible Shrimp Farming" provides a practical approach to improving environmental management in aquaculture. These codes provide techniques known as best management practices (BMPs) for use in shrimp farming. BMPs are considered the best practical means of reducing environmental impacts to those compatible with water quality or resource management goals. BMPs form the basis for environmental management in many types of agriculture in the United States and other nations. The GAA intends for their general publication on codes of practice to serve as a guideline for others to use in developing country-specific or farm-specific codes of practice for shrimp farming. These more specific codes of practices also should contain greater detail about how to implement BMPs. The adoption of the better practices will be voluntary at first, but a self-evaluation program will be initiated to demonstrate progress in adoption and implementation of better practices.

Several countries already are developing codes of practices and the GAA effort on better practices is serving as a model for these country-level codes of practice. Additional information on good management practices for shrimp aquaculture were presented by C. E. Boyd and Maria Haws at the Symposio 5 Centroamericano de Aquacultura held 18-20 August 1999 in San Pedro Sula Honduras. We started with the GAA model and provided greater details about good management practices specifically for Latin American conditions and shrimp culture methods. A document containing the good management practices was published in the symposium proceedings. This document and the GAA "Codes of Practice for Responsible Shrimp Farming" provide most of the information necessary to make country-specific codes of practice for voluntary adoption by shrimp farmers. By early next year, several countries probably will have adopted codes of practice for shrimp farming. I suspect that other types of aquaculture also will rapidly follow the lead of the shrimp industry and prepare code of practices.

The benefits of adopting better practices include the following:

- Reduce negative environmental impacts,
- Provide a means to interact positively with environmental agencies,
- Improve the efficiency of aquaculture,
- Extend better production methodology to farmers,
- Increase prospects for sustainability,
- Serve as part of future environmental regulations,
- Provide a marketing advantage because some consumers want an environmentally friendly product.

The environmental community will probably criticize industry codes of practice because they originated within the aquaculture industry and are voluntary. The criticisms should not deter us, for codes of practice provide the industry a proactive means of dealing with environmental issues that can influence governmental and public perception in a positive way. In the future, these practices could possibly be certified by third party inspectors, become the centerpiece of a certification program, or even take the place of traditional environmental regulations. I believe that the GAA program to encourage preparation and adoption of codes of practice is a very positive and useful approach. Hopefully, it will abate much of the negative attitude that exists in some circles regarding shrimp and fish farming.
Management of Shrimp Ponds to Reduce 
The Eutrophication Potential 
Of Effluents

Claude E. Boyd
Department of Fisheries and Allied Aquacultures
Auburn University, Alabama

There is concern about the effects of nutrients in aquaculture pond effluents on natural waters. This concern arises because nitrogen and phosphorus are contained in pond effluents, and these two nutrients can cause eutrophication of natural waters. In eutrophication, nutrient inputs to water bodies increase nutrient concentrations and cause dense phytoplankton blooms. Phytoplankton blooms increase natural productivity of waters, but too much productivity can lead to an excessive demand for dissolved oxygen and cause chronically low dissolved oxygen concentrations. Low dissolved oxygen can result in the loss of ecologically sensitive fauna and lessen biodiversity. Dense phytoplankton blooms also diminish the natural beauty of water bodies, they sometimes cause taste and odor problems in drinking water and off-flavor in aquatic organisms, some species of phytoplankton may be toxic to other forms of aquatic life, and dead or moribund scums of algae may drift to the shore and cause bad odors in the surroundings. Thus, one objective of most water pollution abatement programs is to limit nitrogen and phosphorus concentrations in effluents to minimize the danger of eutrophication in natural waters. Several management practices contained in the Global Aquaculture Alliance “Codes of Practice for Responsible Shrimp Farming” were selected because they will reduce nutrient inputs to natural waters in the vicinity of shrimp farms.

Nutrients in aquaculture pond effluents mainly come from fertilizers and feeds applied to ponds to stimulate the production of the culture species. Organic fertilizers, e.g., animal manures or other agricultural byproducts, are sometimes applied to ponds. These materials contain nitrogen and phosphorus that are released into the water as the organic fertilizer is decomposed by microbes. Chemical fertilizers, e.g. urea, triple superphosphate, diammonium phosphate, mixed fertilizers, etc., dissolve in water to release nitrogen and phosphorus. Feeds also contain nitrogen and phosphorus. Some of the nitrogen and phosphorus in feeds enter the water when unconsumed feed and feces decompose, and more is added when ammonia is excreted by the culture species. Organic nitrogen and phosphorus are both present in the water as a component of living plankton and soluble organic matter. Inorganic nitrogen is dissolved in the water primarily as ammonia nitrogen and nitrate. Inorganic phosphorus in water may be contained on suspended mineral (soil) particles or in soluble phosphate. Phytoplankton and other plants use ammonia nitrogen, nitrate, and soluble inorganic phosphorus for growth. However, nitrogen and phosphorus contained in dead particulate organic matter or soluble organic matter in the water may be transformed by microbial decomposition to ammonia nitrogen, nitrate, or phosphate. Because organic nitrogen and phosphorus can be transformed to soluble inorganic form by microbes, the eutrophication potential of pond effluents increases as the total concentration of
nitrogen and phosphorus increases. In ponds with heavy plankton blooms, most of the nitrogen and phosphorus may be contained in plankton and detritus rather than in soluble form. Effluents from a pond with low concentrations of ammonia nitrogen, nitrate, and phosphate, but with high plankton abundance, may still have as great a pollution potential as an effluent with high concentrations of ammonia, nitrogen, nitrate, and phosphate. This results because the organic matter (plankton, detritus, and soluble organic matter) that enters natural waters via pond effluent will decompose and release ammonia nitrogen, nitrate, and phosphate.

Many shrimp farmers may not think that pond effluents contain much nitrogen and phosphorus because they do not use organic fertilizers, they use chemical fertilizers sparingly and only near the beginning of the culture period, and the feed conversion ratio is good. Some shrimp farmers obtain a feed conversion ratio as low as 1.5. This means that 1.5 kg of shrimp feed results in the production of 1 kg of shrimp. The conclusion may be that only 0.5 kg of waste is generated in the production of 1 kg of shrimp. Even if the feed conversion ratio is as high as 2, the farmer might think that only 1 kg of waste is released in the production of 1 kg of shrimp.

The relationship among feed input, shrimp production, and waste generation will be analyzed more carefully. The feed used in aquaculture normally is a dry pellet. Shrimp feed contains about 90% dry matter and 10% water. Shrimp, on the other hand, contain about 25% dry matter and 75% water. Thus, in the production of 1 kg of shrimp with 1.5 kg of feed (feed conversion ratio of 1.5), 1.35 kg dry matter in feed yields 0.25 kg dry matter in shrimp. From an ecological point of view, 1.35 kg (1.5 kg feed × 0.9) dry nutritive substance has to be used to produce 0.25 kg (1 kg shrimp × 0.25) of dry matter in shrimp. Thus, the dry matter conversion ratio is only 5.4 (1.35 kg dry feed ÷ 0.25 kg dry shrimp). The ratio of shrimp to wastes of 1:0.5 based on the usual method for estimating feed conversion ratio is an apparent ratio, but the true ratio based on dry matter is 1:4.4.

Suppose that a shrimp feed contains 35% crude protein and 1.2% phosphorus. Crude protein is estimated as percentage nitrogen multiplied by 6.25, so this feed has 5.6% N, and 1.5 kg of this feed contains 84 g nitrogen (1,500 g feed × 0.056) and 18 g phosphorus (1,500 g feed × 0.012). The 1 kg of shrimp produced by the feed will contain 0.25 kg dry matter, and shrimp dry matter is about 11% nitrogen and 1.25% phosphorus. It follows that 27.5 g nitrogen (250 g dry shrimp × 0.11) and 3 g phosphorus (250 g dry shrimp × 0.0125) are contained in the shrimp. The differences between the amounts of nitrogen and phosphorus in the feed and in the harvested shrimp represent the amount of nitrogen and phosphorus entering the pond water. In this example, each kilogram of live shrimp would result in 56.5 g nitrogen and 15 g of phosphorus in wastes. On a per ton basis, this would be 56.5 kg nitrogen and 15 kg phosphorus.

In a pond without water exchange, much of the nitrogen and phosphorus will be removed from the water. Nitrogen will be lost to the air by volatilization of ammonia and by microbial denitrification. Some nitrogen will be contained in organic matter deposited in the pond bottom, and phosphorus will be absorbed by sediment. Recent studies suggested that about 50% of the nitrogen and 65% of the phosphorus added in feed could be removed from the water of a pond without water exchange through physical, chemical, and biological processes. Considering that about 25 to 35% of the nitrogen and 15 to 25% of phosphorus added in feed is recovered in shrimp at harvest, only 15 to 25% of the nitrogen and 10 to 20% of the phosphorus applied in feed would be lost in effluent at pond draining. Of course, with water exchange, there would be a greater loss of nitrogen and phosphorus in effluents, because more nitrogen and phosphorus would be flushed out of ponds before being removed by natural purification processes within the
pond. Even in a pond with zero water exchange, the loss of nitrogen and phosphorus at pond draining might be 12.6 to 21 kg nitrogen and 1.8 to 3.6 kg phosphorus where 1 ton of shrimp is produced at a feed conversion ratio of 1.5 (see example above). Thus, for different levels of production, the nitrogen and phosphorus outputs might be as follows:

<table>
<thead>
<tr>
<th>Production</th>
<th>N (kg/ha)</th>
<th>P (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>6.3 – 10.5</td>
<td>0.9 – 1.8</td>
</tr>
<tr>
<td>1,000</td>
<td>12.6 – 21</td>
<td>1.8 – 3.6</td>
</tr>
<tr>
<td>2,000</td>
<td>25.2 – 42</td>
<td>3.6 – 7.2</td>
</tr>
<tr>
<td>3,000</td>
<td>37.8 – 63</td>
<td>5.4 – 10.8</td>
</tr>
<tr>
<td>4,000</td>
<td>50.4 – 84</td>
<td>7.2 – 14.4</td>
</tr>
</tbody>
</table>

These are rather large amounts of nitrogen and phosphorus, and the effluents from aquaculture can be a threat to cause eutrophication of natural waters into which they are discharged. Several measures can be taken to avoid or minimize eutrophication as follows:

1) Minimize water exchange. By retaining water in ponds for a lower time, there is greater opportunity for removal of nitrogen and phosphorus by natural processes.

2) Use a high quality feed. A feed that is water stable can be eaten more completely by shrimp. Also, a high quality feed results in less feces and metabolic waste.

3) Use feeds with the lowest nitrogen and phosphorus concentrations that are compatible with good feed quality. This will minimize the amount of nitrogen and phosphorus in wastes.

4) Feed conservatively. Overfeeding results in wasted feed and increases the amount of waste. It is important for the shrimp to eat all of the feed put into ponds for both economic and environmental reasons.

5) When draining ponds, try to minimize the velocity of outflowing water so that sediment is not resuspended from pond bottoms. This practice will lower the amount of organic nitrogen and phosphorus in effluents by retaining organic particles within the pond.

6) Maintain good dissolved oxygen concentrations in ponds by not stocking and feeding too much so that the pond can assimilate most of the wastes. The assimilative capacities of ponds differ, and aerated ponds can assimilate much more waste than unaerated ponds. Good dissolved oxygen concentrations favor oxidation of ammonia to nitrate and nitrate can then be denitrified in the sediment.

7) Dry pond bottoms and lime acidic bottom soils between harvests to favor organic matter decomposition. This will reduce the accumulation of organic matter in bottom soils.
CATFISH FARMING

A. BMPS TO REDUCE EFFLUENT VOLUME

- New ponds should have watershed area to pond area ratio of 10:1 or less.

- Use terraces to divert excess runoff around ponds as illustrated in Figure 5. Note: sometimes an additional pond may be built to increase storage on the watershed.

- Maintain good vegetative cover on all parts of watersheds, and where feasible, replace short grass with evergreen trees.

- Harvest fish by seining and without partially or completely draining ponds unless it is necessary to renovate fish stocks or repair pond earthwork.

- Maintain at least 20 cm of storage capacity in ponds during summer and fall. The upper 20-cm length of overflow pipe should be painted a bright color to serve as a guide when adding well water to replace water loss.

- Do not flush well or stream water through ponds. This practice does not improve water quality in ponds.

B. BMPS TO MINIMIZE SUSPENDED SOLIDS THROUGH EROSION CONTROL

- Control erosion on watersheds by providing vegetative cover, eliminating gully erosion, and using terraces to route water from areas of high erosion potential.

- Restrict livestock from watersheds of ponds.
• Eliminate steep slopes on farm roads and cover these roads with gravel.

• Provide grass cover on sides of pond dams or embankments and grass or gravel on tops of dams or embankments.

• Do not leave ponds partially or completely empty in winter and spring, and immediately close drains in empty ponds.

• Efficient mechanical aerators should be installed so that water currents caused by these devices do not cause erosion of pond earthwork.

• Sediment should not be disposed of outside of ponds.

• Install structures to prevent drainpipe discharge from impacting and eroding earthwork.

• Construct ditches with adequate hydraulic cross section, and provide grass cover on sides of ditches.

• Provide check dams in ditches to reduce water velocity and allow sedimentation.

• Settling basins are an alternative method for improving the quality of final draining effluent from catfish ponds where space is available.

• Trees or shrubs could be used in critical areas to shelter ponds from excessive wind velocities and reduce wave erosion of embankments.

• Where possible, effluent from catfish ponds should be discharged into natural wetlands.

C. BMPS TO IMPROVE POND WATER AND EFFLUENT QUALITY
- Select high quality feeds that contain adequate, but not excessive, nitrogen and phosphorous.

- Store feed in well-ventilated, dry bins, or if bagged, in a well-ventilated, dry room. The feed should be used by the expiration date suggested by the manufacturer.

- Apply feed uniformly with a mechanical feeder.

- Do not apply more feed than fish will eat.

- Feeding rates should not exceed 30 kg/ha per day in un-aerated ponds. In ponds with 4 kW of aeration per hectare, feeding rates usually can be increased to 100 to 120 kg/ha per day.

- When uneaten feed accumulates in corners of ponds, it should be manually removed.

- Apply fertilizers only when necessary to promote phytoplankton blooms.

- Use chemical fertilizers and avoid use of animal manures.

- Avoid excessive fertilization by using moderate doses and relying on the Secchi disk visibility to determine if fertilization is needed.

- Apply agricultural limestone to ponds with total alkalinity below 20 mg/l.

- Store fertilizers under a roof in a dry place to prevent rain from washing them into surface waters.

- Apply adequate mechanical aeration to maintain dissolved oxygen concentrations above 4 mg/l.

- Do not have deep water intake structures in ponds.
• Install devices to prevent sediment resuspension by water currents entering drains. Such a device is illustrated in Figure 6.

• Restrict livestock from watersheds of ponds.

• Avoid discharge when harvesting fish, but if ponds must be drained completely, hold the final 20% to 25% of pond volume for 2 or 3 days and then discharge it slowly.

D. BMPS FOR USE OF THERAPEUTIC AGENTS AND OTHER CHEMICALS

• Store therapeutants so that they cannot be accidentally spilled to enter the environment.

• Use good water quality management procedures to prevent unnecessary stress to fish.

• Obtain a definite diagnosis for diseases and a recommendation for disease treatment before applying therapeutic agents.

• Follow instructions on labels of therapeutic agents for dose application method, safety precautions, etc.

• Store water quality enhancers under a roof where rainfall will not wash them into surface waters.

• Copper sulfate applications in milligrams per liter should not exceed 1% of total alkalinity also measured in milligrams per liter or a maximum dose of 1.0 mg/l. Pond water should not be released for 72 hours after application of copper sulfate.

• Sodium chloride applications should not exceed 100 mg/l.

• Lime (calcium oxide or hydroxide) applications should not exceed 100 mg/l.
• Agricultural limestone and gypsum (calcium sulfate) applications should not exceed 5,000 kg/ha and 2,000 kg/ha, respectively.

• Calcium hypochlorite or other chlorine compounds should not be applied to catfish ponds.

E. BMPS FOR NEW PONDS OR FARMS

• New ponds should be constructed according to National Resource Conservation Service (NRCS) standards. Riparian vegetation of trees or shrubs should be preserved or established to provide a vegetative buffer zone along streams.

• New ponds should not be located on watersheds that are already impacted by subdivisions, industrial activities, or row-crops.

• Design of new ponds should conform to NCRS standards and be compatible with implementation of BMPs outlined above.
The reference for the following 9 BMP's is: Claude E. Boyd. 1999. Codes of Practice for Responsible Shrimp Farming, Global Aquaculture Alliance, St. Louis, MO, 42 pp.
Mangroves
Code of Practice

Purpose

The Code is designed to foster greater environmental awareness within the shrimp farming industry to assure continued protection of mangrove forests from potentially adverse impacts of coastal aquaculture. Recognizing the multitude of different conditions impacting mangroves in different countries and regional locations, this Code is to be interpreted as a flexible set of criteria to be used to assist any and all interested parties in formulating codes, regulations, and principles for protecting mangrove forests.

The Code helps to achieve several of the "Guiding Principles of Responsible Aquaculture" by encouraging the following:
- The shrimp aquaculture industry will promote responsible and sustainable development and management practices ensuring the preservation of mangroves and the sustainability of shrimp aquaculture.
- Shrimp aquaculture industries will promote alternative development programs aimed at protecting mangroves while benefiting local communities in mangrove areas.
- Producers shall adhere to national and local regulations applicable to mangroves and to shrimp farming.

Management Practices

It shall be the objective of all adherents to this Code to not harm mangrove ecosystems, and whenever possible, to preserve and even enhance the biodiversity of these ecosystems. The following practices will ensure the protection of mangrove ecosystems:

1. New shrimp farms should not be developed within mangrove ecosystems.
2. Realizing that some mangrove must be removed for canals when new shrimp farms are sited behind mangroves, a reforestation commitment of no net loss of mangroves shall be initiated.
3. Farms already in operation will continue ongoing environmental assessments to recognize and mitigate any possible negative impacts on mangrove ecosystems.
4. All non-organic and solid waste materials should be disposed of in an environmentally responsible manner, and waste water and sediments shall be discharged in manners not detrimental to mangroves.
5. The shrimp aquaculture industry pledges to work in concert with governments to develop sound regulations to enhance the conservation of mangroves including regulations regarding restoration of mangrove areas when old farms located in former mangroves are decommissioned.
6. The shrimp aquaculture industry will promote measures to ensure the continued livelihood of local communities that depend upon mangrove resources.
Site Evaluation
Code of Practice

Purpose

The Code is designed to promote site evaluation as a means to ensure that new shrimp-farming projects are harmoniously integrated into local environmental and social settings. Site evaluation can identify limitations that influence the suitability of a site for farm construction and operation, reveal the possibilities of negative environmental and social impacts, and allow estimates of technical and financial requirements for mitigation of unfavorable conditions. Recognizing that enormous variation in environmental and social conditions exists from site to site, this Code presents adaptable guidelines to assist any and all parties interested in making site evaluations for shrimp farms.

The Code helps to achieve several of the "Guiding Principles of Responsible Aquaculture" and promotes the following:
Use of site evaluation to avoid siting farms where significant technical, environmental, and social problems are likely.
Prevention of significant negative environmental and social impacts through use of site evaluation findings in planning mitigation methods. A proper site evaluation will provide most of the information required to produce an environmental impact assessment (EIA).

Management Practices

All adherents to the Code shall thoroughly evaluate potential sites for shrimp farms to assure that local ecological and social conditions are protected and even enhanced. The following practices will ensure that appropriate sites are selected for shrimp farms:

1. Evaluate hydrologic features including tidal patterns, freshwater influences and flood levels, offshore currents, and existing water uses.
2. Determine water quality characteristics of coastal waters in the vicinity of the site.
3. Ascertaining the suitability of topography, soil, and ecosystem for siting and construction of ponds.
4. Make sure that previous site use has not resulted in contamination of water or soils.
5. Acquire long-term climatological records to determine the likelihood of drastic events such as flood, droughts, or severe storms that could negatively impact the project.
6. Survey the existing flora and fauna with particular concern for effects of the project on ecologically sensitive areas such as migration routes and nesting grounds or protected areas such as parks and refuges.
7. Document regulatory requirements for the site, and consider alternatives for compliance with regulations.
8. Consider alternatives to mitigate potential negative environmental impacts and to alleviate conditions not conducive to shrimp farm construction and operations.
9. Survey local communities to determine demography, resource use patterns, availability of work force, and compatibility with project goals.
10. Consider alternatives to mitigate potential negative social impacts.
11. Determine if any areas within the site are of significant archeological or historical importance and consider methods for their preservation.
Design and Construction
Code of Practice

Purpose

The Code is intended to promote environmental protection through proper shrimp farm design and good construction methods. Good site selection and incorporation of mitigative features in the farm design are the best ways to avoid problems related to flood levels, storms, erosion, seepage, water intake and discharge points, and encroachment on mangroves and wetlands. Planning of clearing and earth moving activities can prevent or greatly limit ecological damage during farm construction. Recognizing that a site-specific approach to design and construction is necessary, the Code provides basic design and construction criteria for environmentally-responsible shrimp farms.

The Code helps to achieve several of the "Guiding Principles of Responsible Aquaculture" and it promotes:
• Use of design features and good construction methods to overcome site limitations and to prevent or mitigate potential negative environmental and social impacts.
• Adoption of successfully proven and accepted design and construction procedures.

Management Practices

Adherents to the Code shall strive to design and construct shrimp farms in a responsible manner to protect the environment and coastal communities. The following practices can afford this protection:

1. Farms should not be built on ecologically sensitive mangrove areas or other wetlands and in places where it is impractical to correct site-related problems such as highly-acidic, organic, or permeable soils.
2. Comply with all environmental impact assessment (EIA) procedures before initiating construction and abide by EIA restriction during construction.
3. Embankments should be designed to prevent erosion, and where practical, methods for reducing seepage through pond bottoms should be included.
4. Ponds should have separate intake and outlet structures to permit control of filling and draining.
5. Inlet and discharge canals should be separate so that water supply and effluent are not mixed.
6. Storms and flood levels should be considered in earthwork design.
7. Infrastructure and access roads should not necessarily alter natural water flows, cause salinization of adjacent land or water, or impound flood water.
8. Canals should be designed to prevent excessive water velocity and scouring.
9. Water intake point(s) should provide a sufficient volume of high quality water available.
10. Pump intakes should be screened, vegetative buffers provided around pump stations, and containments installed to prevent fuel spills.
11. Where possible, vegetative buffer zones, riparian vegetation, and habitat corridors should be maintained, and vegetative cover provided on exposed earthwork.
12. Sediment traps and basins should be incorporated in the design where suspended solid concentrations are expected to be high in effluents.
13. Outfalls should be designed to prevent erosion and avoid discharge of effluents into stagnant water.
14. Disturb as little area as possible during construction.
15. Erosion should be controlled during construction.
16. Cut and fill construction techniques are preferable, and earthwork should be compacted.
17. Degraded areas such as unused soil piles, barrow pits, and uncontrolled refuse dumps should not be created.
Feeds and Feed Use
Code of Practice

Purpose

The Code is designed to improve the efficiency of supplemental feeds and feed management in shrimp farming and to minimize the waste load in ponds. Feeding is a standard practice in shrimp production, because it permits higher production than can be achieved from natural pond productivity. Recognizing that feed is expensive, it should be used wisely to reduce production costs. However, using good feeds and feeding practices also are important steps towards reducing waste loads in pond effluents. Guidelines presented in this Code can be used by feed manufacturers and shrimp producers to improve feeds and feeding practices.

The Code helps to achieve several of the "Guiding Principles for Responsible Aquaculture" and promotes awareness of two major issues:

- Shrimp feed should be made from high quality ingredients by good manufacturing techniques and stored properly.
- Feed should be used conservatively to ensure efficient conversion to shrimp flesh and minimize waste and expense.

Management Practices

Those supporting the Code shall strive to improve feed quality and feeding with the goal of optimizing the conversion of feed to shrimp and reducing the amount of waste entering ponds. This goal can be achieved through the following practices:

1. Feed ingredients should not contain excessive pesticides, chemical contaminants, microbial toxins, or other adulterating substances.
2. Pellet binders and suitable manufacturing techniques should be used to provide a water-stable pellet.
3. Manufacturing processes should provide adequate vitamin and nutrient concentrations in feed.
4. Feed should be purchased fresh and not stored for more than a few months.
5. Feed should be stored in cool, dry areas to prevent mold and other contamination. Do not use contaminated feed.
6. Feed management practices should be implemented to assure the shrimp consume the maximum amount of supplemental feed and not leave excess amounts decomposing in the pond contributing to poor water quality.
7. Feeding rates should be determined from standard feed curves and adjusted for shrimp biomass, appetite, and pond conditions. Feed trays can be used to monitor feeding and prevent under or overfeeding.
8. The most efficient supplemental feeding can be obtained by distributing the supplemental feed several times through the day and night. Supplemental feed should be widely distributed throughout the pond, either by manual or mechanical dispersement or use of feed trays.
9. Appropriate feed curves commensurate with shrimp biomass and appetite should be utilized on a site specific, species specific basis and with the recommendation of shrimp feed specialists.
10. Cut fish should not be used as shrimp feed.
11. Research to reduce the level of fish and other marine meals in shrimp feed should be encouraged.
12. Pond managers should keep careful records of daily feed application rates so that feed conversion ratio (FCR) can be assessed. Reductions in FCR through careful feeding will improve production efficiency and reduce waste loads.
**Shrimp Health Management**  
**Code of Practice**

**Purpose**

The purpose of this Code is to promote shrimp health management as a holistic activity in which the focus is on disease prevention instead of disease treatment. Authorities on shrimp health management recognize that stress reduction through better handling, reasonable stocking densities, good nutrition, and optimal environmental conditions in ponds can prevent most infectious and non-infectious diseases. Treatment should be undertaken only when a specific disease has been diagnosed. Also, effective measures must be taken to minimize the spread of diseases between farm stocks and from farm stocks to natural stocks. This Code provides adaptable guidelines that should provide effective management of shrimp health.

The Code helps to achieve several of the "Guiding Principles for Responsible Aquaculture" and advances three basic premises as follows:

- Many disease problems can be prevented through stress management.
- Disease treatments should be made only after a clear diagnosis of the causative factors.
- Spread of disease should be minimized by reasonable regulation of importations of broodstock and larvae and by isolation and disinfection of affected ponds.

**Management Practices**

Adherents to the Code shall adopt the principles of good shrimp health management to reduce the incidence of diseases and to protect natural fisheries. The following practices should be used to achieve these goals:

1. Shrimp farming associations should work with governments to formulate and enforce regulations to include quarantine procedures for importations and exportations of broodstock, nauplii, and postlarvae.
2. Healthy postlarvae should be used for stocking ponds. Survival of postlarvae should then be optimized by preparing the pond to ensure adequate availability of natural food, by properly acclimating postlarvae before stocking, and by avoiding stress by using appropriate handling and transportation techniques.
3. Good water quality and bottom soil management should be used. Stocking rates should not be excessive and high quality feed and good feeding practices should be used.
4. Strong chemical treatments that can stress shrimp should not be employed.
5. Shrimp should be routinely monitored for disease, and a definite diagnosis obtained for any observed shrimp health problem.
6. For non-infectious diseases related to pond conditions, carry out the best option for disease treatment or for correcting pond conditions.
7. For mild infectious diseases with potential to spread within a farm, quarantine the pond and carry out the best option for disease treatment.
8. For serious infectious diseases that may spread widely, isolate the pond, net harvest remaining shrimp, and disinfect the pond without discharging any water.
9. Dispose of dead, diseased shrimp in a sanitary manner that will discourage the spread of disease.
10. When disease occurs in a pond, avoid transfer of shrimp, equipment, or water to other ponds.
11. Drug, antibiotic, and other chemical treatments should be done in accordance with recommended practices and comply with all national and international regulations.
12. The shrimp industry should work with governments to develop certification programs for disease diagnosis laboratories and pathologists.
13. Each country or geographical area should develop its own pond dry-out, farm situation, and biosecurity strategy.
Therapeutic Agents and Other Chemicals
Code of Practice

Purpose

The Code is intended to foster greater awareness within the shrimp industry of the proper use of certain potentially toxic or bioaccumulative compounds in shrimp production. Careful control over the use of therapeutants and other chemicals in production will assure that farm-reared shrimp are less likely than wild-caught shrimp to contain residues of pollutants or contaminants. Environmental benefits also will accrue from responsible chemical use. This Code contains flexible criteria that will allow prudent use of certain drugs, antibiotics, and other chemicals in production without endangering food safety or threatening the environment.

The Code helps to achieve several of the "Guiding Principles for Responsible Aquaculture" and promotes three basic objectives:
• The shrimp farming industry in each nation should work with governmental and international agencies to develop lists of approved feed additives, pesticides, drugs, antibiotics, and other chemicals and to specify approved uses for each compound.
• Shrimp farmers who adhere to the Code will rely on good management to prevent water quality and disease problems and chemicals should be used only when necessary.
• Chemical use in ponds should only be done after an accurate diagnosis of the situation and treatments should conform to acceptable protocol.

Management Practices

Adherents to the Code should strive to produce a wholesome product for consumers through responsible use of drugs, antibiotics, and other chemicals. Use of the following practices will assure this goal:

1. Shrimp health management at hatcheries and farms should focus on disease prevention through good nutrition, sound pond management, and overall stress reduction rather than disease treatment.
2. Where countries have approved lists of chemicals and chemical uses, only approved chemicals should be used in ponds and only for the use approved. Where such lists are not available, the shrimp industry and individual producers should work with governments to prepare such lists.
3. Shrimp farmers should follow information on product labels regarding dosage, withdrawal period, proper use, storage, disposal, and other constraints on the use of a chemical including environmental and human safety precautions.
4. When practical, antibiograms should be used to select the best antibiotic for use in a particular case, and the minimum inhibitory concentration (MIC) should be used.
5. When potentially toxic or bioaccumulative chemicals are used in hatcheries and ponds, waters should not be discharged until compounds have naturally decomposed to non-toxic form.
6. Careful records should be maintained regarding use of chemicals in ponds as suggested by the Hazard Analysis and Critical Control Point (HACCP) method.
7. Store therapeutants in a cool place and in a secure manner where they will be inaccessible to unauthorized personnel, children, and animals, and dispose of unused compounds by methods that prevent environmental contamination.
8. The shrimp-farming industry should work with governments to develop regulations for labelling the content and percentage of active ingredients in all chemicals including liming materials and fertilizers.
General Pond Operations
Code of Practice

Purpose

The purpose of the Code is to prevent eutrophication, salinization, reductions in biodiversity, and other environmental perturbations by using responsible pond management practices. Experience demonstrates that it is possible to optimize efficiency of shrimp production and be good stewards of the environment at the same time. This Code contains broad guidelines on pond management that can be used to standardize and improve operations for sustainable shrimp farming.

The Code helps to achieve several of the "Guiding Principles of Responsible Aquaculture" and asserts that:

• Responsible pond operations can protect or even improve environmental quality and enhance sustainability.
• Both profitability and environmental sustainability can be achieved at the same time.

Management Practices

It shall be the objective of adherents to the Code to use pond operation methods that are environmentally responsible while allowing profitable shrimp production. The following practices should be used to promote profitable, yet sustainable shrimp farming:

1. Farms should be encouraged to use hatchery larvae rather than wild-caught larvae.
2. Where wild caught postlarvae are used, a screening method should be used to separate by-catch and return it to the estuary.
3. Native species should be cultured whenever feasible; however, if non-native species are used, all applicable regulations should be obeyed regarding importation and inspection.
4. Only healthy postlarvae should be used.
5. Good water quality should be maintained by using stocking and feeding rates that do not exceed the assimilative capacity of the culture system and by using high quality feeds and good feeding practices.
6. Water exchange should be reduced as much as possible.
7. Fertilizers, liming materials, and all other chemicals should be used in a responsible manner and only as needed.
8. Good shrimp health management should be used.
9. Aerators should be positioned and operated to minimize erosion and creation of sediment mounds in pond bottoms.
10. Freshwater from wells should not be used in ponds to dilute salinity.
11. Effluents, sediment, and other wastes should be disposed responsibly.
12. Bottom soils should be evaluated periodically between crops and necessary treatments applied to remediate deterioration in soil conditions that occur during culture.
13. Water inlets and outlets to ponds should be screened to prevent entrance of competitors and release of culture species.
14. Predator control methods that do not require destruction of ecologically important species should be used.
**Effluents and Solid Wastes**

**Code of Practice**

**Purpose**

The Code is designed to increase the awareness of proper waste management within the shrimp farming industry and enhance protection of coastal land and water resources. Recognizing that a number of production activities produce wastes, shrimp producers and processors should formulate systems of waste management for protecting lands and waters in the vicinity of their activities. This Code provides a set of guidelines that can form the framework for responsible waste management that will benefit all coastal resource users including shrimp farming.

The Code helps to achieve several of the "Guiding Principles of Responsible Aquaculture" and specifically recognizes that:

- The shrimp aquaculture industry should promote responsible methods of effluent and solid waste management to protect environment quality and public health.
- Effluent and solid waste management is a continuous activity, and each member farm should strive to improve waste management procedures and reduce amounts of waste released to the environment.
- In countries where quality and volumes of effluent are not regulated by permits from governmental agencies, adherence to the Code is an alternative way of protecting the environment.

**Management Practices**

Adherents to the Code should continuously strive to improve waste management. Particular attention should be given to the following practices:

1. Canals and embankments should be maintained to reduce erosion of above water portions.
2. Minimize water exchange to the extent feasible.
3. Use efficient fertilization and feeding practices to promote natural primary productivity while minimizing nutrient inputs.
4. Store and use fuels, feeds, and other products in a responsible manner to avoid accidental spills that could contaminate water. An emergency plan should be made for containing accidental spills.
5. Ponds should be drained in a manner to minimize resuspension of sediment and prevent excessive water velocities in canals and at effluent outfalls.
6. Where feasible, pond effluents should be discharged through a settling basin or mangrove forest.
7. Design outfalls so that no significant impact of effluents on natural waters occurs beyond the mixing zone.
8. Shrimp pond effluents should not be discharged into freshwater areas or onto agricultural land.
9. Sediment from ponds, canals, or settling basins should be put back into areas from which it was eroded, used as earthfill, or disposed in some other environmentally-responsible way.
10. Sanitary facilities for disposal of human wastes should be provided at hatcheries, farms, and processing plants.
11. Garbage and other farm wastes should be burned, put in a land fill, or disposed of by other acceptable methods.
12. Shrimp farms, hatcheries, and processing plants should comply with existing governmental regulations related to effluents and other wastes.
13. Processing plants, and where necessary, shrimp hatcheries should install effluent treatment systems of appropriate type and capacity.
14. Managers should routinely evaluate waste management procedures and continually attempt to improve them.
Community and Employee Relations
Code of Practice

Purpose

The purpose of the Code is to foster good relationships among shrimp farm officials, workers, and local communities. Aquaculture can be a powerful stimulus to improving the standard of living in coastal communities by providing jobs and services, contributing to the tax base, improving the physical and social infrastructure, and creating a larger and more diverse and dynamic economy. Recognizing that public relations and employee welfare are complex issues, this Code is intended to provide some general guidelines for enhancing the prospects for harmonious interactions with workers and the local community. Conditions, expectations, and mores are highly variable from place to place, so considerable flexibility will be necessary in applying these guidelines.

The Code helps to achieve several of the "Guiding Principles for Responsible Aquaculture" and specifically promotes the following:

- Shrimp farms should employ local workers to the extent possible, provide good working conditions, and wages commensurate with local pay scales.
- Shrimp farms should abide by local laws and regulations regarding the rights of local people to use coastal resources.
- Shrimp farms should be supportive of local communities and engage in community activities.

Management Practices

Shrimp farms range in size from small, family operations to large corporate enterprises. Most of the guidelines given below apply primarily to large shrimp farms:

1. Shrimp farm owners should have clear title or right to their property or other current, legal land concession agreements.
2. Shrimp farm management should schedule meetings with local communities to exchange information. This is particularly important in the planning stages for new farms or expansions.
3. Shrimp farm management should attempt to accommodate traditional uses of coastal resources through a cooperative attitude towards established local interests and environmental stewardship.
4. Shrimp farm management should contribute to community efforts to improve local environmental conditions, public health and safety, and education.
5. Local workers should be employed to the extent possible, and all practical means made to prevent conflicts between local people and workers from outside.
6. Workers should be fairly compensated with respect to local wage scales.
7. Healthy and safe living and working conditions should be provided. Procedures should be established for dealing with illness and accidents, and employers must be responsible for making sure that workers are fully aware of these procedures.
8. Shrimp farm management should have clearly-defined and posted security policies.
9. Employees should have a clear understanding of their duties and of company expectations regarding their performance.