SRAC Publication No. 470

Southern Regional Aquaculture Center

February 1999

Characterization and Management of Effluents from Aquaculture Ponds in the Southeastern United States

Nearly all commercial aquaculture in the southeastern United States is conducted in earthen ponds. Good production from ponds is encouraged by using manufactured feeds or increasing the availability of natural foods by adding fertilizers. Less than 30% of the nitrogen and phosphorus added in feed or fertilizer is recovered at harvest. The remainder of the nutrient load is left in the pond, and may be discharged when it rains or when ponds are drained between crops.

Aquaculture effluents are regulated under the National Pollutant Discharge Elimination System (NPDES) as part of the Federal Water Pollution Control Act of 1972 and its subsequent amendments. The Act designates the U. S. Environmental Protection Agency to administer and enforce the NPDES, although states are encouraged to develop and operate their own programs in lieu of the federal program. Most states originally showed little interest in regulating discharges from aquaculture facilities. However, the remarkable growth of the aquaculture industry in the 1980s caused more and more states to consider developing regulatory statutes.

The Southern Regional Aquaculture Center supported a regional research project, "Characterization of Finfish and Shellfish Aquacultural Effluents" to investigate effluent quality and treatment alternatives. This publication, compiled by Craig S. Tucker, is based on research conducted at University of Florida, Auburn University, Clemson University, Louisiana State University, Mississippi State University, North Carolina State University, Texas A&M University, University of Arkansas at Pine Bluff, University of Georgia, and Waddell Mariculture Center.

In 1990, the Board of Directors of the Southern Regional Aquaculture Center (SRAC) approved the development of a project to investigate the issue of aquaculture effluents. The primary objectives of the project were to: (1) characterize the quality of pond effluents; (2) evaluate procedures for reducing waste discharge; and (3) assess the economics of effluent management. The 3-year project, entitled Characterization of Finfish and Shellfish Aquacultural Effluents, was approved for funding in 1991. This publication summarizes the findings of the project, which are published in SRAC Final Project Report No. 600.

Objective 1

Characterize the quality of water discharged from aquaculture ponds in the southeastern United States.

Quality of Effluents from Channel Catfish Ponds

Channel catfish farming is the largest segment of aquaculture in the United States. In this study, catfish pond effluents were characterized by sampling 45 commercial catfish ponds in Alabama and Mississippi over a 2-year period.

Conclusions

Catfish pond effluent quality varied from pond to pond and from season to season. Effluent quality was poorest (highest concentrations of solids, organic matter, total phosphorus, and total nitrogen) in the summer when fish feeding rates and water temperatures are highest. Catfish pond effluents generally have higher concentrations of nutrients and organic matter than natural stream waters but much lower concentrations than municipal and industrial wastewater. It appears that catfish pond effluents are most likely to exceed regulatory limits for suspended solids and total phosphorus. Other measured water quality variables seldom or never exceeded national or state effluent standards. Treatment of aquaculture effluents will present unique problems because traditional wastewater treatment systems are designed for waters that have much higher concentrations of pollutants.

Quality of Effluents from Channel Catfish Ponds During Harvest

The shape and depth of some catfish ponds make it necessary to drain them annually for fish harvest. As the pond is drained, effluent quality deteriorates as fish are crowded into a small volume of water and sediments are stirred up by the seining operation. This study was conducted to characterize effluents released from channel catfish ponds in Alabama as they were drained for fish harvest.

Conclusions

Concentrations of most substances discharged from ponds were fairly constant as water was released from ponds before seining. Concentrations increased dramatically during the seining phase, and a large fraction of the total amount of organic matter, nitrogen and phosphorus was discharged in a relatively small volume of water. These findings suggest that the best way to minimize the pollution potential of aquaculture pond effluents is to harvest ponds as quickly as possible, and either not discharge water during the seining phase or discharge this highly contaminated water into a settling basin or retention pond.

Quality of Effluents from Crawfish Ponds

As with many types of pond aquaculture, crawfish producers occasionally discharge water from ponds to maintain good water quality and increase production. Water is also discharged from ponds when rainfall exceeds pond storage. This study was conducted to characterize the quality of effluents from 17 commercial crawfish ponds in Louisiana and to describe the relationship between the type and quantity of vegetative forage and effluent quality.

Conclusions

Effluent quality was poorest in the warm season, especially during the summer drainage period. Ponds with native vegetation generally had lower concentrations of nutrients and solids than ponds with rice or sorghum-sudan grass. Effluents from ponds planted with rice or sorghum-sudan grass could require some pretreatment before discharge to reduce the concentration of nutrients and solids. Planting aquatic macrophytes near the pond drain might also create a natural filtration system to reduce the amount of suspended solids and nutrients discharged in effluents of crawfish ponds.

Quality of Effluents from Hybrid Striped Bass Ponds

Production of hybrid striped bass is a rapidly growing segment of aquaculture in the southeastern United States. Water is periodically discharged from ponds used to raise hybrid striped bass but there is little information about the quality and volume of effluents released from commercial culture ponds. This study was conducted to describe the effluents from 20 commercial hybrid striped bass ponds in South Carolina.

Conclusions

The quality of effluents from hybrid striped bass ponds varied greatly from pond to pond, although there was little indication of seasonal variation. The water quality variables most elevated in effluents from these ponds were suspended solids, total nitrogen (including total ammonia) and biochemical oxygen demand.

Quality of Effluents from the Hypolimnia of Watershed Ponds

In some regions, producers use deep watershed ponds to grow catfish. Deep ponds may stratify during the summer and have anaerobic bottom waters (hypolimnia) for prolonged periods. Watershed ponds are usually drained from a drain pipe extending through the dam from the deepest part of the pond. Many watershed ponds also are fitted with trickle tube overflow pipes for deep water release, and hypolimnetic water is discharged following heavy summer rains. This study provides data on selected water quality variables in hypolimnetic waters of watershed ponds in Alabama stocked with channel catfish or combinations of sunfish and largemouth bass.

Conclusions

Hypolimnetic water from deep watershed ponds contained lower dissolved oxygen concentrations and higher concentrations of ferrous iron, total manganese, total sulfide and total ammonia than corresponding surface waters. Discharge of hypolimnetic water from ponds into natural waterways could harm fish and other aquatic organisms. The following steps can be taken to minimize problems with hypolimnetic discharges: 1) construct ponds so that deep water areas are filled with soil; 2) do not use deep water intake overflow pipes; 3) use water circulation devices or sufficient aeration to prevent thermal stratification; 4) harvest fish without draining water from ponds; 5) if ponds must be drained, drain after natural thermal destratification occurs in the fall; and 6) if water must be drained from the bottom of thermally destratified ponds, detain the effluent in holding ponds or reaerate it over a series of cascades before releasing it into natural waterways.

Objective 2

Evaluate management practices to reduce the impact of aquaculture effluents on the environment.

Reusing Water for Multiple Fish Crops

The mass of nutrients or organic matter discharged from ponds is a function of the concentration of the substance in the effluent and the volume of water discharged. Reducing the concentration of potential pollutants in pond effluents is difficult, but it is relatively easy to control discharge volume. The most obvious procedure for reducing the volume of effluents from channel catfish ponds is to harvest the fish without draining the ponds. However, this practice works only if water quality does not deteriorate as the water is reused. This 3-year study was conducted to compare water quality and fish production between annually drained ponds and undrained ponds in Alabama.

Conclusions

Comparison of annually drained and undrained catfish ponds showed little difference in water quality and no difference in fish production. Natural processes, such as nutrient uptake by bottom soils, microbial decomposition of organic matter, denitrification and sedimentation, continually remove potential pollutants from pond water. Operating ponds without draining makes better use of the waste assimilation capacity of ponds and saves significant amounts of water as well as reducing overall effluent volume.

Using Conservative Water Management Practices

Channel catfish ponds in northwest Mississippi were studied to evaluate the reduction in waste discharge possible from: (1) reducing overflow after rains by keeping pond water level below the pond drain; and (2) reusing water for multiple fish crops before draining.

Conclusions

Seasonal changes in overflow volume affected the amount of waste discharged more than seasonal changes in effluent quality. Specifically, waste discharge was greatest in the winter when overflow volume was highest and not in the summer when waste concentrations were highest. So, reducing overflow volume can have a dramatic impact on mass discharge of nutrients and organic matter from catfish ponds. By keeping the pond water level below the level of the drain, rainfall is captured rather than allowed to overflow and annual waste discharge is reduced by 50 to 100% depending on the weather. The volume of water discharged each year was also reduced substantially when fish were harvested without draining ponds. The combination of managing ponds for storage volume and not draining ponds between crops was especially effective at reducing waste discharge.

In ponds managed to capture rainfall, average discharge of nutrients and organic matter was reduced relative to annually drained ponds by more than 50% when ponds were used for 3 years between drainings and by more than 60% and when ponds were used for 5 years between drainings.

Minimizing Water Exchange in Penaeid Shrimp Ponds

Although culture technologies for marine shrimp vary widely, most pond management practices involve some amount of water exchange in the belief that exchange is needed to maintain adequate environmental conditions for good shrimp growth. Obviously, water exchange can greatly increase the volume of effluent discharged from ponds. This study determined the effects of water exchange on marine shrimp production in South Carolina and the effect of water exchange on pond effluent characteristics.

Conclusions

Without resorting to water exchange or some type of filtration, maximum stocking rates for shrimp farms were estimated to be 22 to 44 per square meter, corresponding to a peak feeding rate of about 70 to140 kg/ha per day. This agrees with the estimated “feed assimilative capacity” of static freshwater catfish ponds in the southeastern United States, although higher inorganic nitrogen concentrations were found in shrimp ponds with no water exchange than in freshwater catfish ponds fed at similar rates. In addition, the percentage of nitrogen lost from the system through volatilization and denitrification was lower for marine ponds than for freshwater ponds.

This study indicated that water exchange in intensive shrimp pond culture can be dramatically reduced without sacrificing growth or survival. At the lower limits of intensive production, or upper limits of semi-intensive production, water exchange may be eliminated entirely. This greatly reduces overall waste discharge into adjacent water bodies.

Using Effluents for Irrigation of Soybeans

Although water discharged from aquaculture ponds is often viewed simply as a waste product, it still has value and its reuse may have multiple benefits. If ponds are located near terrestrial crops that require irrigation, pond discharge can be used for irrigation water. That use will reduce waste discharge and benefit the crop. This study characterized water quality in effluents from Georgia catfish ponds and determined the effect of effluents on soybean production.

Conclusions

The total nitrogen available for crops varied from 0.9 to 1.2 kg/ha from each centimeter of water applied. Assuming average irrigation is 30 cm, then available nitrogen ranged from 27 to 36 kg/ha, a significant portion of the nitrogen requirement of many agronomic crops. Although the average soybean yield was 3.6 metric tons/ha, double the average yield in Georgia, the increased yield was the result of irrigation alone and not the nutrients in the irrigation water. Although the nutrient content of pond effluents may be too low to affect crop production, effluent resulting from water exchange can be used to irrigate crops and reduce discharge volume.

Treating Pond Effluents Using Constructed Wetlands

Wetlands act as biological filters to remove pollutants from water, and natural and constructed wetlands sometimes are used for treating agricultural, municipal and industrial waste waters. Wetlands are inexpensive to build and operate and eliminate the need for chemical treatment of wastewater. They also contribute stability to local hydrologic processes and are excellent wildlife habitats. However, the large areas of land needed for wetlands makes their use in treating aquaculture effluents questionable. In this study, a free water surface wetland was constructed adjacent to a commercial channel catfish pond in Alabama to determine its efficiency in removing potential pollutants from pond water.

Conclusions

Passing pond effluents through constructed wetlands reduced waste loads in waters discharged to the environment. Waste loads in the outflow from wetlands were always lower than in untreated waters, regardless of the hydraulic residence time. However, a 4-day hydraulic residence time reduced total phosphorus and biochemical oxygen demand the most.

The disadvantage of wetlands for treating aquaculture pond wastes is the large amount of space necessary to provide an adequate hydraulic residence time. Therefore, it will probably be necessary to integrate wetland treatment of effluents with other pond effluent management procedures to reduce the area of wetland needed. For example, a wetland centrally located on a farm, or connected to an integrated drainage system, would save on construction costs and use land efficiently. Such a system would also allow a wetland to be used to treat the overflow coming from ponds after rainfall. Pond drainings could be staged so that only one pond is being drained at a time, allowing one wetland to serve numerous ponds. Effluent from a constructed wetland could even be pumped back into ponds and reused if needed.

Treating Pond Effluents Using Grass Filter Strips

Draining effluents over grass strips filters solids from animal waste and may be useful for filtering catfish pond effluent. Common and coastal bermuda, dallis and bahia are recommended grasses for warm climates; fescue, reed canary and rye grass are recommended for cool climates. Grass filter strips are highly effective in reducing the concentrations of suspended solids, biochemical oxygen demand, and ammonia, but not efficient in removing algae. This study investigated the effectiveness of grass strips for filtering effluents from Georgia catfish ponds.

Conclusions

Concentrations of suspended solids, organic matter and total nitrogen in catfish pond effluents were reduced by applying the effluent to well established strips of either bahia or bermuda grass. This filtering technique was relatively easy and inexpensive, and may have application if the filtered effluent is to be reused for fish production to conserve groundwater. It could also be used to treat effluent before discharging it to receiving waters.

Objective 3

Analyze the costs of treating effluents from channel catfish ponds.

While water quality and effluent discharge are a concern to farmers, scientists and policy makers, few studies have focused on the economic feasibility of management practices that might be adopted by fish farmers to deal with regulations on effluent discharge. This study analyzed the farm-level economic impact of using four practices to reduce waste discharge from aquaculture: (1) no treatment with the possibility of an imposed tax on effluent discharged; (2) irrigation of rice with effluents from fish ponds; (3) recycling water through constructed wetlands; and (4) circulating water from a catfish pond through a pond stocked with filter-feeding fish (bighead carp). The effect of these practices on net farm income was compared to that of no treatment. In addition, the economic tradeoff between policies and alternative management implications of different enforcement practices was assessed.

Conclusions

All practices and policies to control effluent discharge reduced net farm revenues and created additional barriers to potential catfish farmers, particularly for small-scale (less than 130 hectares) farms. Under various farm size and management scenarios, rice irrigation was most often the favored treatment alternative. Higher investment and maintenance costs prevented constructed wetlands from being a profitable option. For constructed wetlands to be economically feasible, producers would need investment tax credits or other incentives. Effluent standards and tax charges could be an effective means of internalizing fish pond effluent discharge, although they may be feasible only for large farms. Though small farms are less likely to produce enough effluent to harm the environment, limited access to capital also makes them less likely to adopt new technologies. Effluent standards and tax charges affect farmers, so policy makers must account for the impact of proposed effluent reduction policy on the welfare of fish farmers.

Recommendations for Managing Aquaculture Pond Effluents

The results of this project suggest that the impact of aquaculture pond effluents on the environment can be reduced by using relatively simple management practices. Some of these practices require additional labor and expense to implement, and may not be applicable to all culture situations. However, many of the practices examined in this project are logical extensions of good overall farm management or are simple solutions that do not require extra expense or labor. All aquaculturists should strive to reduce the impact of their activities on the environment to the greatest extent possible. The following recommendations should help achieve that goal.

- Use high quality feeds and efficient feeding practices. Feeds are the origin of all pollutants in catfish pond effluents. High quality feeds and good feeding practices reduce waste production and improve effluent quality.

- Provide adequate aeration and circulation of pond water. Maintaining good dissolved oxygen levels enhances the appetite of fish and encourages good feed conversion. By distributing oxygen throughout the pond, water circulation improves the degradation of organic matter in pond bottoms and reduces the amount of organic matter in effluents.
- Minimize water exchange. Routine water exchange is of questionable value as a water quality management procedure and greatly increases effluent volume.
- Operate ponds for several years without draining. Reusing water for multiple fish crops is one of the best methods of reducing waste discharge from ponds. This project showed that good fish production can be maintained for at least 3 years in undrained ponds. Reusing water also reduces the need for pumped water to refill ponds. When ponds must be drained for levee repair, the last 10 to 20% of water can be held for 2 or 3 days so that pollutants can settle out before the water is discharged.
- Capture rainfall to reduce pond overflow. Maintaining storage volume by keeping the pond water level 7 to 9 cm (2 to 3 inches) below the level of the drain greatly reduces the volume of water that overflows when it rains. Capturing rainfall also reduces the need for pumped water to maintain pond water levels.
- Allow solids to settle before discharging water. After seining ponds that are partially drained for fish harvest, hold the remaining water in the pond for 2 to 3 days to allow solids to settle. An even better method is to not discharge this last portion of water.
- Reuse water that is drained from ponds. Instead of draining ponds for fish harvest, water can be pumped to adjacent ponds and then reused in the same or other ponds. Production ponds can be built with higher levees, or water levels maintained with more free board, to provide storage volume. Water from one pond can be transferred to another with a low-lift pump and then transferred back by siphon.
- Optimize watershed areas. Watershed ponds should not have watershed areas larger than necessary to keep ponds full, because excessively large watersheds increase runoff into ponds and result in high discharge. Runoff from watersheds may be partially diverted from ponds by terracing or other means.
- Treat effluents by using constructed wetlands. Constructed wetlands are efficient in removing potential pollutants but require large areas of land. Treating only the most concentrated effluents in the final stages of draining would minimize the amount of land needed for constructed wetlands and significantly improve the quality of effluents.
- Use effluents to irrigate terrestrial crops. Under certain conditions, the water discharged from ponds may have value as irrigation water for crops.

Publications and Presentations

The results of this Southern Regional Aquaculture Center project were reported in 15 refereed scientific journal articles, 4 Extension publications, 21 papers presented at scientific meetings, and 1 graduate degree thesis. These publications and presentations are listed in the SRAC Final Project Summary No. 600.

The work reported in this publication was supported in part by the Southern Regional Aquaculture Center through Grant No. 94-38500-0045 from the United States Department of Agriculture, Cooperative States Research, Education, and Extension Service.