V. PROGRESS REPORTS

A. CHARACTERIZATION OF FINFISH AND SHELLFISH AQUACULTURAL EFFLUENTS

Progress Report
For the Period
May 1, 1991 to August 31, 1994

FUNDING LEVEL:

Year 1 .... $145,000
Year 2 .... $169,000
Year 3 .... $141,500
Total $455,500

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PROJECT OBJECTIVES:

1. Characterize aquaculture effluents for finfish and shellfish aquaculture production systems.

2. Determine best management practices and investigate available and new treatment technologies to maintain high effluent water quality. These technologies will include water reuse, conservation and recycling techniques.

3. Compare the economics of the management practices and treatment technologies in Objective 2.

4. Develop and disseminate educational materials and conduct demonstration projects for producers and policy makers. This objective will be conducted throughout the duration of this project.

ANTICIPATED BENEFITS:

Results from this study do not give immediate benefits to the industry. The results obtained, however, apply to all aquaculture in the Southeastern United States. Characterization of aquacultural effluents and investigation of best management techniques will be invaluable to the industry as permitting of effluents of all types becomes more stringent. This data will give the aquaculture industry a pro-active position as pertains to agency permitting policies.

PRINCIPAL ACCOMPLISHMENTS:

Aquacultural effluents were characterized for catfish levee ponds by Mississippi State University, for watershed ponds by Auburn University, hybrid striped bass by Waddell Mariculture Center and crawfish effluents by Louisiana State University. Twenty commercial catfish ponds were used in the levee pond effluent study. High nutrient input rates and favorable conditions for plant growth during summer months resulted in high phytoplankton growth, settleable solids, suspended solids, chemical oxygen demand, and biochemical oxygen demand (BOD). Total phosphorous, soluble phosphorous and total nitrogen were also highest in summer. Ammonia and nitrate were highest in the cooler months because photosynthesis was reduced. The seasonable water quality parameters have positive implications on when water is released as most effluent is released during the winter when effluent water quality parameters are best. However, retention ponds for treatment would be more effective during summer.

Water samples were collected from 25 commercial catfish ponds in central and west-central Alabama. Ranges for variables were as follows: BOD_5; 1.9-35.54 mg/L; settleable solids; 0-1.8 mg/L; suspended solids; 5.2-336.7 mg/L; volatile solids; 0.02-221.0 mg/L; total phosphorous; 0-1.85 mg/L; soluble reactive phosphorous; 0-0.74 mg/L; total Kjeldahl nitrogen; 0.58-14.04 mg/L; total ammonia nitrogen; 0.008-8.071 mg/L; nitrite-nitrogen; 0.001-1.410 mg/L; nitrate-nitrogen; 0-6.661 mg/L; dissolved oxygen; 0.8-16.8 mg/L; pH; 4.9-9.5. Concentrations of water quality variables were skewed toward the lower ends of these ranges. Concentrations of some variables were occasionally higher than those normally encountered in natural streams and exceeded recommended effluent concentration limits.

Watershed ponds with maximum depths of 3-5 m which thermally stratify during warm months are sometimes used for commercial aquaculture. Hypolimnetic water in six watershed ponds for aquaculture in Alabama were depleted of dissolved oxygen and had 2.4-43.2 mg/L of ferrous iron, 0.01-0.25 mg/L of total manganese, 0.24-3.59 mg/L of total ammonia nitrogen, and 0.07-1.29 mg/L of total sulfide. Concentrations of nitrite-N and 5-day BOD were no higher in hypolimnetic water than in normal surface water of aquaculture ponds. Volumes of oxygen-depleted water averaged 3.2 to 20% of total pond volumes, but much greater volumes of pond water contained less than 3 or 5 mg/L of dissolved oxygen. Discharge of hypolimnetic water from aquaculture ponds into natural waterways could have a negative impact on water quality.

Seventeen commercial and two experimental crawfish ponds in south-central and southwest Louisiana were selected for effluent characterization. The ponds represented cultivation systems including rice-crawfish ponds (rice-crawfish rotation, rice double cropping); sorghum-sudan grasses or colonized by native terrestrial/native aquatic vegetation); and wooded ponds (native terrestrial/native aquatic vegetation and leaf litter). Macrophytic standing crop was estimated in each pond in mid-October, mid-January, and mid-April with quadrat sampling. Effluent samples were collected on four days in a two-week period in November 1991 (late fall), February 1992 (winter), and late March - early April 1992 (spring). Summer samples were collected on at least three days during pond draining from late April through early July. Water was analyzed for parameters decided upon by the SRAC working group.

The Waddell Mariculture Center (WMC) assessed commercial striped bass hybrid (SBH) pond and effluent water quality. An attempt has been made to include commercial ponds with a wide range of production goals, including fingerling production ponds. Saltwater and freshwater ponds were included as well. Since pond dynamics can result in dramatic short-term fluctuations in many water quality parameters, more frequent sampling of SBH ponds at WMC was done. WMC ponds include intensive juvenile production ponds and grow-out ponds stocked at two densities. The lower stocking density and feeding rate was close to the average of commercial farms and the higher density was approached or slightly exceeded the limits of fish production in ponds without water exchange. All data sets were sent to North Carolina State University for inclusion into databases.

Excluding fingerling production ponds, the fish biomass encountered in the commercial ponds ranged from 450 to 12,500 lbs/ac with an average of 3,700 lbs/ac. Feeding rates for production ponds ranged from 2 to 133 lbs/ac/day with an average of 50 lbs/ac/day. It is generally believed that digestion processes within the pond were capable of assimilating about 100 lbs/ac/day of feed if supplemental aeration is available to maintain dissolved oxygen. Thus, at the higher feeding rates being used by some commercial SBH farms, a degree of water exchange may be necessary to transfer part of the digestion process to the receiving stream or highland crops. Indeed the highest water exchange rates have been encountered in these ponds with the highest feeding rates.

In summary, the potential for adverse environmental impact from effluents of striped bass hybrid ponds is no greater than that of catfish ponds. Through thoughtful and well-informed farm design and operation, the potential for environmental impact can be virtually eliminated.

In order to determine the best management practices (BMP) for catfish effluents it was necessary to determine the timing and quantities of effluents discharged from commercial catfish farms in Mississippi.

Data were collected from commercial catfish farms with 10,413 water surface acres devoted to food fish production, 1,261 water surface acres devoted to fingerling production and hatcheries that hatch more than 100 million catfish fry annually. These data indicated that the following conclusions are warranted:

- The cost of pumping (economics) tends to minimize the amount of water used on catfish farms.

- Food fish and fingerling production results in only about 20 inches of water per acre per year being discharged into the environment.

- Discharge of water from excess rainfall for food fish producers and management practices (draining ponds prior to stocking fry) for fingerling producers account for most of the water released.

- The time of discharge is such that the water in ponds contains the seasonally lowest concentration of potential pollutants when discharged.

- The time of discharge is such that the receiving streams are at, or near, their maximum flow.

- Hatchery discharge water presents few, if any, potential problems.

- Based on these data and analysis, the commercial catfish industry presents minimal environmental pollution problems from effluent discharge.

- There is no apparent need to develop a plan for discharge water treatment at this time.

Researchers in Mississippi also found that the best time to release effluents from catfish ponds was during the winter when water quality was best. This coincided with the rainy season when most effluents were released. The study also found that water quality from ponds not drained each year had suitable water quality as in ponds where biological processes reduced nutrients and organic matter in excess of a single pond - volume discharge. This results in less effluents and reduced pumping costs.

Research at Auburn University indicated that of the nitrogen, phosphorous, and BOD discharged, 50% was discharged in the last 15-20% of the effluent discharged. Of the settleable solids discharged, 50% was released in the last 5% of the effluent discharged. 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 to not discharge water during the seining phase or to discharge this highly contaminated water into a settling basin or retention pond. It is feasible to allow effluents to flow untreated into the environment during the pre-seining phase of draining as concentrations of potential pollutants are low. Results from undrained and drained ponds were similar in the Alabama study. It was concluded that harvest without draining was a feasible technique for reducing the pollution potential of catfish farming.

A study utilizing fish effluents for crop irrigation was conducted in Georgia. Both soybean and wheat were grown. It was concluded that pond effluent can be applied as irrigation water to crops to satisfy a portion of the nitrogen requirement, but little phosphorous is provided. Pond water is generally not changed by flushing (25%), but effluent application to cropland could reduce the volume of effluent reaching natural systems. Pond flushing and refilling may reduce the amount of emergency aeration required for channel catfish ponds.

The influence of water recirculation in outdoor ponds coupled with the use of filter feeding fish was investigated as a BMP at a commercial catfish operation in southeast Texas. They found that effluent parameters were within the ranges reported by other authors. This research suggests, although the pond systems were managed inconsistently, that production was significantly higher in the recirculated ponds versus static ponds with only a slight increase in levels of some of the measured water quality parameters.

Investigators at North Carolina State University researched the use of water hyacinth based treatment systems and wetland plant nurseries for effluent treatment. To look at the effectiveness of the water hyacinth based treatment system, a system was set up at Tidewater Research Station, Plymouth, N. C. Two different flow rates of 8000 l/d and 16000 l/d were chosen and studied. The system was found to be fairly efficient in removing suspended solids. The highest removal efficiency was about 90% while the average removal efficiency was 60%. The average removal efficiency, at the lower rate of 8000 l/day, was 67% while the average removal efficiency at the higher flow rate of 16000 l/day was 51%. Some reduction of phosphates was observed in the system. The average removal efficiency at the lower flow rate was 16.5% while the average removal efficiency at a higher flow rate was 9.5%. The average removal efficiency for nitrates at the lower flow rate was 38% while the average efficiency at the higher flow rate was 11%. The average TKN removal efficiency at the lower rate was 42% while the average removal efficiency at the higher flow rate was 31%. Thus, better efficiency was obtained at the higher detention time. Though a reduction in ammonia-N content of the effluent was observed in some cases, overall, the ammonia-N content of the effluent did not show any appreciable reduction and seemed to increase in quite a few cases which could have been caused by:

a) Decomposition of organic matter into ammonia.

b) Fixation of N_2 from the atmosphere by blue-green algae.

c) Nitrifying bacteria not having a chance to establish themselves.

The use of aquaculture effluents to grow nursery plants was also investigated. The three wetland plant species propagated during the two year study grew very well with no additional nutrient input. From this perspective, aquaculture pond water/effluent is a suitable (low cost) irrigation and nutrient source for the propagation of those plants. From an aquaculture effluent control point of view, the only major benefit was suspended solids removal. From a farmer's perspective, this is an important finding. Through the application of this technology or by utilizing a constructed wetland, aquaculture pond farmers have an alternative to discharging untreated waters.

Researchers from the University of Arkansas at Pine Bluff (UAPB) conducted economic analyses on effluent management strategies for catfish and hybrid striped bass production in ponds and for trout production in raceways. Effluent management strategies analyzed for the warmwater pond systems included: using pond water to irrigate rice, use of constructed wetlands, and use of filter-feeding fish stocked in ponds. For the trout model, effluent management strategies analyzed included: constructed wetlands, filter-feeding fish stocked in ponds fed by the raceways, and the use of settlement basins. Results showed that effluent treatment with these technologies would increase production costs by $0.02 to $0.05 per pound for catfish and $0.28 to $0.31 per pound for hybrid striped bass.

The use of effluent for crop irrigation was shown to be the least expensive treatment option. The technique selected for effluent treatment, however, will be determined by regulations and impact on production. However, all treatments analyzed reduced net farm revenues due to either treatment cost, optimal farm size, or stocking rates. This study also showed that imposing effluent control will create barriers for new catfish farmers, particularly small-scale (less than 320 acres) farms.

An economic engineering approach was used to construct cost estimates for the parameters shown below:

- 3 levels of production
  - small - 30,000 to 50,000 lbs/yr
  - medium - 100,000 lbs/yr
  - large - 230,000 lbs/yr
- 2 raceway sizes
  - 6’X 35’X 3'
  - 12’X 70’X 3'
- 3 flow rates
  - 500 gpm
  - 1500 gpm
  - 3000 gpm
- 2 management levels
  - new
  - experienced
- 2 final fish weights
  - 14 oz
  - 48 oz
- 5 effluent treatment methods
  - surface flow constructed wetlands
  - subsurface flow constructed wetlands
  - settlement basin
  - filter-feeding bighead carp
  - no treatment

Filter-feeding bighead carp had an ability to reduce the BOD level. Only when BOD levels were reduced to 2.5 mg/l did the constructed wetlands become feasible. The wetland system appeared to be more cost effective at lower water flow rates and with smaller fish.

Bighead carp production may not be practical in all trout producing regions. When bighead carp were removed from the model, net returns remained the same, but water flow rates (500 gpm) were reduced. When a tax of $60 per mg/l BOD discharged was levied, net returns were reduced. However, new producers or smaller farms in the model, paid the tax on effluent discharge rather than build constructed wetlands. Net returns were reduced by 1% to 2%.

A tremendous amount of work has been done by scores of researchers on the characterization of effluent from flow-through fish systems, particularly those from salmonid production. The enormous variation seen in the reported values illustrates the importance of factors such as mode of operation during measurement, stocking density, composition of feed and feed conversion efficiency, and the intensity of water use. Designers of systems for waste treatment options must consider very site-specific and management-specific parameters in planning to meet the myriad of environmental regulations applicable to flow-through systems in aquaculture.

<u>IMPACTS:</u>

It is difficult to estimate the impacts of the study directly on production farmers. The data collected does characterize aquaculture effluents and presents data on BMP's. This data will be valuable to both farmers and regulators as they develop permitting criteria and options. Economic data indicates the most feasible effluent treatment methods and BMP's. If treatment methods are required by public agencies, they could cause economic barriers to entry into the aquaculture industry.

PUBLICATIONS:

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Ghate, S. R. and G. J. Burtle. 1993. Water quality in channel catfish ponds intermittently drained for irrigation. Proceedings of an Aquaculture Engineering Conference: Techniques for Modern Aquaculture, edited by J. K. Wang, American Society of Agricultural Engineers, St. Joseph, MO. pp. 177-186.

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Ghate, S. R., G. J. Burtle, and M. C. Smith. 1993. Characterization of water quality in catfish (*Ictalurus punctatus*) ponds under selective harvesting production system. World Mariculture Society/South Atlantic Regional Aquaculture Conference. January 27-30. pp 19.

SUPPORT:

YEAR	SRAC FUNDING	OTHER SUPPORT					TOTAL SRAC+ OTHER SUPPORT
		UNIVERSITY	INDUSTRY	OTHER FEDERAL	OTHER	TOTAL OTHER SUPPORT	
1	145,000	90,294				90,294	235,294
2	169,000	146,369				146,369	315,369
3	141,500	129,375				129,375	270,875
Total	455,500	366,038				366,038	821,538