SPLIT-POND AQUACULTURE SYSTEMS: DESIGN REFINEMENTS FOR CATFISH PRODUCTION AND EVALUATION FOR CULTURING OTHER SPECIES

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Participants

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PROJECT OBJECTIVES

Objective 1. Evaluate split-pond designs for catfish aquaculture.

a. Evaluate four split-pond pumping systems at commercial scale (USDA-ARS Stoneville, USDA-ARS Oxford, and Mississippi State University)
b. Improve pumping efficiency of paddlewheel pumps for split-ponds (University of Arkansas at Pine Bluff)
c. Evaluate effects of whole-pond aeration on split-pond performance (Auburn University and USDA-ARS Oxford)

Objective 2. Evaluate split-ponds for culture of warmwater species of commercial value other than catfish.

a. Evaluate existing split-pond designs for baitfish aquaculture (University of Arkansas at Pine Bluff)
b. Develop engineering design criteria for baitfish aquaculture (University of Arkansas at Pine Bluff)

ANTICIPATED BENEFITS

In an effort to remain competitive in the face of adverse economic conditions, some catfish farmers have started using intensive, outdoor culture systems called split-ponds. Despite widespread adoption, optimum split-pond design is unknown and commercial systems vary widely in pump type, water exchange rate, and management of the two basins. Further, the apparent success of split-ponds for growing catfish has generated interest in the possibility of culturing other species, especially baitfish. The project will evaluate important design or management options for producing ictalurid catfish, including pumping systems and oxygen management, and will develop engineering design criteria for baitfish aquaculture. Results of this project will allow catfish and baitfish farmers to make informed decisions regarding split pond design.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. *Evaluate split-pond designs for catfish aquaculture.*

Subobjective 1a. *Evaluate four split-pond pumping systems at commercial scale*

USDA-ARS Stoneville, USDA-ARS Oxford, and Mississippi State University

This sub-objective will 1) provide pump performance data on the common pumping systems used in split-ponds; 2) evaluate fish performance and water quality in split-ponds with four pumping systems (four water flow rates); and 3) document operational problems or limitations associated with the four pumping systems.

Four, 7-acre earthen ponds at the National Warmwater Aquaculture Center at Stoneville, Mississippi, were modified into split-ponds in 2014 by constructing an earthen levee to divide ponds into a fish-holding section (approximately 20% of total pond area) and a waste-treatment section (80% of pond area). Four pumping systems were installed: a) slow-turning paddlewheel, b) fast-turning paddlewheel, c) high-speed screw-type pump, and d) high-speed axial flow turbine pump. Four, 10-hp paddlewheel aerators were installed in the fish sections of each pond. Construction will be complete in late autumn 2014. Pump performance studies will begin in winter 2015 and production studies will begin in spring 2015.

Subobjective 1b. *Improve pumping efficiency of paddlewheel pumps for split-ponds.*

University of Arkansas at Pine Bluff

A paddlewheel-type pump developed at the University of Arkansas at Pine Bluff has found wide commercial use in split-ponds. However, pump design and commercial application need to be further refined and optimized to maximize water flow rate and minimize energy usage.

The drag-force equation was used to establish working models for sizing paddlewheel pumps to various culture conditions, with respect to power consumption and water flow rate. Engineering parameters involved in establishing the models were rotational speed and wetted surface area of paddle. Also, intensive field data (power consumption and water flow rate in relation to the engineering parameters) were collected from 12 split pond systems (4.5 to 11 acres) on two commercial catfish farms in Arkansas to validate the models. In 2014, a total of 10 measurements were obtained and added to previously obtained data. A total of 80 measurements were used to refine the models. Those parameters were collected as natural changes of rotational speed and water depth of the paddle occurred during the ordinary management of each pond. Power consumption and water flow rate measured from field observations were compared with those predicted by the theoretical models developed in this study.

Under field conditions, power consumption and water flow models predicted actual power consumption with 96% accuracy and water flow rate with 75% accuracy. Based on the engineering models, increasing wetted surface area of paddles is more energy efficient than increasing rotation speed in achieving proper water flow rate and also minimizes mechanical failure due to high torque. However, at a certain threshold of wetted surface area (especially if wetted area is increased by increasing paddle length) the power requirement could increase as the attempt to decrease rotational speed is made to achieve a target water flow rate.

A pilot-scale paddlewheel was designed based on the engineering models that were developed and installed in a newly-built engineering pond in order to test different types of paddles in controlled conditions. The basic water circulator had eight paddles, each consisting of seven wooden blades. The wooden blades (5.5-inches by 40 inches) were fastened onto galvanized square tubes bolted to a central hub. The wooden blades spanned the width of each paddle. The paddlewheel was driven by a 3-hp motor coupled to a gear-box that directly reduced the rotational velocity of the shaft to 7.8 rpm. The motor was controlled by a variable frequency drive installed to allow further manipulation of rotational speed. The levee between two adjacent 0.25-acre ponds at the Aquaculture Research Station at UAPB was breached in two places to accommodate the installation of two galvanized metal culverts (4-feet diameter, 10-feet long) joining the ponds to create a new 0.5-acre split pond. Both culverts had channels attached to the culture basin to accommodate PVC-coated wire mesh. To guide water, a baffle was installed equidistant between the two culverts and perpendicular to the earthen dividing levee extending to a distance of 75% of the total length of the algal basin. Two sets of unique paddles will be constructed, in addition to the flat paddle design. The three paddle wheel designs will be tested at various combinations of rotational velocities and water depths.

Six, 0.5-acre split ponds at the Aquaculture Research Station at UAPB, have been under construction in order to evaluate the production performance of spilt ponds with a newly designed paddlewheel blades. Construction will continue and be completed by February, 2015.

Subobjective 1c. *Evaluate effects of whole-pond aeration on split-pond performance.*

Auburn University and USDA-ARS Oxford

The original split-pond concept involved no water quality management in the waste-treatment section of the system. Dissolved oxygen concentrations commonly fall to near 0 mg/L each night during the summer growing season. The Auburn University component of this project focuses on the possible benefits of using mechanical aeration in the waste-treatment section of the split-pond culture system.

Work was conducted at a commercial catfish farm in west Alabama. The farm currently has seven split-ponds, each with a fish culture section of about 2 acres. Two, 10-hp floating, electric paddlewheel aerators were placed in the waste treatment section of each of four ponds, while three ponds without aeration in the waste treatment area (one additional pond is currently being constructed and will be added as a fourth control pond next year) served as controls. Water samples were collected biweekly beginning in late July at the inflow and outflow of the waste-treatment cells; once the water became colder in October, samples were collected monthly.

Samples were analyzed for Secchi disk visibility, pH, and concentrations of chemical oxygen demand (soluble and total), total ammonia nitrogen, nitrite, nitrate, total nitrogen, total phosphorus, and chlorophyll *a*. Dissolved oxygen concentrations were monitored by an automated system installed and operated by the farmer. Aerators were purchased in April, but circumstances related to complete connection of aerators to the automation system delayed aerator operation in the waste treatment cells until the end of July.

The average concentrations of water quality variables measured between July and October are presented in Table 1. There appears to be a slight reduction in chlorophyll *a* and TAN concentrations between treatment and control, but none of the differences are statistically significant. The study must be conducted over an entire growing season before conclusions can be made.

Table 1. Average pH, Secchi disk visibility, and concentrations of other water quality variables in control ponds and in ponds with aerated waste cells for seven sampling data (late July – late October, 2014)

	Control ponds (n = 3)		Aerated ponds (n = 4)	
Variable	In	Out	In	Out
pH	7.82	7.92	8.01	7.98
Secchi disk visibility (inches)	9.47	10.19	13.43	15.00
Chlorophyll *a* (µg/L)	151.26	172.95	117.44	135.21
Total ammonia nitrogen (mg/L)	4.40	4.44	3.49	3.51
Nitrite-nitrogen (mg/L)	0.217	0.189	0.331	0.307
Nitrate-nitrogen (mg/L)	0.359	0.354	0.399	0.368
Total nitrogen (mg/L)	6.198	6.087	5.595	5.328
Total phosphorus (mg/L)	0.342	0.273	0.363	0.358
Chemical oxygen demand, total (mg/L)	26.515	27.375	26.435	27.138
Chemical oxygen demand, soluble (mg/L)	21.769	21.563	22.465	23.281

Pond water and catfish fillet samples have been collected at 3-week intervals from two split-pond systems located at the Delta Experiment and Research Center, Stoneville, MS, and the six commercial split-ponds in Alabama. Water samples are being analyzed for concentrations of geosmin and 2-methylisoborneol (MIB) which are responsible for the earthy and musty off-flavors, respectively, in channel catfish. Collected water samples are also being monitored for phytoplankton community structure to determine the presence of certain species of cyanobacteria (blue-green algae) attributed as sources of geosmin and MIB in catfish production ponds. Catfish fillet samples are being evaluated instrumentally for concentrations of geosmin and MIB and by sensory evaluation (flavor check) to determine the bioaccumulation of these compounds and flavor quality of catfish during the growout of crops of catfish in the split-ponds. Preliminary results indicate that both earthy and musty off-flavors can occur in catfish raised in split-ponds, and these off-flavor episodes can mimic the intensities observed in commercial earthen ponds (non-partitioned).

Objective 2. *Evaluate split-ponds for culture of warmwater species of commercial value other than catfish.*

Previous split-pond research has focused on growing catfish as the primary crop. The apparent success of split-ponds for growing catfish has generated interest in the possibility of culturing baitfish. However, suitability of the split-pond for baitfish culture is unknown and considerable innovation may be needed to accommodate culture considerations unique to small fish species.

Subobjective 2a. *Evaluate existing split-pond designs for baitfish aquaculture.*

University of Arkansas at Pine Bluff

This subobjective will explore the initial feasibility of using split ponds for baitfish production. Six, 0.1-acre experimental split-ponds were constructed based on an existing catfish split-pond design. A fine-mesh barrier fence was used to partition off 20 percent of total pond area as the culture unit, and a slow-rotating (5.4 rpm) 0.25-hp gearmotor-driven paddlewheel was used to circulate water through the culture unit. Sheet-metal "wings" extending from each side of the paddlewheel to the barrier fence directed the water flow into the culture unit. A diagonal baffle across two-thirds of the waste treatment unit was used to direct the water flow through the entire section. Golden shiners (mixed sizes of young of the year, average weight of 0.31 g per fish) were stocked on July 9, 2014, into 6 regular ponds and 6 split-ponds at two rates, 27.5 pounds/acre and 71.7 pounds/acre (approximately 100,000 or 150,000 fish/acre). Each pond was equipped with a 0.5-hp vertical pump aerator. Paddlewheels operated daily from 0800 until 2200 and aerators from 2200 until 0800. Fish were fed a 32% crude protein floating catfish feed once daily to apparent satiation. Loggers recorded the temperature every four hours at three depths in two split-ponds and two regular ponds. Water quality (dissolved oxygen, temperature, pH, total ammonia nitrogen, and chlorophyll *a*) and zooplankton concentrations were monitored. Initially, ponds were covered with netting to exclude predatory birds but the netting was lost in a windstorm on July 23. Scare tactics were employed but ponds were regularly visited by great egrets and kingfishers. Ponds were harvested October 9-10, after 92 days. Losses to predators were likely responsible for reduced survival in all ponds, as very few sick fish were observed. Curiously, survival rates in the regular ponds were lower than in the split-ponds (average of 17.5 percent versus 26.8 percent in the split-ponds). Average individual weight of fish in the split-ponds was less than that of fish in the regular ponds, but growth of golden shiners in pond culture is reduced by increased fish density.

Subobjective 2b. *Develop engineering design criteria for baitfish aquaculture.*

University of Arkansas at Pine Bluff

<u>Design and testing a rotary screen fish barrier for baitfish aquaculture</u>.

Interest in applying the split-pond system to species other than catfish has substantially increased. A major issue with using split-ponds for small fish species is the need to prevent fish from escaping the fish-holding section. Barriers must reliably retain fish while allowing appropriate water flow. Small-mesh screens or barriers will be prone to fouling or clogging by debris moved along in the water flow needed to recirculate water between the two sections of the systems. Devices to retain fish must balance reliability, simplicity, resistance to clogging and ease of cleaning.

A prototype rotary screen fish barrier (RoSFiB) for a 5-acre split pond system was designed and is being fabricated. The effective submerged area, rotational speed and diameter of the rotary screen fish barrier were determined using a previously developed engineering equation. Using the best possible estimation of engineering parameters for the equation (initial resistance of clean screen: 0.019 m, filterability: 0.05 m^{-3}, speed of strainer: 2.4 m^2/min, dynamic loss: 0.00005m, coefficient of discharge: 0.6, friction loss through screen: 0.019 m, and target water flow: 20 m^3/min), the diameter of RoSFiB was established at 2.4 m (7.8 feet) to accommodate an effective submerged screen area of 5.1 m^2 (assuming a 3.2-mm mesh screen) at a screen rotational speed of 2 rpm. In order to drive the RoSFiB, a 1-hp motor will be coupled to a gear-box that directly reduces the rotational velocity of the shaft to 7.8 rpm. The motor will be controlled by a variable frequency drive installed to allow further manipulation of rotational speed. The fish barrier will be installed in a baitfish farm in Lonoke, Arkansas, which is currently renovating a 5-acre traditional pond into a split pond system (10% fish basin and 90% water treatment basin). Two culverts will connect the two basins and a paddlewheel pump equipped with a 3-hp motor will be used to move the water. Each culvert will also have a RoSFiB to prevent the fish from escaping. The pump will be placed in the waste treatment side and the two RoSFiB will be mounted in the fish basin. Construction will be continued and completed by May, 2015. Upon completion of construction, 100,000-150,000 young fathead minnows/acre will be stocked in the pond (total 500,000-750,000 in the fish basin) in mid-May to evaluate the growth, survival rate, and size distribution of fathead minnows in the split pond system.

<u>Contribution of natural foods in split-ponds to golden shiner production.</u>

Split-pond systems, by excluding fish from the majority of the pond volume, should provide a zooplankton refuge and possibly increase secondary productivity overall through constant cropping of a portion of zooplankton biomass. This subobjective will be to compare zooplankton communities in experimental split-pond systems and traditional ponds to determine the relative abundance of natural foods.

A 6-week study was conducted to evaluate the use of natural foods by adult golden shiners (mean individual weight = 1.98 g), stocked at 500 pounds/acre into 6 regular and 6 split-pond systems from 11 May to 18 June, 2014. In the split-ponds, fish were confined to 20% of pond area by a fine mesh barrier, and water was circulated through the culture unit for 12 hours each day. Fish were fed at 3% body-weight every day (32% protein floating feed) in the 3 replicates of each pond system type while in the rest of the ponds, the fish were not fed. Ponds were covered by netting for the duration of the study. Preliminary results show that average net yield or survival (37%) did not vary among the treatment groups but was low overall due to depredation from blackbirds and herpetofauna. Overall, unfed fish in the split-ponds had a lower final weight, condition (K) and gonadosomatic index (GSI) than fish in the other treatment groups. These results indicate that for this split-pond design and study duration, traditional ponds contributed more natural foods towards fish production when compared with split-ponds. Spawning was observed in all the ponds and resultant fry and juveniles found on the waste-side of the split-ponds is an issue that remains to be addressed in the design of split-pond systems for baitfish. Determining the ratio of DNA to RNA will be useful in comparing relative growth of the zooplankton populations in split- and regular ponds. A protocol is being developed to quantify DNA (calf thymus) and RNA (Baker's yeast) from standards. The same procedure will be used to quantify DNA and RNA from zooplankton samples. Zooplankton will be homogenized and DNA and RNA will be stained simultaneously and quantified using a flow cytometer.

IMPACTS

This is a new project and most studies will start after the performance period of this report. No impacts can be reported.

PUBLICATIONS. MANUSCRIPTS OR PAPERS PRESENTED

Presentations

Stone, N. 2014. Split-ponds for golden shiners? Aquaculture Field Day, University of Arkansas at Pine Bluff, Pine Bluff, AR. October 2, 2014.

Park, J. 2014. Engineering fundamentals of split pond system. Aquaculture Field Day, University of Arkansas at Pine Bluff, Pine Bluff, AR. October 2, 2014.

Kaimal, S., and N. Stone. 2014. Evaluation of the use of natural foods in traditional and split-pond systems for raising golden shiners (*Notemigonus crysoleucas*). Poster presentation, Aquaculture Field Day, University of Arkansas at Pine Bluff. Pine Bluff, AR, October 2, 2014.

McCoy, K., S. Kaimal, M. A. Smith, and N. Stone. 2014. Summer production of golden shiners in split- and traditional earthen ponds. Poster presentation, Aquaculture Field Day, University of Arkansas at Pine Bluff. Pine Bluff, AR, October 2, 2014.

Smith, M. A., and N. Stone. 2014. Winter production of golden shiners (*Notemigonus crysoleucas*) in split- and traditional earthen ponds. Poster presentation, Aquaculture Field Day, University of Arkansas at Pine Bluff. Pine Bluff, AR. October 2, 2014.

RESULTS AT A GLANCE

An engineering design model for the paddlewheel pump designed at the University of Arkansas at Pine Bluff accurately predicts water flow and power consumption under field conditions. The model is based on rotational speed and wetted surface area of paddle, and predicted power consumption with 96% accuracy and water flow rate with 75% accuracy. The model can be used to design paddlewheel pumps for specific split pond applications without the need for expensive field testing.