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The promise of In-Pond Raceway Systems, part 1

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Four-year Alabama project improves design, operational efficiency

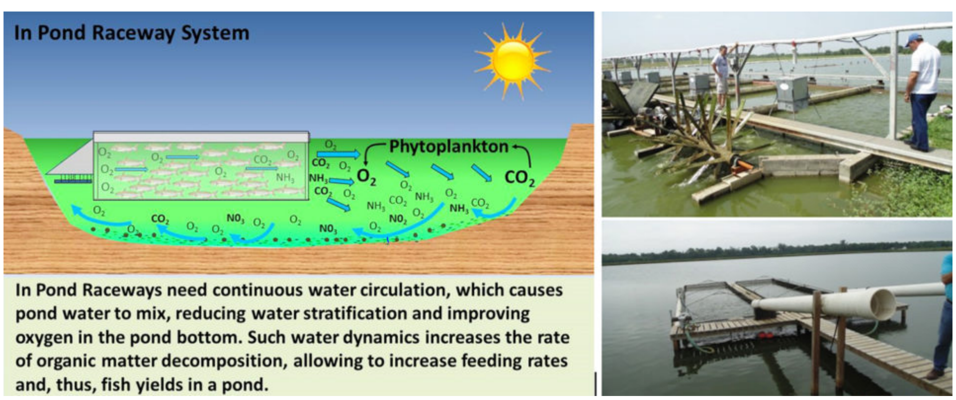

Fig. 1: Illustrative representation of an IPRS and images of fixed and floating IPRS installed at commercial catfish farms in Alabama.

As world population and seafood demand continue to increase, intensification of aquaculture is unavoidable while fisheries resources, land and freshwater become more limited in many regions. The increase in global trade of aquaculture products also requires more competitive and efficient production approaches by farmers and processors to deliver high quality products to meet global demand.

Freshwater pond aquaculture, in particular, will be further challenged to intensify production, while using less water and zeroing effluents, as government agencies continues to impose more regulation on water uptake and effluent discharge. In addition, consumer awareness on the origin, safety and sustainability of food continues to increase and has driven wholesalers and retailers to impose a cascade of demands for certification of aquaculture products that farmers and processors must meet.

Aquaculture enterprises must move towards more intense and sustainable production strategies, and require more efficient use of water, feed, labor, energy and other resources to maintain high quality products at competitive prices compared to other fish, seafood and animal meats available to consumers.

Aquaculturists are always looking for ways to increase fish yield, as they often associate productivity with increased business competitiveness and profits. However, production in pond aquaculture is limited by the amount of wastes (mainly decaying phytoplankton and metabolic and fecal residues of fish) the biota in a pond can assimilate while maintaining satisfactory water quality for growth and health of fish.

Dissolved oxygen is typically the first limiting factor to fish yield in ponds. Early morning dissolved oxygen in pond water has an inverse relationship to feeding rate, phytoplankton abundance and fish biomass. Pond aeration provides additional oxygen, improves water circulation, reduces water stratification and accelerates the decomposition of wastes. Supplemental aeration, thus, is a worldwide tool farmers use to improve water quality, while increasing feeding rate and fish yield from ponds.

However, in ponds with no water exchange, despite all the aeration that can be supplied, ammonia poisoning is generally considered the second limiting factor of production. Total ammonia concentration increases proportionally to the amount of organic wastes entering the ponds. Thus, feeding rate and decay of dead phytoplankton has a direct relationship to total ammonia levels in pond water.

With more aeration, farmers can stock more fish and add more feed to a pond, targeting higher fish yields. However, this can lead to an excess of organic wastes and nutrients, which favors growth of dense phytoplankton blooms in the ponds. Intense photosynthesis by microalgae can cause pond water pH to reach values above 9.0 at noon and afternoon hours, which increases the risk of unionized ammonia toxicity in heavily fed ponds.

For this reason, in addition to aeration, farmers need to set upper limits to feeding rates, monitor afternoon ammonia and pH levels and apply strategies to prevent excessive phytoplankton. Since water exchange is becoming more restricted in freshwater pond aquaculture, updated pond management and production strategies, in addition to just increasing aeration, are needed to improve water quality to further increase fish yield in heavily fed ponds.

In-Pond Raceway System (IPRS)

The In-Pond Raceway System (IPRS) is a promising strategy to further increase fish yield in static ponds. Instead of growing fish free in the pond, in the IPRS fish are confined at high densities in floating or fixed raceways (Figs. 1 and 2). Water circulation and aeration is continuously provided to each raceway, maintaining adequate and safe oxygen levels in the growing cells, independently of the oxygen status in the pond.

The raceways seldom exceed 3 percent of total pond surface area. The IPRS was first conceived and developed at the School of Fisheries, Aquaculture and Aquatic Science – Auburn University (SFAAS-AU) in the early 1990s. Initially, units were small and constructed with wooden panels. Since then, researchers at SFAAS-AU have conducted several experimental- and commercial-scale evaluations to understanding the potential, advantages and limitations of farming catfish in IPRS compared to conventional or highly aerated catfish ponds. Such evaluations also contributed to improve the design, construction and operation of IPRS, culminating with the semi-commercial size floating raceways made with a metallic frame lined with high density polyethylene (HDPE) and a more efficient airlift device to aerate and circulate the water through the raceways and pond.

Results from the semi-commercial scale evaluation of IPRS at Auburn University

A four-year project is in progress at Auburn University to refine IPRS management protocols, improve design and operational efficiency and assess economic feasibility of semi-commercial scale IPRS to produce catfish. The first year's goal was to demonstrate that market size catfish (average weight of at least 680 g and minimum weight of 450 g) could be produced in a growing period of 8 to 10 months, at a yield twice the average yield of 7,800 kg/ha attained in conventional catfish ponds in Alabama.

Four 0.4-ha earthen ponds were each equipped with an IPRS (Figure 2). The IPRS units in B1 and B2 were 63.6 m^3 in volume (4.9 m wide, 10.7 m long and 1.2 m water depth), while in B3 and B4 smaller units of 45.3 m^3 were used (3.1 m wide; 12.2 m long and 1.2 m water depth). Each IPRS pond was supplied with 2.5 HP of aeration and water circulation effected by two regenerative air blowers.

One 1.5-HP blower propelled the air lift apparatus at the entrance of the IPRS raceway, while another 1.0-HP blower propelled the air lift apparatus of the water moving unit installed at a pond corner diagonally opposite from the IPRS unit. A 55-m long and 1.5 m high baffle curtain, made of woven plastic fiber, was installed diagonally inside each pond to direct the water circulation around the entire pond.

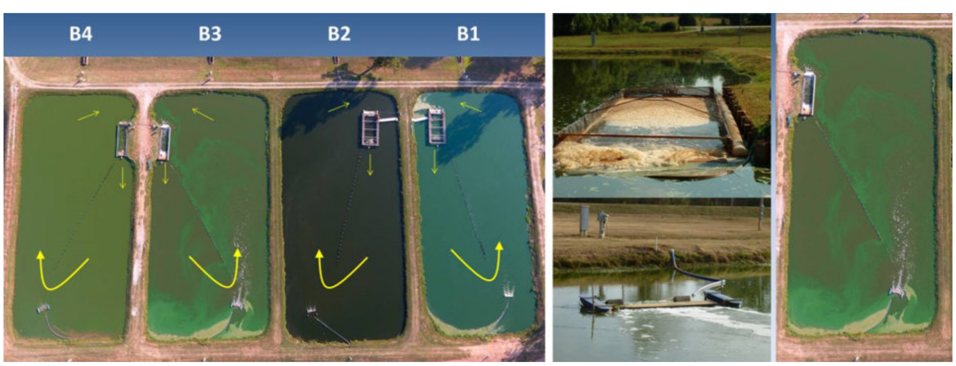

Fig. 2: Aerial view of the four B-ponds housing the IPRS units. The raceways in ponds B1 and B2 (63.6 m3) were larger and occupy 1.3 percent of total pond area, while in ponds B3 and B4 raceways were 45.4 m3 each and covered 0.9 percent of pond area. In each pond, a curtain baffle was assembled extending diagonally from one of the end corners of each raceway towards the opposite corner of the pond,

where another water-moving device was located, to promote a more effective water circulation in the ponds, indicated by the yellow arrows in the photo (original photo by David Cline). A detailed view of the floating raceway and the water-moving device in Pond B3 is shown in the images to the right above.

The raceways were stocked with 41-g hybrid catfish fingerlings (female channel catfish *Ictalurus punctatus* x male blue catfish *I. furcatus*) on March 22, 2016. Fish were fed 32 percent crude protein commercial floating catfish pellets (4 to 6 mm) once or twice a day, depending upon water temperature. Each feeding event lasted for 3 to 5 minutes, until near momentary satiation of fish.

Dissolved oxygen, temperature and other pond water parameters were regularly monitored. Catfish reached market size in early December 2016. Raceways were harvested after nearly 270 days of culture (Figure 3), and fish were sold to an Alabama catfish processor. A summary of the production results is presented in Table 1.

Fig. 3: Harvest of fish from the IPRS was accomplished by fitting a live car at the end of the raceway, removing the end screen of the raceway and pushing a bar grader inside the raceway to corral fish into the live car. The live car with all fish was then pulled to the edge of the pond. With a crane and a basket (boom), fish were loaded into the hauling tanks and transported live to the processing plant.

Kubitza, Raceway, Table 1

	Pond B1	Pond B2	Pond B3	Pond B4
Raceway volume (m3)	63.6	63.6	45.4	45.4
No. of fish stocked	11,030	11,086	8,083	7,821
Feed used (kg)	9,699	9,817	8,200	7,733
Harvested biomass (kg/raceway)	6,388	6,601	5,510	5,467
Final mean weight (g)	617	794	712	817
Pond gross yield (kg/ha)	15,971	16,502	13,774	13,666
FCR	1.64	1.60	1.59	1.50
Standing crop in raceways (kg/m3)	100.5	103.9	121.4	120.4
Survival (%)	86.4	75.0	95.7	85.6

	Pond B1	Pond B2	Pond B3	Pond B4
Water quality variable:	Pond B1	Pond B2	Pond B3	Pond B4
Dissolved oxygen inside raceway (range in ppm)	2.2 – 9.2	2.4 – 9.8	1.9 – 9.2	1.8 – 9.9
Afternoon water p (ranTotal alkalinity (range as ppm CaCO3)	100 to 117	68 to 78	52 to 72	80 to 84
Afternoon water pH (range)	7.0 - 9.5	7.0 - 8.0	7.0 - 9.0	7.0 - 9.5
Maximum afternoon TAN (mg/L)	4.80	8.00	4.80	1.80
Maximum afternoon NH3 (mg/L)	1.66	0.50	0.34	0.01
Maximum NO2- (mg/L)	1.50	1.50	1.60	0.80
Most predominant water color	Green	Light brown	Green	Green
Most common algae bloom	SBG (1)	No blooms	SBG (1)	SBG (1)
Secchi disk at summer and early fall (m)	0.12 – 0.28	0.35 – 0.66	0.16 – 0.32	0.15 – 0.38

Table 1 – Production results from the first-year study of farming hybrid catfish using IPRS technology at Auburn University (270 days of growout; fed 32 percent CP pellets; 0.4 ha ponds, each set up with one IPRS unit; initial fish weight 41 to 43 g).

(1) SBG – surface blue green (cyanobacteria) blooms

Production, feeding rate and water quality

Catfish yield ranged from 13,660 to 16,500 kg/ha and exceeded the target value of 15,600 kg/ha in ponds B1 and B2. Average feeding rates ranged from 70 to 90 kg/ha/day. Maximum feeding rates of 300 to 350 kg/ha/day was reached in all the ponds early fall (late September, in USA), when fish already weighed more than 550 g. Dissolved oxygen concentrations were often low at early morning hours during summer months in all the ponds.

However, inside the raceways oxygen was seldom below 3 mg/L. Dissolved oxygen close to 2 mg/L inside the raceways were registered a few days, when dissolved oxygen in the open pond water declined to values around 1 mg/Liter, as can be seen in Figure 4 for pond B3, the pond that had the lowest oxygen levels.

Other parameters of water quality are summarized in Table 1. Maximum levels of total ammonia nitrogen (TAN) were 1.8 mg/L in pond B4 and as high as 8.0 mg/L in Pond B2. Fish were exposed to the highest concentration of unionized ammonia ($N\text{-}NH_3$ = 1.66 mg/L) in pond B1, since the afternoon water pH in that pond often reached values around 9.0 and 9.5 due to the presence of dense phytoplankton blooms.

In pond B2, despite the high total ammonia levels, toxic ammonia levels were not a concern at all, since phytoplankton blooms did not become established in that pond to cause pH to increase (afternoon pH ranged from 7.0 to 8.0 in pond B1). Nitrite concentration in all ponds remained well below the 7 mg/L LC_{50}-96h determined for channel catfish.

Nonetheless, pond preparation protocol included the application of salt (NaCl) to prevent nitrite toxicity of fish. Chloride levels in pond water ranged from 100 to 140 ppm for all ponds, except for water in B1, which had 300 ppm of chloride.

Fig. 4: Illustration of the early morning dissolved oxygen concentration in the pond (blue area) and inside the raceway (green area) in pond B3. The green area above the blue area indicates how much oxygen the aeration device added to the water at the entrance of the raceway, keeping dissolved oxygen levels inside the raceway often above 3 mg/L (minimum desired level) and seldom below 2 mg/L, even when pond DO approached values close to 1 mg/L.

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