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Occurrences of growth related target dissolved oxygen and ammonia in different catfish pond production systems in southeast Arkansas

John C. Farrelly, Yushun Chen*, Sagar Shrestha

Aquaculture and Fisheries Center, University of Arkansas at Pine Bluff, Mail Slot 4912, 1200 North University Drive, Pine Bluff, AR 71601 USA

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ABSTRACT

Maintaining optimum water quality is vital for catfish pond production. Water quality performance was compared among traditional earthen ponds (TP), intensively aerated ponds (IP), and split-ponds (SP), from May to October, 2012, in southeast Arkansas. Overall mean DO concentrations were above the target DO level (3.0 mg/L) in all ponds without system difference. Total ammonia nitrogen (TAN) in the IP system always had higher values and the overall mean (4.2 mg/L) was higher than other systems (<1.0 mg/L). The current study found similar DO performance among the three production systems, with a less than significant increasing occurrences of growth related target DO level from the IP to the SP, and then to the TP systems. The IP system had a less than significant higher percentage of TAN events above the target level (70% events > 1.0 mg/L) and a significant higher percentage of NH_3 events above the target level (47% events > 0.6 mg/L) than the other two systems. But the high DO concentrations may have reduced the ammonia stress on fish growth in the IP system. Catfish farmers may consider adopting the two new production systems, especially the SP system, on their farms since the overall water quality performance is comparable to and even better than the traditional TP system, plus with higher feed inputs that rendered higher production from preliminary analysis in the new systems. More comprehensive production and cost analysis need to be conducted before the large scale full adoption.

1. Introduction

The catfish industry first began in the United States in the 1960s (Engle, 2003) and catfish was No. 5 of U.S. top ten seafood consumed in 2000 and has now fallen to No. 7 on the list (Hanson and Sites, 2013). The industry peaked in 2003 when it produced close to 300 million kg of round weight catfish, however, ever since then it has been on a downward trend (Hanson and Sites, 2011). Several factors including feed prices peaking $562/ton in August 2012, competition with imports which account for 78% of all frozen fillet sales in the U.S., and the decrease in market catfish prices could be contributing to the current state of the industry (Hanson and Sites, 2013). Catfish farmers in the Southern U.S. are testing new production systems to combat the problems current facing the industry. Traditional earthen catfish ponds were very large reaching up to 40 acres in size (Hargreaves and Tucker, 2003). However, with the discovery that smaller ponds enhanced feeding, disease control, water quality management, and other activities in catfish production, ponds have decreased in size and most ponds built now range from 10 – 12 acres (Hargreaves and Tucker, 2003). Traditional ponds (TP) use aeration rates of roughly 2.76 to 3.68 kW/ha (Tucker, 2005). Some farmers are adding aerators to existing ponds and creating intensively aerated production systems (IP). The industry aeration rate averaged close to 4.6 kW/ha (Matt Recsetar, personal communication) but there are a few farmers that are increasing aeration rates with some reaching 11.05 kW/ha (Torrans, 2005a). As intensification of catfish culture in ponds increases, aeration is necessary and has helped increased yields from 2000 to 3000 kg/ha/yr in the 70s to 4000 to 6000 kg/ha/yr in the 1980s (Hargreaves, 2002). Yields in ponds have even been able to reach 7845 to 11,956 kg/ha (Wurts and Wayne, 1996; Chen et al. 2013, unpublished data). Aeration in aquaculture ponds is extremely important and has a direct relationship to the amount of feed consumed and net fish production. Harvest weight, survival, average weight of fish, and feed conversion ratio (FCR) can all be influenced by the amount of aeration that occurs in a given pond (Andrews et al., 1973; Hollerman and Boyd, 1980; Lai-Fa and Boyd, 1988; Torrans, 2005b).

In addition to the IP system, a new innovative catfish production system called the “split-pond” system (SP) developed at Mississippi State University has been an attractive alternative for catfish farmers in the Southern U.S. in recent years (Tucker, 2009). Split-ponds are typically constructed by dividing a traditional earthen

* Corresponding author. Tel.: +1870 575 8136.
E-mail addresses: cheny@uapb.edu, limnologychen@yahoo.com (Y. Chen).

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Table 1
Characteristics (mean ± SD) of pond size, aeration rate, and stocking density of three catfish pond production systems. TP: traditional ponds, SP: split ponds, IP: intensively aerated ponds. The split and traditional ponds were stocked with both carryover and stocking fish.

Production system	*n*	Area (ha)	Aeration rate (kW/ha)	Stocking density (fish/ha)
SP (Entire pond)	2	4.4 ± 0.0	5.1 ± 0.0	20,976 ± 421
SP (Fish zone)	2	1.1 ± 0.0	21.5 ± 0.3	88,567 ± 4727
TP	3	4.9 ± 0.0	3.1 ± 0.0	19,793 ± 0
IP	4	1.8 ± 0.3	14.5 ± 1.9	25,530 ± 852

pond into two sections, an algal growth basin or waste treatment area (about 80% of the total area) and a fish-holding area (20% of the total area). Typically, in the SP system, fish are held at five times the density of traditional catfish ponds (Tucker, 2009). Split ponds were developed as an alternative to the partitioned aquaculture system developed at Clemson. However, the premise of the split ponds is the same. The increased algal photosynthesis corresponds with an increase in the overall rate of detoxification of pond water (ammonia removal) (Brune et al., 2004). In the SP system, good fish production, high feeding rates, and low feed conversions are the norm (Tucker, 2009). For example, in a 2009 study of a commercial split pond, 17,880 kg/ha of fish were produced with a FCR of 1.83 (Tucker, 2009). The daily feeding rates averaged 162 kg/ha and the maximum daily feeding rate averaged 250 kg/ha from the end of August through September (Tucker, 2009). Net catfish production ranged from 17,000 to close to 20,000 kg/ha and had FCRs below 2.0 from a nine-year study in experimental and commercial split ponds (Tucker, 2009).

To our knowledge, there is no study comparing water quality performance among these different pond production systems. Understanding these characteristics and differences will help farmers manage water quality in these pond systems. Therefore, the objective of this study is to compare the water quality, especially dissolved oxygen (DO) and ammonia, in the above-mentioned pond production systems.

2. Materials and methods

2.1. Experimental ponds and fish

This study was conducted in commercial catfish farms in Chicot County, southeast Arkansas. Two SP, three TP, four IP ponds were selected for the study. Pond size ranges from 4.4 ha for SP, 4.9 ha for TP, and 1.8 ha for IP (Table 1). Aeration rates were 5.0 kW/ha in split ponds, 3.1 kW/ha in traditional, and 14.5 kW/ha in intensively aerated (Table 1). Hybrid catfish (channel catfish female × blue catfish male) were stocked at 20,976 fish/ha in split ponds (carryover and stock hybrid catfish), 19,793 fish/ha in traditional ponds (carryover and stock hybrid catfish), and 25,530 fish/ha (stocker hybrid catfish only) in intensively aerated ponds. Detailed information on pond size, aeration rate, and stocking density were presented in Table 1.

2.2. Aeration management

Each TP (Fig. 1a) was equipped with two 7.5 kW aerators located in one corner of the ponds (14.9 total kW). When dissolved oxygen (DO) fell below 3.5 mg/L, one aerator was turned on. If DO dropped below 2.5 mg/L, the second aerator was turned on. In rare events when DO fell below 1.5 mg/L, an extra tractor powered aerator was placed into the pond. Each IP (Fig. 1b) was equipped with two 7.5 kW aerators and one 11.2 kW aerator (26.2 total kW) spread out along one side of the pond in the left, center, and right. When DO fell below 5.0 mg/L, one 7.5 kW aerator was turned on. The 11.2 kW aerator was turned on when DO fell below 4.5 mg/L. The second 7.5 kW was turned on if DO fell below 4.0 mg/L. Each SP (Fig. 1c) was equipped with three 7.5 kW aerators (22.4 total kW) located in the fish zone facing the waste zone. In the fish zone, when the DO fell below 4.0 mg/L, one 7.5 kW aerator was turned on. When DO fell below 3.0 mg/L, a second aerator was turned on and finally if DO fell below 2.0 mg/L the third aerator was turned on. Emergency aeration using a tractor powered aerator was again used if DO did not return above 2.0 mg/L in the split ponds. Fish were fed with commercial feed (28% protein) to satiation 7 days a week in all ponds.

2.3. Water quality monitoring

To obtain a comprehensive understanding of water quality conditions in the ponds, three sampling frequencies (i.e., monthly, weekly, and within a 24-h period) were conducted throughout this study. Each pond was sampled once at the 50 cm layer from the surface from nine sites during the monthly and weekly sampling frequency (Fig. 1a–c). During the monthly and weekly sampling, the ponds were monitored in the morning from 0900 to noon. We rotated sampling these ponds to make sure all ponds were monitored at similar time slots. In the 24-h sampling frequency, each pond was sampled at two sites. One site was on the aerator side in the middle of the pond. The other was directly opposite of the first site. First, all ponds were sampled each month from May to October 2012 to record temperature (°C), dissolved oxygen (DO, mg/L, by a handheld multiparameter meter, YSI Model Pro2030, Yellow Springs OH), Secchi disk visibility (SD, cm, by a Secchi disk), pH (pH unit, by a handheld EcoSense pH meter), and flow (m^3/s, by a handheld flow meter, split ponds only) in the field. Water samples were collected by acid-washed bottles at the 50 cm layer from pond surface and brought back with ice to the lab for analysis of total ammonia nitrogen (TAN, mg/L), chlorophyll *a* (μg/L), total nitrogen (mg/L), total phosphorous (mg/L), alkalinity (mg/L as $CaCO_3$), and hardness (mg/L as $CaCO_3$). Unionized ammonia (NH_3, mg/L) was calculated using an empirical table that relates unionized ammonia ratios to pond water pH and temperature (Boyd and Tucker, 1998). The second sampling frequency was conducted every week during June, July, and August 2012 to record water temperature, DO, SD, pH, flow, and TAN. The third sampling frequency was a 24-h period sampling (i.e., 0500, 0900, 1200, 1600, 2000, 2400,), which was conducted once (i.e. one 24-h cycle) per month in June, July, and August to record water temperature, DO, pH, and TAN. In June, pH was not measured in the split or intensively aerated ponds at 0500 and was not measured in any ponds at 0900 due to a broken pH meter. Therefore NH_3 was not calculated for any of these times slots. All water sample analysis was conducted using the standard methods (APHA, 2005). Feed information was also collected from cooperating farmers. Most of these ponds had automatic DO monitoring systems installed. However, we were not able to get access to these data. Thus, all the following analyses were based on our manually monitored data.

2.4. Statistical analyses

One way repeated measures ANOVA and Tukey tests were used to test the effects of production systems on the above mentioned water quality parameters. Water temperature, DO, pH, SD, TAN, and