Aquacultural Engineering 75 (2016) 14–21

Contents lists available at ScienceDirect

Aquacultural Engineering

journal homepage: www.elsevier.com/locate/aqua-online

# Oxygenation zones in conventional and split earthen catfish ponds in eastern Arkansas

John C. Farrelly[a], Yushun Chen[a,b,*], Christopher Laskodi[a]

[a] Aquaculture and Fisheries Center, University of Arkansas at Pine Bluff, 1200 N. University Dr., Slot 4912, Pine Bluff, AR 71601, USA
[b] Institute of Hydrobiology, Chinese Academy of Sciences, 7 South Donghu Road, Wuhan, Hubei 430072, China

ARTICLE INFO

*Article history:*
Received 18 December 2015
Received in revised form 7 April 2016
Accepted 24 April 2016
Available online 28 September 2016

*Keywords:*
Oxygenation zones
Conventional ponds
Split ponds
Catfish
Dissolved oxygen

ABSTRACT

Dissolved oxygen (DO) is one of the most important water quality variables associated with catfish culture. Understanding the oxygen dynamics in commercial catfish aquaculture ponds is important for understanding when oxygen problems could arise throughout the growing season. Oxygenation zones (OZ, here defined as the area with DO reaching 2.5 mg/L or greater) in both conventional (CP) and split (SP) earthen ponds were determined and compared in July and August, 2013. Hach Hydrolab data sondes were placed in the ponds, and DO concentrations were measured hourly from 9:00 P.M. to 9:00 A.M. for three consecutive nights. Variables including OZ volume, total DO mass in OZ, kg of DO/m$^3$, fish density in OZ, and kg of fish/m$^3$ in the OZ, and DO isopleths were determined using average DO concentrations. The smallest sizes or lowest volumes of the OZs occurred at 5:00 A.M. in both systems. The OZ volumes at 5:00 A.M. showed no significant difference between systems in both months. The entire fish zone was completely oxygenated in August in the SP ponds. The CP system was considered completely oxygenated at both 12:00 A.M. and 9:00 A.M. in both months, and the OZ volumes were significantly larger than those in the SP system at the same time slots. The fish density and kg of fish/m$^3$ in the OZ reached the highest at 5:00 A.M. in both systems in both months but without system difference. These results could help farmers evaluate the overall water quality performance of the two pond production systems.



## 1. Introduction

The catfish industry first began in the United States in the 1960s (Engle, 2003). Catfish was fifth on the U.S. top ten list of seafood consumed in 2000 and has now fallen to seventh on the list (Hanson and Sites, 2013). The industry peaked in 2003 when it produced close to 300 million kilograms of round weight catfish; however, ever since then it has been on a downward trend (Hanson and Sites, 2011). By 2012, less than 136 million kilograms of catfish was being produced (Hanson and Sites, 2013). Several factors including feed prices peaking at $562/t 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).

Many techniques have been developed for growing catfish throughout the maturation process of the industry. For instance, maintaining adequate water quality in production ponds is vital to high overall production. Many water quality variables can directly influence catfish aquaculture. For example, dissolved oxygen (DO), which is considered one of the most important variables, has been shown to affect the growth (Andrews et al., 1973; Carlson et al., 1980), feeding rate (Carlson et al., 1980; Torrans, 2005, 2008; Green and Rawles, 2011), net yield (Torrans, 2005; Green and Rawles, 2011), individual weight of fish (Torrans, 2005; Green and Rawles, 2011), feed conversion ratio (FCR) (Andrews et al., 1973; Torrans, 2005), and mortality in extreme DO depletion events (Torrans, 2005). The industry has also been using hybrid catfish, a male blue catfish *Ictalurus furcatus* crossed with a female channel catfish *I. punctatus*, for years as a way to stay competitive within the aquaculture industry. Hybrid catfish have been shown to tolerate DO depletions better, have higher mean individual weight, lower FCRs, higher production in some circumstances, higher nugget yield, lower fillet fat, and have better fillet yield and dress-out percentage (Dunham et al., 1983; Argue et al., 2003; Li et al., 2004; Green and Rawles, 2011). While there are many benefits to using hybrid catfish, the net yield of channel catfish and hybrid catfish grown under similar conditions did not show significant differences (Green and Rawles, 2011).

* Corresponding author at: Institute of Hydrobiology, Chinese Academy of Sciences, 7 South Donghu Road, Wuhan, Hubei 430072, China.
*E-mail address:* yushunchen@ihb.ac.cn (Y. Chen).

http://dx.doi.org/10.1016/j.aquaeng.2016.04.008
0144-8609/

**Table 1**
Individual pond descriptions. SP: split ponds, CP: conventional ponds.

| Production system | Area (ha) | Aeration rate (kW/ha)[a] | Stocking density (fish/ha)[a] | Weight stocked (kg/pond) | Date stocked |
|---|---|---|---|---|---|
| SP-1 | 2.79 | 35.5 | 31,967 | 3955 | 4/8/2013 |
| SP-2 | 2.79 | 35.5 | 29,377 | 3638 | 4/8/2013 |
| CP-1 | 3.24 | 6.9 | 14,908 | 5237 | 3/1/2013 |
| CP-2 | 3.24 | 6.9 | 14,576 | 5570 | 3/6/2013 |

[a] Aeration rates and stocking density in the SP systems were calculated based on the fish zone area.

Along with maintaining adequate water quality and using hybrid catfish to continue to remain competitive, catfish farmers in the Southern United States are also implementing new production systems to combat the problems currently facing the industry. Traditionally, earthen catfish ponds were very large reaching up to 16 ha 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 4 to 5 ha (Hargreaves and Tucker, 2003). Conventional ponds (CP) use aeration rates of roughly 2.76–3.68 kW/ha (Tucker, 2005). In addition to the CP systems and other production systems, an innovative catfish production system called the “split-pond” (SP) was developed at Mississippi State University and has been an attractive alternative for catfish farmers in the Southern U.S. in recent years. Split ponds are typically constructed by dividing a conventional earthen 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 split-pond system, fish density is five times that of conventional catfish ponds (Tucker, 2009). Split ponds were developed as an alternative to the partitioned aquaculture system developed at Clemson University. However, the premise of the split-ponds is the same. A smaller zone will hold the fish, and the larger waste area will treat fish waste and produce oxygen during the day through photosynthesis. In split-pond systems, 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). From a nine-year study in experimental and commercial split-ponds, net catfish production ranged from 17,000 to close to 20,000 kg/ha and had FCRs below 2.0 (Tucker, 2009). The split-pond system has been tested, and there is an increasing trend of applications in commercial ponds in the Mississippi Delta. We have compared occurrences of growth-affecting DO and ammonia in these different culture systems in previous studies (e.g., Farrelly et al., 2015). However, we are still not clear on the DO dynamics and distribution in these systems, which will be very useful in evaluating the overall water quality performance and understanding DO limitations in these systems.

Thus, the objective of this study was to determine and compare oxygenated zones of conventionally operated and split-pond production systems. Results of this study may aid farmers in deciding which production system is better for their farm in the current catfish industry.

## 2. Materials and Methods

### 2.1. Experimental ponds and fish stocking

Two split ponds (SP) and two conventional earthen ponds (CP) in eastern Arkansas were selected for this study. Mean sizes of the ponds were 2.8 ± 0.0 and 3.24 ± 0.0 ha for the SP and CP systems, respectively. The stocking densities for the SP and CP systems were 30,672 ± 1831 and 14,742 ± 234 fish/ha. Both the CP and SP systems were equipped with three regular 10-hp paddlewheel aerators. Aeration rates were 35.0 ± 0.0 and 6.9 ± 0.0 kW/ha for the SP and CP systems, respectively. Aeration rates and stocking densities for the SP system were calculated using only the size of the fish zone. Detailed information of the individual ponds used is presented in Table 1.

### 2.2. Data sondes set-up and data collection

An area of water was considered to be in the oxygenation zone (OZ) if its DO was 2.5 mg/L or greater. The OZs were quantified twice for each system in July and August, 2013. The ponds were sampled in an alternating fashion (i.e. SP-1, CP-1, SP-2, and CP-2). DO was measured at 40 cm below the surface from 9:00 P.M. to 9:00 A.M. by using Hydrolab DS5X Multivariablesonde (HachHydromet ®) data loggers. Data loggers were held in place by a 3.66-m steel pipe driven into the pond bottom with a sledgehammer. Another 0.61-m pipe with a 0.3-m chain welded to it was attached to an adjustable piece of metal that was attached to the original 3.66-m pipe. Depending on how deep the 3.66-m pipe was driven into the pond bottom, an adjustable piece of metal could be moved up or down to set the DO probe of the data logger at 40 cm below the surface.

The fish zone of each split pond was measured and marked with stakes to spread the Hydrolab data loggers out in a grid formation. For example, the fish zone in SP-2 was measured to be roughly 80-m by 80-m. Two rows of data loggers were placed at 40% and 80% of the distance from the shore where the aerators were placed. The two rows of data loggers were placed at 31.2 m and 62.4 m from the aerators side, respectively (Fig. 1). The three columns of data loggers were placed at every 20 m across the pond, which was 25% of the total distance across the pond (Fig. 1). Stakes were placed along the sides of the banks where data loggers were to be placed (at the previously mentioned measurements). Rope was attached

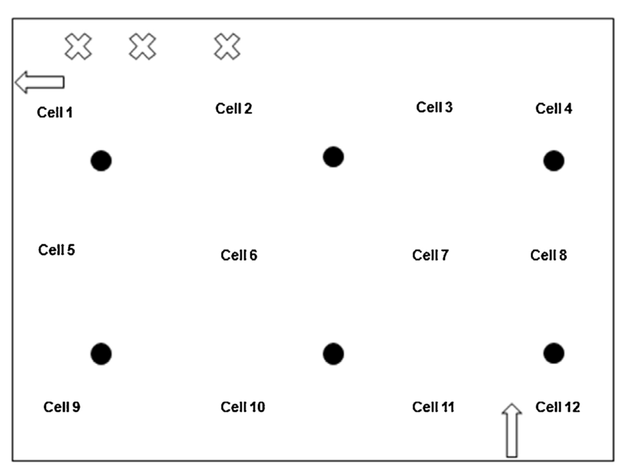


**Fig. 1.** Hydrolab data loggers (round dots) placement in fish zone of split-ponds. Arrows represent where water leaves and enters the fish zone during the day. The three Xs indicate aerators. The fish zone was divided into spatial cells to quantify oxygenation zones.