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Fish stocking density impacts tank hydrodynamics

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Abstract

The effect of stocking density upon the hydrodynamics of a circular tank, configured in a recirculation system, was investigated. Red drums *Sciaenops ocellatus* of approximately 140 g wet weight, were stocked at five rates varying from 0 to 12 kg m^{-3}. The impact of the presence of fish upon tank hydrodynamics was established using in-tank-based Rhodamine WT fluorometry at a flow rate of 0.23 l s^{-1} (tank exchange rate of 1.9 h^{-1}). With increasing numbers of animals, curvilinear relationships were observed for dispersion coefficients and tank mixing times. Stocking densities of 3, 6, 9 and 12 kg m^{-3} resulted in a 0.2-, 0.5-, 2.4-, and 3.2-fold decrease in mixing time relative to that observed for empty tanks ($P<0.001$).

Keywords: Red drum; Hydrodynamics; Hydraulic residence time; Rhodamine; Dispersion number

1. Introduction

Considerable care must be taken during all phases of the engineering process of recirculating aquaculture systems (RAS) to ensure system stability and profitability. Of significance in this regard is the design of the central holding units since poor architecture can strongly influence hydrodynamics (Rasmussen and McLean, 2004). Poor tank hydrodynamics may affect dead volumes, metabolite dilution, fish exercise and behavior, feed dispersion and opportunity, water quality and waste management, and animal health and susceptibility to disease (Burley and Klapsis, 1988; Griffiths and Armstrong, 2000; Odeh et al., 2003; Rasmussen et al., 2004). An in-depth grasp of the hydrodynamic environment, therefore, represents a critical feature that must be taken into consideration if enhanced production potential and operational success is to be realized with RAS. Equally, a thorough appreciation of those factors that influence the tank mixing process must also be recognized to permit elite tank design and management. Although stocking density is known to influence production potential and thus profitability (Jørgensen et al., 1993; Irwin et al., 1999) little is known of the effect of stocking upon in-tank mixing processes. Such information could represent an important parameter that might be gainfully employed during tank engineering and production.

Several studies have examined general tank mixing processes (Burley and Klapsis, 1988; Rasmussen and McLean, 2004) whereas a number of works have considered fish hydromechanics (Weihs, 1973; Webb, 2002; Blake, 2004). However, although it might be anticipated that the presence of fish within a tank positively influences the mixing process, categorical support for this conjecture does not exist. Indeed, studies

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that have examined the effect of fish upon tank mixing provide contradictory results (cf. Burley and Klapsis, 1985; Watten and Beck, 1987; Watten et al., 2000). The reasons for these inconsistencies are various but may reflect methodological difficulties, especially in the use of outlet only measurements of tracers, differences in stocking densities employed or tank depth. More accurate discrimination of the impact of fish upon tank mixing should be obtainable using in-tank tracer measurements (Rasmussen et al., 2005). Accordingly, the objective of the present study was to evaluate the impact of fish upon tank mixing processes and specifically to determine whether stocking density influenced the hydrodynamic environment of RAS tanks. Five different stocking densities were examined (0–12 kg m^{-3}) and their impact upon mixing recorded using in-tank tracer measurements.

2. Materials and methods

All studies were undertaken using a four tank seawater recirculating aquaculture system (Fig. 1). This system had been in continuous operation for a period of two years for the holding of red drum, cobia and summer and southern flounders. Throughout this period, no mortalities were recorded in any of the tanks. The recirculation configuration comprised a KMT-based (Kaldnes Miljøteknologi, Tønsberg, Norway) moving bed biofilter, a bead filter (Aquaculture Technologies Inc., Metaire, LA, USA) for solids removal, a protein skimmer and a UV sterilizer (Aquatic Ecosystems, Apopka, FL, USA). The fluidized bed was oxygenated using diffusion air lines connected to a 1 hp Sweetwater remote drive regenerative blower (Aquatic Ecosystems, Apopka, FL, USA). Water temperature (22 °C) and DO_2 (>7 mg l^{-1}) were monitored daily using an Y85 Series dissolved oxygen meter (YSI Inc., Yellow Springs, OH). Total ammonia nitrogen (TAN; range: 0.01–0.35 mg l^{-1}) was monitored daily by spectrophotometric analysis (Hach Inc., Loveland, CO, USA). Nitrite (range: 0.06–0.36 mg l^{-1}) and nitrate (range: 3.9–24.5 mg l^{-1}) levels were quantified once weekly. Salinity (8‰) was measured with a temperature compensated refractometer (Aquafauna Bio-Marine, Hawthorne, CA, USA). Lighting was derived from phosphorescent tubes positioned 6 m above the system.

Tank 1 (Fig. 1) was used as the experimental tank whereas tanks 2 and 4 were employed to hold experimental animals. To maintain a constant flow into tank 1, water was pumped from tank 3 using a submersible pump (Little Giant Pump, Oklahoma City, OK, USA). This strategy was employed to avoid changes in flow due to the accumulation of organic matter within the bead filter. Water flow into tank 1 was monitored using a Dialog MM3 flow meter (Master Meter, Mansfield, TX, USA). Flow rates into the tank were controlled using valve adjustments to the feeder line from tank 3. Throughout all studies, flow rate was maintained at 0.23 l s^{-1} with a tank exchange rate of 1.9 h^{-1}. The inlet was a single inlet with a diameter of 0.038 m. The inlet was

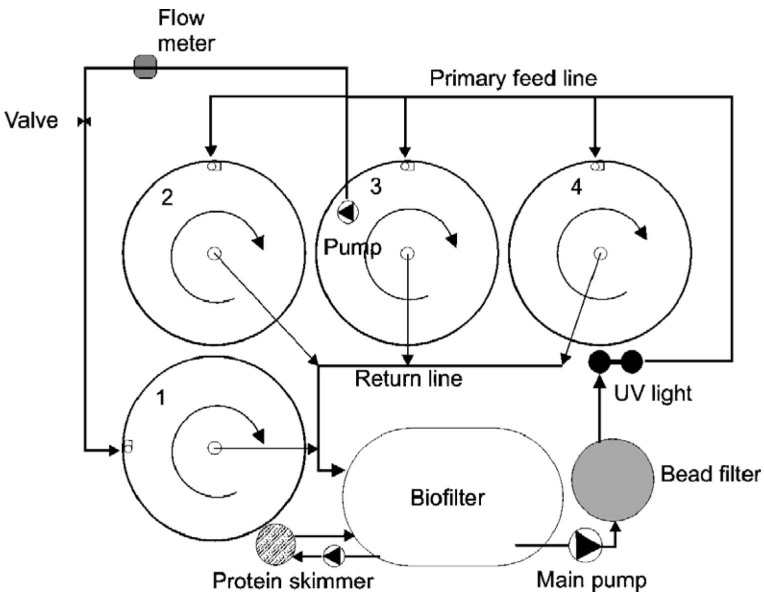

Fig. 1. Diagram illustrating the overall design features and configuration of the experimental marine recirculating aquaculture system employed during the current investigations. All measurements were taken from tank number 1, whereas water supply was derived from tank number 3.