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Simple low-cost Recirculating Aquaculture System for Native Amazonian fish hatchery under controlled conditions

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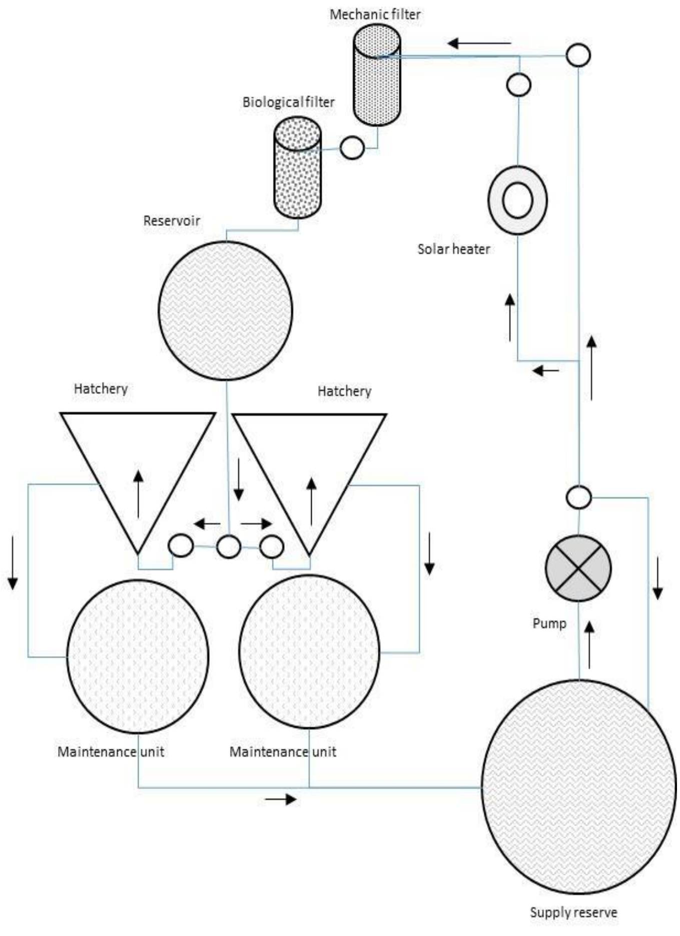
Graphical Abstract

Tropical fish hatching coupling (TFHC)



Abstract.

This research has focused on the generation of an economic, efficient and safe technology that allows adequate control of water consumption and uses recirculation to control factors associated with water quality. Aquaculture companies interested in providing a recirculating aquaculture system (RAS) for tropical fish farming can replicate this prototype to be successful in all areas of production. The design was based on the use of locally available components, equipment and recycled containers for mechanical and biological filters. Two recirculation systems were implemented: i) maintenance of aquatic organisms (MAO); ii) tropical fish hatching coupling (TFHC). In both cases, operating tests were performed with electric and solar heaters. The requirements for oxygenation, evacuation, separation of biosolids, biofiltration, CO_2 degassing, fish metabolites, pathogens control, temperature maintenance and variables measurement were all adapted and solved. Results show that the RAS provides controlled conditions for temperature, dissolved oxygen and pH stability. Nitrogen was safely removed in quantities acceptable to tolerant levels. Environmental adaptation for artificial hormonal induction treatments create a significant temperature increase. Solar heating adaptations stabilized this process; oxygen remained saturated and at respectable levels. The biofilter systems kept all important water quality parameters in balance. The recirculation systems removed NO_2 and NO_3 organic load. The recirculation flow rate was regulated in the MAO at approximately 10 l/min, a replacement rate of 120% per hour; while in the TFHC a flow rate of 7 l/min per incubator was used, i.e. 14 L/min in the system, which implies a replacement of 280% in the incubators and 170% in the maintenance tanks.

Introduction

As part of the adaptation process in captivity, Amazonian reophilic, native species group, requires hormonal induction. Adequate facilities must be provided in order to get control of the reproduction processes necessary [1]. Having access to a laboratory helped to improve production processes that were relevant, such as: i) dosage and monitoring of hormonal induction treatment; ii) control of female spawning and male ejaculation; iii) egg fertilization, hydration and hatching; iv) larval harvesting and subsequent post-larvae nursery for breeding as juveniles [2].

In the Amazonian Ecuadorian region, exist approximately 14 hatcheries that focus on reproduction [3], nevertheless only four of the respective hatcheries produce *Piaractus brachymus* fry, consistently [Burgos, *obs. pers.*]. It is necessary to increase and diversify in the knowledge of RAS (Recirculating Aquaculture Systems) using local social-economical context, where required to adapt technology towards its affordability and resources to increase production [4]. In addition, it should also be noted that in the Amazon there are many species of commercial interest that are also flagship umbrella species such as *Brycon amazonicus*, *Prochilodus nigricans*, *Pseudoplatystoma fasciatum*, among others [5]; Laboratory support is essential in helping species in captivity make their spawning possible [6].

Recirculation systems in aquaculture allow controlled aquatic environments with stable conditions in terms of physical-chemical quality of the water; and especially temperature with very little variation, if new influent water is controlled [7,8]. Thus, this research has concentrated on the generation of an economic, efficient and safe technology that allows the adequate control of influent flow and recirculation. Factors associated with water quality such as temperature, dissolved oxygen, pH, suspended solids, and Nitrogen in its various forms are also controlled.

Materials and Methods

Experimental area; the initiative was performed at the UEA's aquatic resources program at the Center for Research, Postgraduate Studies and Amazon Conservation -CIPCA-, located at Km. 44 of the Puyo-Tena road, 550 m.s.a.l. Located in a tropical rainforest, the ecosystem has an average environmental temperature of 24 Cº, and between 3600 and 5500 mm annual precipitation. The freshwater used came from Piatúa River with 21°C, ph 7, and it is the same source for the CIPCA's aquaculture system.

RAS design and construction; It was based on the use of locally available components. Recycled containers for mechanical and biological filters were used. The entire system was split into two recirculation systems, both continuously adjusted to achieve greater efficiency. Special attention was put into the systems temperature preservation. In both systems, heaters producing (20 Watts per 100 L) were tested and eventually solar radiators were installed. Each system was equipped as follows:

i) Maintenance of aquatic organisms (MAO). This system had two broodstock tanks. A 650 L supply reservoir was used and a centrifugal pump (0,5HP). Flow was regulated by return valves and a main access valves, which sent water to the solar heater at a higher altitude. Temperature control was carried out by flow valves, which forced water to descend by gravity to the mechanical filter (60L) and biological filter (60L). This is where it passed to a second high reservoir (250L) that allowed pressure in the water column to be regulated and open accessibility to the maintenance production units (250 L each).

ii) Tropical fish hatching coupling (TFHC). This system has two hatchery and two maintenance units for aquatic organisms coupled to each other. It has a 650 L supply reservoir, centrifugal pump (0,5HP) with return valves for flow regulation, main access valve, which sends to the solar water heater at higher altitudes. Temperature control is carried out by means of passage valves so that it descends by gravity towards the mechanical filter (60L) and biological filter (60L). Where it passes to a second high reservoir (500L) that allows regulating of the pressure created in the water column and accessibility to the Woyranovich type incubation units of 200 L each, and maintenance units (250 l each).

The requirements for oxygenation, evacuation and separation of biosolids, biofiltration for excretion products, degassing of CO_2 and fish metabolites, control of pathogens, maintenance of temperatures and facilitation of measurement of variables were adapted and solved according to manuals available [8,9]. UV lamps for water disinfection were not used.

Booting the system; the modules were operated only with primary source water for 14 days before each spawning, The biological filter's microorganisms colonization period was achieved to provide better system cycling

Hatchery test running, *Brycon amazonicus* testing took place in the hatchery support system for two years in a row, for seven spawning events. The egg production was 300±50g, the broodstock were approximately 5 to 6 years of age with an average weight 3,75±0,35 kg. Five groups of breeders were selected, two females and three males for each spawning, thus, an animal load of 20kg is estimated for MAO line and between 400g and 600g of eggs for TFHC. The replacement and recirculation rates were carried out by means of flow regulation measurements based on the balance of fish's support oxygen requirements consumption and eggs' hatch suspension, value estimated around O_2 6mg/L [6].

Evaluation system performance, basic measurements were made of temperature, pH, dissolved O_2 (% saturation and mg/l concentration), nitrogen as NO_2 and NO_3, with and without hatch process.

Statistical analysis, the dependent variables were the factor controlled by the built hatchery module as: Temperature, nitrogen, pH and Oxygen concentration. These were compared in a completely random way, considering as blocks treatments, the water inlet, the first prototype; and the two systems without and hatch process. ANDEVA was realized and after mean discrimination were performed.

Results and Discussion

As was explained, the water supply has 21°C, which is a low temperature to undertake the processes of induction to spawn and incubation of fertilized eggs [1,6]. The recirculation system provides managed conditions to facilitate this process with greater stability in temperature, concentration of dissolved and saturated oxygen, pH, and removal of nitrogen in quantities and forms that can be toxic [10]. As observed in Table 1, the more stabilized factor was the temperature while NO_2 and NO_3 suffered changes due to the animal load during the spawning period, maintaining a toxic free level during the hatchery process. An even greater stability was observed using and adopting the solar heater.

Table 1, Physical-chemical parameters of water in different types of recirculation

Factor of measurement	Recirculation treatments					
	Water inlet	**First prototype**	**MAO without load**	**MAO in hatch**	**TFHC without load**	**TFHC in hatch**
Temperature (°C)	$21±1^a$	$22±1^{ab}$	$24±0,5^c$	$24±0,5^c$	$24±0,5^c$	$24±0,5^c$
pH	7±0,35	7±0,3	7±0,3	7±0,3	7±0,3	7±0,3
Dissolved Oxygen [O_2 mg/l]	6,5±0,5	6,75±0,7	6,75±0,7	6,75±0,7	6,75±0,7	6,75±0,7
Saturated Oxygen (%)	$84±12^a$	$94±5^b$	$94±5^b$	$94±5^b$	$94±5^b$	$94±5^b$
Conductivity (μs)	36±15	36±15	36±15	36±15	36±15	36±15
Nitrite [NO_2 mg/l]	$0,2±0,1^a$	$0,1±0,05^b$	$0,1±0,05^b$	$2±0,01^c$	$0,1±0,05^b$	$2±0,01^c$
Nitrate [NO_2 mg/l]	$1±0,1^a$	$0,8±0,2^b$	$0,8±0,2^b$	$4±0,3^c$	$0,8±0,2^b$	$5±0,3^c$

Note: super indices ^{a}, ^{b} and ^{c} are significant statistical difference

The MOA and TFHC modules systems adaptation was made possible with the artificial induction treatments for *Brycon amazonicus*, due the temperature increment and stabilization, trough solar heaters. Moreover, oxygen remains in saturation concentration; and NO_2 and NO_3, was removed by the biofilter systems and remained stable and below concentrations that do not affect the organisms in the recirculation systems [11].

The recirculation flow rate was regulated in the MAO at approximately 10 l/min, i.e. a replacement rate of 120% per hour; while in the TFHC a flow rate of 7 l/min per incubator was used, i.e. 14 L/min in the system, which implies a replacement of 280% in the incubators and 170% in the maintenance tanks. The objective of the over-dimensioning of the recirculation was to ensure adequate handling conditions.

Conclusions

The construction and improvement of the recirculation system with the two lines; makes possible the adequate conditions for the artificial induction of reophilic fish such as *B. amazonicum*; being a suitable installation for these procedures. It is found that this type of recirculation system in which certain adjustments can been made, helps to facilitate other conditions according to the species that is available.

The incorporation of the solar heating system allows two important benefits within the layering process, such as the rise in temperature and its stabilization, which regulates and alleviates the performance of the filtration system. Moreover, mechanical and biological filters allows a significant removal and steadying of nitrogenous materials, such as NO_2 and NO_3, despite having animal load, both in maintenance and incubation.
The environmental conditions of CIPCA have allowed the sexual maturity of the reophilic species; thanks to the management of the water temperature; the same one that is in a range of temperature between 24 and 27°C.

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