A simple and low-cost recirculating aquaculture system for the production of *Arapaima gigas* juveniles

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Abstract: A simple and low-cost recirculating system (RAS) for production of arapaima (*Arapaima gigas*) juveniles is described. Twenty arapaima fry (mean 13.0 cm, 12.0 g) were housed in three production tanks and fed a high HUFA diet resulting in 90% of fry successfully progressing to juveniles (mean 17.4 cm long; 40.2 g). The fish were then reared for a further 72 days fed on commercial extruded pellet feed achieving a mean length of 42.6 cm and 656.6 g. The simple and low-cost RAS holds good potential for production of *Arapaima gigas* juveniles.

Keywords: Amazon, Ecuador, Aquaculture

Un sistema artesanal de recirculación de agua para el producción de juveniles de *Arapaima gigas*

Resumen: Se presenta un sistema artesanal de recirculación de agua (SRA) de bajo costo. Veinte alevines de arapaima (mean 13.0 cm; 12,0 g) fueron alimentados con una dieta artificial alto en HUFA con una supervivencia de alevines a juveniles (mean 17,4 cm long; 40,2 g) de 90%. Posteriormente los juveniles fueron mantenidos en las mismas condiciones por 72 días con una dieta balanceado extruido y alcanzaron un tamaño promedio de 42,6 cm y 656,6 g. Se considera que este sencillo SRA tiene potencial como alternativa tecnología para el producción de juveniles de *Arapaima gigas*.

Palabras clave: Amazonia, Ecuador, Acuicultura

In open pond culture, in the Amazonian region, arapaima (*Arapaima gigas*) fry are susceptible to water quality changes, predation, bacterial and parasitic infections (Araujo et al. 2009; Núñez 2012; Delgado et al. 2013; Mathews et al. 2014; Serrano-Martínez et al. 2014). As one of the main hurdles to successful aquaculture of arapaima is the production of juveniles for on-growing in ponds (Núñez 2012), and floating cages (Gonçalves de Oliveira et al. 2002), or perhaps production in recirculating aquaculture systems (Schaefer et al. 2012), it is imperative to improve the survival of fry to juveniles.

Although recirculating aquaculture systems (RAS) allow for greater control over water chemistry, water temperature, and isolation from pathogens; for many organisms cultured in RAS there exists susceptibility to high levels of ammonia, nitrite, pH and dissolved carbon dioxide, low levels of dissolved oxygen, along with the requirement for intensive management (Masser et al. 1999). Arapaima is an ideal candidate for RAS due to high tolerance for ammonia (Sagratzi Cavero et al. 2004), and otherwise unfavourable levels of dissolved respiratory gases because they are obligate air breathers (Schaefer et al. 2012). This high tolerance eliminates the requirement for back-up systems in the event of pump failure or electrical outages in the RAS which would otherwise cause difficulties for other finfish species. Furthermore arapaima is well suited to high density RAS culture conditions because the species does not exhibit intraspecific aggression within same-size cohorts (Schaefer et al. 2012).
We developed this simple low-cost RAS with the objective of promoting arapaima aquaculture at the artesanal level in Ecuador’s Amazon region. The RAS is composed of three elevated production tanks (57 cm from floor to base of tanks), pre-sump and main sump, utilising 1 m³ circular-cylindrical HDPE plastic tanks (diameter 131 cm x height 81 cm) (Indeltro S.A.). The system is based on pumped flow to the production tanks with return gravitational flow to the pre-sump, and cross-flow to the main sump (Figures 1 & 2).

A 0.55 kW continuous duty centrifugal pump (Paolino model PKm 65, flow rate 42 l/min) draws water from the bottom of the main sump to pump under pressure to the production tanks (Figure 2). The pump flow rate to the tanks was set at 850 lph due to the flow-rate capacity limitation of the 18 watt ultraviolet lamp sterilizer (AquaMedic Helix Max; maximum flow-rate 1 m³/hr).

Excess pumped water is sent back to the main sump before the inline ultraviolet sterilizer via a bypass line. At a flow rate of 283 lph to each production tank, a complete water exchange per tank is achieved within 2 hrs.

Mechanical filtration is composed of a simple readily available 39 x 60 x 30 cm perforated plastic crate modified to suspend over the pre-filtration tank. The plastic crate houses a 52 x 61 cm 500 µm nylon mesh screen that receives the discharge from the production tanks by gravity flow (Figure 2). Beneath the nylon mesh screen are 80 x 50 cm polyester felt pads (5 µm) for further filtration of suspended solids. Within the pre-filtration tank we used water hyacinth (Eichhornia crassipes) for preliminary biological filtration and removal of nitrate (Díaz et al. 2014) (Figure 2).

Figure 1. Schematic diagram of the recirculating aquaculture system (bv = PVC ball valve).
Final biological filtration is achieved via a down-flow semi-submerged rock biofilter (crushed dolomite #57, bed depth 12 cm) utilising one 39 x 60 x 30 cm perforated plastic crate suspended in the main sump. A further 52 x 61 cm, 500 µm nylon mesh screen, receives the inflow to the biofilter and contains 450 g of granulated activated carbon (GAC) (Figure 2). An uneven floor meant that production tank water volumes were set at 439 liters, 452 liters, and 493 liters, with a corresponding water depth of 32.5 cm, 33.5 cm, and 36.5 cm per production tank, respectively. In addition, the pre-filtration tank holds 972 liters and the main sump with biofilter holds 662 liters, thus giving an overall system capacity of 3.02 m³/hr. No PVC cement or PVC pipe glue was used anywhere in the construction of the system. We threaded PVC pipe connections and sealed with teflon tape. Elsewhere reinforced plastic hose was fitted using stainless steel clamps.

The suction line from the main sump to the centrifugal pump is 19 mm (Ecuador 3/4”) PVC pressure pipe, including the bypass line back to main sump. The bypass flow rate is adjusted via a 19 mm (Ecuador 3/4”) PVC ball valve (Figure 2). The pressure line to the UV sterilizer is 19 mm (Ecuador 3/4”) reinforced hose, however the reinforced hose leaving the UV sterilizer to the production tanks is 25 mm (Ecuador 1”) in order to create a pressure drop with the UV sterilizer polycarbonate housing to protect the rubber seals of the housing from damage. Twenty-five millimetre (Ecuador 1”) PVC ball valves are used to adjust the flow rate to production tanks. All drain lines are 50 mm (Ecuador 2”) reinforced plastic hose, including the connection between the pre-sump and main sump. The return line from production tanks to the pre-sump is lifted to 90 cm (from floor level) for control of water height in the tanks, and an inverted 50 mm T is fitted and connected to a vertical 40 cm long piece of 50 mm (Ecuador 2”) hose to work as a siphon break (Figure 2).

Production tanks were stocked at a density of 8, 6, 6, fry per tank. This stocking density was purely the result of the difficulty of obtaining legally farm-produced arapaima fry in Ecuador. Probiotic (INVE Sanolife MIC-S) was added to each production tank at an initial rate of 0.7 g/day. After 21 days, this was increased to 0.9 g tank/day. On collection from reproductive ponds, fry were fed live artemia for the first 10 days (Guerra et al. 2002; Franco-Rojas and Peláez-Rodríguez 2007) before acclimation to a commercial crumble diet (S500 Crumble #3, Gisis S.A., 50% protein) for a further 12 days before shipment. On arrival at the RAS, fry were switched to a high HUFA diet (Artemac #4, Aquafauna Bio-Marine, Inc., 57% protein) and fed six times a day. Fry were initially fed at a rate of 8.5% bodyweight/day of Artemac, however, this was subsequently reduced to 3.7%.

Figure 2: A: Main sump showing biofilter, centrifugal pump, and UV steriliser setup. Note bypass line before the UV steriliser. B: Detail of return line to sump. Note tanks sitting on plastic crates to give head height for gravitational flow to pre-sump. C: Detail of pipework to control water depth in tanks with simple siphon break. D: Pre-sump showing simple screen filter, water hyacinth (Eichhornia crassipes), and pipework for cross flow to main sump (see text for details).
bodyweight/day as the higher initial rate resulted in large amounts of uneaten feed. On transformation to juveniles (mean 17.4 cm long, 40.2 g) the arapaima were fed initially 10 x day. This was subsequently reduced to 8 x day; then to 4 x day; and finally to 3 x day as fish increased in size. Pellet size was 2.2 mm for the first 19 days and then progressively increased to 3.0 mm, 4.0 mm, and 5.0 mm. Throughout the experiment juvenile arapaima were fed to satiation. Initially this corresponded to 5% per day of total estimated biomass; by day 23 this had been reduced to 3.7% of total estimated biomass; and by day 38 food consumption was 2.5% of total estimated biomass; by day 58 the arapaima juveniles were fed 2.1% per day of total estimated biomass; and by day 72 this had decreased to 1.3% per day of estimated total biomass. Any uneaten feed and faeces were siphoned from production tanks at the end of each day. This amounted to approximately 400 litres of replacement water, equivalent to a 13% daily water exchange.

Fish were sampled 2-3 times per month in order to avoid undue stress and because the arapaima would stop feeding for 24 hrs after handling (see Gomez 2007). Fish were measured for total body length and wet weight. Two to three fish were randomly caught from each production tank using a scoop net. Ammonia was measured via a Salifert ammonia test kit. Nitrate, nitrite, pH, and carbonate hardness were measured using aquarium test strips (eSHA Aqua Quick Test). Water temperature and dissolved oxygen was monitored via a Hach portable meter model HQ30d.

Water temperature ranged between 25.8 to 30.5 °C over the 97 days of the experiment, pH 6.4 - 7.2 (with one peak at pH 8), carbonate hardness between 53 to 178 mg/l (with two peaks to 356 mg/l). Throughout the study ammonia remained below 0.25 mg/l and nitrite was fairly constant at 1 mg/l (except for one peak to 3 mg/l). Nitrate ranged from 0 to 25 mg/l.

Within 24 hrs after fry were introduced to the production tanks, fry readily accepted Artemac. However, in order to initiate filter feeding behaviour a gentle current was required. By adjusting the directional flow of water to the tanks, a clock-wise current (1.4 cm s$^{-1}$) was created within production tanks. As fry tended to stay in the area of water influx to tanks, Artemac needed to be carefully applied to the area where the fry congregated. There was a tendency for wastage of around 20% of the applied Artemac. As fry were easily alarmed we refrained from handling fry until their transformation to juveniles after 25 days. Survival rate of fry to juveniles was 90%. The mortality of two fry was ultimately attributed to a delay in transport between Lago Agrio, Provincia Sucumbios, and release of fry to the RAS. This delay resulted in fry being held in sealed polyethylene bags without water exchange or addition of fresh air/oxygen for 96 hrs. Fry transformed to juveniles after 25 days in the RAS. The total alevin and fry period was estimated to be 77 days. Survival rate of juveniles was 100%. Arapaima juveniles achieved a mean final length of 42.6 cm and 656.6 g in 72 days (Figures 3 and 4). Final biomass of juveniles was estimated as 11,818.8 g from an initial biomass of 723.6 g.

Figure 3. Growth and weight of arapaima held for a total of 97 days in the RAS. Length data is absent for fry before shipment.

The design of the recirculating aquaculture system was based on simplicity. We decided that for the RAS to be successful it must be simple enough for anyone with a basic plumbing knowledge to be able to build anywhere in Ecuador’s Amazon region, where potable fresh water or treated mains water, and stable electric power is available. We also purposely used materials that are readily available throughout Ecuador, where only the ultraviolet lamp sterilizer could be considered as specialized equipment. The whole system is able to be disconnected and moved to any location in Ecuador where ambient temperatures are with the desired range for A. gigas (27.5 - 32.4 °C, Núñez et al. 2011). At an estimated turnkey cost of $2,000 USD, the system is sufficiently economical to be built by low-income families and impoverished communities in the Ecuadorian Amazon,
perhaps via the availability of small zero interest government grants. Capacity of the system is also readily scalable where more tanks may be added by simply increasing pump capacity, UV lamp wattage, functional area of the mechanical filter and biofilter, and/or increasing the biomass of water hyacinth by installing a shallow pre-sump to act as a constructed wetland of greater surface area (Díaz et al. 2014).

Variation in the ability of the semi-submerged rock biofilter to convert nitrite to nitrate was due to pH of system water (DeLong and Losordo 2012), coupled with clogging of the biofilter by biofilms. Similarly the wide variation in carbonate hardness was attributed to clogging of the biofilter restricting water passage through the dolomite chip medium. Although submerged rock biofilters are the most easy to construct, such biofilters are prone to caking and clogging thereby reducing the efficiency of the biofilter (Malone and Burden 1988). We recommend the installation of an upflow pressurized fluidized bed biofilter as described by Malone and Burden (1988) or greater use of water hyacinth as the medium for biological filtration (Díaz et al. 2014).

As indicated by Schaefer et al. (2012) the potential for culture of A. gigas in recirculating aquaculture systems is high. Such a low-cost system as described here can give empowerment to low-income families and communities in the Amazon region by producing strong and healthy juveniles for on-growing in ponds (Pereira-Filho et al. 2003; Núñez 2012) and floating cages (Gonçalves de Oliveira et al. 2002).

Recommendations for future research

Additional experimentation is required to determine optimum stocking densities for A. gigas fry in recirculating aquaculture systems. Further research to determine the feasibility of producing A. gigas juveniles to 2-3 kgs in recirculating systems for live sale to local markets could be both productive and valuable.

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References


Figure 4. Juvenile arapaima reared from fry in the simple recirculation aquaculture system.


