LOW-HEAD RECIRCULATING AQUACULTURE SYSTEM FOR JUVENILE RED DRUM PRODUCTION

Timothy Pfeiffer*[1], and Paul Wills[2]

[1] USDA Agricultural Research Service, Sustainable Marine Aquaculture Systems, 5600 U.S. Hwy 1 North, Fort Pierce, FL 34946. Tel: 772-465-2400, x360; Fax: 772-466-6590; E-mail address: timothy.pfeiffer@ars.usda.gov

[2]Harbor Branch Oceanographic Institute at Florida Atlantic University, Center for Aquaculture and Stock Enhancement; 5600 U.S. Hwy 1 North, Fort Pierce, FL 34946. Tel: 772-465-2400, x454; Fax: 772-466-6590; E-mail address: pwills2@hboi.fau.edu

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Introduction

The USDA Agricultural Research Service and the Center for Aquaculture and Stock Enhancement at Harbor Branch Oceanographic Institute-FAU (HBOI-FAU) are collaborating to evaluate low-head recirculating aquaculture system designs to intensively produce red drum juveniles as part of the Florida Fish and Wildlife Conservation Commission's (FWC) saltwater hatchery network initiative. The design and performance data collected from these systems, as well as systems being evaluated at Mote Marine Laboratory, Sarasota, FL, and the FWC Saltwater Experimental Research Facility, Port Manatee, FL will be utilized to design the recirculating aquaculture systems that FWC plans in the new hatcheries throughout the state of Florida. The design of the phase I (25mm to 45 mm SL juvenile) through phase II (60 mm to 100 mm SL juvenile) production recirculating aquaculture systems include a nine-tank system and a ten-tank system. For the phase II to phase III (>130 mm SL juvenile) production cycle, the larger red drum juveniles are cultured in replicated larger 4-tank RAS low-head systems.

<u>Phase I to Phase II Systems</u>

A. Low-head propeller pump system design

The system consist of ten round polyethylene tank with a diameter of 60 inches and a depth of 34 inches for a total tank volume of 410 gallons (Aquatic Eco-System, Apopka, FL). A 2-inch bulk head fitting (Slip x FIPT) was installed in the center of each tank for drainage and connected to an external standpipe (2-inch diameter) that controlled water height in the tank. The ten tanks were setup in two rows of five tanks with the outflow from each external standpipe connected to a 4-inch drain manifold for each row of tanks. The water from the drain line for each set of five tanks gravity-flowed into a 24-inch diameter Wave Vortex filter (70 gallons) (W. Lim Corporation, San Diego, CA). Outflow from the two system vortex filters entered a 6-inch manifold that drained into a 4 foot wide x 8 foot long x 3.5 feet deep fiberglass sump (839 gal).

Water from the sump is returned to the tanks and transported through the water treatment unit by a 1 HP propeller pump (single phase, 208 V). The water treatment unit consists of a open polygeyser filter unit filled with approximately 20 ft^3 of EN plastic floating media (International Filter Solutions, Marion, TX) and a 25 ft^3 moving bead biofilter with

Kaldness media (Clearwater Low-space Bioreactor, Aquatic Eco-Systems, Apopka, FL). The polygeyser and LSB filters are placed in series and the water flow rate through the filters is on a continuous loop from and back to the sump at a flow rate of approximately 100 gpm. Return water flow back to the tanks is roughly 120 gpm to provide each tank with a return flow rate of 10-12 gpm. Thus, the tank turnover time is approximately 0.6 hr or 1.6 tank turnovers per hour. The water flows through a 10 bulb, 550-watt UV sterilizer (Model no. UV300-2, Aquatic Ecosystems, Apopka, FL) before returning to the tanks. Any excess water flow from the propeller pump (approximately 20 gpm) flows to a packed column unit filled with bio-ball polypropylene media material. Adequate oxygen concentration in the tanks is maintained by a continuous low flow of liquid O_2 gas into a 12-inch ultra fine bubble diffuser located in each tank. A top view schematic of this system is presented in Figure 1.

System maintenance. On a daily basis the tank center drains, the swirl separators, the polygeyser filter, and sump are purged daily to remove any settled solids. On a weekly basis the center and external standpipes of the tanks are plunged with a scrub brush to remove any accumulated solids and minimize biofilm buildup which hinders flow out of the tanks into the drain manifold. The drain line is cleaned on an as needed basis with a rotary spray nozzle and pressure washer unit to minimize biofilm in the drain line. The tank and sump sidewalls are brushed approximately every week. Settled solids accumulated on top of the polygeyser filter are vacuumed off on an as needed basis.

System water quality. This system has been in continuous operation with varying numbers and biomass loads since November of 2007. The number of fish in each tank ranged from over 3500 per tank at initial stocking with a mean size of 4.0 g to a minimum of approximately 500 fish per tank after with a mean weight of over 60 g. Fish biomass in the tanks have ranged from 10 kg/m^3 at initial stocking to a peak of 60 kg/m^3 before reducing biomass by moving the larger fish into another system. Daily feed rates per tank have been greater than 1.0 kg of feed per day (45% CP). Water temperature has been maintained at $25^0C \pm 2^0C$ and salinity maintained by float valve control in a range between 10 and 13 ppt. Total ammonia nitrogen ranged between 0.2 and 1.2 mg/L and nitrite nitrogen was in the 0.1 to 0.3 mg/L range. System pH and alkalinity ranged between 7.0 and 8.0 and from 125 to 275 mg/L $CaCo_3$, respectively. Graphs of the volumetric TAN conversion rates for the polygeyser and moving bead filters are varying influent TAN concentrations are presented in Figures 2 and 3.

B. Hybrid Low Energy Recirculation System

The small-scale "Hybrid" system consists of nine separate modules which incorporates a Waterline double drain fish culture tank paired to a Waterline "Torus" biofilter. The nine fiberglass tanks are five feet in diameter and approximately three feet in depth for a total tank volume of 425 gallons. The double drain of each tank has a central sump 0.83 ft in diameter and 0.3 to 0.5 feet in depth. A one-inch drain line from the center sump is used to purge the accumulated solids from the sump. A slotted two-inch diameter center standpipe is used in the transport of mid-column water from the tank to the torus filter. The center standpipe fits into a bulkhead fitting at the bottom of the sump which is then plumbed to the torus biofilter via a two to three inch diameter pipe. Water is air-lifted into the biofilter through a three-inch diameter pipe by flowing air at the bottom of the filter approach pipe via a 0.75-inch diameter tubing. Air for the Phase I to Phase II systems is supplied by a 3.5 hp, 3-phase regenerative blower (Model no. HRB-502, Republic Sales, Dallas, TX). The torus filters are filled with approximately four cubic feet of floating plastic media. Three different types of media were used in the filters – AMB™, Kaldness™ K1, and MB3™ structured media. Water flow through the filters is approximately 20 gpm and the filtered water returns back to the tank by gravity.

A relatively small, secondary “polishing loop” is included in the system design for fine particulate filtration, oxygen supplementation, and UV sterilization. A 1-1/2 inch diameter bulkhead fitting was placed in the tanks for surface water removal and tank water height regulation. Surface water from the tanks drains into a 3-inch diameter drain manifold which then flows into the sump. Plastic extruded netting, 0.25 to 0.50 inch mesh size, is wrapped around the surface drain pipe is used to prevent fish mortalities or media from flowing into the drain manifold. Water from the sump is continuously recirculated through a 4 ft^3 polygeyser filter and a 1.4 ft^2 sand filter (Model no. TA35, Aquatic Ecosystems, Apopka, FL) via a 0.75 hp centrifugal pump (Model no. JP1, AES). Flow through each unit is approximately 30 gpm. Water outflow from the polygeyser filter drops through a degas tower with four distribution plates that has either coarse and medium matala matting on top of the plate to remove fine particles before returning to the sump. Return water to the tanks passes through an 80-watt UV sterilizer (Emperor Aquatics, AST-80-2) and a 45-gallon oxygen cone (Waterline Ltd., Charlottetown, P.E.I., Canada). Return water flow into each tank is control by a one-inch ball valve. A top view schematic of this system is presented in Figure 4.

<u>System maintenance</u>. On a daily basis the polygeyser filter, torus filters, sand filter, and sump are purged or backwashed daily for solids removal. The polygeyser was set to backwash approximately every 4-6 hours. The tank sump is purged 2-3 times daily to remove any accumulated solids in the tank sump. The matala filter pads are exchanged daily with cleaned pads. On a weekly basis the center and drain pipes of the tanks are plunged with a scrub brush to remove any accumulated solids and minimize biofilm buildup which hinders flow out of the tanks into the drain manifold. The drain line is cleaned on an as needed basis with a rotary spray nozzle and pressure washer unit. The tank and sump sidewalls are brushed approximately every week.

<u>System water quality</u>. This system has been in operation with varying numbers and biomass loads since December of 2007. The number of fish in each tank has been over 3500 per tank at initial stocking with a mean size of 4.0 g and has varied depending on the grading needs. After four months of initial stocking the mean number per tank was approximately 500 with a mean weight of over 60 g. Fish biomass in the tanks have ranged from 5 kg/m^3 at initial stocking to a peak of 55 kg/m^3 before grading and removal of the larger size fish. Daily feed rates per tank have been greater than 1.0 kg of feed per day (45% CP). The water temperature is $25^0C \pm 5^0C$. The range is larger because the system blower for airlift utilization is located outside and the outdoor air temperature has greater fluctuation than the indoor temperature. Salinity is between 10 and 13 ppt. Total

ammonia nitrogen ranged between 0.2 and 1.2 mg/L and nitrite nitrogen was in the 0.1 to 0.3 mg/L range. System pH is usually in the 7.3 to 7.7 range as the air input to the torus filters and degas towers helps keep CO_2 to a minimum in the system. Alkalinity was maintained around 200 mg/L $CaCo_3$ by sodium bicarbonate dosing. The VTR for varying influent TAN concentration for the 4 ft^3 polygeyser is shown in Figure 5. A graph of the VTR for the different media in the torus filter at two different daily feed rates is presented in Figure 6.

Phase I to Phase II Systems

A. Low-head propeller pump system design

The system consists of four dual-drain, round fiberglass tanks 10 feet in diameter and 3.5 feet in depth for a total tank volume of approximately 2055 gallons. A sump 15 inches in diameter by 10 inches deep is in the center of each tank. The sump is covered by a 3-inch diameter slotted standpipe with a PVC bottom plate allowing approximately a gap of 0.25-inches around the sump. The plate also has radial 0.25-inch slots for water and solids to enter. The standpipe is fitted into a 3-inch diameter bulkhead at the bottom of the sump that provides mid-column water flow to the torus filter. Each tank torus filter is filled with 13ft^3 of MB3™ floating plastic media. Water flow into the filters is air-lifted through a 4-inch diameter approach pipe using a 0.75-inch diameter airline located near the bottom of the pipe into the filter. Water flow through the filters is approximately 30-35 gpm and the filtered water returns back to the tank by gravity. A 3-inch diameter pipe with ball valve is plumbed into the sump for purging of accumulated solids from the sump. A 1-ft wide x 2-ft long x 2-ft deep tank sidebox with a 4-inch diameter opening at the bottom is used for surface water removal from the tanks into a 6-inch diameter drain line manifold. Surface water out of the sidebox flows to the system drum filter (Model 801, WMT, Baton Rouge, LA). A 40 micron screen is used on the drum filter which is in line before the 10-ft x 10-ft x 4-ft sump. The custom fabricated sump is divided into five compartments, four which hold media (~40 ft^3 of MB3™ media) and is aerated to keep the media moving. Water flows through the four 2-ft x 8-ft compartments before reaching the last compartment (2-ft x 10-ft). A 2-hp propeller pump is used to return the water to the tanks. Flow from the propeller pump is separated to a low-head counter cross-flow (LHCCF) oxygenator (approximately 150-200 gpm) and return flow to the tanks (200 - 240 gpm). Liquid oxygen flows into the LHCCF oxygenator at 5 Lpm per unit. Each LHCC tower is 2-ft wide x 6-ft high x 2-ft deep. Water flow into the top of each tower at the top is controlled by a 3-inch ball valve and flows through four distribution plated before returning to the sump. Each 2-ft x 2-ft distribution plate has forty 3/8-inch holes for water dispersion. Liquid oxygen is injected into the tower at the bottom and passes through the plates in a zigzag counter flow to the water movement. LOX volume into the towers is controlled by a flow meter with an adjustable valve. Additional LOX is added to the tanks using 12-inch ultra-fine bubble diffusers and controlled with 0-5 scfm acrylic flowmeters. A schematic of this system is presented in Figure 7.

<u>System maintenance</u>. The torus filters are purged daily and the tank sumps are purged twice daily. System drain lines from the sidebox to the drum filter are cleaned with the pressurized rotary nozzle on as needed basis. Return lines from the torus filters are plunge out twice weekly and more often if the gravity flow back into the tanks is

observed to be restricted. Tank side boxes and the drum filter diverter box are scrubbed twice weekly for biofilm removal. Foam buildup in the moving bed biofilter/sump is removed daily. Tanks scrubbings are conducted on an as needed basis and coordinated to minimize fish culture disturbance.

System water quality. This first of four of these systems was completed and stocked with fish at the end of January 2008. The second system was online in April and the third system recently stocked in June 2008. All three systems currently (June 2008) have 250 kg of red drum juveniles, weighing over 100g each, in each tank. The first two systems have been operating as high as 60 kg/m^3 with daily feed rates over 4 kg per tank (45% CP). The water temperature has been fairly steady at $25^0C \pm 2^0C$, although the air blowers supplying air for the moving bead and torus filters are outside. Salinity of the system is running between 11 and 14 ppt. Total ammonia nitrogen has been under 1.5 mg/L and nitrite-nitrogen usually under 0.5 mg/L. System pH is well above 7.0 as the air input to the moving beds and torus filters minimizes CO_2 buildup in the system. Alkalinity is maintained around 200 mg/L $CaCo_3$ by daily dosing with sodium bicarbonate. The VTR for varying influent TAN concentrations of the long flow pathway moving bead biofilter for the first system in operation is shown in Figure 8. A graph of the VTR for the large-scale torus filters ($13ft^3$) for the second system that has been in operation is presented in Figure 9.

Figure 1. Phase I to Phase II System: Low-head propeller pump RAS design.

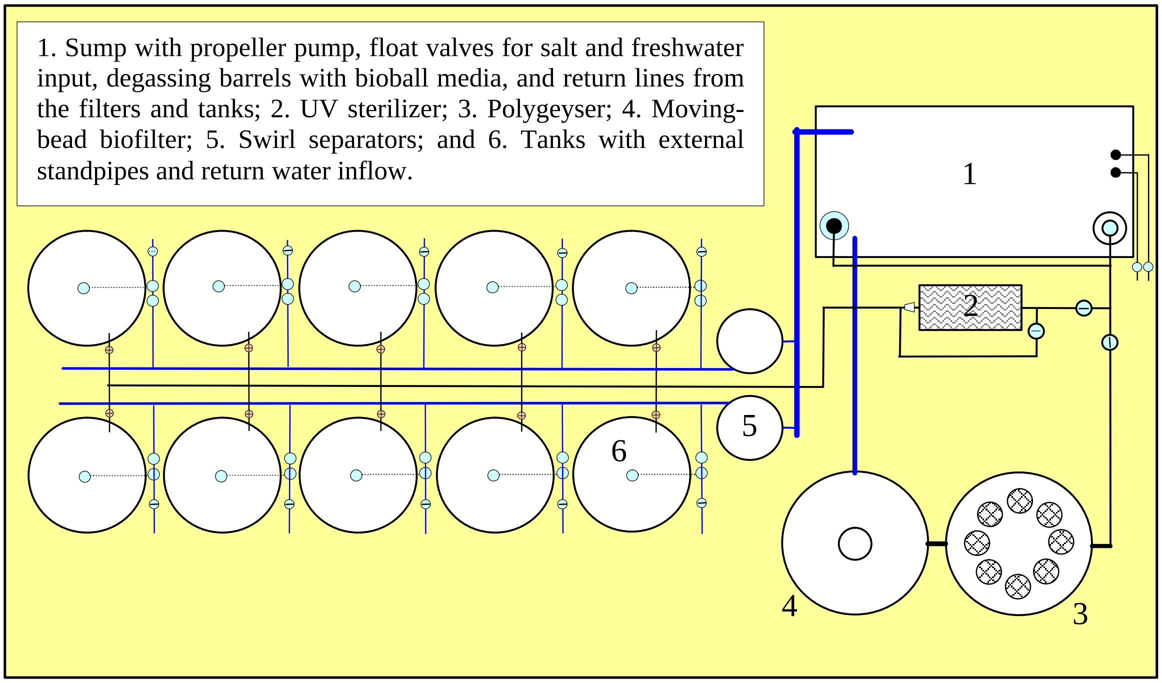


Figure 2. Volumetric nitrification rate (VTR) for a polygeyser filter with 20 ft^3 of EN media utilized in the low-head recirculating aquaculture system for red drum fingerling production.

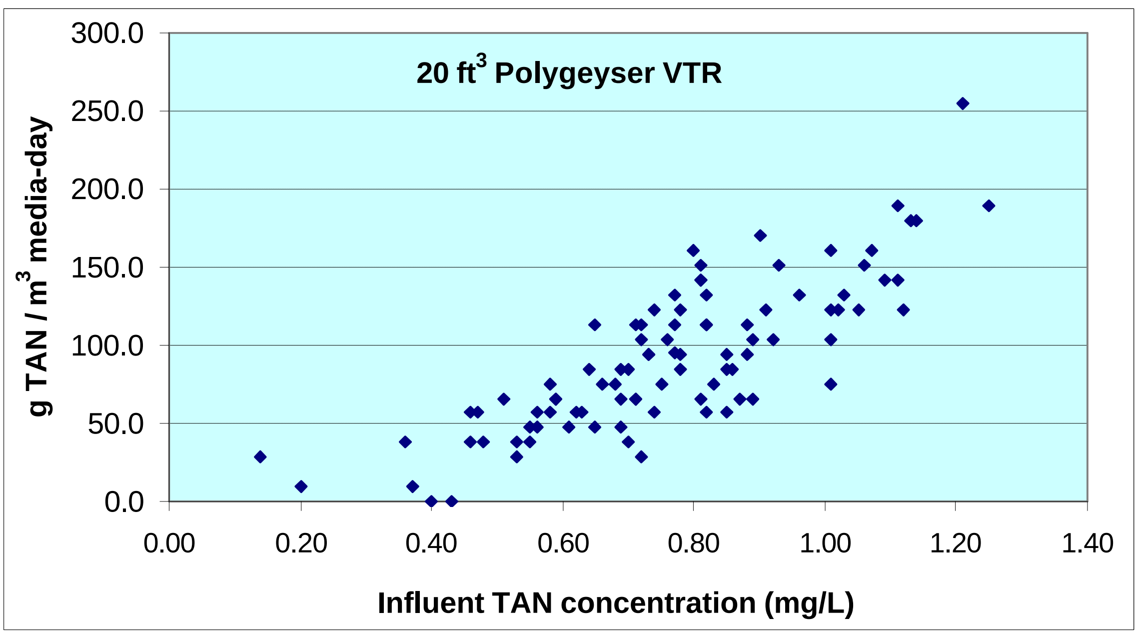


Figure 3. Volumetric nitrification rate (VTR) for a moving bead biofilter with 25 ft^3 of AKA floating plastic media utilized in the low-head recirculating aquaculture system for red drum fingerling production.

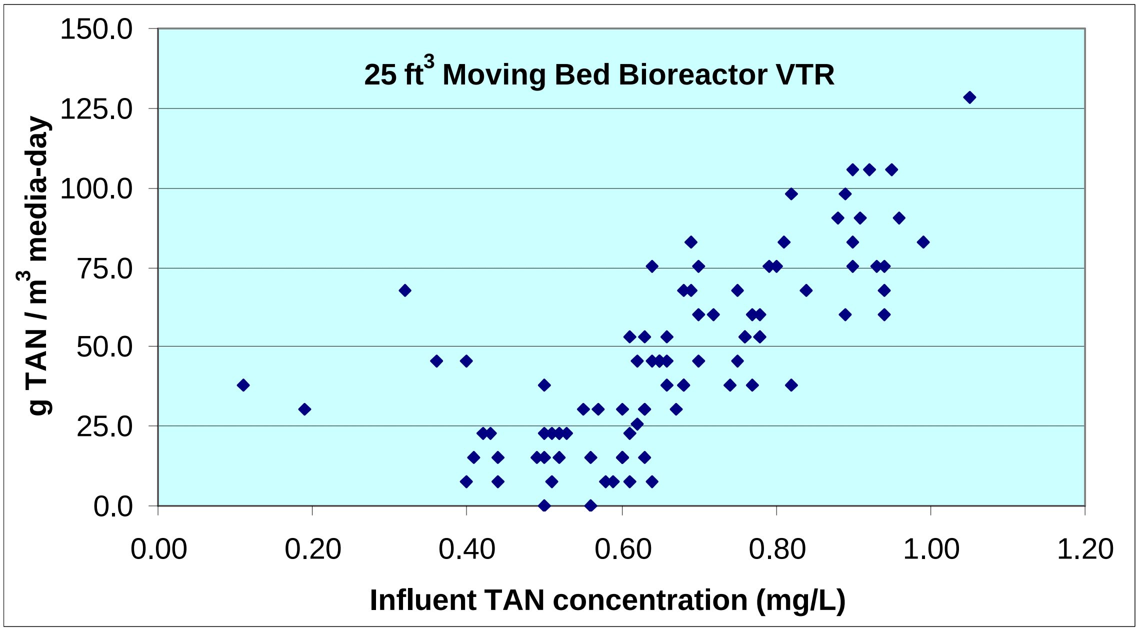


Figure 4. Phase I to Phase II System: Hybrid low energy RAS design.

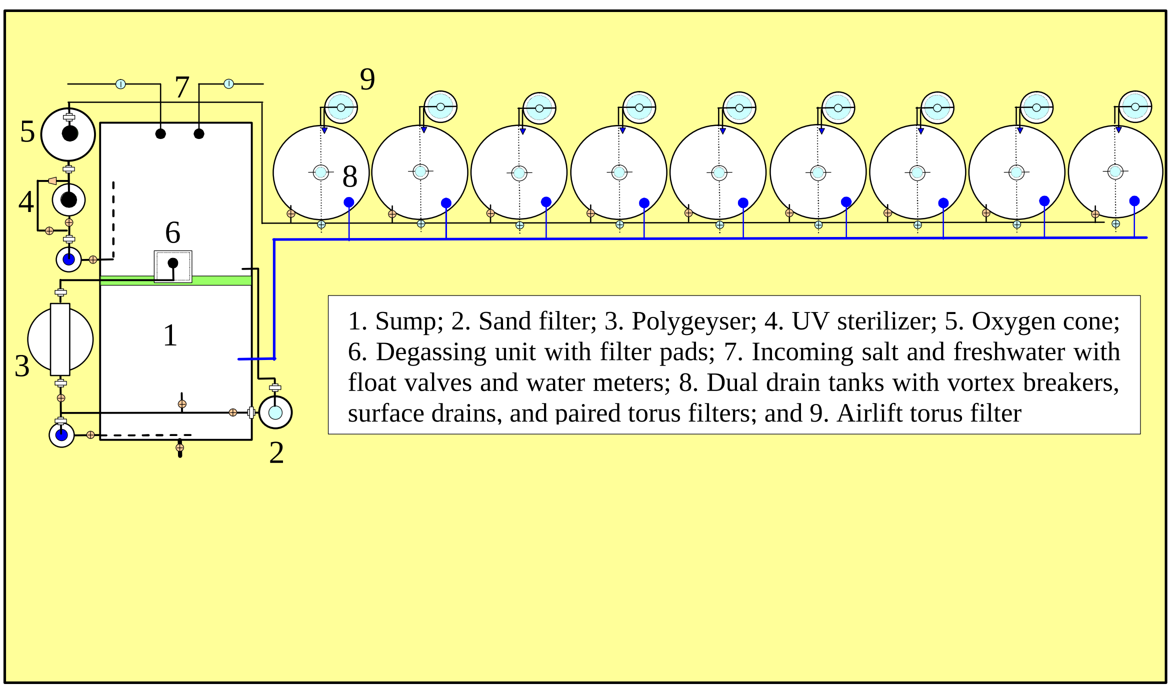


Figure 5. Volumetric nitrification rate (VTR) for a polygeyser filter with 4 ft^3 of crimped floating plastic media utilized in the low-energy hybrid recirculating aquaculture system for red drum fingerling production.

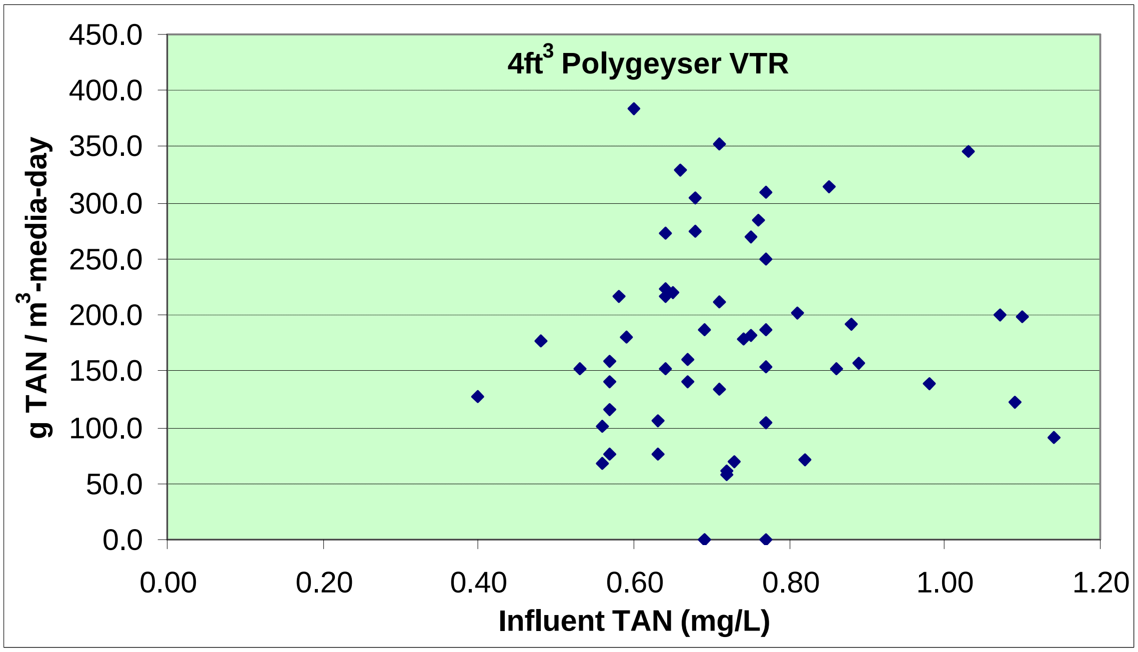


Figure 6. Volumetric nitrification rate (VTR) for the torroid filters with 4 ft^3 of different floating plastic media utilized in the low-energy hybrid recirculating aquaculture system for red drum fingerling production. The volumetric nitrification rates (N=3) were determined all through the day and at two daily feeding rates (900 g and 300 g/d).

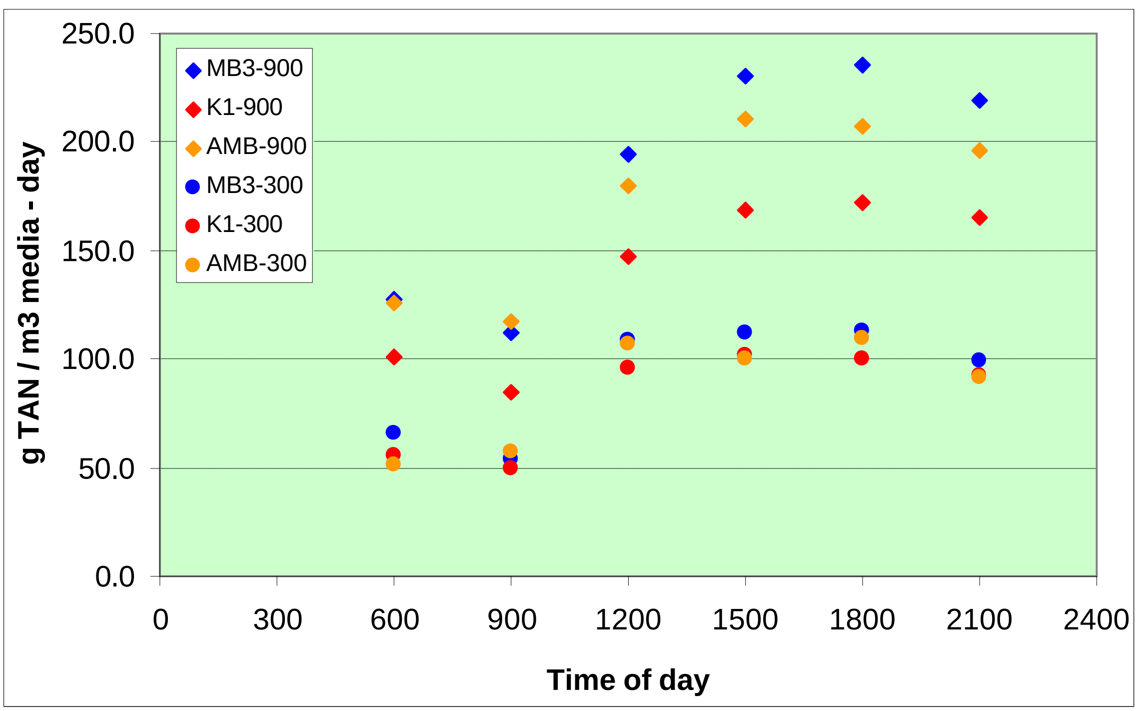
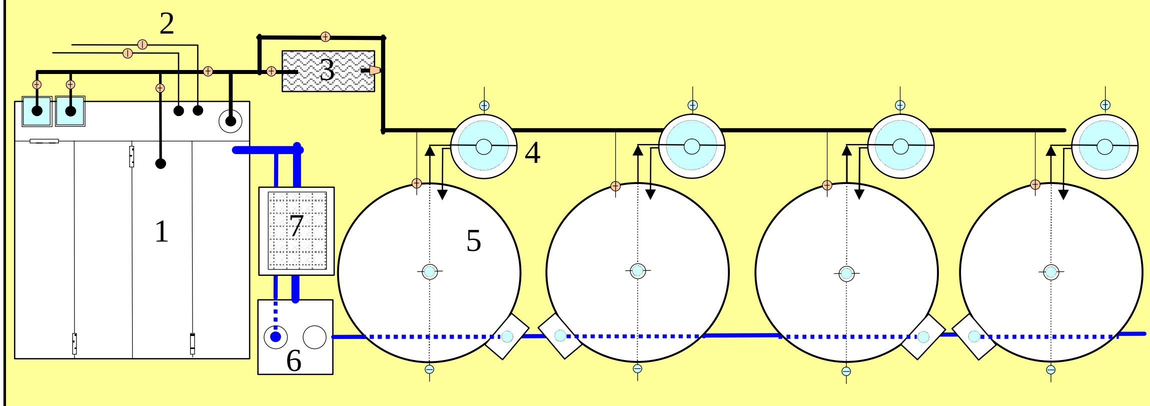


Figure 7. Phase II to Phase III: Low–head RAS design.



1. Long flow pathway moving bed reactor with cross flow oxygenator, float valves, and propeller pump; 2. Incoming salt and freshwater lines with float valves and water meters; 3. UV sterilizer; 4. Torrus filters with 13ft^3 of MB3 floating plastic media; 5. Ten-foot diameter tanks w/ center sump and sidebox drain; 6. Diverter box; and 7. 60 micron drum filter.

Figure 8. Volumetric nitrification rate (VTR) for a long flow pathway moving bed biofilter with 160 ft^3 of MB3 floating plastic media at varying TAN influent concentrations that was utilized in a lowhead recirculating aquaculture system for red drum fingerling production.

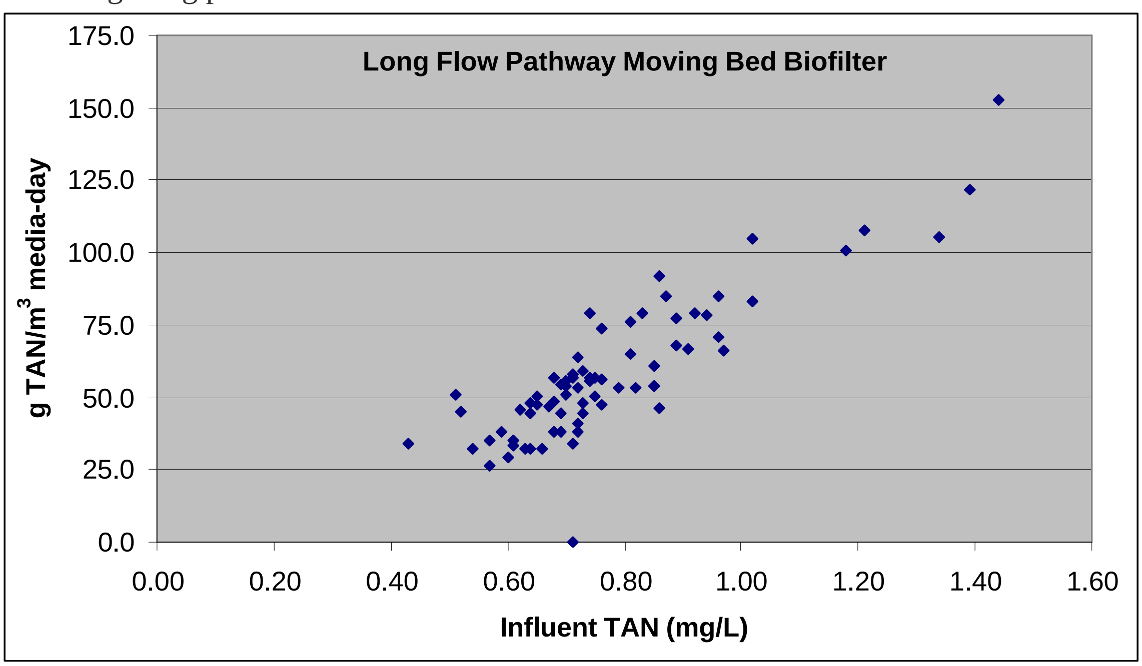


Figure 9. Volumetric nitrification rate (VTR) for the torrus filters with 13 ft^3 of MB3 floating plastic media utilized in the low-energy hybrid recirculating aquaculture system for red drum fingerling production. The volumetric nitrification rates for each torrus filter was determined for varying concentrations of influent total ammonia nitrogen (TAN) concentration.