Airlifted Polygeyser® RAS for the Marine Shrimp
Liptopenaeus vannamei

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Spring 2022

Figure 1 A 4 ton, PG6000 airlifted PolyGeyser® marine shrimp production system with localized sludge digestion.

Spring 2022
Shrimp production options in POLY for small scale producers

AST is currently developing RAS technologies to produce shrimp in tanks. At the same time AST is supporting both large scales and small-scale production through the sales of filters, mainly the salt saving PolyGeyser®, into the existing industry. This document summarizes our best recommendations (as of January 2022) for the sizing and operation of our small scale 4-9 metric ton (1200–2400-gallon) systems that appear capable of producing 45-90 kg (100-200 lbs) of 25 count shrimp (18 grams each) in a 4-5 month production cycle. These small airlifted systems can be configured into a “CaRASel” configuration consisting of replicated systems to produce up to about 200 lbs (90 kg) per week while taking advantage of the relatively low capital associated with mainly plastic components.

Figure 2 AST's experimental set up of three 4-ton PG6000 systems.

AST has been studying the RAS production of shrimp for the last 5 years under the auspices of a USDA SBIR research grant. This grant has allowed us the opportunity to study the problem inhouse. The AST designs for shrimp can be referred to as “clearwater” or “fixed-film” to contrast to the “biofloc” designs that currently dominate the commercial production in tanks and is also widely used in pond production. The biofloc systems take advantage of suspended bacteria (or floc) in the tank to process waste produced by shrimp. In contrast the AST fixed film approach focuses on the rapid removal of solids to reduce the waste-load, then processes the dissolved organics and ammonia using bacteria growing on the surface of the plastic media in the PolyGeyser®.

The biofloc industry has found by experience that the peak sustainable production with this technology is around 5 kg/m^3 (Ray, 2012). Experts using carbon supplements can do better, but the biofloc process has some intrinsic limits that begin to manifest themselves around this density. Fixed film processes offer promise of overcoming this limit. In AST's limited experience 10 kg/m^3 appears to be a practical commercial production target. The clearwater technologies provide a better basis for controlling water quality and ultimately raising the production density.

From a commercial point of view, production must be reliable and cost effective. The airlifted PolyGeyser design presented here attempts to achieve higher production targets in a simple system characterized by moderate capital and operational cost. Water pumps and most electrical components are eliminated from the design. Moving parts are virtually eliminated. Manual labor is largely limited to feeding, pass-bye inspection, and harvesting. The key issue that we are confronted with is raising the production density to increase the profitability of the RAS.

Figure 3 Twenty-five count shrimp produced 12 weeks after stocking of 1 gram shrimp.

The airlifted PolyGeyser® configuration was originally propagated as an energy saving configuration for finfish and is well documented in Gudipati and Malone (2007) which is a refinement of our earlier design guideline summarized in Malone and Beecher (2000). The airlifted PolyGeyeser® has been commercially applied for fingerling (200-1000 gallons) through growout (20,000-80,000 gallons) marine and fresh finfish applications over the last 15 years so its performance characteristics are well known. It is a sound base for an evolving shrimp production format.

Figure 4 The beads become coated with a nitrifying biofilm. The PolyGeysers® are effective fixed film bioreactors even as they capture solids.

The systems proposed here are designed to be compatible with marine salinities (typically 25 ppt for shrimp) with operation pH range of between 7.5-8.0 (alkalinity>100 mg-$CaCO_3$/L) and temperature between 25-30^oC. At a design density over around 10 kg/m^3, the dissolved oxygen is expected to hold above 5 mg/L and carbon dioxide levels below 10 mg/L. The system is sized for a moderate load on the bioclarifier of around 16 kg/m^3-day (1 lb/ft^3-day) while maintaining TAN and nitrite-nitrogen levels below 1 mg-N/L. The systems are designed to minimize water loss (8-32 liters/kg fed or 1-4 gallons/lb fed) so a build-up of refractory organics can be expected to produce a tea to coffee colored water. The color is harmless, but can be remedied with use of ozone (Christensen et al. 2000).

Our focus here is the application of two of our larger plastic PolyGeyser® models, PG 6000 and the PG 12000 which hold 85 and 170 liters (3 and 6 ft^3) of media respectively. Figure 1 illustrates a PG6000 placed adjacent to a 4.5 m^3 (4.5 metric tons or 1200 gallon) Polyethylene tank. The two units are connected by a 7.6 cm (3”inch) airlift designed to generate a recirculation flow of 114 lpm (30 gpm) providing a tank turnover of 40 minutes while supplying adequate flow to the filter (1.3 lpm/liter or 10 gpm/ft^3) to assure oxygen supply for the fixed-film bacteria in the submerged bead bed. The illustrated system is also equipped with a 340 liter (90 gallon) localized digestor. Table 1 summarizes the underlying design and Table 2 summarizes specific sizing assumptions.

The water leaving the tank flows through the filter by gravity. Exiting the top of the filter the water then drops to the floor creating a siphon effect. Air is injected at the bottom of the “U” lowering the density so the air/water mixture can be pushed up and back into the tank. The unit is designed to work with energy saving submergence to lift ratios of 4-5 and provides for oxygen replenishment and carbon dioxide stripping for up to about 0.75 pounds of food addition each day. A supplemental in tank airstone extends the aeration capacity to around 2 lbs per day. The airlift discharge can be modified to facilitate foam removal and/or flow measurement.

The PolyGeyser unit operates as a bioclarifier and it simultaneously captures solids while it grows biofilm. The bed will begin to clog and must be backwashed to re-establish recirculating flow. In shrimp culture at the 10 kg/m^3 (0.083 lb/gal) density, average feed loading on the filter is relatively light and only once a day backwashing is required to keep the unit working. During peak loading, backwashing 2-3 times a day may be required to maintain flow (midway through the growout). Failure to backwash will lead to a rise in nitrite concentration, as reduced flows cannot supply enough oxygen to complete the nitrification process.

Units that are equipped with localized sludge storage are designed to pneumatically move sludge from the PolyGeyser to the sludge basin. The sludge is then separated by gravity and the transport water is returned to the PolyGeyser. These units reduce water loss to less than 0.5 gallons/lb fed extending system water turnover to over 2 years. The sludge component can be operated to provide for denitrification eliminating nitrate accumulation as an issue.

Management of these systems is minimal. The principal obligation of the operator is feeding. The units may be hand fed 2-4 times daily, or automatic fed continually day and night. The systems should be periodically visually inspected to confirm recirculation flows, air distribution between systems and within a system between the airlift and air stones. Backwashing is pneumatic and sludge removal from the filter is perhaps a weekly task, without the localized sludge digestor. Sludge removal from systems with sludge digestors may be required every two months. Otherwise, the key obligation is to maintain the aeration equipment and temperature, particularly in the cooler months. Water levels in the tank must be maintained at the centerline of the airlift discharge pipe.

Points of failure for tank growout are power failure, which can lead to oxygen depletion in the tank, and overfeeding, which can lead to a deterioration of water quality, particularly nitrite as oxygen supplies to the bead bed are depleted. More commonly, mismanagement leads to reductions in harvest numbers, quality, and size.

CaRASel Production

To increase production, multiple RAS can be configured into a CaRASel (Figure 5) that has enough tanks so one will mature every week. With high quality genetics and warm temperature, 25 count shrimp (18-19 grams each) can be produced from 1 gram in 12 weeks. With some contingency for losses and slow growth, 13-15 RAS can be configured to assure weekly delivery at the system capacity. The CaRASel configuration facilitates a secure transition from a demo scale unit producing 100-300 pounds every 4-5 months to weekly production that converts to annual production from 5,000 to 15,000 pounds per year. Further expansion can be accomplished by scaling up the tank and filter size or by replicating the PG3000 or PG6000 carousel.

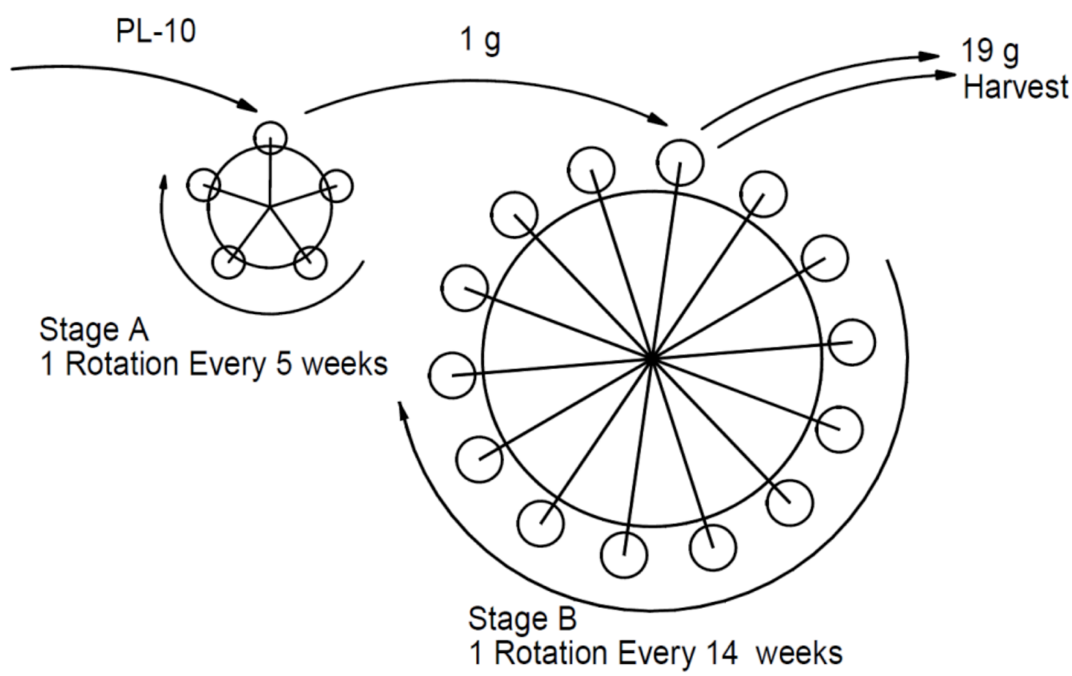

Figure 5 Fourteen independent systems can be sequentially loaded to produce a weekly output of 25 count shrimp. 14 systems are used for a 12-week growout to provide a reserve against losses.

Figure 6 illustrates a suggested layout for a Stage A and Stage B growout configuration. The blower system is held in a separate mechanical room, which can be ventilated from the outside to avoid heat buildup in the summer or internally for winter operation. No electricity or lighting is in the production room for the RAS operation, which can be on a concrete slab or gravel base. The illustrated system does not utilize localized sludge digestors and typically would be supported by an external sludge digestion pond.

Shrimp can be produced in a greenhouse in a “green water” system or in a building with minimal lighting. Shrimp do not require light for growth. A production cycle can be completed under total darkness or red lights (shrimp don’t see red light). If a greenhouse is used, careful consideration should be given to its heating in the winter and high temperature avoidance in the summer. The practical range for shrimp production is 25-30^{o}C (75-85^{o}F). High temperature control in the humid south can be problematic, as the popular “swamp coolers” require low humidity to operate effectively as evaporative coolers. Operating outside the optimum range will reduce growth rates, or in the extreme, lead to death.

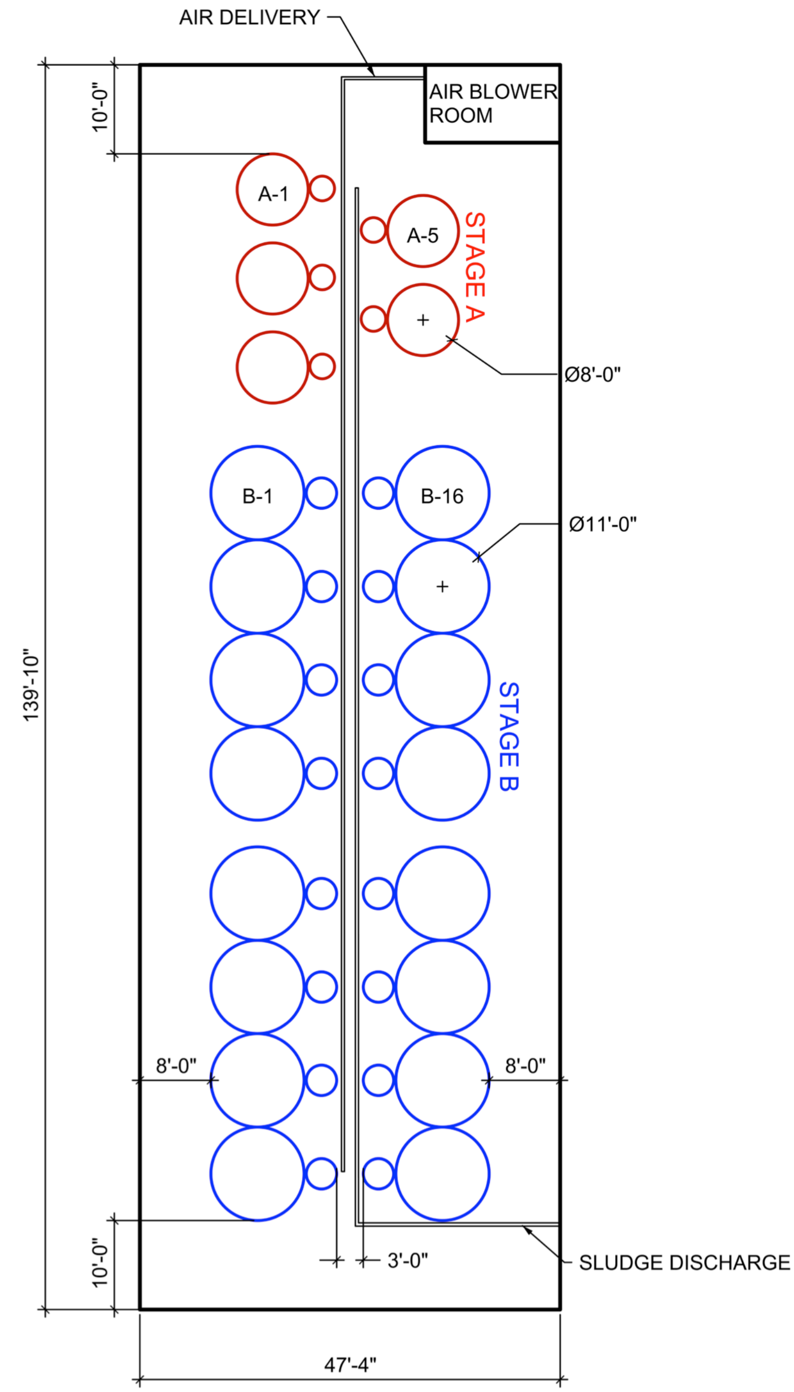

Figure 6 This green house was developed to support two stages of growth to produce a 100 pounds a week of 20-25 gram shrimp

Additional Reading:

Christensen, J. 2000. Development of a model for describing accumulation of color and subsequent destruction by ozone in a freshwater recirculating aquaculture system. *Journal of World Aquaculture Society* Vol 3, No.2:167-174

Malone, R.F. and L.E. Beecher. 2000. Use of floating bead filters to recondition recirculating waters in warmwater aquaculture production systems, *Aquacultural Engineering*, 22:1, pp. 57-73.

Malone, R. and S. Gudipati. 2007. Airlfited-PolyGeyser combination facilitates decenralized water treatemtn in reciculating Marine Hatchery Systems. In Stickney, R., Iwamoto, and M. Rust (editors). *Aquaculture and Stock Enhancement of Finfish: Proceedings of the Thirty-fourth U.S>-Japan Aquaculture Panel Symposium*, San Diego, California, November 7-9, 2005. US Department of Commerce, NOAA tech. Memo NMFS-FS/SPO-85, 76 p.

Ray, A. 2012. Chapter 13: Biofloc technology for super-intensive shrimp culture. in *Biofloc Technology-A Practical Guide Book, 2nd Edition*. Edited by Y. Avnimelech, The World Aquaculture Society, Baton Rouge, Louisiana, United States.

(If you have problems obtaining copies of these documents you can request assistance at info@ASTfilters.com)

Tables of specification

Table 1: Basic underlying assumptions used in system sizing analysis.			
Parameter	**Stage A (Nursery)**	**Stage B (Growout)**	**Comment**
Duration (days)	30	120	Varies with genetics and temperature
Size range (g)	0.01-1	1-25	Ranges may vary with feeding and genetics
Final density (kg/m^3)	2	10	Emerging standard for clear water RAS
% body weight fed daily	15-8	8-2	Typical practice
Max nitrite-N (ppm)*	0.5	1.0	recommendation well below biofloc conditions
Stage % survival **	80	80	Conservative estimate
FCR	------	1.3-1.4	Typical practice
*Industrial objectives often set at 1.5 ppm when harvesting at Stage B **70-90 percent typical of production with good practices			

Table 2: Major components and sizing criteria used for shrimp production in the airlifted PolyGeyser® configuration			
Component	**Sizing Criteria (Metric units)**	**Sizing Criteria (English units)**	**Comment**
PolyGeyser	62.5 L/kg-day	1 ft^3 /lb-day	sized to keep Ammonia -N and nitrite-N < 1ppm
rotometer	2.83 lph/liter	0.1 cfh/ft3	controls backwash frequency and biofilm harvesting
Airlift	0.46 m/sec (or cm/sec)	<1.5 ft/sec velocity 7-10 gpm/lb fed day	Aerates, circulates, and strips carbon dioxide
Tank	2.5 m3/kg-day	>300 gallons/lb fed-day	lowers shrimp density; stabilizes water quality
Linear air pump	85-113 lpm/lb fed-day	3-4 cfm/lb fed-day	services airlift and airstone(s) in in tank aerating and stripping carbon dioxide
		Optional items	
Sludge digestor	>83 l/kg fed-day	>10 gals/lb fed-day	minimizes water loss; stabilizes sludge; denitrifies; preserves salt
Foam fractionator	>8 lpm/kg	>1 gpm/lb fed-day	improves water clarity
Ozonator	10-15gms ozone/kg fed	5-7 gms ozone/lb fed	improves water quality, reduces bacterial counts

Table 3: The 4.5 ton (1200 gallon) RAS marine shrimp system specifications		
Component	**Size**	**Comment**
PolyGeyser (PG6000)	85 liters (3 ft^3)	supports 1.4-1.8 kgs (3-4 lbs) feed per day at peak
rotometer	2.83 lph (0.1 cfh)	controls backflush frequency at about 1 per day; may have to be increased at peak loading
Airlift	7.6 cm (3 inch) airlift	provides 75-115 Lpm (20-30 gpm) circulation
Tank	4.5 m^3 (1200 gallons)	lowers shrimp density; stabilizes water quality
Blower/Air pump	250 lpm (8.8 cfm)	
	Optional items	
Sludge digestor	83 lpm/kg-fed-day (>10 gals/lb fed-day)	minimizes water loss; stabilizes sludge; denitrifies; preserves salt; sizing based on daily average
Foam fractionator	8 lpm/kg fed-day (>1 gpm/lbfed-day)	improves water clarity
Ozonator	10-15 gms/kg (5-7m gms ozone/lb)	improves water quality, reduces bacterial counts; improves water appearance; optional
	Performance Indicators	
Stocking Number	4000	back calculated from harvest target and mortality (assuming shrimp are stocked at stage PL 12)
Stocking density	1049/m^2	
Stocking density	881/m^3	
Target harvest No.	2600	
Target Harvest Density	10.2 kg/ m^3	
Target Harvest Weight	46.4 kg (102.2 lb)	
Assumed Mortality	20 %	conservative estimate
Peak Feed rate	0.54 kg/day (1.2 lbs/day)	
Average daily feed	0.41 kg/day (0.9 lbs/day)	
Feed conversion	1.5	will be higher if shrimp are overfed
Peak Filter load	6.4 gm/l-day 0.4 lbs/ft^3-day	for about of week around the middle of the growout period
Tank turnover	40-60 minutes	
System Turnover	1308 days	measure of water reuse
Assumed temperature	30°C	presumed optimum for growout; growth will be lower if the water temperature is lower
Cumulative Feed Burden (CFB)	120,066 mg/L	mean feed application rate divided by sludge volume discharge rate; measure of water reuse
Peak TAN Target	1.0 mg-N/L	may be approached at peak feed loading
Peak Nitrite Target	1.0 mg-N/L	
Footprint	8.18 m^2 (88 ft^2)	
Height	1.52 m (5 ft)	could be higher factoring in airlift
	Per Run	
Feed	73 kgs (160.5 lbs)	
Water loss	608 liters (160.5 gals) 13.1 l/kg (1.57 gal/lb)	without localized sludge basin
Salt replacement	15.2 kg (33.5 lbs)	
Nitrate accumulations	337 mg-N/L	
RAS electricity	1239 KWhr 26.7 KWhr/kg shrimp	excludes heating and building using linear air pumps

Table 4: The 9 ton (2400 gallon*) RAS marine shrimp system specifications		
Component	**Size**	**Comment**
PolyGeyser (PG12000)	170 liters (6 ft^3)	supports 2.8-3.6 kgs (6-8 lbs) feed per day at peak
rotometer	5.66 lph (0.2 cfh)	controls backflush frequency at about 1 per day; may have to be tripled during peak loading days
Airlifts (2)	7.6 cm (3 inch) airlift	provides 150-230 lpm (40-60 gpm) circulation
Tanks (2)	4.5 m^3 (1200 gallons)	lowers shrimp density; stabilizes water quality,
Blowers/Air Pumps (2)	250 lpm (8.8 cfm)	
	Optional items	
Sludge digestors (2)	83 lpm/kg-fed-day (>10 gals/lb fed-day)	minimizes water loss; stabilizes sludge; denitrifies; preserves salt
Foam fractionators (2)	8 lpm/kg fed-day (>1 gpm/lbfed-day)	improves water clarity
Ozonators (2)	10-15 gms/kg (5-7m gms ozone/lb)	improves water quality, reduces bacterial counts; improves water appearance
	Performance Indicators	
Stocking Number	8000	back calculated from harvest target and mortality (assuming shrimp are stocked at stage PL 12)
Stocking density	1049/m^2	stocking density
Stocking density	881/m^3	
Target harvest No.	5200	
Target harvest density	10.2 kg/ m^3	
Target harvest weight	93 kg (204.4 lb)	
Assumed Mortality	20 %	conservative estimate
Peak Feed rate	1.08 kg/day (2.4 lbs/day)	
Average daily feed	0.82 kg/day (1.8 lbs/day)	
Feed conversion	1.5	will be higher if shrimp are overfed
Peak Filter load	6.4 gm/l-day 0.4 lbs/ft^3-day	for about of week around the middle of the growout period.
Tank turnover	40-60 minutes	
System Turnover	1308 days	
Assumed temperature	30^{o}C	presumed optimum for growout; growth will be lower if the water temperature is lower
Cumulative Feed Burden (CFB)	120,066 mg/l	mean feed application rate divided by sludge volume discharge rate; measure of water reuse
Peak TAN Target	1.0 mg-N/l	may be approached at peak feed loading
Peak Nitrite Target	1.0 mg-N/l	
Footprint	16.35 m^2 (176 ft^2)	
Height	1.52 m (5 ft)	could be higher factoring in airlift
	Per Run	
Feed	146 kgs (321 lbs)	
Water loss	1216 liters (321 gals) 13 l/kg (1.57 gals/lb)	without localized sludge basin
Salt replacement	30.4 kg (67 lbs)	
Nitrate accumulation	337 mg-N/L	
RAS electricity	2478 KWhr 26.7 KWhr/kg shrimp	excludes heating and building using linear air pump
*Based on two 1200 gallon polymer tanks		