Growout Trials in the Waddell Mariculture Center's Prototype Commercial Raceway

The South Carolina Department of Natural Resources' Waddell Mariculture Center has been operating a prototype commercial shrimp growout raceway for over a decade. It is managed as a minimal exchange, biofloc-based, superintensive system. Once the biofloc community is established, freshwater is added only to replace evaporative losses. It is housed in a greenhouse, which together with the absence of saltwater inputs and the use of only SPF disease-free stock, creates a biosecure facility. The raceway design has undergone many reconfigurations, attempting to improve performance of its operation, or to evaluate specific management strategies.

In its current configuration the raceway is approximately 110 ft by 25 ft with a surface area of 271 m^2 and a volume of 235 m^3. 56 airlifts, powered by a 5 hp blower, gently mix the water and move it slowly around a center partition. This mixing is important for preventing the formation of settled organic material on the bottom, for aeration, and for circulating injected oxygen throughout the system. A 10 kw, 150 Lpm oxygen generator and two 1 hp water pumps inject oxygen into the raceway at two locations after the shrimp biomass grows to a level requiring supplemental oxygen beyond that supplied by the airlifts. A 1 hp pump circulates raceway water through a heat exchanger powered by a 1,000,000 Btu propane-fueled boiler. This permits year-round production, maintaining the water at 28-30 ^{o}C throughout the winter. Two 6 m^3 external settling tanks are plumbed into the raceway and can be operated as necessary to control the level of biofloc solids as desired. Sodium bicarbonate is added as needed to maintain alkalinity levels above 100 mg $CaCO_3$/L.

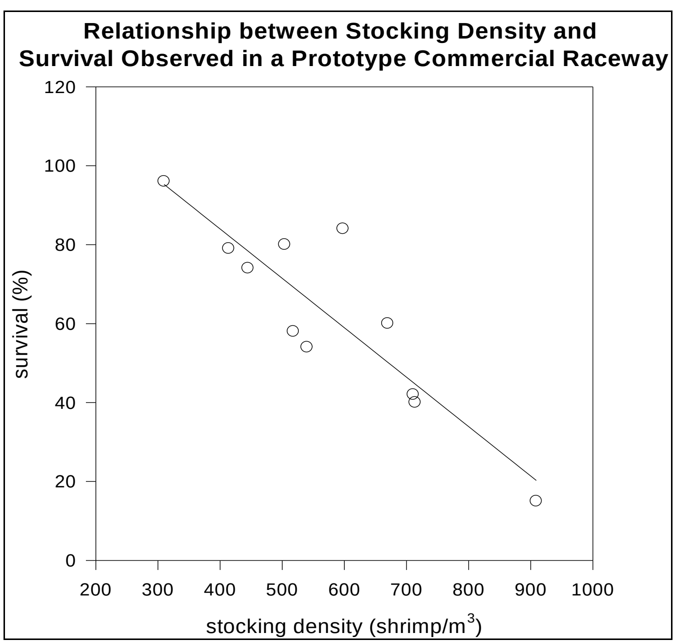
A 30 m^3 nursery tank is situated in a second greenhouse adjacent to that housing the large raceway. PLs are raised to juveniles prior to stocking the growout raceway. Approximately two weeks prior to stocking, water from the large raceway starts circulating through the nursery, slowly converting both tanks into one system. This permits the juveniles to become thoroughly acclimated to the water in the growout raceway prior to stocking. When the large raceway is harvested, all of the water is retained in a lined holding pond, the shrimp removed, and the seasoned biofloc water immediately pumped back into the raceway. By maintaining the biofloc community intact, subsequent spikes of ammonia and nitrite are minimized. Juveniles can be stocked directly from the nursery by opening a valve, permitting them to flow into the growout raceway without additional handling. Alternatively, for research purposes, the juveniles are first weighed and then placed in a chute with flowing water circulated from the raceway for direct delivery into the growout system. The possible disadvantage of reusing seasoned water from one trial to the next is the demonstrated accumulation of chemicals in the system. When aged water from the growout raceway is diluted with fresh, filtered seawater, growth rate is improved significantly, suggesting an inhibitory effect associated with the aged water.

Since 2003 twelve complete growout trials have been run in this system. Because the purpose of these experiments was to evaluate different management approaches, there is considerable variety among the starting conditions and resulting harvests, as shown in the summary table. Juvenile stocking sizes have ranged from direct stocking to 5.0 g, and stocking densities from 310/m^3 to 909 m^3. Production levels as high as 8.0 – 8.2 kg/m^3 have been achieved, with survival rates over 80%. Experiments have pushed the stocking densities higher with mixed results. There appears to be no relationship between stocking density and harvest production, however there exists a significant negative relationship between stocking density and survival rate (adjusted $r^2 = 0.768$, $P < 0.001$, $n = 11$, power of the test = 0.980). In some growout trials mechanical problems led to mass mortalities or reduced growth. In trial

18 an algal crash was followed by massive shrimp mortalities as well as the death of most micro- and macro-zooplankton even though all water quality parameters were consistently good. An adequate explanation was never determined. A conclusion that one might draw from these trials is that a superintensive biofloc-based system has the potential for excessive variability. Consistency of the biofloc community between runs and the reliability of production results over time must be priority goals for future research.

Trial #	Duration (days)	Stocking Size (g)	Stocking (shrimp/m³)	Growth (g/week)	FCR	Survival (%)	Harvest Size (g)	Total harvest (kg)	Production (Kg/m³)
8	113	0.01	504	1.26	1.9	80	20.4	1,922	8.2
9	124	1.0	540	1.39	2.6	54	25.6	1,765	7.5
10	59	4.0	598	1.47	1.4	84	16.4	1,879	8.0
11	140	2.4	445	0.96	2.4	74	21.5	1,529	6.5
12	71	5.0	310	0.71	3.2	96	12.2	857	3.6
13	146	1.6	670	0.88	2.5	60	20.0	1,877	8.0
14	112	1.5	714	1.04	3.5	40	18.1	1,207	5.1
15	212	0.5	909	0.60	*	15	18.7	611	2.6
16	124	0.8	711	0.86	3.4	42	16.1	1,127	4.8
17	128	1.3	414	0.77	2.2	79	15.3	1,408	6.0
18	43	1.6	326	1.59	*	3.5	11.4	35	0.1
19	132	2.0	518	0.89	1.7	58	18.8	1,324	5.6

Summary of the results of twelve growout trials in the Waddell Mariculture Center's prototype commercial raceway.

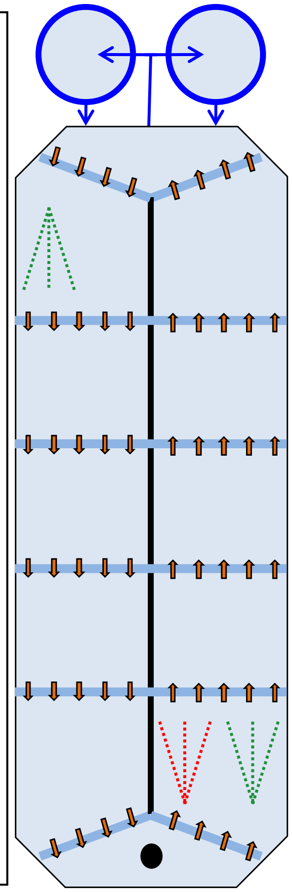


There is a strong negative relationship between stocking density and survival rate based on 11 growout trials in the prototype commercial raceway.

The 235 m^3 prototype commercial shrimp raceway at the Waddell Mariculture Center.

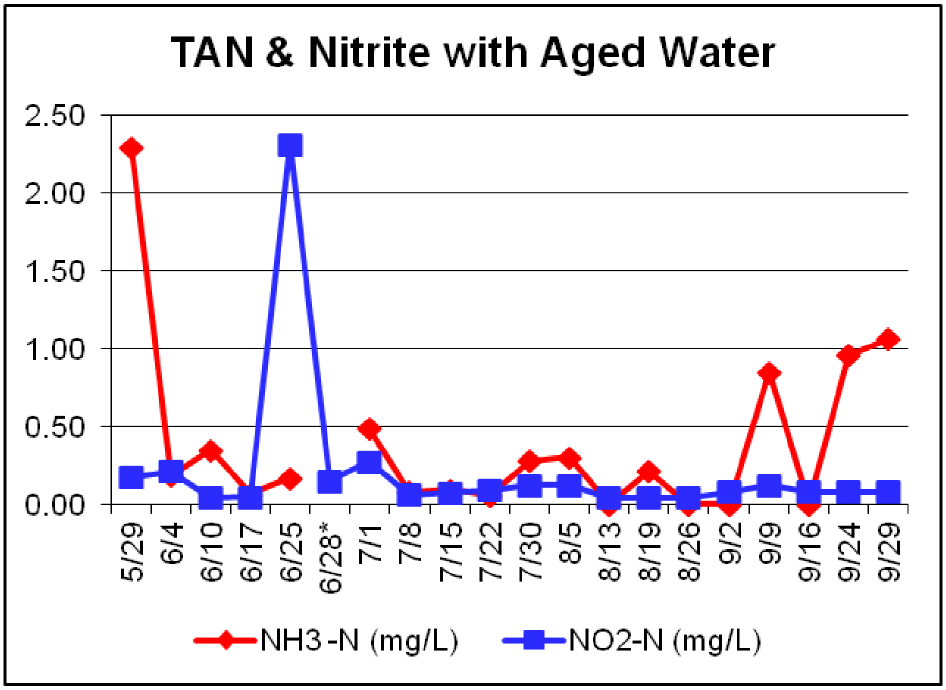
56 airlifts mix and circulate the water, preventing solids from accumulating on the bottom, providing aeration, and distributing injected oxygen throughout the system.

Item	Specs	Purpose
Raceway	235m^3, 271 m^2 110' x 25'	Shrimp growout
Settling tanks	≈ 6000 L operating volume	Solids settling
O_2 generator, 1 hp pumps (2)	10 kW, 150 Lpm pump output = 70-80 gpm	Oxygen injection
Boiler, 1 hp pump	1,000,000 Btu propane boiler	Raceway heating
5 hp blower, 56 airlifts	Blower output ≈ 180 cfm	Water movement, aeration

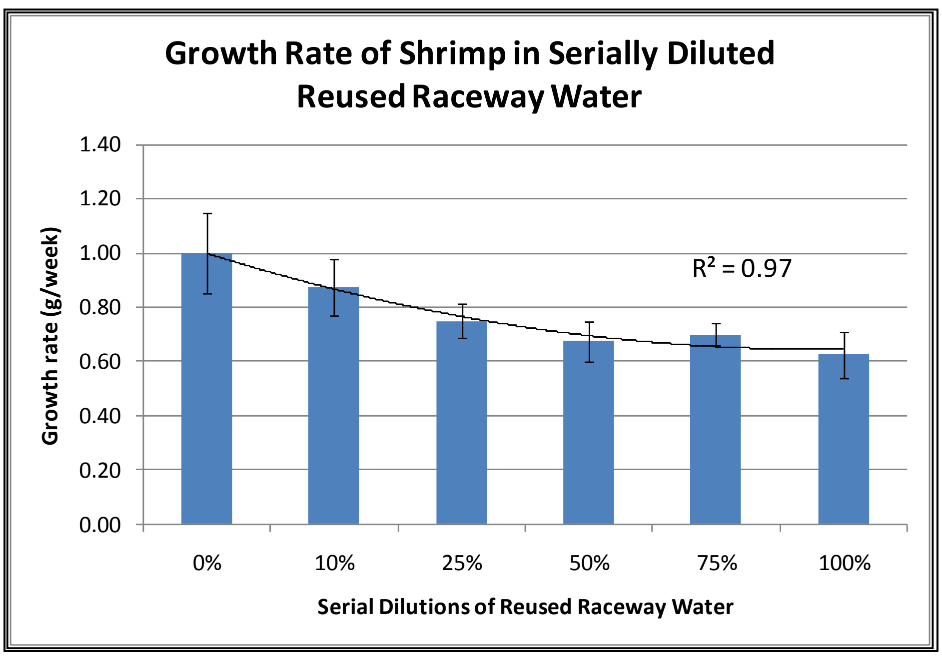


Current specifications and diagram of the Waddell Mariculture Center prototype commercial raceway.

30 m^3 nursery tank in greenhouse immediately adjacent to the greenhouse housing the growout raceway, and the chute by which juveniles are transferred to the raceway.



When seasoned biofloc water is reused for a second growout, the ammonia and nitrite spikes are minimized.



Shrimp growth appears to be inhibited by aged,biofloc water from previous growout runs and is improved when that water is diluted by fresh, filtered seawater.

Chemical Accumulation throughout Trial 17						
	Water (mg/L)		BioFloc (µg/g)		Shrimp (µg/g)	
Element	Week 0	Week 18	Week 0	Week 18	Week 0	Week 18
Al	0.008	0.005	306	519	27.4	10.1
As	0.001	0.029	0.5	8.3	0.0	2.3
B	1.62	1.55	63.1	47.6	5.9	4.8
Cd	0.003	0.004	0.6	0.9	0.0	0.3
Ca	137	137	46,985	34,146	34,449	24,312
Cr	0.001	0.001	3.2	5.3	1.0	0.6
Cu	0.032	0.104	118	90	167	96
Fe	0.002	0.038	503	1,486	35.5	26.6
Pb	0.001	0.000	0.0	1.8	0.0	2.0
Mg	651	655	16,726	8,153	3,033	2,747
Mn	0.013	0.189	402	137	6.4	9.6
Mo	0.003	0.020	1.9	3.0	0.0	0.4
Ni	0.005	0.008	5.5	7.2	1.5	0.3
P	15	670	38,763	21,700	12,085	11,713
K	302	289	9,296	10,650	13,077	14,601
Se	0.002	0.008	4.0	6.3	0.0	1.6
Na	4,607	4,972	31,086	27,064	8,193	7,566
S	393	446	9,459	11,018	7,627	7,645
Zn	0.008	0.136	260	662	67.4	67.5

Various chemicals can accumulate in the water and biofloc of a system during the course of a growout run.