Intensive production and preliminary economic analyses from growing *Litopenaeus vannamei* in limited discharge biofloc-dominated greenhouse-enclosed raceways

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Nursery Systems' Benefits

- Use of a nursery can provides better survival, facility utilization, control over predators, water quality, growth and feed utilization while reducing grow-out cycle by 20-30 d compare to direct stocking
- Producers in Ecuador, Mexico and other areas affected by WSSV reported good shrimp survival when PL are kept in water temp. >32C
- In temperate climate greenhouse-enclosed nursery systems can increase the number of shrimp crops/year

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Use of Limited Discharge Practices

- Studies showed that the *L. vannamei* can be cultured with reduced water exchange without adverse affect on the growth, survival and yield
- In limited discharge systems, shrimp depend on commercial feed as the primary source of food
- Microbial communities in these systems can serve as a source of single cell protein that provides supplemental food source

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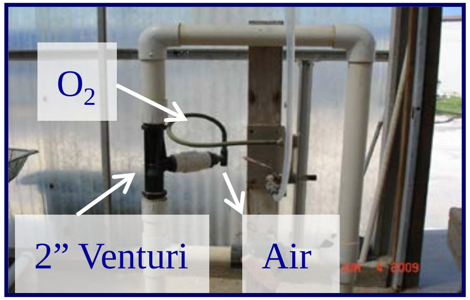
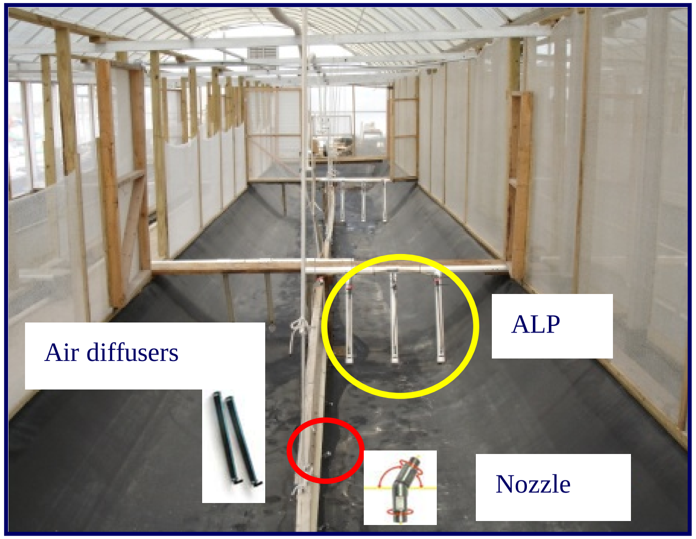
Texas A&M AgriLife Research Nursery System

- Six 68.5 m^2 (40 m^3) greenhouse-enclosed raceways with a mean water depth of 0.45 m originally designed to overwinter shrimp broodstock and was later modified to accommodate nursery of young PL



- Every RW has eighteen, 5.1 cm airlift pump, six 1 m air diffusers, a Venturi injector operated by a 2 hp centrifugal pump, a pressurized rapid sand filter and a center partition positioned over a 5.1 cm PVC pipe with spray nozzles to enhance bottom water circulation



40 m^3 Raceway in operation - note the color of water and the the floating bioflocs

The AgriLife Research Early Nursery Studies

- Cohen et al. (2005) stocked (3,300 PL/m^3) in 2 RWs in a 50-d trial with low water exchange (1.1%/d) and found that shrimp exposure to high nitrite levels (up to 26 mg/L) for 2 wks had no adverse effect on shrimp survival (>98%), growth (1.1 g juveniles), FCR (<1), and yields (>4 kg/m^3)
- The exposure had no adverse effect on growth and survival of the shrimp in the grow-out phase as good growth (1.32 g/wk with 21.2 g av. wt. after 106 d) and survival (80%) were reported when the shrimp were stocked (50/m^2) in HDPE-lined outdoor ponds operated under limited water discharge

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The AgriLife Research Nursery System

- Mishra et al. (2008) compared two methods of suspended-solids removal (sand filtration and foam fractionator) and their effect of on system performance
- In their 71-d study, four RWs were stocked with *L. vannamei* at a density of about 4,000 $PL_{4\text{-}5}/m^3$
- Two RWs were equipped with FF and were operated with water exchange of 3.35%/d while the other two were operated with no FF and water exchange of 9.37%/d

Treatment	Wt_o (mg)	Wt_f (g)	Yield (kg/m^3)	Survival (%)	FCR
FF-2 [1]	0.6	1.91 [a] [3]	7.64 [a]	100 [a]	0.97 [a]
FF-3 [1]	0.6	2.00 [a]	6.89 [a]	92.4 [a]	1.08 [a]
WE-1 [2]	0.6	1.73 [b]	3.92 [b]	55.9	1.64 [a]
WE-4 [2]	0.6	1.43 [b]	4.74 [b]	81.8 [a]	1.36 [a]

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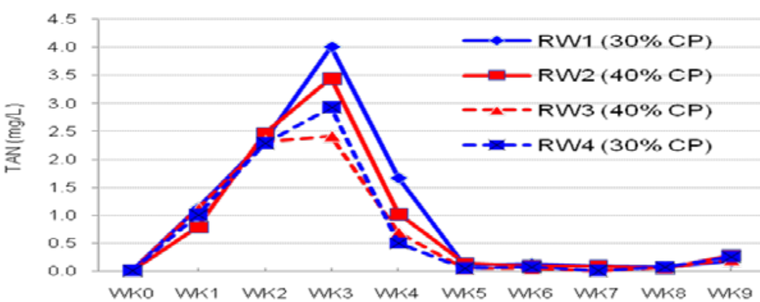
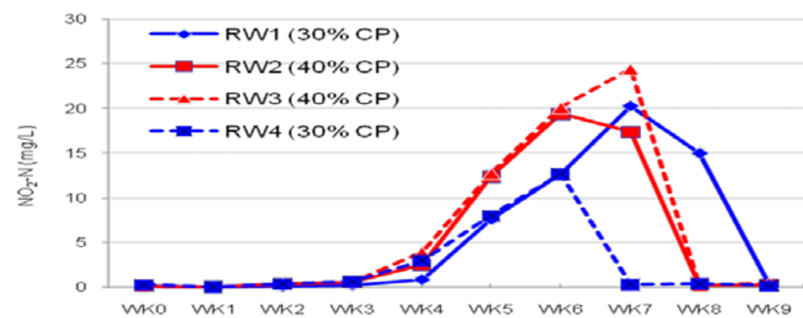
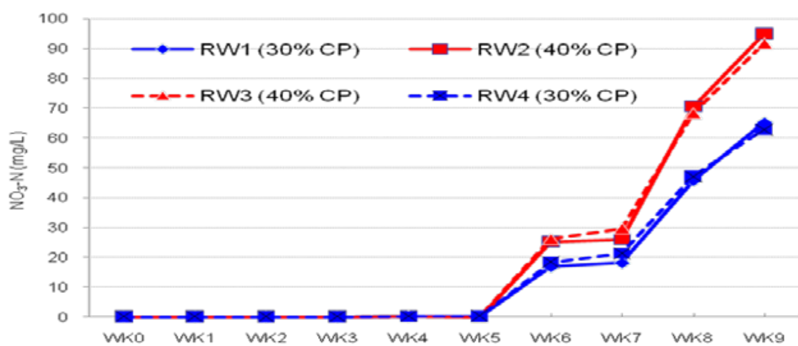
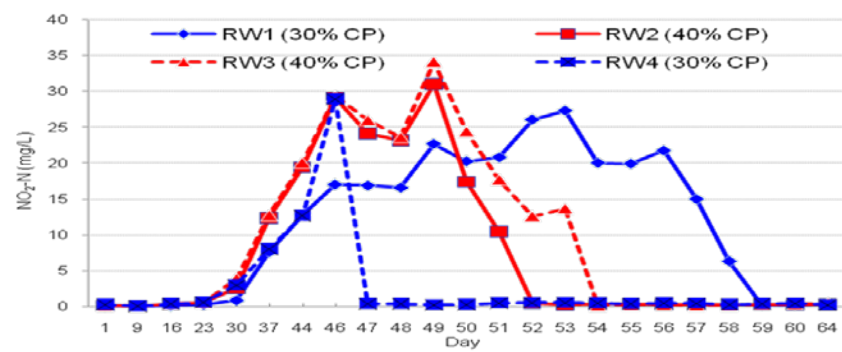
2009 Nursery Trial (Correia et al., 2010)

- This 62-d study (5,000 $PL_{10\text{-}12}/m^3$) evaluated the effect of high and low protein feed on growth, survival and selected WQ indicators and the potential use of molasses to prevent ammonia & nitrite build up under no exchange
- Molasses (24% C): Day 10-18: 500 mL every other day; from Day 19 on, molasses supplementation targeted conversion of ammonia to bacteria biomass assuming each 1 g of TAN requires 6 g of C
- Each RW was equipped with inline DO monitoring system (YSI 5200 system)









2009 Nursery Trial (Correia et al., 2010)

- Significantly higher nitrate levels in the high-protein diet
- Molasses can be used to enhance development of bacterial floc and to prevent ammonia build up in the culture medium
- Molasses was not effective in preventing nitrite build up
- DO monitoring was very useful in feed management

Variables	**30% CP**	**40% CP**
Final weight (g)	$0.94^{a} \pm 0.00$	$1.03^{a} \pm 0.02$
Survival (%)	$82.3^{a} \pm 11.26$	$84.1^{a} \pm 6.07$
FCR	$0.91^{a} \pm 0.05$	$0.82^{a} \pm 0.05$
Yield (kg/m^3)	$3.70^{a} \pm 0.49$	$4.18^{a} \pm 0.23$

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Use of intensive nursery system in commercial operations

Loma Alta Aquaculture San Perlita, TX

- Pond-side greenhouse-enclosed nursery in low salinity water (2-3 ppt) to avoid dragonfly predation
- 10,000-5,000 $PL_{10\text{-}12}/m^3$; Av. Survival: 80-97%; Av. wt: 0.1-0.25 g (30-35 d); FCR: 0.7-1.0
- Survival in grow-out ponds stocked with juveniles from the nursery RWs was higher than direct stocking (71% vs. 50%)
- The farm benefitted from off-season lower PL cost
- Stocking the grow-out ponds with juveniles, provided the farm with competitive edge as shrimp were harvested before any other farms

Nursery RWs Ocean Boy, FL, USA – Inland low salinity

- 300 m^3 nursery RWs stocked with $PL_{8\text{-}10}$ at 4-22 PL/L; 20-64 d cycle; shrimp were stocked in tanks filled with diluted NSW (25 ppt) filled to one fourth the working volume; acclimation to 2 ppt over 2 wks; water exchange when TAN or NO_2-N exceed 1.0 and 0.5 mg/L, respectively
- Survival: 44-99%; FCR: 0.7-1.4; Av. wt: 15-910 mg;

Inland freshwater (<1 ppt): Primary Nursery in greenhouse-enclosed 30 m^3 tanks, NSW chlorinated to 20 ppm, slow acclimation transfer at 0.01 g into 1 ha covered lined/earthen greenhouse-enclosed pond for Secondary Nursery at 1,400/m^2 (20 hp/ha – PW)

Ecuador Nursery System

- Farms use nursery raceways to enable stocking of larger shrimp which reduces the grow-out cycle duration and provides more crops/year
- Stocking 60-70 $PL_{10\text{-}12}$/L or less kept for 10-15 days
- Most "RWs" are 30-100 m^3 HDPE-lined
- Aeration by perforated PVC pipes or air stones
- Most structures are under greenhouses
- Supplemental heating sometime is provided with flexible black plastic piping connected to a boiler
- Water exchange start with 10%-15%/d and increased according to WQ and waste buildup

Info provided by Mr. Juan Aguire

Intensive Nursery AQUASOLES, Sonora

Important factors to be considered: Optimal DO (airstones, air diffusers, O_2 vs. Venturi), mixing (use of airlift pumps), feed & feed management, carbon supplement, control of SS, TSS, pH, alkalinity, temperature

# TKs	Vol. m^3	Tot. PLs Stocked	Tot Juv. Harvested	PL/L	Sur. (%)	Av. Wt. (g)	Load kg/m^3	FCR	Cycle (d)
38	91	79.8×10^6	71×10^6	21	89	0.092	1.87	1.04	29

Genitech Intensive Nursery: 5 PL_{18}/L, 3 hp pump, two 86 m^3 circular TKs each with two a^3 All Aqua injectors, AeroTube air diffusers & 7 hp air blower
Note: water circulation was initiated at PL_{23}

DOC	Date	Vol.	PL	Probiotics (g)				Feed/d	Feed	Prop	Temp.	DO	Alka.	pH	NH_3-N	TAN	NO_2-N	NO_3-N	Av. Wt.	Bio.	Bio.
		(m^3)	age	PRO-W	Efinol	Hatcheries		(g)			(C)	(mg/L)	(mg/L)		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(g)	(kg)	(kg/m^3)
0	4/16/11	86	18	180	180			400	AQUAXEL 300-600	100	27.5	7.8							0.016	6.8	0.079
1	4/17/11	86	19	180	180			1,550	AQUAXEL 300-600	100	28.5	6.2									
2	4/18/11	86	20	180	180			1,800	AQUAXEL 800	100	28.3	6.1							0.037	15.7	0.183
3	4/19/11	86	21	180	180			1,800	AQUAXEL 800	100	29.5	6.3									
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23	5/9/11	86	41	0	270	270		13,200	VIMIFOS MIGAJA 1/VIMIFOS RACEW.	50 / 50	31.1	4.2	255	7.3	0.13	7.90	0.10	3.10	0.424	180.2	2.095
24	5/10/11	86	42	0	450	450		13,200	VIMIFOS MIGAJA 1/VIMIFOS RACEW.	50 / 50	30.7	4.2	225	7.3	0.09	4.50	1.09	4.30			
25	5/11/11	86	43	0	450	450		13,200	VIMIFOS MIGAJA 1/VIMIFOS RACEW.	50 / 50	30.3	4.5	285	7.4	0.05	2.40	2.80	3.80			
26	5/12/11	86	44	0	450	450		13,200	VIM. MIJ 1/ EPACK NL / STRES P. 8/12	60 / 20 /20	27.6	4.8	200	7.5	0.13	5.60	1.18	4.50	0.52	221.0	2.570
27	5/13/11	90	45	0	0	0		6,000	VIMIFOS MIGAJA 1 / EPACK NL	70 / 30	26.8	4.9	265	7.7	0.14	3.70	1.13	0.20	0.644	222.9	2.590
TK 3		Stocking:	425,000 PL_{18}				Density: 5 PL/L		Survival:	0.81%		FCR	0.73		Final Weight: 0.644 g				Yield:	2.59 kg/m^3	
0	4/16/11	90	18	180	180			400	AQUAXEL 300-600	100	27.1	7.9							0.016	6.8	0.08
1	4/17/11	90	19	180	180			1,550	AQUAXEL 300-600	100	28.5	6.5									
2	4/18/11	90	20	180	180			1,800	AQUAXEL 800	100	28.3	6.5							0.031	13.2	0.15
3	4/19/11	90	21	180	180			1,800	AQUAXEL 800	100	29.4	6.1									
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23	5/9/11	90	41	0	270	270		13,200	VIMIFOS MIGAJA 1/VIMIFOS RACEW.	50 / 50	30.9	4.6	245	7.3	0.13	6.80	0.26	3.40	0.422	179.4	2.09
24	5/10/11	90	42	0	450	450		13,200	VIMIFOS MIGAJA 1/VIMIFOS RACEW.	50 / 50	30.7	4.5	230	7.3	0.04	2.20	0.95	2.60			
25	5/11/11	90	43	0	450	450		13,200	VIMIFOS MIGAJA 1/VIMIFOS RACEW.	50 / 50	30.2	4.5	240	7.4	0.05	2.40	2.37	1.20			
26	5/12/11	90	44	0	450	450		13,200	VIM. MIJ 1/ EPACK NL / STRES P. 8/12	60 / 20 /20	26.5	4.9	185	7.5	0.17	7.10	0.50	4.50			
27	5/13/11	90	45	0	0	0		13,200	VIMIFOS MIGAJA 1 / EPACK NL	70 / 30	27.2	4.7	210	7.3	0.12	7.00	0.82	0.80	0.545	231.6	2.69
28	5/14/11	90	46	0	0	0		12,600	VIMIFOS MIGAJA 1 / EPACK NL	70 / 30	26.7	4.6	230	7.3	0.08	5.10	0.99	0.75			
29	5/15/11	90	46	0	0	0		12,600	VIMIFOS MIGAJA 1 / EPACK NL	71 / 30	26.5	4.8							**0.707**	221.7	2.58
TK 4		Stocking:	425,000 PL_{18}				Density: 5 PL/L		Survival:	0.74%		FCR	0.88		Final Weight: 0.707 g				Yield:	2.58 kg/m^3	

Forty 100 m^3 (1st Stage) & Sixty 330 m^3 (2nd Stage) RWs Hainan, China

Grow-out Systems

- Recent advances in super-intensive, limited-discharge, biofloc systems for the culture of *Litopenaeus vannamei*, suggest that these systems can be profitable when used to produce live or fresh (never frozen) shrimp for niche markets
- Researchers, supported in part by the United States Marine Shrimp Farming Program have been working to improve system efficiency and make this technology economically viable

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Grow-out Systems

- These systems offer improved biosecurity with reduced risk of crop losses to viral diseases
- Furthermore, operating these systems with no water exchange minimizes the negative impact from effluent on receiving waters
- Use of greenhouse-enclosed super-intensive limited discharge biofloc systems can potentially:
  - ✓ Reduce water usage and effluent discharge
  - ✓ Increase biosecurity
  - ✓ Be constructed close to markets

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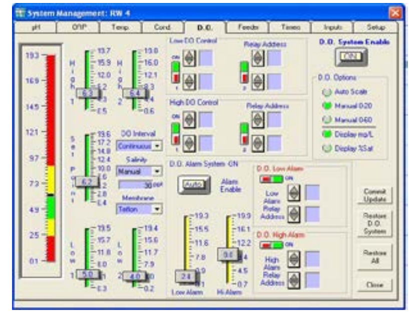
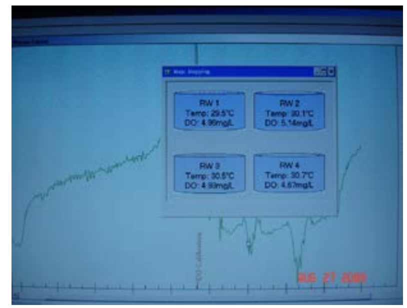
Grow-out Systems

Super-Intensive

- These systems require substantial inputs to satisfy the high oxygen demand of the shrimp and the microbial communities
- Performance is improve when these systems are equipped with automation for environmental and water quality control





Grow-out Systems

- Previous studies at the Texas A&M AgriLife Research Mariculture Lab have utilized a combination of a pump driven Venturi injectors, airlifts & air diffusers to provide adequate DO and mixing
- Recently we began looking into a non-Venturi alternative currently used in several wastewater treatment facilities in Florida
- This technology may be successfully transferred to biofloc systems and other types of aquaculture

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New Concepts in Grow-out

- According to the manufacturer these pump-driven nozzles are capable of providing a 3:1 air to water ratio
- In contrast, our current Venturi system provides a ratio of < 1:1 and requires supplementation of O_2 to at high biomass loading (>7-8 kg/m^3)
- A 106 d study conducted in 2011 in two 100 m^3 RWs stocked at 390 shrimp/ m^3 produced 25 g shrimp at 8.4 kg/m^3 with weekly growth of 1.46 g/wk, survival of 83%, and FCR of 1.7
- Home-made foam fractionators and settling tanks were used to control solids

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2012 Study Objectives – 100 m^3 RWs

- Evaluate the ability of the a^3 nozzles to maintain adequate mixing of the biofloc and eliminate the use of pure oxygen
- Evaluate the effect of the a^3 nozzles on the shrimp
- Determine if the foam fractionators (FFs) and settling tanks (STs) can control particulate matter & dissolved organics in the culture medium despite the anticipated increase in loading in biomass, and feed input
- Determine the benefit from using inline YSI 5200 DO monitoring system

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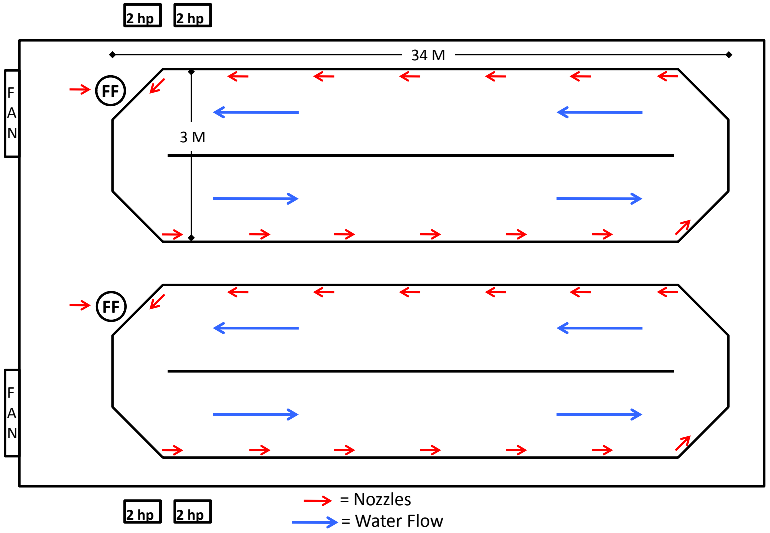
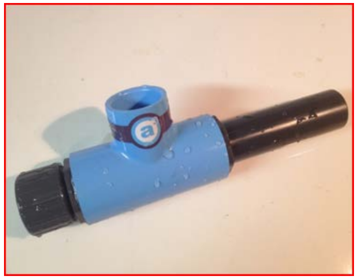
Materials & Methods – 100 m³ RWs

- 14 nozzles were positioned inside each RW
- Every RW had 1 additional a³ nozzle to run a home-made foam fractionator
- Each RW had two 2 hp pumps which could be operated independently or simultaneously depending on loading factors (e.g., biomass, DO concentration)





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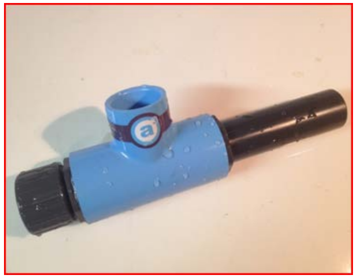
Materials & Methods – 100 m^3 RWs

Foam fractionator

- Home-made foam fractionator (≈ 0.30 m in diameter and ≈ 2 m tall) operated with one nozzle at a flow rate ≈ 28 Lpm



Settling Tank

- Conical tank 2 m^3, flow rate 8.5- 20 Lpm, supplied from a side-loop off aeration pump and land application of sludge

Materials & Methods – 100 m^3 RWs

- A 63 d study in two 100 m^3 RWs filled with a mixture of seawater, freshwater, and biofloc-rich water from a previous study
- Municipal FW served to offset losses to evaporation & solids removal
- RWs stocked with juveniles (3.6 g) at 500/m^3 originated from a cross of Taura Resistant and Fast-Growth genetic lines (SIS Islamorada, FL)

- Fed a 35% CP feed (HI-35, Zeigler Bros., Gardners, PA)
- Feed was delivered by belt feeders 24h/day

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Materials & Methods – 100 m^3 RWs

- Temperature, salinity, dissolved oxygen, and pH were recorded twice daily
- Settleable (SS) were measured daily
- Total suspended solids (TSS) were measured twice/wk
- TAN, NO_2-N, NO_3-N, VSS, turbidity, $cBOD_5$, and RP were monitored weekly
- Alkalinity maintained daily at ≈160 mg/L using sodium bicarbonate
- Each RW was equipped with a YSI 5200 monitoring system to provide continuous DO and temperature readings

Results – 100 m^3 RWs

- Mean TAN levels were low: 0.3 mg/L (0.15-0.59)
- Mean NO_2-N levels were low: 0.36 mg/L (0.10-1.4)
- NO_3-N levels increased from 67 mg/L to 308.8 mg/L
- FFs use began on Day-7, STs from Day-22
- Mean TSS levels were 292 mg/L
- Mean SS levels were 12 mL/L
- The use of FFs and STs was adequate to control solids within the targeted ranges at feed loads of 22 kg/RW/d
- The YSI 5200 monitoring system operated with no problems throughout the trial and provided valuable information for better feed and DO management

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Results – 100 m^3 RWs

- Despite relatively high mean DO levels (85.7 % saturation) supplemental oxygen was provided intermittently between Day-22 and Day-44 for various reasons
- The second 2 hp pump was engaged on Day-44, when biomass was estimated to be about 8.2 kg shrimp/m^3
- No O_2 supplementation was provided during the final 16 days until harvest (9.03 kg shrimp/m^3)
- Observed improved FCRs over 2011 trial (1.48 vs. 1.77), good survival (79.5%), and excellent growth (>2.1 g/wk)
- Decreased grow-out duration to 22.7 g shrimp from 94 d to 63 d

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Summary of 63-d grow-out study in two 100 m^3 raceways stocked with *L. vannamei* (3.60 g) at 500/m^3

RW	Yield (kg/m^3)	Av. Wt. (g)	Survival (%)	FCR	(g/wk)
1	9.20	22.76	80.8	1.43	2.13
2	8.86	22.67	78.2	1.53	2.12
Average	**9.03**	**22.72**	**79.5**	**1.48**	**2.13**

2012 Study Objectives - 40 m^3 RWs

- To study the performance of *L. vannamei* juveniles when fed two commercial diets under high density and no water exchange
- To study the changes in selected WQ indicators in RWs stocked with these shrimp
- To study the benefit from using the YSI 5500 DO monitoring system as a management tool in operating a super-intensive, zero-exchange shrimp production system

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Materials & Methods - 40 m^3 RWs

- Six 40 m^3 EPDM-lined RWs (Firestone Specialty Products, Indianapolis, IN) filled with seawater and biofloc-rich water from an earlier nursery trial
- Salinity was adjusted to 30 ppt
- Stocking: 500 juveniles (2.66 g/m^3) from the same source used in the previous study
- Each RW had eighteen 5.1 cm airlifts, six 1 m long air diffusers (AeroTube, Colorite Division, Tekni-Plex, Austin, TX) and a center longitudinal partition over a 5.1 cm PVC pipe with spray nozzles fed by a Venturi injector operated by a 2 hp pump

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Materials & Methods - 40 m^3 RWs

- Raceways were operated with no water exchange
- Evaporation was compensated weekly using municipal freshwater (1-2 ppm mg/L chlorine)
- Three RWs were fed the HI-35 ($1.75/kg) while the other three received the SI-35 ($0.99/kg) feed (Zeigler Bros., Gardners, PA)
- Feed was distributed continuously by belt feeders
- Rations were initially determined using an assumed FCR of 1.4, growth of 1.5 g/wk, and mortality of 0.5%/wk, and were adjusted according to twice a week growth samples

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Materials & Methods - 40 m^3 RWs

- RWs had optical DO probes and YSI 5500 monitoring systems
- DO, temperature, salinity, and pH twice daily; TAN, NO_2-N, NO_3-N, alkalinity, SS, turbidity, TSS, VSS, and $cBOD_5$ once a week
- Alkalinity was adjusted to 150-200 mg/L (as $CaCO_3$) using sodium bicarbonate
- Each RW had a small FF (VL 65 Aquatic Eco Systems, Apopka, FL) and a settling tank which were used to control particulate matter and dissolved organics, targeting TSS and SS levels in the ranges of 200-300 mg/L and 10-14 mL/L, respectively

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Result: 2012 Study, 40 m^3 RWs

- The optical DO probe worked very well in the biofloc environment
- The YSI 5500 monitoring system improved feed management and minimized DO fluctuations
- TSS, turbidity and VSS levels remained significantly higher in the SI-35 treatment
- These results may be related to the higher non-digestible ingredients in the SI-35 with fiber at 2.69% vs. 1.61% and ash at 11.11% vs. 9.55%, respectively
- TAN and NO_2-N levels were low (< 0.5 and 1.22 mg/L, respectively) in all six RWs throughout the trial
- NO_3-N increased from about 40 mg/L at the study initiation to 359 mg/L at the end of the trial

		HI-35		SI-35	
		Mean	Min - Max	Mean	Min - Max
Temperature (C)	a.m.	29.6	27.5-30.7	29.5	28.1-30.5
	p.m.	30.5	28.2-31.6	30.3	28.8-31.5
DO (mg/L)	a.m.	5.9	4.6-7.0	5.9	4.6-7.6
	p.m.	5.5	4.7-6.6	5.5	4.5-7.0
pH	a.m.	7.1	6.6-7.5	7.1	6.7-7.5
	p.m.	7.1	6.2-7.6	7.1	6.3-7.5
Salinity (ppt)		28.3	24.4-36.5	28.3	24.6-36.7
ALK (mg/L)		208[a]	123-274	171[b]	102-230
TSS (mg/L)		223[a]	115-552	278[b]	155-460
VSS (mg/L)		161[a]	92-435	205[b]	117-288
SS (mL/L)		8	2-21	11	2.5-27
Turb. (NTU)		90[a]	46-132	125[b]	68-246

Performance of shrimp fed HI-35 & SI-35 diets in a high-density 67-d in biofloc dominated system

	HI-35	SI-35
Final Weight (g)	22.12 ± 11.35[a]	19.74 ± 8.28[b]
Growth (g/wk)	2.03 ± 0.01[a]	1.76 ± 0.10[b]
Total Biomass (kg)	389.8 ± 1.77[a]	348.5 ± 9.21[b]
Yield (kg/m^3)	9.74 ± 0.04[a]	8.71 ± 0.22[b]
FCR	1.25 ± 0.01[a]	1.43 ± 0.04[b]
Survival (%)	87.4 ± 0.52[a]	88.3 ± 4.18[a]

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Economic Analyses

Economic analyses were performed on:

- Effect of culture system and the two diets on shrimp performance
- The economic analysis summary included:
  - Cost of Production, Net Returns, Net Present Value, Internal Rate of Return, Payback Period

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Trial A 2011 Study Results

"Fast" Growth Line with HI-35

RW	Stocking (Juv/m^3)	Stock (g)	Harvest (g)	Days	Growth (g/wk)	(g/d)	Sur (%)	Yield (Kg/m^3)	FCR	Water Use L/1 kg	Sal (ppt)
1	500	1.9	22.16	81	1.75	0.25	87.6	9.66	1.39	169.0	18
2	500	1.9	23.63	82	1.86	0.27	81.5	9.59	1.44	160.8	18
3	500	1.9	23.36	82	1.83	0.26	80.7	9.40	1.45	149.0	18
4	500	1.9	23.79	83	1.85	0.26	79.3	9.39	1.45	161.0	18
5	500	1.4	25.12	85	1.95	0.28	78.9	9.87	1.44	148.2	30
Av.			**23.61**	**83**	**1.85**	**0.26**	**81.6**	**9.58**	**1.43**	**157.6**	
SD			0.94		0.06	0.01	0.3	0.18	0.02	7.9	

2012 Two Diet Study*: HI-35 v SI-35

	RW	Stocking (Juv/m^3)	(g)	Harvest Size (g)	Days	Growth (g/wk)	Sur (%)	Yield (Kg/m^3)	FCR	Water Use (L/kg)
HI-35	1	500	2.66	22.26	67	2.02	87.20	9.70	1.24	23.2
	3	500	2.66	22.29	67	2.02	87.85	9.79	1.25	17.9
	5	500	2.66	22.45	67	2.04	86.76	9.74	1.26	28.3
	Average	**500**	**2.66**	**22.33**	**67**	**2.03**	**87.27**	**9.74**	**1.25**	**23.1**
SI-35	2	500	2.66	19.06	67	1.69	93.04	8.87	1.4	21.1
	4	500	2.66	20.81	67	1.87	84.78	8.82	1.41	25.5
	6	500	2.66	19.49	67	1.73	86.71	8.45	1.48	22.7
	Average	**500**	**2.66**	**19.79**	**67**	**1.76**	**88.18**	**8.71**	**1.43**	**23.1**
	B1	500	3.6	22.76	63	2.13	80.8	9.20	1.43	38.59
	B2	500	3.6	22.67	63	2.12	78.2	8.86	1.53	44.00
	Average	**500**	**3.6**	**22.72**	**63**	**2.13**	**79.5**	**9.03**	**1.48**	**41.30**

*** Use of juveniles from a cross between Taura resistant and fast-growth genetic lines**

Comparison of Production Results From 2011 to 2012

Treatment	2011 A	HI-35 40 m^3	SI-35 40 m^3	HI-35 100 m^3
Stocking density (Juveniles/m^3)	500	500	500	500
Survival rate (%) **+7.0%, +8.1%, -2.6%**	81.6	87.3	88.2	79.5
Growth rate (g/wk) **+9.7%, -4.9%, +15.1%**	1.85	2.03	1.76	2.13
Stocking size (g) **+50%, +50%, +100%**	1.8	2.7	2.7	3.6
Harvest size (g) **-5.5%, -16.1%, -3.8%**	23.6	22.3	19.8	22.7
FCR **-12.6%, 0%, +3.5%**	1.43	1.25	1.43	1.48
Crop length (days) **-19.3%, -19.3%, -24.1%**	83	67	67	63
Production (kg/m^3) **+1.7%, -9.1%, -5.7%**	9.58	9.74	8.71	9.03

Economic Analysis

- Performed a 10-year cash flow analysis to estimate:
  - Cost of production, Net returns to land, Net present value, Internal rate of return, and Payback period
- Prices/Costs used in analysis
  - Shrimp sales price: averaged $7.20/kg ($3.27/lb)
  - Commercial row-out feed from Zeigler Brothers
    - Semi-Intensive (SI-35): $0.99/kg or $0.452/lb
    - Hyper-Intensive (HI-35): $1.75/kg or $0.795/lb
  - Juveniles production cost: $20.00/1,000
  - Interest rate for loans: 8%
- Initial investment = $991,997

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Economic Analysis

Summary of Production and Sales for Super-intensive Recirculating Shrimp Production Systems 2011 Compared to 2012 Trials – Metric Units

	2011	HI-35 40 m^3	SI-35 40 m^3	HI-35 100 m^3
Production, kg/crop	38,320	38,960	34,840	36,120
Crops per year	4.4	5.5	5.5	5.8
Production, kg/year	168,608	214,280	191,620	209,496
Production MT/year	169	214	192	209
Selling price, $/kg	7.20	7.20	7.20	7.20
Total Sales per year, $	1,213,978	1,542,816	1,379,664	1,508,371

Study results extrapolated to: One greenhouse system (GH), each consists of eight 500 m^3/m^2 grow-out RWs and two 500 m^3/m^2 nursery RWs. Budget results are based on production figures

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Summary of Enterprise Budgets for Super-intensive Recirculating Shrimp Production Systems 2011 Compared to 2012 Trials $/kg

	2011	HI-35 40 m^3	SI-35 40 m^3	HI-35 100 m^3
Gross Receipts	7.20	7.20	7.20	7.20
Variable Costs	5.38	4.06	4.54	4.31
Income Above Variable Cost	1.82	3.14	2.66	2.89
Fixed Cost	0.59	0.47	0.53	0.48
Total of All Specified Expenses	5.97	4.53	5.07	4.79
Net Returns Above All Costs	1.23	2.67	2.13	2.41
Payback period, years	2.9	1.4	1.9	1.6
Net present value ($ mil.)	1.0	2.9	2.0	2.6
Internal Rate of Return (%)	31.3	66.6	50.1	60.6

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Opportunities for the Future

- Improved technology & experience continues to:
  - Increase growth rate
  - Improve FCR
  - Increase survival
  - Increase yield
- **BIG CAVEATS REMAIN !!!**
  1. Must have year-round PL supply!
  2. Research must show back-to-back-to-back… production is feasible
- Financial analyses are focusing research to sharpen competitiveness

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