Design and management of super-intensive nursery systems for the Pacific White Shrimp, *Litopenaeus vannamei*

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Introduction

- Traditional shrimp farming greatly relies on water exchange to maintain water quality
- This has resulted in receiving steams degradation which resulted in disease outbreaks and massive crop losses
- Raising SPF shrimp under biosecure conditions with minimal water exchange can greatly improve shrimp farming sustainability

Introduction

- Previous studies have indicated good shrimp yields using low water exchange practices
- Because feed is the major driving force of intensive production systems, it is important to optimize its use to maximize profit while minimizing water quality deterioration
- In limited/no water exchange systems, feed quality and its effect on the culture medium can play a major role in shrimp performance

Introduction

Shrimp production can take place in single-, two-, or multi-phase systems

- In a single-phase system, PL are stocked directly into grow-out ponds in which they stay until the harvest
- In two and three-phase systems, grow-out ponds are stocked with juvenile shrimp that were raised first in small ponds or tanks - a stage referred to as the nursery stage

Introduction

Use of nursery phase has several advantages over direct stocking:

- It offers higher survival, better facility utilization, and greater control over predators, WQ and feed
- It can serve as a quarantine that can minimize losses to viral disease outbreaks
- In temperate climate areas greenhouse-enclosed nursery systems can offer extension of the grow-out season

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Disadvantages of Nursery Systems

- It increases shrimp handling
- It is labor-intensive and less forgiving
- It requires well-trained biologists to operate
- Construction costs are higher than conventional ponds
- In Taura infected areas sometimes better shrimp survival have been reported when PL were stocked directly in grow-out ponds

Intensive Nursery Systems Design Criteria

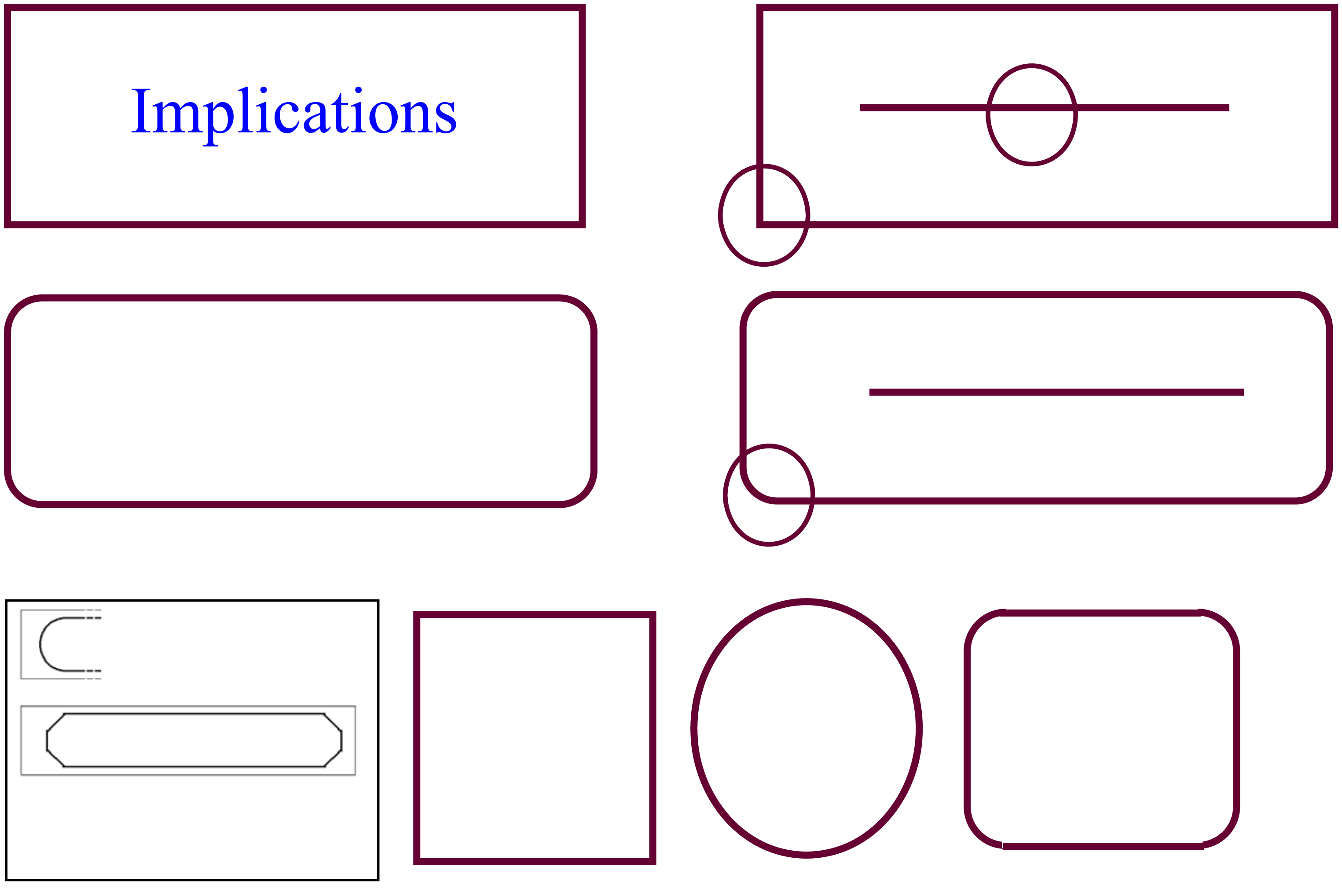
- Shapes
- Dimensions
- Covered vs. Opendoor
- Aeration & Oxygenation
- Filtration & Biofiltration
- Bottom/Surface area vs. Water volume
- Water flow, waste management, bottom slope
- Vertical / Artificial substrate
- Harvest & Transport

Intensive Nursery Systems Design Criteria

Shapes

- Circular
- Square
- Rectangular
- Raceway shape

Intensive Nursery Systems Design Criteria



Intensive Nursery Systems

Design Criteria

- Tank positioning: above ground or in ground: pros and cons
- Construction material:
  - concrete, bricks, fiberglass, plywood, HDPE (high density polyethylene), PVC (polyvinyl chloride), Hypalon (chlolorosulfonated polyethylene-CSPE), CPE (chlorinated polyethylene), EPDM (ethylene propylene diene monomer)

Intensive Nursery Systems

Design Criteria

- Use of reservoir
- Intake & Water delivery system
- Walls and bottom color
- Operating water depth
- Freeboard and netting
- Bottom slope and sump
- Use of a center partition
- Stocking densities & expected yields

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Intensive Nursery Systems

Design Criteria

- Greenhouse cover
  - Temperature consideration, salinity changes, light intensity
- Initial water treatment
  - Filtration, Foam fractionation, Chlorination, Ozonation, Ultra violet
- Water treatment during production
- Factors affecting stocking density
- Harvest methods

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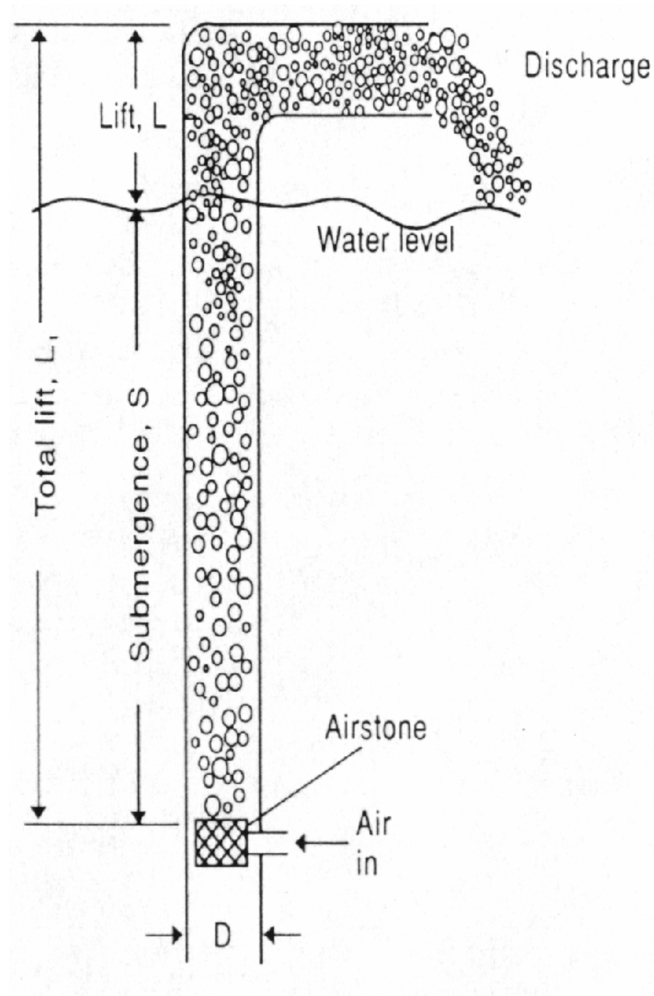
Intensive Nursery Systems

Design Criteria

- Outlet diameter
- Water level control (nested stand pipe, external valve, swivel stand pipe etc.)
- Filter pipes and mesh sizes
- Sump & Harvest basin
- Use of multiport valve
- Water circulation methods
  - Paddlewheel aerators, Aspirators, Fountain type aerators, Airlift pumps, Electric pumps, Air diffusers

Airlift pumps

- Airlift pump is a type of air diffuser that can be used for aeration and water circulation
- It consists of a vertical tube with an air diffuser placed inside the tube at, or near, its bottom



One of the main factor affecting the efficiency of an airlift pump is the submergence of the lift tube

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Intensive Nursery Systems

Design Criteria

- Water circulation using airlift pumps
  - Collar type airlift pump with a 90° elbow
  - Regular airlift pump with a 90° elbow
  - Slotted airlift pipe

Intensive Nursery Systems

Design Criteria

Air distribution & Aeration

- Air supply
- Air delivery system & friction losses
- Air diffuser & airstones – positioning, bubble size, fouling & cost issues
- Venturi injector and valve configuration
- Bottom manifold and valve configuration

Air Blower Selection

Three common types of air blowers are available:

- The rotary vane
- The rotary lobe
- The regenerative blower or centrifugal

Selection of an air blower depends on air flow rate and system head (or pressure) requirements

- The total pressure that a blower has to produce depends on the depth of submergence of the diffuser, the pressure losses through the the distribution systems and the diffusers

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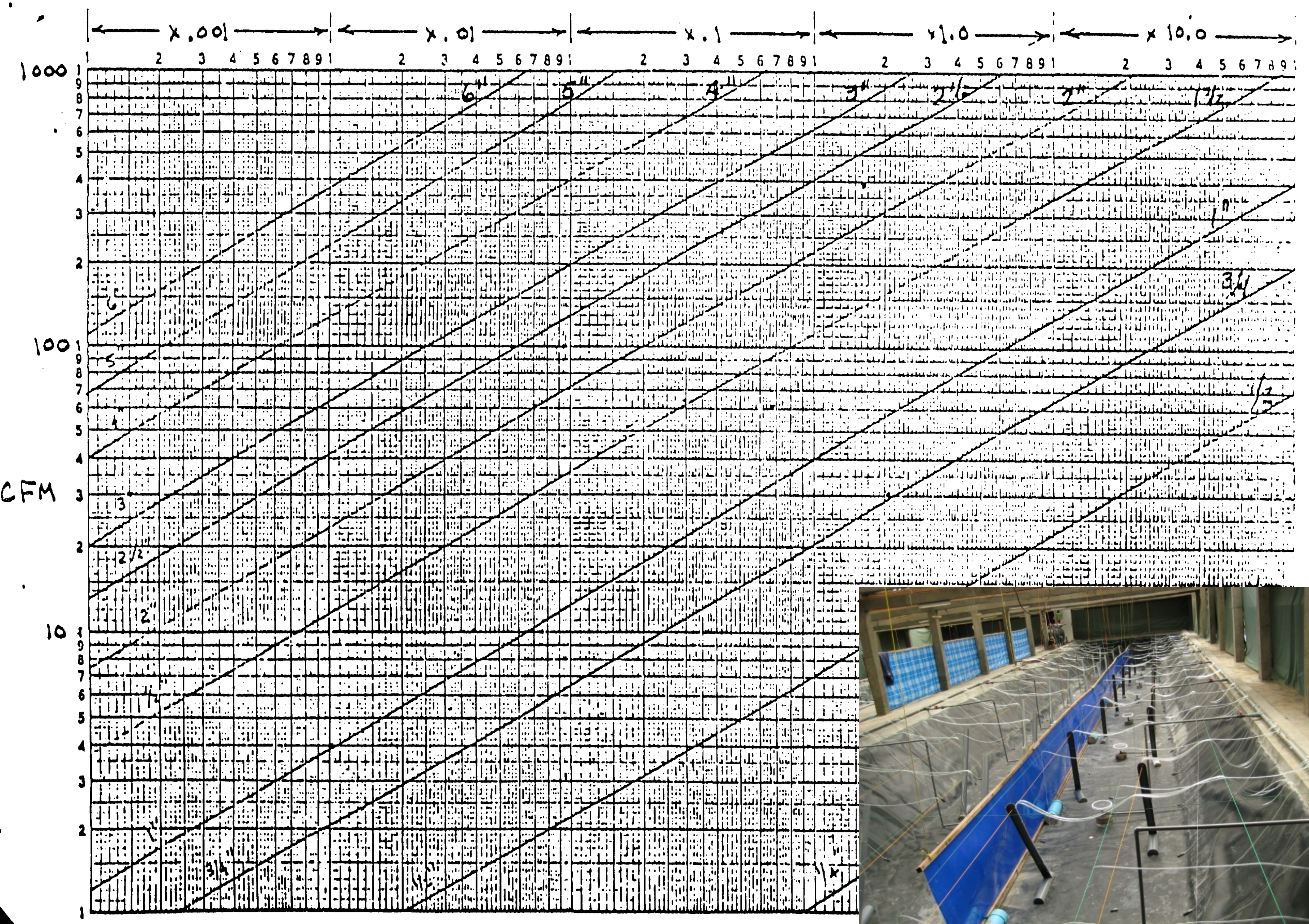
PRESSURE LOSS IN INCHES WATER GAUGE (IWG) PER FOOT OF PIPE



Air Blower Selection

- A rotary van blower produces relatively high pressure (PSI)
  - A ½ HP regenerative blower can provide as much air volume (60 cfm) as 5 HP rotary vane blower
  - Therefore, adequate air blower selection can conserve energy and cost

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Air Blower Selection

PSI=pound per square inch

IWG=inches of water gauge or pressure

1 PSI=27.69 IWG or 2.31 feet (0.70 m)

2 PSI=55.37 IWG or 4.61 feet (1.41 m)

3 PSI=83.05 IWG or 6.92 feet (2.11 m)

4 PSI=110.74 IWG or 9.29 feet (2.81 m)

5 PSI=138.42 IWG or 11.54 feet (3.52 m)

- Therefore, if you try to get air down to a 4' depth (1.22 m or 48") all you need is 2 PSI because it can reach 55" (1.4 m) at 2 PSI

AgriLife Research – Nursery Conceptual Design and Use of Limited Discharge Nursery Systems in Commercial Shrimp Production Facilities

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System Components – Original Settings

- A center partition, bottom spray manifold, airlift pumps, air diffusers, rapid sand filter with pump and multiport valve, Venturi injector, air blower, alarm system, and filter pipes with different filter screens
- Water treatment:
  - Mechanical filtration
  - Biofiltration components

Raceway Management

- Population estimate at stocking
- Postlarvae quality
- Water preparation
- Algal culture
- PL acclimation
- WQ & Control (DO, pH, Sal., TAN, NO_2, alk.)
- Growth monitoring
- Rations & FCR

PL Quality

- Use of hatchery produced SPF Growth or Taura Resistant PL vs. wild seedstock
- Use of certified hatcheries
- Routine testing of the PL and certificate of health
- Sign of stress
- Use of stress tests
- Fouling

PL Counts

- A study conducted in commercial shrimp farm in Panama showed that water temperature affect PL population size estimate
- Samples taken at 19^{o} C resulted in 11-25% higher PL numbers than samples taken at 29^{o} C
- Adequate mixing of the PL is very important in order to get representative counts
- Targeted CV of the samples taken should be no greater than 10%

Water Preparation

- Mechanical filtration
- Chlorination, ozonation, UV
- Fertilization - things to watch for
- Algal inoculation - things to watch for
- Use of carbon source

PL Acclimation

- Dissolve oxygen
- pH
- Temperature
- Salinity
- Feeding

Water Quality

- Parameters to be monitored and frequencies
- pH control, alkalinity, TAN
- Temperature control
- Salinity

Growth Monitoring

- Frequencies
- Use of information for feed management

Raceway Management

Feed & Feed Management

- Newly hatched *Artemia*
- Starter feed - Zeigler PL Redi Reserve
- Rangen 45% protein (#0, 1, 2, 3)
- Feed rate
- Number of feedings per day

Raceway Management

Daily observations

- PL health condition – macro and micro
- Feed consumption
- Bottom condition (dip net, viewing tube)
- Molts

Raceway Management

- Aeration & Airlift pumps regulation
- Water quality (DO, pH, temp., TAN, NO_2, alkalinity, salinity)
- Multiport valve function
- Water filtration
  - Filter media, pressure gauge, backwashes
- Use of the bottom manifold
- Use of the Venturi injector

Raceway Harvest

Preliminary observations and preparation

- Water level, molting, stress signs, H_2S buildup

Harvest time & duration

Harvest methods:

- Drain harvest, use of dip nets

Estimating survival

- By weight
- By volume

DO, Temp., pH, ammonia

Raceway Monitoring Equipment

- DO meter, pH meter, electronic balances (sample weighing & harvest), refractometer, ammonia, nitrite, alkalinity and chlorine testing kits, Imhoff settling cone, hemacytometer, Secchi disk, microscope, dissecting scope

Material & Supplies

- Dry feed, *Artemia* cysts with hatching tanks, fertilizers, oxygen cylinders with regulators, CO_2 cylinder with regulator, dip nets, beakers, Petri dishes, dissecting tools

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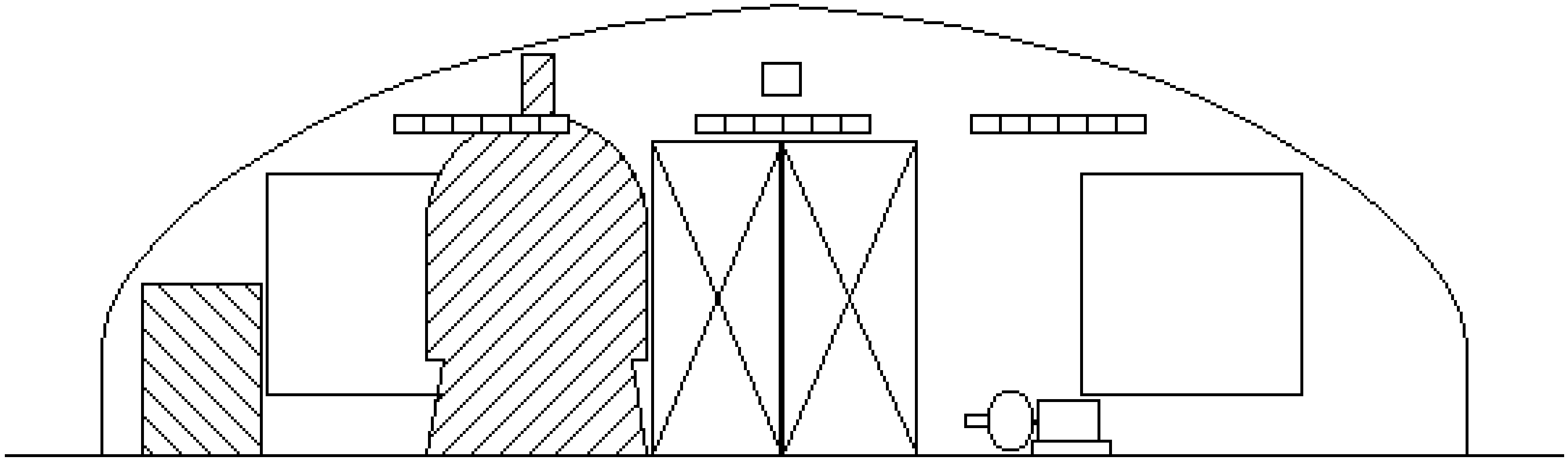

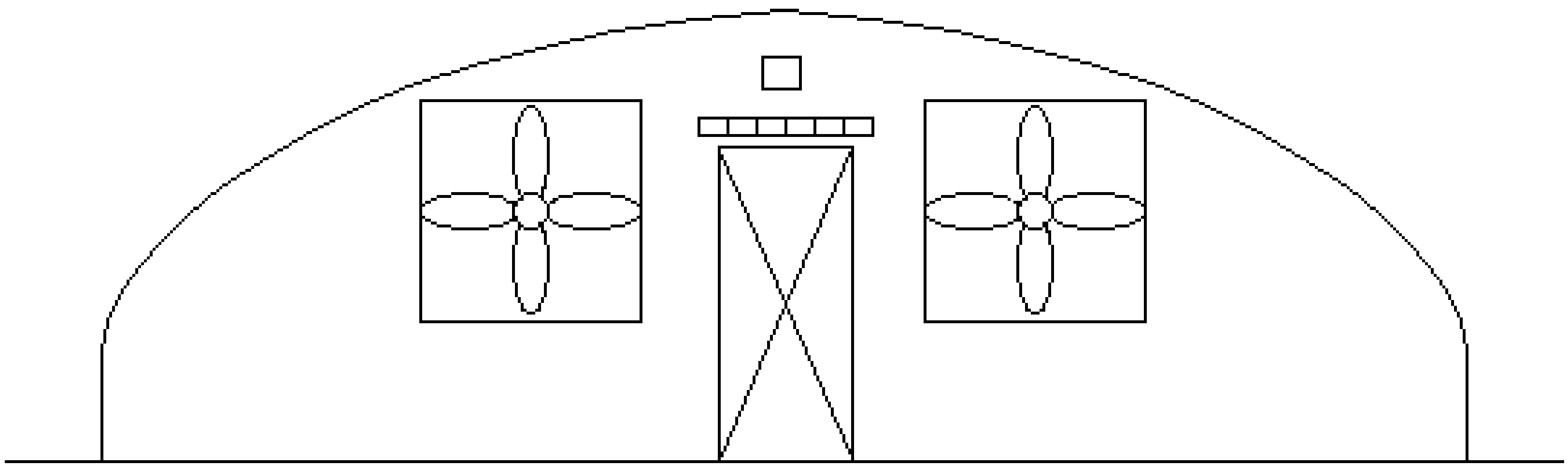

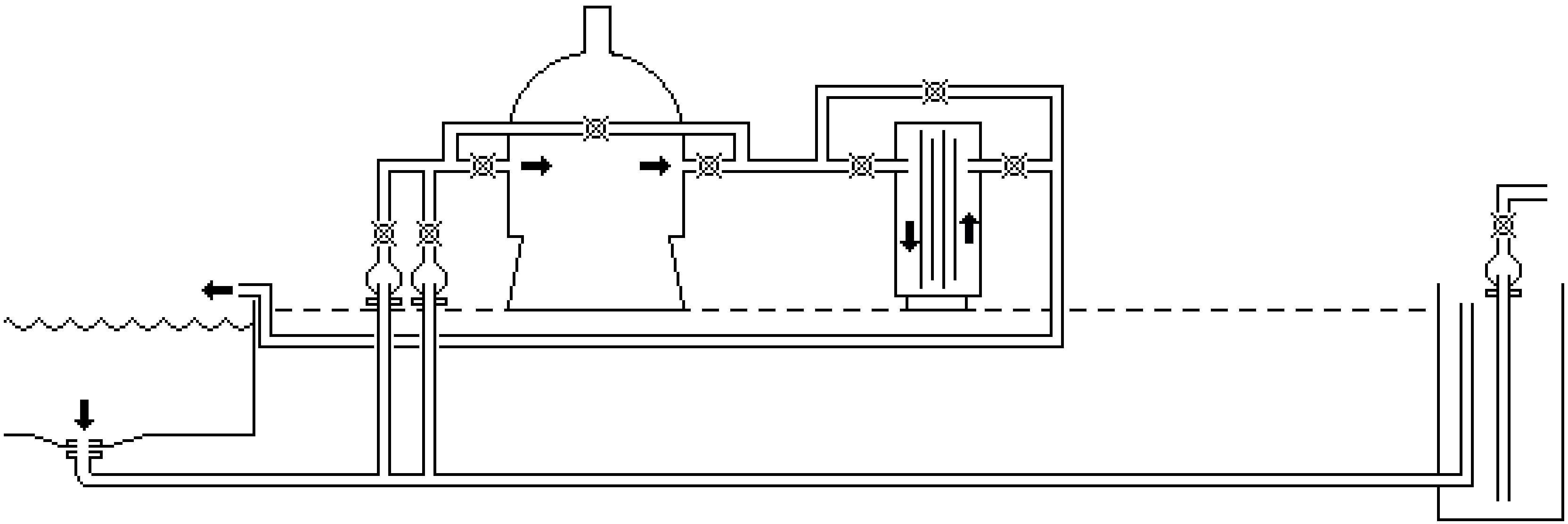

Use Intensive Nursery in Commercial Facilities

R&G Shrimp – Palcios, Texas

- Raceways were designed after the nursery system developed by AgriLife Research
- Construction cost were under $5,000 per raceway, material, equipment and construction cost included
- Two HDPE-lined raceways under greenhouse (29 x 2.4 x 0.9 m), 65 m^3, 71 m^2
- Each raceway was equipped with eighteen 7.5 cm airlift pumps, six 0.9 m air diffuser, partition over a bottom manifold, venturi injector, rapid sand filter and oxygen injection system

R & G Shrimp, Palacios, TX
Nursery *Litopenaeus vannamei* 2001

PL /m^2	PL /m^3	Wt_0 (mg)	Days	Wt_f (g)	Yield (kg) /m^2	Yield (kg) /m^3	Sur. (%)	FCR
42,000	46,000	1	34	0.1	5.11	5.62	101	<1
39,000	43,000	1	34	0.1	5.04	5.59	98	<1

Loma Alta Aquaculture San Perlita, Texas

- A 49 ha shrimp farm that used low-salinity water (2.5-3.0 ppt) to raise the Pacific White Shrimp
- The farm started to use greenhouse-enclosed nursery raceways after suffering chronic low survival in the grow-out ponds due to dragonfly predation
- Nursery raceways are similar to those used by AgriLife Research in Corpus Christi

Loma Alta Aquaculture - Texas

- Except for the water needed to offset seepage and evaporation, no water was exchanged for the first two weeks after stocking
- About 1 wk before moving the juveniles into the grow-out ponds, new water was introduced to acclimate the shrimp to the farm's salinity

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Loma Alta Aquaculture - Texas

- Kerosene heaters were used for short periods in extremely cold weather
- In most cases, water pH stayed below 8.7
- Injection of CO_2 was used to lower pH when a high levels (9.5) were observed
- Ammonia and nitrite concentrations were generally low, concentrations in extreme cases were 13.5 mg/L and 0.38 mg/L, respectively

Loma Alta Aquaculture - Texas

- 10,000-5,000 PL_{10-12}/m^3
- Average survival: between 80 and 97%
- Average weight: between 0.1 and 0.25 g
- FCR: between 0.7 and 1.0
- Shrimp survival in ponds stocked with juveniles from the raceways was 71% compared with the 50% observed in the direct stocked ponds

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Loma Alta Aquaculture - Texas

- Besides the improved survival at harvest, the farm was able to purchase PL at lower cost during low demand period
- Stocking the grow-out ponds with juveniles, enabled the farm to receive higher prices as shrimp were harvested before any other farms
- The nursery facility provided the farm with greater flexibility (e.g., production of two crops/y of small shrimp or one crop/y of large-size shrimp)

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Retrofitted intensive nursery raceways Semacua Hatchery, Salinas, Ecuador

Twelve 120 m^3 RWs

Stocking:

- 20-80 PL_{7-15}/L

Duration:

- 10-15 d

Water exchange:

- Reduction from 300 to 5%/d

Eliminating use of antibiotic

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Nursery Facilities - Industrias Pecis – Yucatan, Mexico

- Twenty-four 80 m^3 (130 m^2) greenhouse-enclosed RWs
- Stocking density: 35 PL/L
- Duration: 21-28 d
- Management: daily siphoning, 0-50% water excahnge/d, use of heat exchanger with biofilter in the cold months

Industrias Pecis – Beneficial Effect of Nursery

PL Source	Stocking Size (mg)	Average Survival (%)	FCR	# Cycle/ Year
Nursery	150-200	75	1.4	3.2
Hatchery	1-5	55	1.9	2.3

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Nursery in Low-salinity Water

Wood Bros., Arizona

- Raceways description
  - Water depth at the shallow-end: 1.22 m; bottom slope: 1%; a 0.3 m deep settling area at the deep-end with a 0.30 m outlet fitted with a filter pipe
  - Each raceways was equipped with a pump, a rapid sand filter, a flat-laying heat exchanger, a surface spray bar, a Venturi injector, a bottom spray manifold, six air diffusers and six banks of four 7.6 cm airlift pumps

WBSF – Ion Composition

Element or Compound	Natural Seawater at 35 ppt salinity	Natural Seawater diluted to 2.2 ppt salinity	WSBF Wellwater of 2.2 ppt salinity
Cl	19,354	1,215	891
Na	10,770	677	724
Sulfate-S	2,712	171	173
Mg	1,290	81.3	15.3
Ca	412	25.9	187
K	399	25	12.5
B	4.5	0.25	1.33
P	0.06	0.004	0.03
Fe	0.04	0.0005	0.31
Zn	0.007	0.0005	<0.01
Pb	0.001	0.0002	0.27
Bicarbonate	142	8.9	201

Nursery results Woods Bros. Shrimp Farms, Gila Bend, AZ

PL /m^2	PL /m^3	Wt_0 (mg)	Days	Wt_f (g)	Yield (kg) /m^2	Yield (kg) /m^3	Sur. (%)	FCR
19,200	12,700	2.5	34	0.1	2.34	1.54	100	0.7
20,400	13,500	2.5	35	0.09	2.10	1.34	100	0.7

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Intensive nursery culture of the Pacific white shrimp *Litopenaeus vannamei*, under biosecured and limited discharged greenhouse-enclosed raceways

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CSREES USDA Education Research Extension

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USMSFP

Background

- With the rapid expansion and intensification of the shrimp farming industry, the impact of nutrient-rich water has become an issue of greatest concern
- The shrimp farming industry has been criticized by different organizations as being environmentally irresponsible

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Background

- Governmental agencies have taken regulatory actions to set effluent water quality standards and discharge limitations
- Viral disease outbreaks severely affected shrimp production worldwide
  - Wild shrimp populations have recently been found to be infected with virulent pathogens

Background

- Shrimp production under zero or limited water exchange can significantly reduce negative environmental impact, minimize the spread of viral pathogens and reduce crop losses to viral disease outbreaks
- Previous studies have demonstrated that reduced water exchange does not compromise production

The AgriLife Research Nursery System

- Samocha et al. (2002) described system modifications and new management practices that led to significant reduction in water usage in the nursery phase without negative impact on the shrimp
- Early studies with this system used the sand filter for filtration of the incoming water and for particulate matter removal from the culture medium

The AgriLife Research Nursery System

- Cohen et al. (2005) stocked (3,300 PL/m^3) in two raceways in 50-d nursery trial with low water exchange (1.1%/d) and found that exposure of the shrimp to high nitrite concentrations (up to 26 mg/L) for about two weeks had no adverse effect on survival (>98%), growth (1.1 g juveniles), FCR (<1), and yields (>4 kg/m^3)

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The AgriLife Research Nursery System

- Furthermore, this 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

The AgriLife Research Nursery System

- The transition into low water exchange practices in operating the nursery system required implementation of more efficient methods to regulate particulate matter concentrations in the culture medium as the sand filter was found to be inefficient under limited water discharge conditions

The AgriLife Research Nursery System

- An early a 74-d study (Handy et al., 2004) evaluated three tools for particulate matter (PM) removal from the culture medium (bead filter-BF, foam fractionator-FF, and sand filter-SF)

PM Control	PL $/m^3$	Wt_f (g)	Yield (kg/m^3)	Sur. (%)	FCR	New Water (%/d)
BF	3,780	0.65	2.42	96.3	1.70	1.35
SF	6,540	0.85	5.26	100.1	1.09	0.47
FF	5,010	0.69	3.18	97.8	1.50	2.06

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Objectives

- To minimize mortality and water exchange during the nursery phase of SPF *Litopenaeus vannamei* postlarvae
- To evaluate potential use of foam fractionator as a tool to control particulate and dissolved organic matter in culture water
- To study the effect of reduced water exchange on shrimp growth, survival, health and selected water quality indicators

Materials & Methods

- A 71-d nursery study was conducted at the AgriLife Research Mariculture Lab, Corpus Christi, TX
- Five-day old PL of *Litopenaeus vannamei* where stocked in four 40 m^3 HDPE-lined greenhouse-enclosed raceways (RWs) at a density of 4 PL_5/L

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Materials & Methods

- Particulate matter control:
- Each of the four RWs was equipped with a pressurized sand filter
- Two of the four RW's were outfitted with foam fractionator (FF) and were operated with 3.35% daily water exchange
- The other two RW's operated with 9.37% daily water exchange

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Water Treatment

- Water Source: natural sea water from the Upper Laguna Madre with salinity adjusted to about 30 ppt with municipal chlorinated freshwater
- Incoming water was filtered to 350 µm and was chlorinated with a targeted initial concentration of 10 ppm chlorine 30 min post application

Materials & Methods

Fertilization

Fertilizer	Amount	Concentration (g/m^3)
Urea	225 g	2.25 as N
Sodium silicate	292 g	1.55 as Si
Phosphoric acid	30 ml	0.138 as P

Algal Inoculation

RWs were inoculation with the *Chaetoceros muelleri* (3.8 x 10^4 cells/ml)

Materials & Methods

Feed & Feeding:

- For the first 10 days: newly-hatched *Artemia* nauplii and 50% CP Redi Reserve™ dry diet (Zeigler Bros., Gardners, PA)
- Rest of the trial 45% CP PL dry feed (45/10 swim-up, Fry #1, #2, #3 & #4, Rangen Inc., Buhl, ID)
- Feed was provided four times daily
- Daily rations were adjusted every 2-3 days, based on feed consumption and monitoring of animal growth

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Materials & Methods

Water quality indicators

- Twice daily: temperature, DO, pH, salinity
- Daily: turbidity, settleable solids, algal cell density
- Weekly: NH_4-N, NO_2-N, NO_3-N, $cBOD_5$, COD, RP, TSS and VSS

Biosecurity Applications

- Water filtration chlorination
- Positioning of the culture tanks under a greenhouse structure protected by wire shocker to exclude potential predators
- Nets were cleaned and dried after each use to minimize the introduction of diseases
- Shrimp samples from the RW's were sent every two weeks to diagnostic lab (TVMDL) to test for viral pathogen of concern (TSV, YHV, WSSV and IHHNV)

Statistical Analysis

- Repeated Measures ANOVA was used to compare daily and weekly water quality between treatments
- One way ANOVA was used to determine differences between treatments in survival (arcsine transformed), mean final weights, FCR and yields
- All differences were analyzed at $\alpha=0.05$

Results

- No significant difference in water temperature, dissolved oxygen, pH and salinity between RW's operated with or without foam fractionators
- Significant differences were found between treatments in nitrite-nitrogen, reactive phosphorus (RP), turbidity, and algal cell density specify where it was higher

Summary of selected daily WQ indicators by treatment

RW ID	Temp. (C) a.m.	Temp. (C) p.m.	DO (mg/L) a.m.	DO (mg/L) p.m.	pH a.m.	pH p.m.	Salinity (ppt)
FF [1]	26.3	27.4	6.0	5.9	7.2	7.2	25
WE [2]	26.2	27.4	6.2	6.3	7.3	7.3	27

[1] Foam Fractionator - Raceways operated with 3.35% daily water exchange
[2] Water Exchange - Raceways operated with 9.37% daily water exchange

Summary of weekly WQ indicators by treatment

RW	PO_4	NO_2-N	NO_3-N	NH_4-N	TSS	VSS	$cBOD_5$
	mg/L						
WE[1]	3.4 **a**[3]	6.4 **a**	7.2 a	0.2 a	110 a	60 a	41 a
	(2.8 [4])	(6.4)	(7.6)	(0.6)	(84.7)	(55.8)	(36.9)
FF [2]	4.7 **b**	3.7 **b**	6.5 a	2.6 a	126 a	65 a	49 a
	(4.4)	(4.5)	(3.6)	(6.5)	(98.)	(73.7)	(30.9

[1] RWs operated without foam fractionator and 9.37% daily water exchange make changes as above
[2] RWs operated with foam fractionator and 3.35% daily water exchange
[3] Means with similar superscripts are statistically not significant at α=0.05
[4] Standard deviation

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Summary of selected WQ indicators by treatment

RW	Turbidity (NTU)	SS (mL/L)	Algae (cell/ml x 10^4)
FF[1]	39 [a 3]	1.5 [a]	403 [a]
WE[2]	20 [b]	3.4 [a]	220 [b]

1 Raceways operated with Foam Fractionators (3.35% daily water exchange)

2 Raceways operated with increased water exchanged (9.37% daily water exchange)

3 Numbers having similar superscripts are statistically similar (α=0.05)

Result

- All shrimp submitted for disease diagnosis showed no signs of viral infections
- Histological observations suggest that the shrimp raised with increased water exchange regime showed greater levels of fouling and intestinal bacterial load than shrimp raised with lower water exchange

Performance of *Litopenaeus vannamei* stocked at 4 PL/L in a 71-d nursery trial in greenhouse-enclosed raceways operated with different water exchange rates

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]	6.88 [a]	92.4 [a]	1.08 [a]
WE-1 [2]	0.6	1.73 [b]	3.91 [b]	55.9 [a]	1.64 [a]
WE-4 [2]	0.6	1.43 [b]	4.74 [b]	81.8 [a]	1.36 [a]

[1] RWs operated without foam fractionator and 9.37% daily water exchange make changes as above

[2] RWs operated with foam fractionator and 3.35% daily water exchange

[3] Means with similar superscripts are statistically not significant at $\alpha=0.05$

Results

- Results from this study suggest that nursery of the *L. vannamei* can be conducted in the greenhouse-enclosed RW's supported by sand filters and inexpensive FF with high biomass load, excellent growth, yield, survival and FCR
- Foam fractionators were effective tools for controlling PM in the culture water and can be used to reduce water exchange
- Biosecurity measures were adequate in preventing the introduction of pathogens into culture water

Result

- Raceways operated with foam fractionators had significantly higher algal densities than raceways operated with the higher water exchange
- It is possible that larger amount of pathogen were introduced into the raceways operated with higher water exchange compare to the other two operated with reduced water exchange

Conclusions

- Better shrimp performance was observed during the nursery phase when raceways are operated with reduced water exchange and foam fractionators compare to raceways operated with higher water exchange

Intensive nursery of the Pacific White Shrimp *Litopenaeus vannamei* in greenhouse-enclosed raceways using low and high-protein diets under no water exchange

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Aquaculture 2010
San Diego, Mar 1-5

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Objectives

A 62-d trial was conducted with postlarvae of the Pacific White Shrimp, *Litopenaeus vannamei* to improve feed management and water quality during the nursery phase under no water exchange

Specific objectives were:

1. To determine the effect of substituting high-protein for low-protein feed on shrimp growth, survival and selected water quality indicators

Objectives

2. To determine if molasses can be used to prevent ammonia and nitrite build up in a zero exchange system
3. To study the effect of no exchange on water quality and shrimp performance
4. To evaluate the benefit of using a continuous dissolved oxygen monitoring system as a management tool

Material & Methods

- The study was carried out in four 40 m^3 (68.5 m^2) EPDM lined greenhouse-enclosed raceways (RW) at the Texas AgriLife Research Mariculture Laboratory, Corpus Christi, TX

- Each RW was equipped with a center longitudinal fiberglass partition positioned over a 5.1 cm PVC pipe with sprayer nozzles

Material & Methods

- Each RW had eighteen 5.1 cm airlifts, and six 1m long air diffusers for mixing and circulation

- Airlifts & diffusers were positioned equally throughout the RWs and were operated continuously using a 3 hp regenerative blower
- In addition, each RW had, a centrifugal 2 hp pump and a Venturi injector

Material & Methods

- The Venturi was capable of injecting atmospheric air or a mixture of oxygen and air

- Dissolved oxygen was continuously monitored in each RW by a YSI 5200 Recirculating System Monitor

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Material & Methods

- Raceways were filled with natural seawater, chlorinated to 10 ppm, and dechlorinated by aeration
- Salinity was adjusted to 30 ppt using municipal freshwater
- TSS & VSS were controlled by using foam fractionators

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Material & Methods

- Each RW was fertilized with 225 g urea, 32 ml phosphoric acid and 290 g sodium silicate
- The following day they were inoculated with *Chaetoceros muelleri* (70,000 cells/mL)
- Each RW was stocked (5,000 PL/m^3), a day after the algae inoculation, with ten to twelve-day-old postlarvae (PL_{10-12}) *L. vannamei*

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Material & Methods

- From Day 10 through Day 18, each RW received 500 mL of molasses every other day to promote bacterial floc development
- From Day 19 on, molasses supplementation was based on the ammonia level using 6 g of carbon for each 1 g of ammonia found in the culture medium as described by Samocha et al. (2007)
- From Day 30 until termination no molasses was added as ammonia concentrations were consistently below 0.5 mg/L

Material & Methods

- PL were fed newly hatched *Artemia* nauplii (~40/PL/d for four days)
- For the first 26 days PL were fed a combination of dry diets to include: PL Redi-Reserve (Zeigler Bros. Inc.); Surestart #3 & #4 (Salt Creek Inc.); and Fry #0 & #1 (Rangen Inc.)
- Shrimp were sampled twice/wk to monitor health and growth and to adjust daily rations

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Material & Methods

- Beginning Day 27, shrimp in two RWs were fed 30% CP Rangen Fry #2 while those in the other two RWs were fed Fry #2 with 40% CP
- Diet particle size was increased to Fry #3 and #4 according the shrimp size
- Rations ranged from 50% of the total estimated shrimp biomass for the first days after stocking to 4% of the estimated biomass during the final week of the trial

Material & Methods

- Rations were adjusted based on feed consumption
- Feed was distributed by hand four times per day
- During the last 18 days of the study, an additional feeding (30% of total daily ration) was delivered by three belt feeders/RW

Material & Methods

- Temperature, dissolved oxygen, pH, salinity, and algal cell density were monitored daily
- Turbidity, alkalinity, and settleable solids (SS) were monitored every other day
- TAN, NO_2, NO_3, PO_4, $cBOD_5$, TSS, and VSS were monitored once a week

Material & Methods

- Data was analyzed using SPSS statistical software
- Repeated measures ANOVA was used to determine significant differences between treatments in water quality indicators
- One way ANOVA was used to determine differences between treatments in survival, mean final weights, FCR, and yields
- All differences were analyzed at significance level of $\alpha = 0.05$

Results

- No statistically significant differences were found between the two treatments in temperatures, DO, and pH
- Statistically significant differences were found between treatments in alkalinity and nitrate-N
- No statistically significant differences were found between treatments in mean final weight of the shrimp

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Results

Table 1. Means for daily water quality indicators monitored over 62-d nursery trial

RW	Temp. (C)		DO (mg/L)		pH		Salinity
	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	(ppt)
30% [1]	27.6	28.7	5.7	5.7	7.5	7.4	30.2
40% [2]	27.7	28.7	5.6	5.7	7.4	7.3	31.5

Results

Table 2. Means for weekly water quality indicators monitored over 62-d nursery trial

RW	$cBOD_5$ (mg/L)	TAN (mg/L)	NO_2-N (mg/L)	RP (mg/L)	TSS (mg/L)	VSS (mg/L)	Alk (mg/L)	SS (mL/L)	Turb. (NTU)	Algae ($x10^4$)
30%	18	0.85	4.15	3.1	223	115	155[a]	5.9	163	243
40%	19	0.75	5.8	3.9	208	108	145[b]	6.5	145	194

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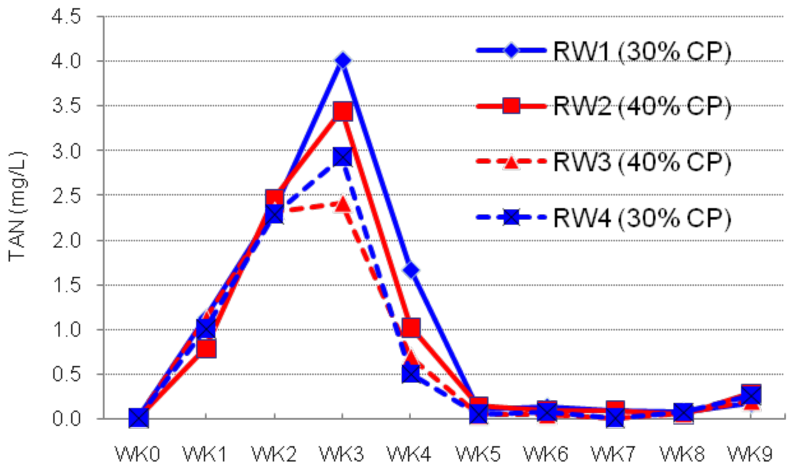
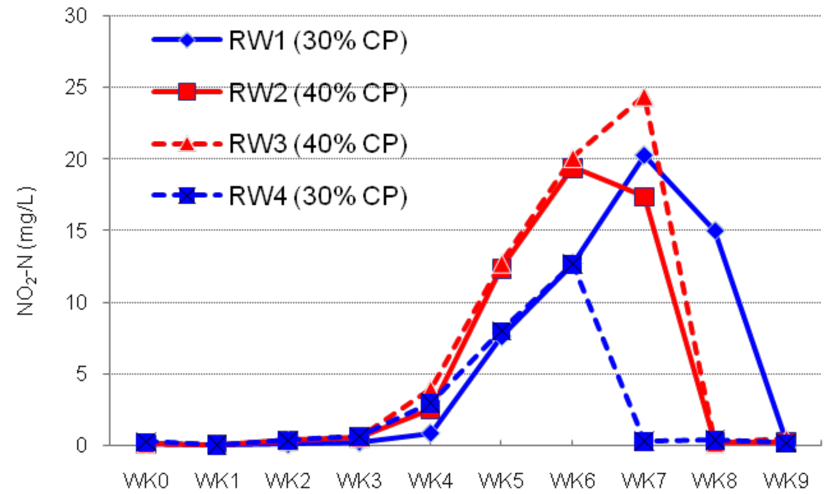
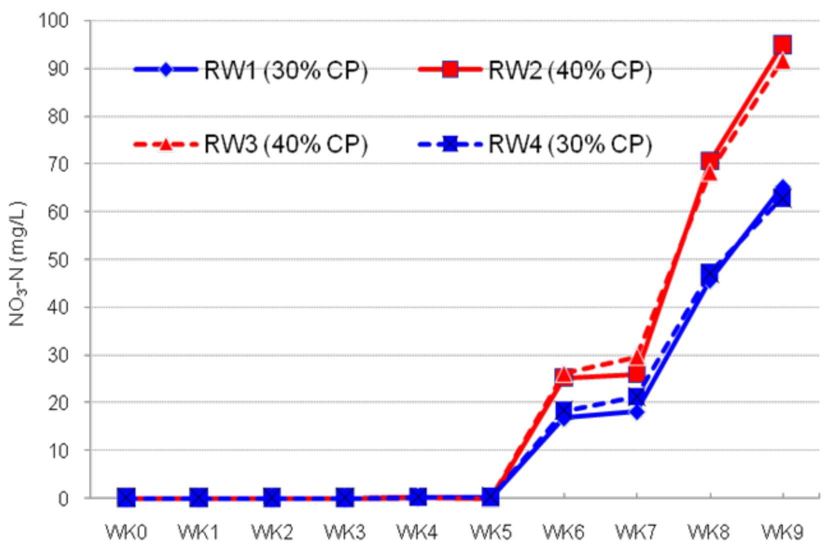
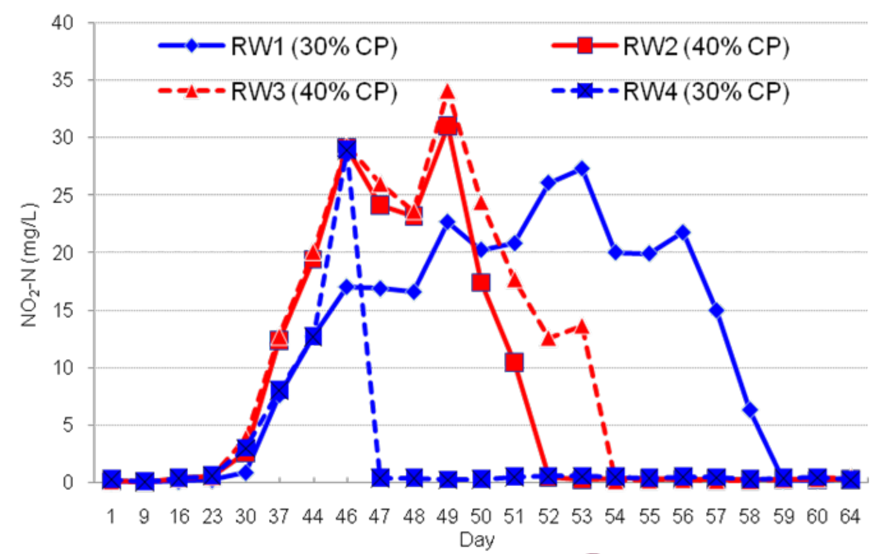
Weekly variations in water quality of the raceways during a 62-d nursery study using low (30% CP) and high-protein (40% CP) feeds









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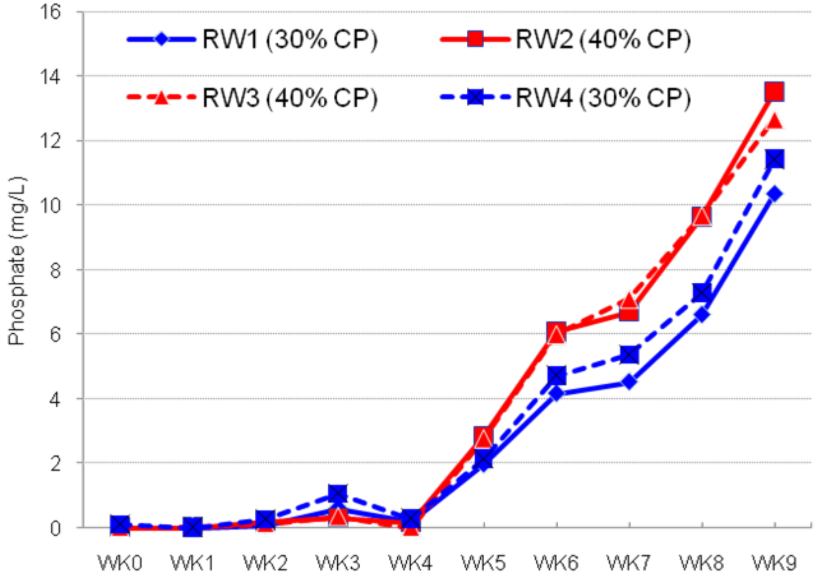
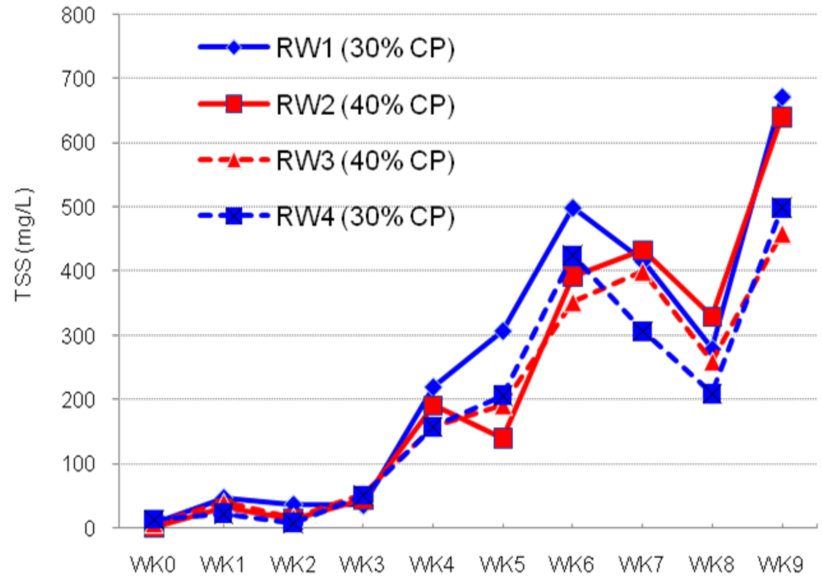
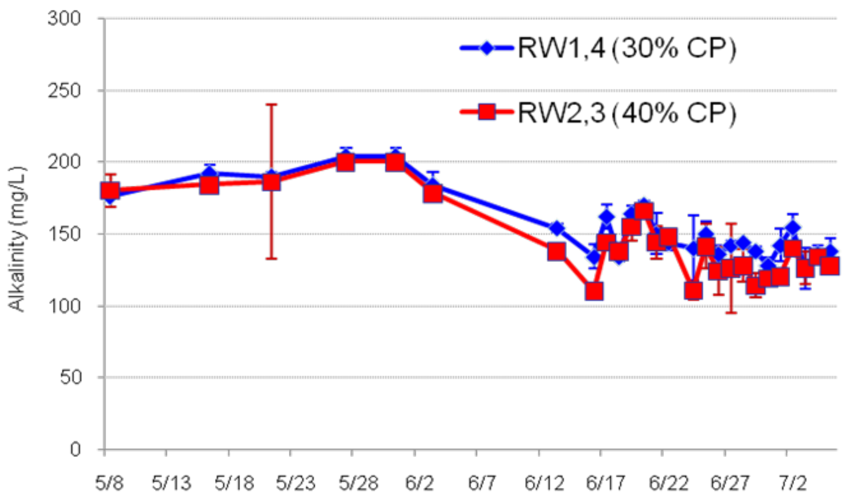
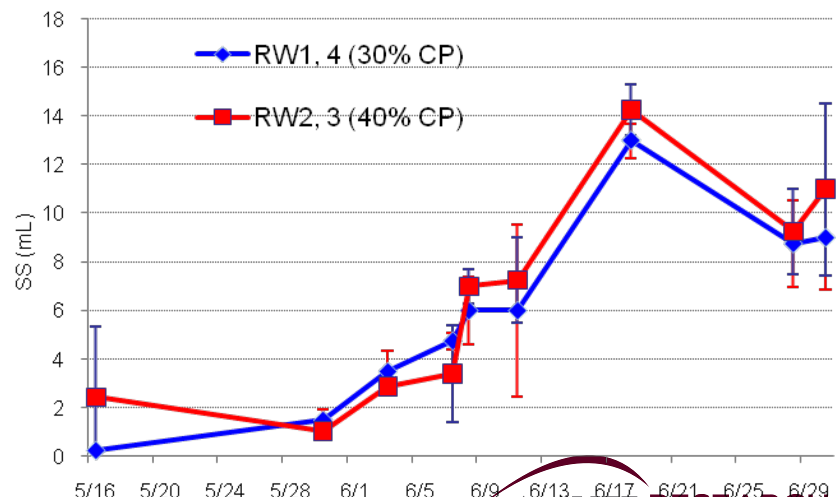
Weekly variations in water quality of the raceways during a 62-d nursery study using low (30% CP) and high-protein (40% CP) feeds









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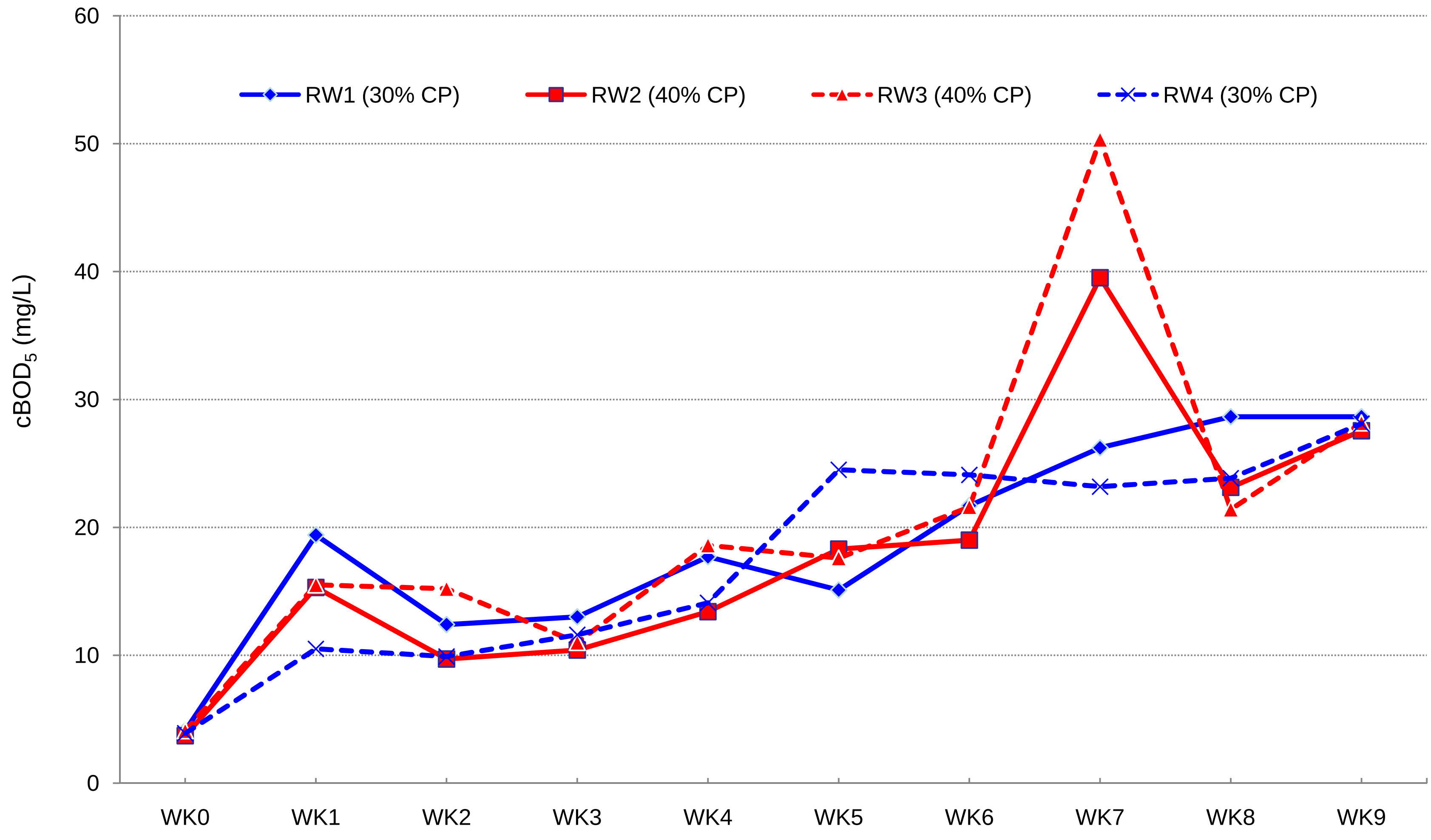
Weekly changes in $cBOD_5$



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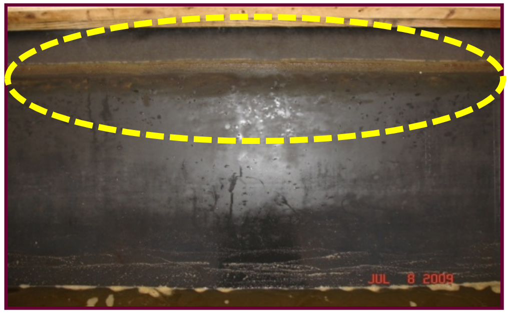
Summary by treatment of shrimp performance criteria at the end of 62-d nursery trial

Variables	30% CP	40% CP
Final weight (g)	0.94 ± 0.00	1.03 ± 0.02
SGR (%/day)	11.03 ±0.01	11.19 ±0.05
Survival (%)	82.29 ±11.26	84.13 ±6.07
FCR	0.91 ± 0.05	0.82 ± 0.05
Yield (kg/m^3)	3.70 ± 0.49	4.18 ± 0.23



High consumption of natural food

↓

Low FCR

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Conclusions

- No significant differences in shrimp performance when fed the low-protein diet (30% CP) compared to high-protein feed (40% CP)
- The higher levels of nitrate and nitrite found in the high-protein diet are most likely because of the higher nitrogen content of the feed
- Molasses can be used to enhance development of bacterial floc and to prevent ammonia build up in the culture medium
- Molasses supplementation was not effective in preventing nitrite build up

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Acknowledgements

- Funding: National Institute of Food & Agriculture (NIFA) USDA, Texas AgriLife Research; USAID, The National Academy of Sciences; CAPES & CNPq Brazil
- Feeds: Zeigler Bros. & Rangen Inc.,
- PL Supply: Harlingen Shrimp Farms, Shrimp Improvement Systems
- DO monitoring systems: YSI Inc.
- Foam fractionators: Aquatic Eco System
- Air diffusers: Colorite Plastics
- RWs liner: Firestone Specialty Products
- Firestone Specialty Products for the EPDM liner

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