High-density Nursery & Grow-out of Pacific White Shrimp in Biofloc-dominated, Limited-exchange Systems

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The Seafood Deficit

- Global seafood demand continues to increase...
- ...but supply from capture fisheries is at -- or beyond -- the Maximum Sustainable Yield
- Aquaculture's mission is to cover the seafood deficit by **sustainably** intensifying production on a smaller environmental footprint
- This goal increasingly is shared by producers, retailers, and consumers alike
The Market Drives Sustainability

- Consumers' market decisions drive the trend for sustainable seafood

- Their concerns include:
  - excessive discharge of nutrient-rich effluent
  - introduction of pathogens to natural waters
  - feeds based on marine fish products
  - use of antibiotics for disease control
  - potential impacts of escapes on wild stocks
  - use of dwindling freshwater resources
The Problems of Flow-through

➢ Traditional pond culture relies on high rates of water exchange
➢ As a direct result, it is not bio-secure and so runs a greater risk of...
  ➢ introducing pathogens to the culture environment with incoming water
  ➢ discharging nutrient-rich effluents – and possibly pathogens -- to natural waters
  ➢ escape of non-native stock to the local aquatic ecosystem
Two Hurdles to RAS Expansion

➢ Sustainability requires a shift from flow-through to Recirculating Aquaculture Systems (RAS)

➢ RAS expansion proceeds slowly because...
  ➢ it now is less expensive to discharge waste than to treat it – this is remedied by strict enforcement of environmental standards
  ➢ water treatment requires technical expertise not yet widely found in aquaculture teams – this is solved by advanced WQ training
The Biofloc Option

➢ The high-level biosecurity of RAS eliminates many problems inherent in flow-through

➢ Previous work demonstrated the feasibility of producing high shrimp yields with no water exchange in *biofloc-dominated* systems

➢ **Biofloc** is a natural assemblage of living (algae, bacteria, protozoa) and non-living (uneaten feed, waste) components

Emerenciano et al., 2011 WAS Natal, Brazil
Biofloc-dominated (BFD) Systems

➢ designed to support high yields of fish or shrimp
➢ provides WQ stability
➢ requires constant oxygen supply & mixing
➢ marine floc is *rich* in some amino acids, but *deficient* in others and in vitamin C
➢ super-intensive BFD systems use high-quality feed to supply nutrients missing in typical floc
Autotrophic & Heterotrophic Systems

- **Autotrophs** are primary producers: macroalgae, microalgae, and some bacteria (e.g., nitrifiers)
- **Heterotrophs** are all other organisms
- Each has specific metabolic requirements and different effects on water quality
- Biofloc systems may be classified as autotrophic, heterotrophic, or "mixotrophic"
- **Mixotrophic** systems balance features of the other two types
Heterotrophic Systems

- Compared to autotrophic nitrification systems...
  - microbial production is *40 times higher*
  - $O_2$ consumption is much higher
  - $CO_2$ production is much higher, reducing pH

- Greater effort & resources are needed to manage fully heterotrophic systems

- In particular, they require very careful control of organic carbon additions
Heterotrophic vs. Autotrophic Systems

The basic reactions frame WQ management...

**heterotrophic**

*Requirements*: [ammonia] + [oxygen] + ["alkalinity"] + [organic carbon]

*Products*: [bacterial biomass] + [water] + [carbon dioxide]

**autotrophic**

*Requirements*: [ammonia] + [oxygen] + ["alkalinity"]

*Products*: [bacterial biomass] + [water] + [carbon dioxide] + [nitrate]
The "Mixotrophic" Approach

➢ Balances hetero- & autotrophic systems

Requirements: [ammonia] + [oxygen] + ["alkalinity"] + [organic C from feed]

Products: [bacterial biomass] + [water] + [carbon dioxide] + [nitrate]

The Samocha Mixotrophic System
1/3 heterotrophic + 2/3 autotrophic
Design and Operation of Super-Intensive Biofloc-Dominated Systems for the Production of Pacific White Shrimp

- The Texas A&M AgriLife Research Experience -

By: Tzachi M. Samocha, David I. Prangnell, Terrill R. Hanson, Granvil D. Treece, Timothy C. Morris, Leandro F. Castro and Nick Starsinic
The Manual

➢ **Objective**: Encourage expansion of sustainable BFD as developed in the Samocha lab

➢ **Funding**: NOAA, through *National Sea Grant*

➢ **Participants**:

➢ Texas A&M AgriLife Research
➢ Auburn University
➢ Florida Organic Aquaculture
➢ Texas Sea Grant Extension Service
The Manual

➢ describes design & operation of the biofloc systems developed over 20 years at Texas A&M AgriLife Research Mariculture Lab

➢ emphasizes the most recent *L. vannamei* production trials

➢ written in a non-academic style to target a wider group of stakeholders -- especially entrepreneurs interested in building a pilot BFD system
The Manual -- some highlights

➢ 15 Chapters + appendices, Excel sheets & video

➢ *Chapter 3: Biofloc* -- its composition, structure, development, & advantages
  • *Chapter 5: Site Selection & Production System*
  • *Chapter 6: System Treatment & Preparation*
  • *Chapter 7: Water Quality Management* – controlling DO, ammonia, pH, alkalinity, temperature, salinity, suspended solids, turbidity, and waste products in indoor BFD systems
The Manual -- some highlights

- Chapter 8: Nursery Production
- Chapter 9: Grow-out
- Chapter 12: Disease & Biosecurity
- Chapter 13: Economics of BFD
- Chapter 15: Trouble-shooting Table
Nursery production of the Pacific White Shrimp, *L. vannamei*, in 100-m³ RWs under a zero-exchange biofloc-dominated system operated with a³ injectors

Tzachi Samocha, Leandro Castro, David Prangnell, Tom Zeigler, Craig Browdy, Tim Markey, Darrin Honious, and Bob Advent


62-d Nursery Trial, Two 100-m$^3$ RWs

Objectives

➢ Evaluate...

➢ $a^3$ injectors in maintaining DO & mixing
➢ safety of the injectors for very young PLs
➢ effect of injectors on growth, survival, & FCR
➢ changes in WQ during the nursery phase
The Texas A&M AgriLife Biofloc System

- Two 100-m³ RWs
- GH with shade cloth, exhaust fans
- YSI 5500D Online DO monitoring
- 14 pump-driven a³ injectors/RW
- Two 2-HP pumps/RW
- One foam fractionator/RW
- One settling tank/RW
- One digester/2 RWs
62-d Nursery Trial, Two 100-m³ RWs

➢ 90% disinfected SW + 10% nitrifier-rich SW (30 ppt)

➢ 540 PL₅₋₁₀/m³ hybrid Fast-growth/Taura-resistant

➢ 0.94±0.56 mg with CV = 59.7%!

➢ continuous feeding from Day 2

➢ Online YSI 5500D DO monitor with optical probe

➢ alkalinity adjusted 2/wk with NaHCO₃ to 160 mg/L

➢ Vibrio monitored 2/wk (TCBS for yellow & green colonies)
62-d Nursery Trial, Two 100-m³ RWs

- **KI-Nitrifier™** (Keeton Industries) & sugar for nitrogen control
  - 0.26 mg/L (days 1, 4, 7, 10, & 32)

- **Ecopro®** (EcoMicrobials) Probiotic with stabilized bacterial spores
  - 0.2 mg/L every 3rd d, + 0.055 mg/L on Day 1, 0.4 mg/L on Day 39, & 0.3 mg/L on Day 42
62-d Nursery Trial, Two 100-m³ RWs

**Foam Fractionator**
- one a³ injector, flow rate ≈ 28 Lpm, fed from the pump’s side loop
- fabric to de-water, dry, & collect accumulated organic sludge

**Settling Tanks**
- conical, 2 m³, flow rate ≈ 20 Lpm, fed from the pump’s side loop
- fabric to de-water, dry, & collect accumulated organic sludge
62-d Nursery Trial, Two 100-m³ RWs

Solids & Biofloc Control

- TSS maintained at 250 - 350 mg/L
- waste disposal
62-d Nursery Trial, Two 100-m³ RWs

➢ Day 1-8: EZ-Artemia + dry feed (Zeigler Raceway Plus)

➢ Then: Zeigler RP + Zeigler PL 40-9 with V-pak™

➢ Feed size & rate adjusted based on growth & size variation, with continuous delivery by belt feeders

<table>
<thead>
<tr>
<th></th>
<th>Temp. (°C)</th>
<th>Sal. (ppt)</th>
<th>DO (mg L⁻¹)</th>
<th>pH</th>
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<td>AM</td>
<td>Mean</td>
<td>26.4</td>
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<td>Max</td>
<td>30.2</td>
<td>31.1</td>
<td>7.9</td>
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</table>
62-d Nursery Trial, Two 100-m³ RWs

TAN (mg L⁻¹)

NO₂⁻N (mg L⁻¹)

TSS (mg L⁻¹)

SS (mL L⁻¹)
Green-colony *Vibrio* remained below 50 CFU/mL and less than 2% of yellow-colony concentrations throughout the trial.
### 62-d Nursery Trial, Two 100-m³ RWs

540 PL₅₁₀/m³

<table>
<thead>
<tr>
<th>RW</th>
<th>Yield (kg/m³)</th>
<th>Av. Wt. (g)</th>
<th>Max (g)</th>
<th>Min (g)</th>
<th>CV (%)</th>
<th>Sur. (%)</th>
<th>FCR</th>
<th>Sugar (kg/RW)</th>
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<td>B1</td>
<td>3.43</td>
<td>6.49</td>
<td>11.9</td>
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<td>6.43</td>
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<td>31.0</td>
<td>94.6</td>
<td>0.81</td>
<td>33.1</td>
</tr>
</tbody>
</table>

- low temp over first 3 wks resulted in a longer trial
- high size variation required frequent individual weight monitoring to determine feed particle size
- high variation may have prevented full crop growth
- size variation continued to harvest
62-d Nursery Trial, Two 100-m$^3$ RWs

- stocking in nitrifier-rich water avoided exposure to high TAN & nitrite
- probiotics may have contributed to the low FCR
- TCBS agar plates were a good tool in monitoring safe & pathogenic Vibrio
- a$^3$ injectors did not damage very small PLs
- one 2-hp pump maintained DO at 4.4-8.5 mg L$^{-1}$ for 3.43 kg shrimp m$^{-3}$ with no need for oxygen
USE OF A NON-VENTURI AIR INJECTION SYSTEM FOR PRODUCTION OF *Litopenaeus vannamei* IN 100-m³ RWs UNDER BIOFLOC-DOMINATED ZERO-EXCHANGE RACEWAYS

Tzachi Samocha, Leandro Castro, David Prangnell, Tom Zeigler, Craig Browdy, Tim Markey, Darrin Honious, and Bob Advent


63-d Grow-out Trial in Two 100-m$^3$ RWs

Objectives

- Evaluate...
  - ability of $a^3$ injectors to maintain DO & mixing
  - effect of injectors on growth, survival, & FCR
  - WQ changes during grow-out
63-d Grow-out Trial in Two 100-m$^3$ RWs

M & M

- RWs (same as nursery) with 75 m$^3$ diluted SW & 25 m$^3$ biofloc-rich water
- 500/m$^3$ juveniles (3.60 g) from a cross between Taura-resistant & Fast-growth genetic lines
- 35% CP commercial feed (HI 35 Extra Short-cut, Zeigler Bros., Gardners, PA)
- feed delivered 24/7 by belt feeders
### 63-d Grow-out Trial in Two 100-m³ RWs

<table>
<thead>
<tr>
<th></th>
<th>Temp (°C)</th>
<th>Salinity (ppt)</th>
<th>DO (% Sat)</th>
<th>DO (mg/L)</th>
<th>pH</th>
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<tbody>
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<td>29.3</td>
<td>87.2</td>
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<td>Mean</td>
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<td>29.2</td>
<td>84.2</td>
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<td>68.4</td>
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<tr>
<td></td>
<td>Max</td>
<td>31.1</td>
<td>34.8</td>
<td>96</td>
<td>6.3</td>
</tr>
</tbody>
</table>
63-d Grow-out Trial in Two 100-m³ RWs

Results

➢ **ammonia-N** low: 0.3 mg/L (0.15-0.59 mg/L)

➢ **nitrite-N** low: 0.36 mg/L (0.10-1.4 mg/L)

➢ **nitrate-N** increased from 67.0 mg/L to 308.8 mg/L

➢ mean TSS: 292 mg/L, mean SS: 12 mL/L

➢ FF & ST started Day 7 & Day 22, respectively

➢ Use of these tools was adequate to maintain solids within the targeted range at feed loads of 22 kg/RW/d
despite relatively high DO (85.7% sat), pure O₂ was added intermittently between Days 22 & 44

the second 2-hp pump was engaged on Day 44 at estimated biomass of 8.2 kg/m³

no oxygen provided during the final 16 days

a³ injectors (with only air) supported 9.2 kg/m³ yield
1. Careful feed management reduces size variation
2. Commercial nitrifying bacteria accelerate development of a healthy mixotrophic system and limit PL exposure to high TAN & nitrite
3. Juvenile shrimp (6.4 g) can be produced with high survival & a very low FCR (0.81)
4. Mixotrophic BFD systems with air-driven a³ injectors support high yields (9.2 kg/m³) with low TAN & nitrite, and without adding organic carbon
# Preliminary Economic Analysis


<table>
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<tr>
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<th>2011</th>
<th>HI-35 100 m³ - 2012</th>
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<tbody>
<tr>
<td>Production, kg/crop</td>
<td>38,320</td>
<td>36,120</td>
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<tr>
<td>Crops per year</td>
<td>4.4</td>
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<tr>
<td>Production, kg/year</td>
<td>168,608</td>
<td>209,496</td>
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<tr>
<td>Production MT/year</td>
<td>169</td>
<td>209</td>
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<tr>
<td>Selling price, $/kg</td>
<td>7.20</td>
<td>7.20</td>
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<tr>
<td>Total Sales per year, $</td>
<td>1,213,978</td>
<td>1,508,371</td>
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<tr>
<td>Variable Costs</td>
<td>5.38</td>
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<tr>
<td>Income Above Variable Cost</td>
<td>1.82</td>
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<tr>
<td>Fixed Cost</td>
<td>0.59</td>
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<tr>
<td>Total of All Specified Expenses</td>
<td>5.97</td>
<td>4.79</td>
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<tr>
<td>Net Returns Above All Costs</td>
<td>1.23</td>
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<tr>
<td>Payback period, years</td>
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<tr>
<td>Net present value ($ mil.)</td>
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<tr>
<td>Internal Rate of Return (%)</td>
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