Microbial Ecology and Management of Biofloc Systems

Andrew J. Ray*, Andrew J. Shuler, John W. Leffler, and Craig L. Browdy

*South Carolina Department of Natural Resources; Waddell Mariculture Center; AndrewJRay@gmail.com

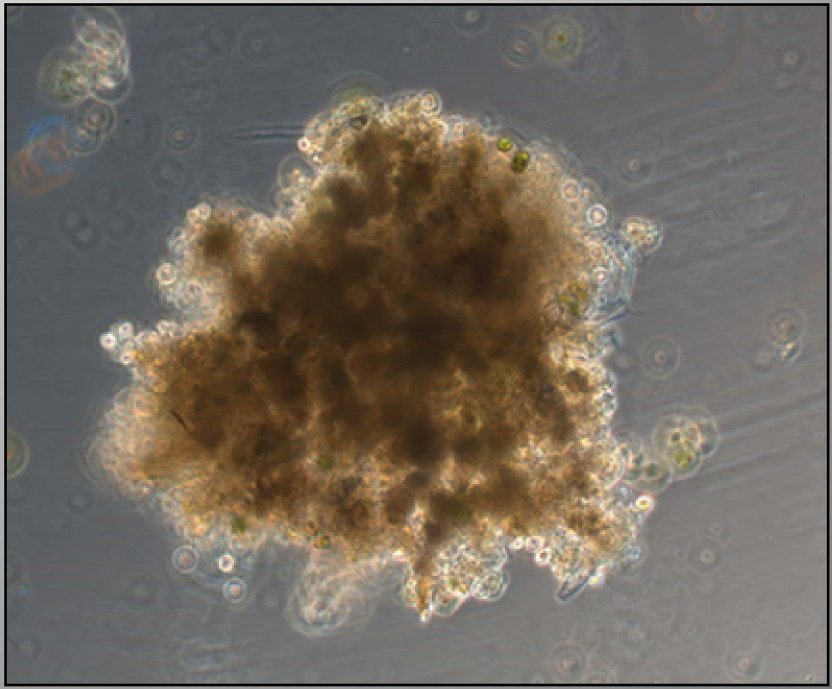
in: **The Rising Tide: Proceedings of the Special Session on Sustainable Shrimp Farming**

Minimal-Exchange Super-Intensive (MESI) Systems

- Lined ponds/raceways
- Controlled nutrient inputs
- High stocking density
- Flocculated particles (Biofloc)
- Intense aeration and/or oxygenation

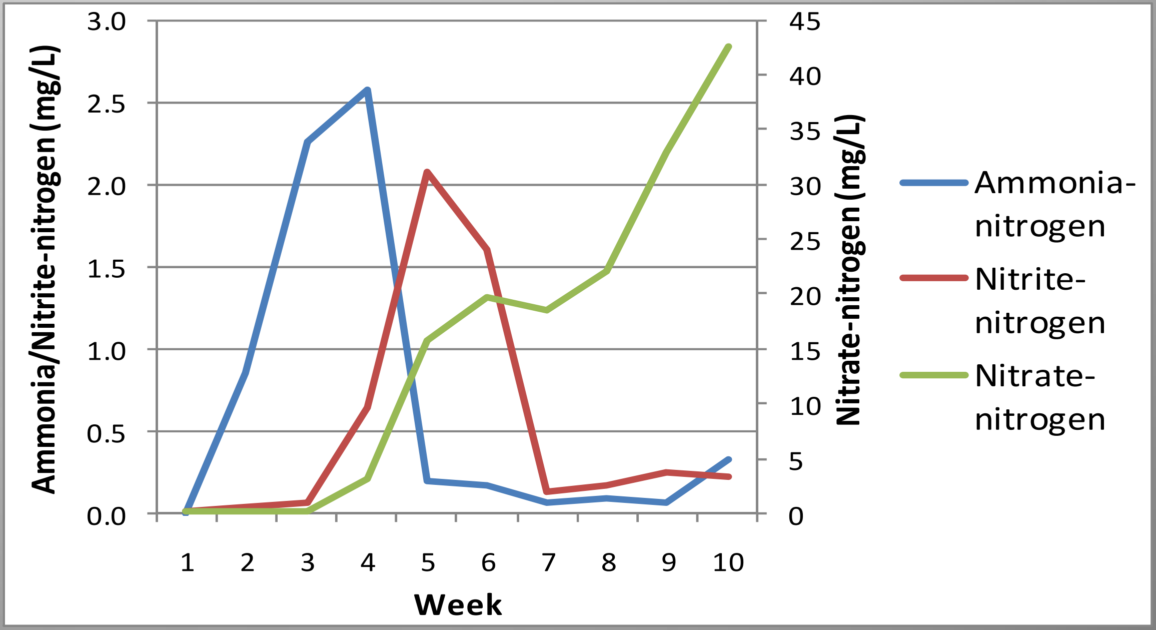
The Microbial Community

- Algae, bacteria, zooplankton
- Partially contained within biofloc
- Water quality maintenance
- Nutritional benefits
    - Leber and Pruder 1988, Moss 1995, Moss and Pruder 1995, Moss et al. 2006, Wasielsky et al. 2006



Water Quality

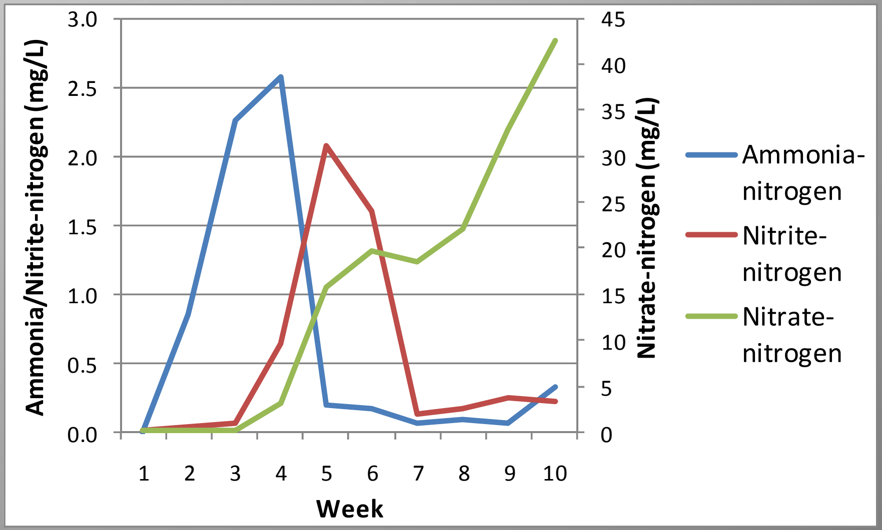
- Nitrification
  - Chemoautotrophic Bacteria
    - $NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$
- Nutrient Assimilation
  - Heterotrophic Bacteria
    - NH_4^+
  - Algae
    - NH_4^+
    - NO_3^-
    - PO_4^-



Important Bacterial Groups

- Nitrifying
  - Constant function
  - Results in nitrate
  - Can be slow to establish
- Heterotrophic
  - Rapid growth
  - Efficient nutrient assimilation
  - Carbohydrate stimulation!
- Drawbacks
  - Oxygen consumption
  - Alkalinity consumption, pH decrease
  - Pathogenic bacteria

http://www.hydra-aqua.com/ekmps/shops/kawakoi/resources/image/2_PondBacteria.jpg



Algae

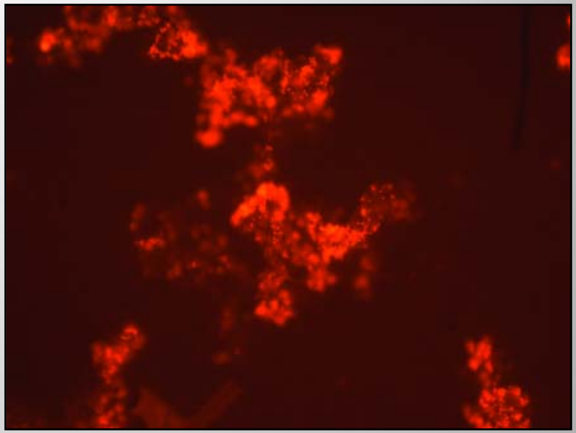
- Assimilate Ammonia, Potentially Nitrate and Phosphate
- Daylight
  - Net oxygen production
    - The time it is most needed
  - pH increase
- Potential Nutrition
- Drawbacks
  - Diurnal function
  - Can bloom and crash
  - Harmful Algae Blooms (HABs)

Zooplankton

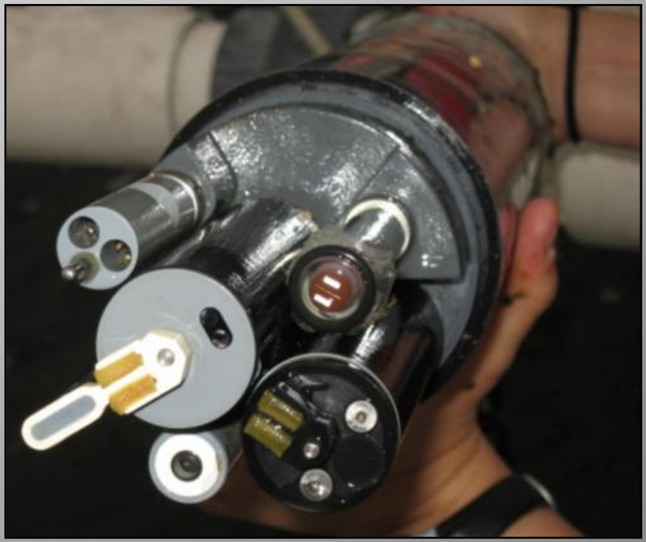
- Groups
  - Small protists such as heterotrophic ciliates, flagellates, and dinoflagellates
  - Micro-zooplankton such as rotifers
  - Macro-zooplankton such as copepods and nematodes

- Continue Nutrient Cycle
- Potential Food Source for Shrimp

Microbial Monitoring



- Microscopy
  - Light microscope
  - Epifluorescence
    - Pigments or stains
    - Subsequent quantification using image analysis
- Pigment Probes
  - Chlorophyll
  - Cyanobacteria Pigments
  - Real-time
  - No taxonomy



- Fatty Acid Bacterial Indicators
  - Abundance of branched and odd chain FAs

System Management = Microbial Management

- Shrimp Density
- Light Availability
- Solids Concentration

Shrimp Density

- Nutrient Input
- Potential Grazing Pressure
- Increased Density May Push Systems Towards Bacterial Domination
  - Brune et al. 2003
  - Algae can process up to aprox. 56 g/m/day of 35% protein feed
  - Bacterial processes have increasing responsibility for water quality

Shrimp Density Experiment

- 13 Week Long Experiment
- 32, 3.5 m diameter, outdoor, zero-exchange tanks
- Shrimp stocked at approximately 100 m^{-2} and 300 m^{-2}
- Characterized the microbial community
  - Light microscopy with categorical ranking
  - Epifluorescence microscopy with quantitative image analysis
  - Bacterial indicator fatty acid quantification

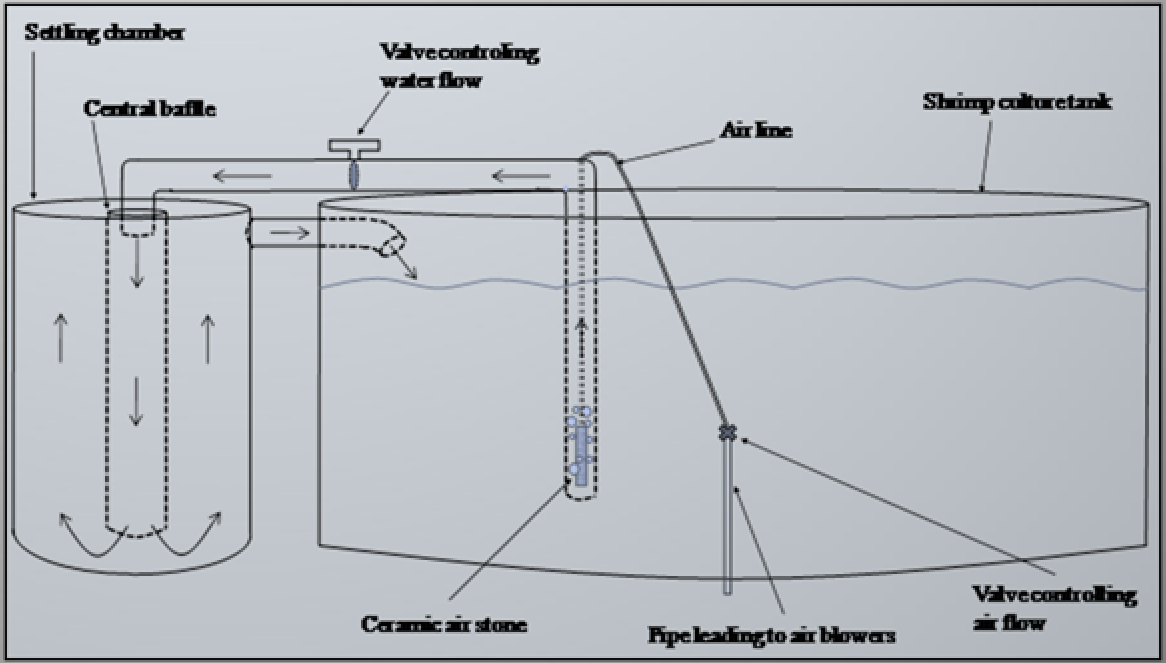
- Results of Increased Density (Ray 2008)
  - ↑ bacteria
  - ↑ rotifers
  - ↓ cyanobacteria

Light Availability

- Photosynthetically Active Radiation (PAR)
  - Wavelengths important for photosynthesis
  - 400 – 700 nm
  - Algal productivity
- PAR Extinction Coefficient
  - Probe with data recorder
- Solids
  - Contribute to shading

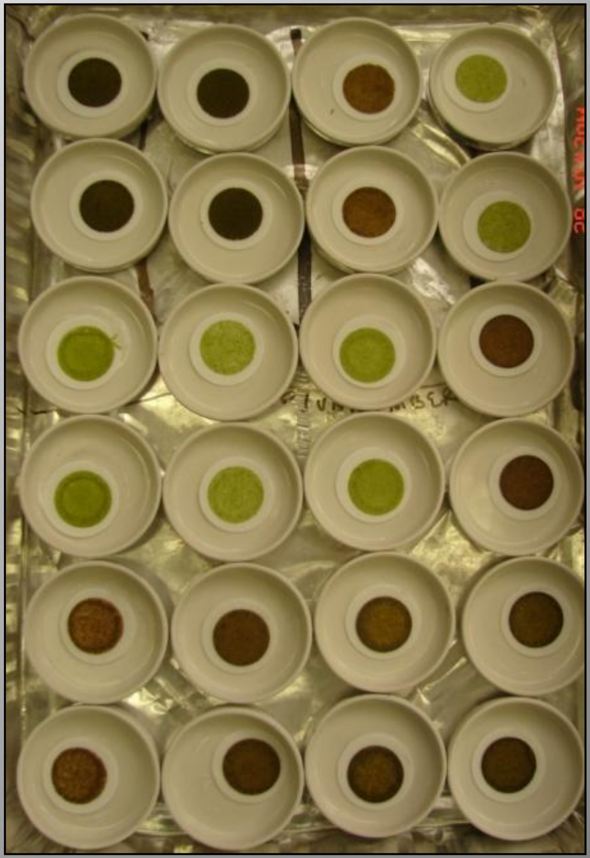
Solids (Biofloc) Concentration

- Monitoring Techniques
  - Total Suspended Solids (TSS)
  - Volatile Suspended Solids (VSS)
  - Turbidity (NTU)
  - Imhoff Cones
- Management
  - Settling Chambers
    - Inexpensive
    - Low Energy
- Experiments
  - Same Tank System As Previously Described



Solids Management

- ↑ shrimp production (41%)
- ↑ PAR availability
- ↑ net photosynthetic oxygen production
- ↓ algal biomass
- ↓ bacteria
- ↓ cyanobacteria
- ↓ rotifers
- ↓ nematodes
- ↓ nutrient concentrations



Summary

- The Microbial Community
  - Water quality
    - Bacteria
    - Algae
  - Potential supplemental nutrition
- Simple Monitoring Program
  - Light microscopy
  - Turbidity
  - Nutrient concentrations
- Management
  - Carbohydrate addition
    - To compensate for nitrification
    - Early system establishment
  - Solids management
    - Low turbidity (~20-35 NTU)

Reference

- Alonso-Rodriguez, R. and F. Paez-Osuna. 2003. Nutrients, phytoplankton and harmful algal blooms in shrimp ponds: a review with special reference to the situation in the Gulf of California. Aquaculture 219:317-336.
- Brune, D.E., G. Schwartz, A.G. Eversole, J.A. Collier and T.E. Schwedler. 2003. Intensification of pond aquaculture and high rate photosynthetic systems. Aquacultural Engineering 28:65-86.
- Burford, M.A., P.J. Thompson, R.P. McIntosh, R.H. Bauman and D.C. Pearson. 2003. Nutrient and microbial dynamics in high-intensity, zero-exchange shrimp ponds in Belize. Aquaculture 219:393-411.
- Burford, M.A., P.J. Thompson, R.P. McIntosh, R.H. Bauman and D.C. Pearson. 2004. The contribution of flocculated material to shrimp (*Litopenaeus vannamei) nutrition in a high intensity, zero-exchange system. Aquaculture 232:525-537.*
- Ebeling, J.M., M.B. Timmons and J.J. Bisogni. 2006. Engineering analysis of the stoichiometry of photoautotrophic, autotrophic, and heterotrophic removal of ammonia-nitrogen in aquaculture systems. Aquaculture 257:346-358.
- Hargreaves, J.A. 2006. Photosynthetic suspended-growth systems in aquaculture. Aquacultural Engineering 34:344-363.
- Leber, K.M. and G.D. Pruder. 1988. Using experimental microcosms in shrimp research: The growth-enhancing effect of shrimp pond water. Journal of the World Aquaculture Society 19:197-203.
- Moss, S.M. 1995. Production of growth-enhancing particles in a plastic-lined shrimp pond. Aquaculture 132:253-260.
- Moss, S.M., G.D. Pruder, K.M. Leber and J.A. Wyban. 1992. The relative enhancement of *Penaeus vannamei growth by selected fractions of shrimp pond water. Aquaculture 101 (3-4):229-239.*
- Moss, S.M., I.P. Forster and A.G.J. Tacon. 2006. Sparing effect of pond water on vitamins in shrimp diets. Aquaculture 258:388-395.
- Ray, A.J. 2008. The effects of simple management techniques on microbial community dynamics within biofloc-based culture systems and the relationship to shrimp (*Litopenaeus vannamei*) production. Master's Thesis. The College of Charleston, Charleston, South Carolina, USA.
- Wasielesky, W. Jr., H. Atwood, A. Stokes and C.L. Browdy. 2006. Effect of natural production in brown water super-intensive culture system for white shrimp *Litopenaeus vannamei. Aquaculture 258:396-403.*
- Zimba, P.V., A. Camus, E.H. Allen and J.M. Burkholder. 2006. Co-occurrence of white shrimp, *Litopenaeus vannamei, mortalities and microcystin toxin in a southeastern USA shrimp facility. Aquaculture 261:1048-1055.*

Thank You

Research on intensive shrimp culture systems at the WMC has been supported by grants from the USDA CSREES, US Marine Shrimp Farming Program, the USDA Integrated Organic Program and by the National Institute of Standards and Technology.

Thank you Heidi Atwood, Kirsten Ayers, Ben Colvin, Asher Dale, Amy Dickson, Mauricio Emerenciano, Alfredo Galvez, Jason Haveman, Traci Holstein, Kristen Hoke, Alisha Lawson, Beth Lewis, Brad McAbee, Gloria Seaborn, Jesus Venero, Luis Vinatea, Joe Wade, Emmet Wright, and the staff of the Waddell Mariculture Center.