Insights into the Functional Roles of Major Components of Microbial Communities in Zero Exchange Super-Intensive Shrimp Systems

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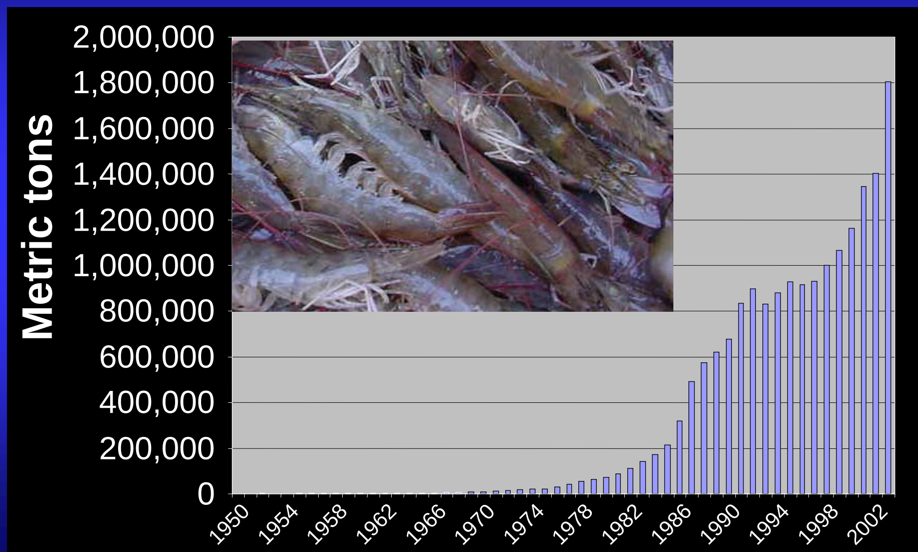
Aquaculture Production of Penaeid Shrimp 1950-2003



- Habitat destruction
- Land use
- Water use
- Pollution
- Disease

Waddell Mariculture Center
Environmentally Responsible Technologies

Aerated zero exchange microbial floc based ponds:

- ↓ eutrophication
- ↓ sedimentation
- ↓ escapement
- ↑ nitrogen assimilation
- ↑ water quality stability
- ↑ growth factors
- ↓ production costs
- ↓ pathogen introduction

Sustainable Shrimp Farms

	New Water	Recycled Water
Mean Wt. (g)	13.3 ± 0.73	13.6 ± 1.01
Survival (%)	76.3 ± 6.53	73.9 ± 5.83
Production kg/M	1.09 ± 0.04	1.04 ± 0.11
FCR	2.1 ± 0.06	2.1 ± 0.17

- Selective breeding
- Recirculation
- Water reuse
- Specialized feeds

- Environmentally friendly farms
- Inland shrimp farming
- Specialized markets

Looking to the Future
Next Generation Systems

- Biosecure raceways
- Density 200-500/m^2
- SPF growth line PL
- Nursery phase to 1g, 4g
- Salinity 15 or 30 ppt
- Feeding twice daily - trays
- Zeigler raceway diets
- Oxygen injection
- Bicarbonate additions
- Heat exchange systems
- Sludge capture, dewatering
- Water reuse between crops
- Microbial community management

WMC Raceway Harvest Data

	11/00		01/02			03/03	11/03	11/04	08/05
Days	140	140	132	132	140	76*	113	123*	59**
Density	200	200	300	300	300	300	420	450	499
Wt (g)	19.3	18.9	14.6	15.4	17.1	16.6	21.0	25.6	16.4
Growth (g/wk)	1.16	1.20	0.93	0.99	1.02	1.52	1.69	1.46	1.47
Surv (%)	60.1	63.9	70.5	71.7	55.2	91	79.5	54.3	84.0
Prod (kg/m)	2.3	2.4	3.1	3.3	2.8	4.5	6.8	6.3	6.7
FCR	2.8	2.8	1.8	2.0	1.9	1.5	1.9	2.6	1.3

* Stocked 1g. nursed juveniles

** Stocked 4g. nursed juveniles

Microbial Community

- Water Quality
  - Aeration to reduce water exchange rates
  - Increased microbial recycling of waste
  - Improve control of important parameters
    - dissolved oxygen
    - biochemical oxygen demand (BOD)
    - ammonia
    - hydrogen sulfide
  - Reduce sludge buildup

Microbial Community

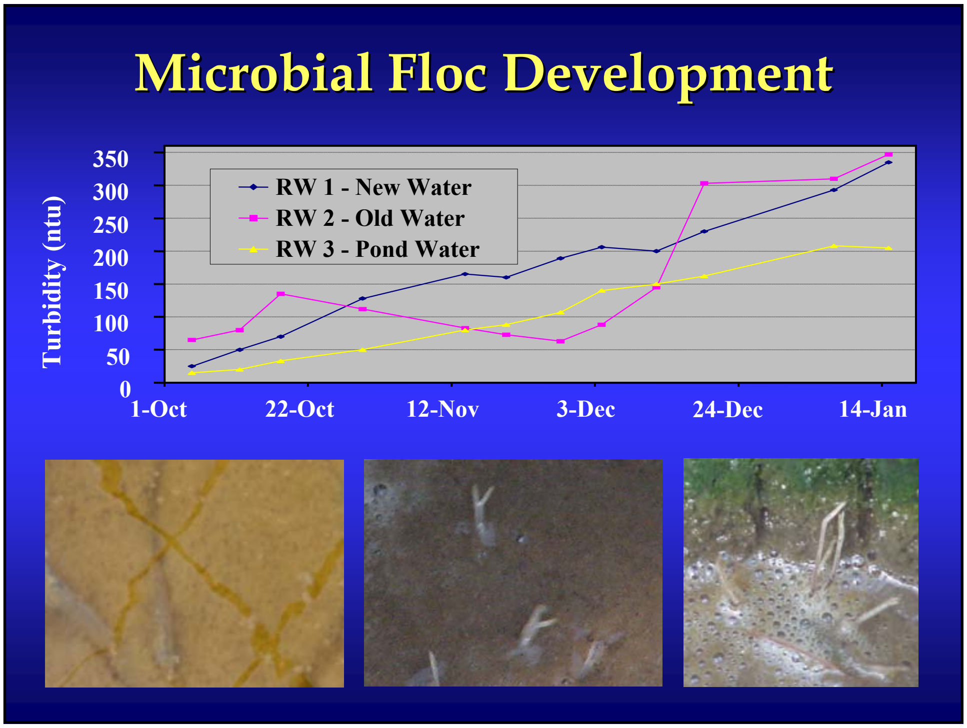
- Growth and health
  - Reduce opportunities for pathogens
    - viral
    - bacterial
  - Promote natural productivity to enhance growth and production particularly in extensive and semi-intensive systems
  - Pond water growth factors
  - Improved pond conditions

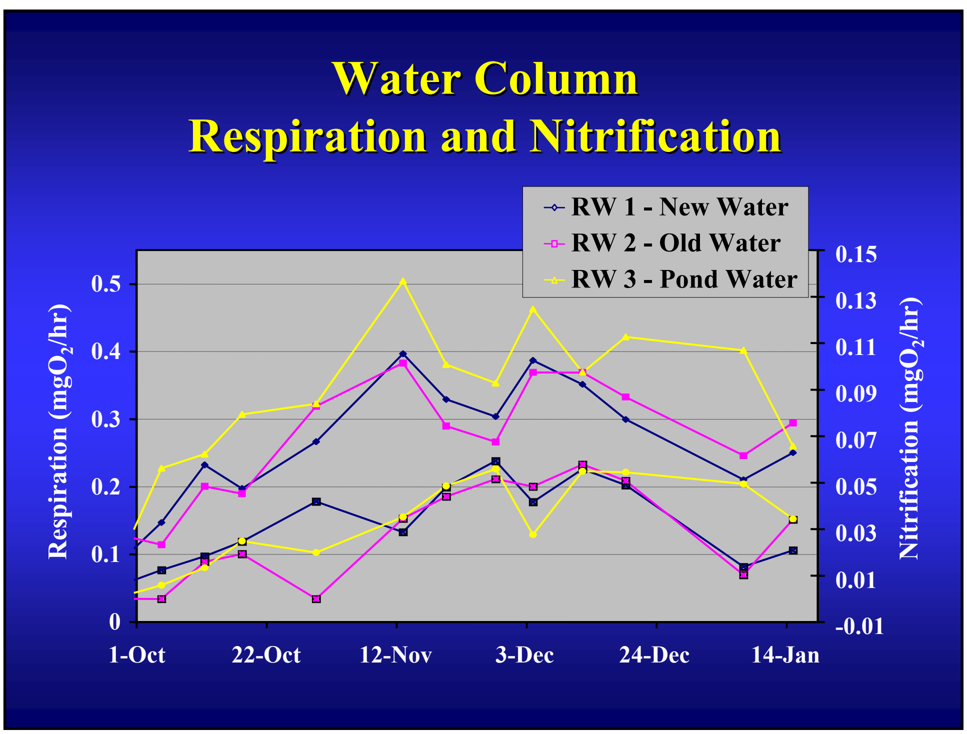
Nutrients and Microbial Community

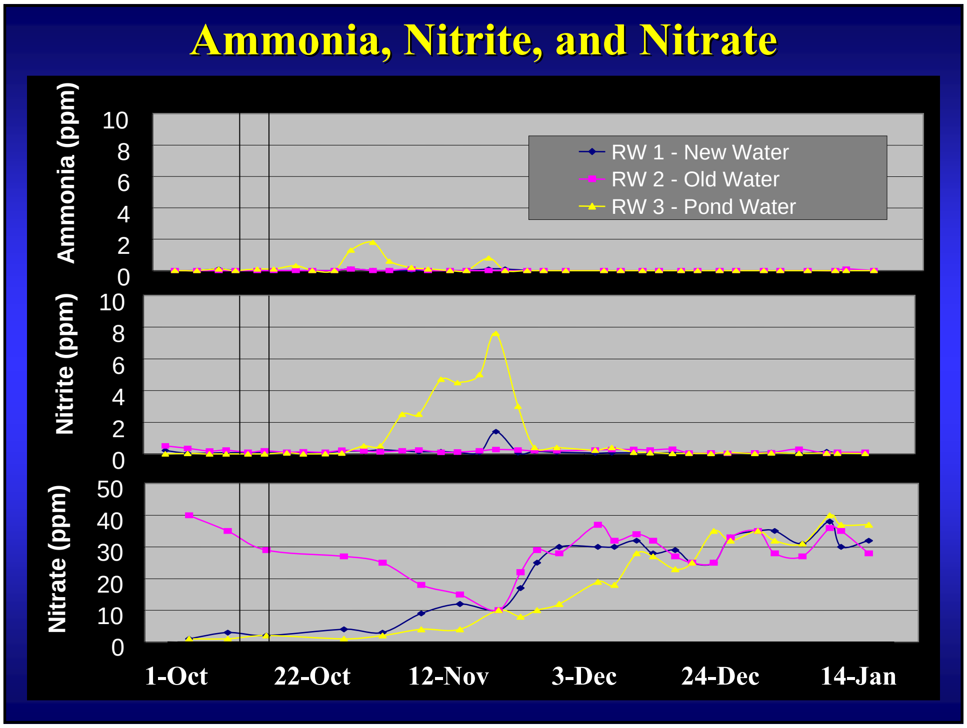
- Turbidity, secchi, TSS, VSS, settleable solids
- Dissolved inorganic nitrogen
  - Ammonia, Nitrite, Nitrate
- Oxygen consumption
  - Dark bottle O_2 = respiration + nitrification
- Oxygen production
  - Light bottle O_2 = Primary Production - (respiration + nitrification)
- Nitrification
  - Dark bottle – Inhibited dark bottle
- Chlorophyll
- Bacterial Abundance

Microbial Community

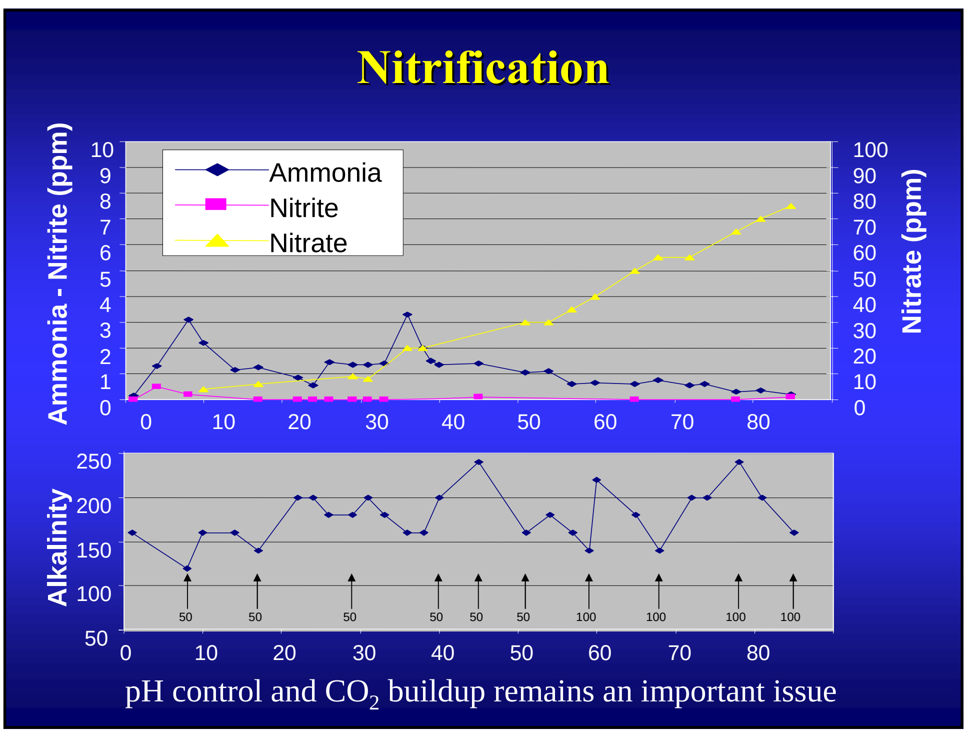
- Heterotrophs – bacteria
  - Nitrogen uptake – lower salinities
  - Floc substrates
  - Sludge degradation
- Chemoautotrophs
  - Nitrogen cycling
  - Nitrification
  - Denitrification
- Photoautotrophs – phytoplankton
  - Growth enhancement – photosynthesis
  - Nitrogen uptake


Microbial Floc Development
RW 1 - New Water
RW 2 - Old Water
RW 3 - Pond Water
Turbidity (ntu)
350
300
250
200
150
100
50
0
1-Oct
22-Oct
12-Nov
3-Dec
24-Dec
14-Jan


Water Column
Respiration and Nitrification
RW 1 - New Water
RW 2 - Old Water
RW 3 - Pond Water
Respiration (mgO2/hr)
0.5
0.4
0.3
0.2
0.1
0
Nitrification (mgO2/hr)
0.15
0.13
0.11
0.09
0.07
0.05
0.03
0.01
-0.01
1-Oct
22-Oct
12-Nov
3-Dec
24-Dec
14-Jan



Ammonia, Nitrite, and Nitrate
Ammonia (ppm)
Nitrite (ppm)
Nitrate (ppm)
RW 1 - New Water
RW 2 - Old Water
RW 3 - Pond Water
1-Oct
22-Oct
12-Nov
3-Dec
24-Dec
14-Jan

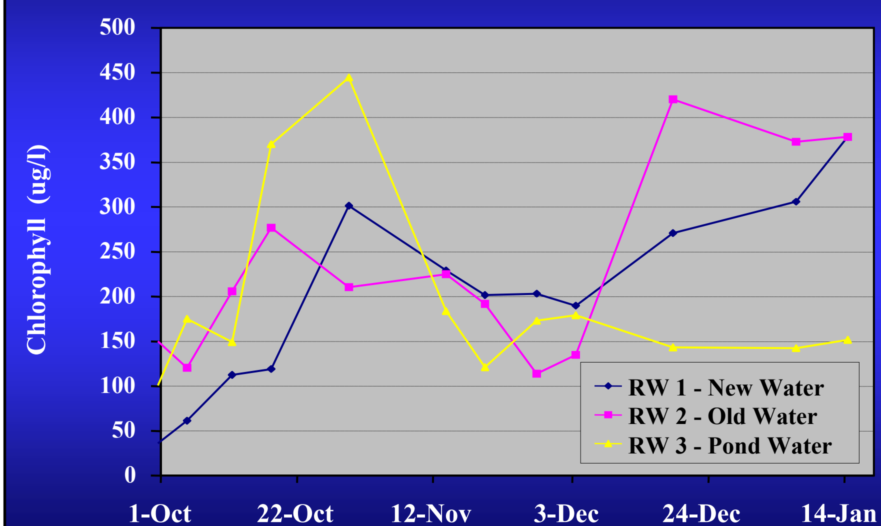


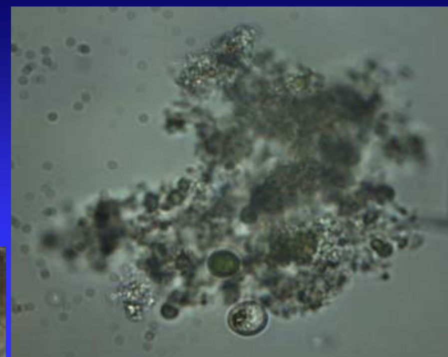
Nitrification
Ammonia - Nitrite (ppm)
Nitrate (ppm)
Ammonia
Nitrite
Nitrate
Alkalinity
pH control and CO_2 buildup remains an important issue

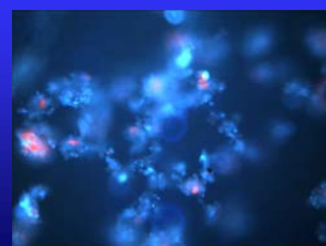
Effect of pH on Growth and Survival

	5.1	5.9	6.5	7.0	Control
pH range	4.9-5.3	5.7-6.2	6.3-6.7	6.8-7.2	7.8-8.1
Mean Survival	98.4	95.5	100	100	100
Mean Final Weight	2.19	2.51	2.58	2.71	2.90
Tukey test (final weight)	A	B	B	CB	C

The Role of Photoautotrophs

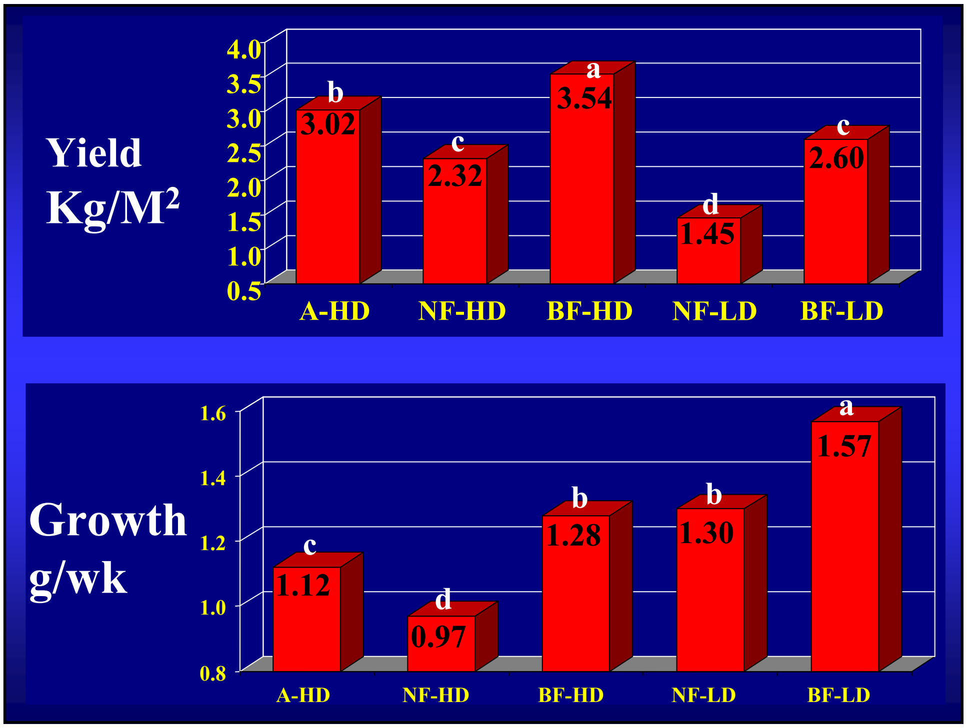




Microbial Community Management

- **Fertilization**
  - supplemental
  - feed formulation
- **Disinfection**
- **Habitat**
  - substrates
    - bottom
    - water column
- **Bacterial amendments**
  - following disinfection
  - shift community composition
- **Cropping**
  - Controlled exchange
  - Filtration



Net Ecosystem Production (NEP)

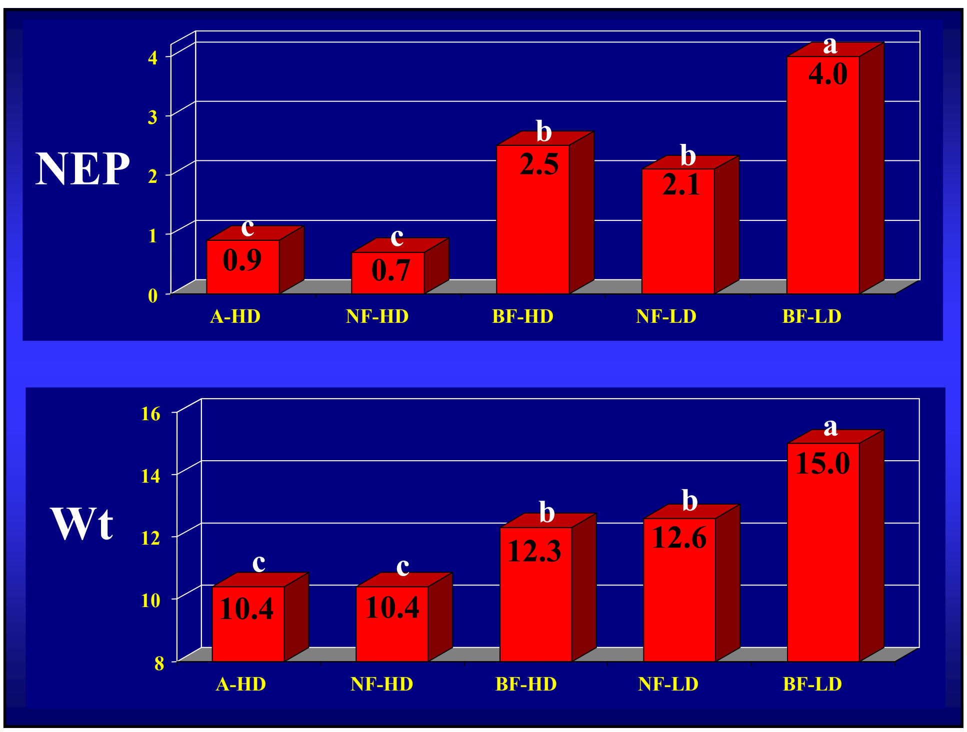
NEP = [mid-day O2 production] – [mid-day O2 use]

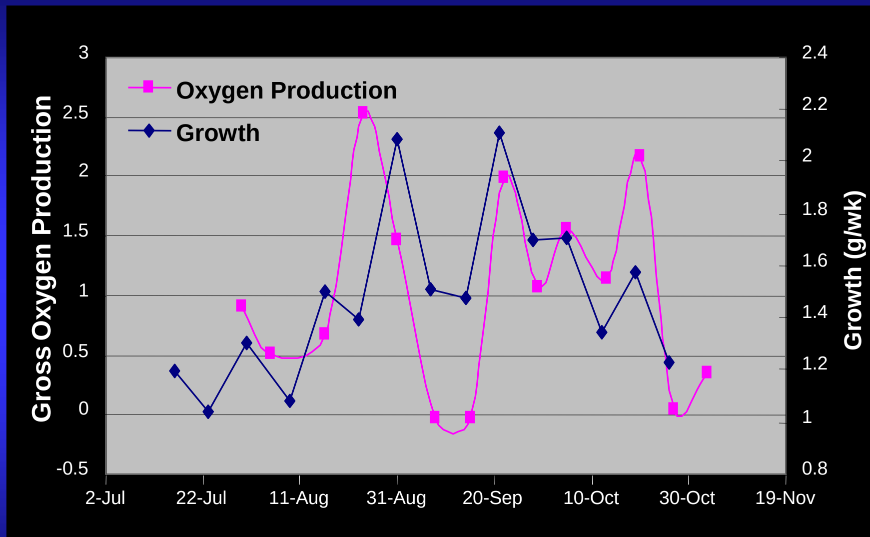
When NEP >1,
O2 production exceeds demand
(i.e., algae dominate)

When NEP <1,
O2 demand exceeds production
(i.e., heterotrophs and nitrifyers dominate)

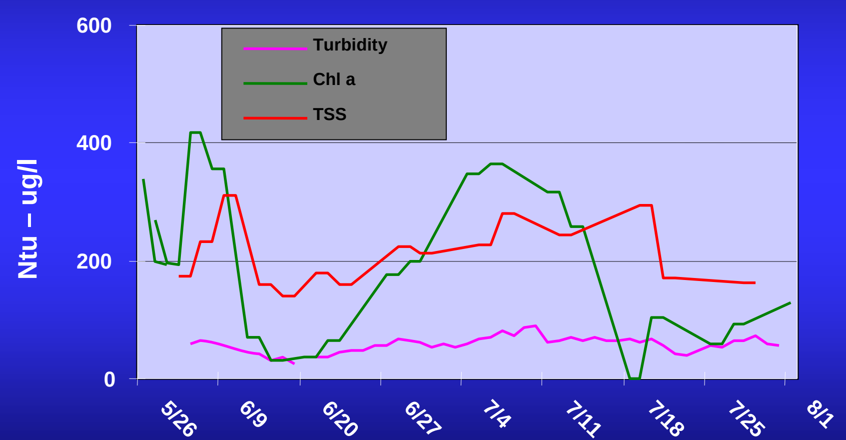
High Density Tank Study – 300/M^2

	Static	Bead filtered
Mean Weight (g)	10.4 ± 0.8 a	12.3 ± 1.0 b
Growth Rate (g/wk)	0.97 ± 0.09 a	1.28 ± 0.12 b
Survival (%)	55.7 ± 5.7 a	71.9 ± 5.0 b
Production (kg/M)	2.32 ± 0.25 a	3.54 ± 0.25 b
FCR	1.84 ± 0.10 a	1.57 ± 0.10 b
Chlorophyll (mg/m3)	251 a	167 b
NEP (O2 - Prod. / Demand)	0.66 a	2.53 b





Controlled Filtration for Management of Microbial Floc Density



Experimental System

Super-intensive shrimp culture raceway

Microcosm tanks

Water pumped daily

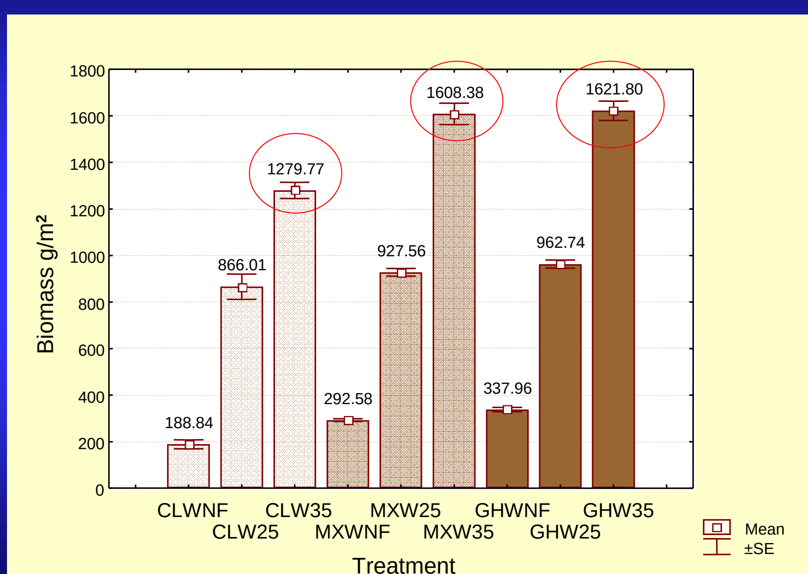
Objectives

- Design a system for evaluation of interactions between advanced nutritionally complete and environmentally friendly diets and system microbial communities
- Apply the experimental system for the study of growth enhancing effects of raceway microbial communities
- Develop efficient feeding practices, recycling of waste material, while minimizing sludge production from super-intensive systems

Experimental Design

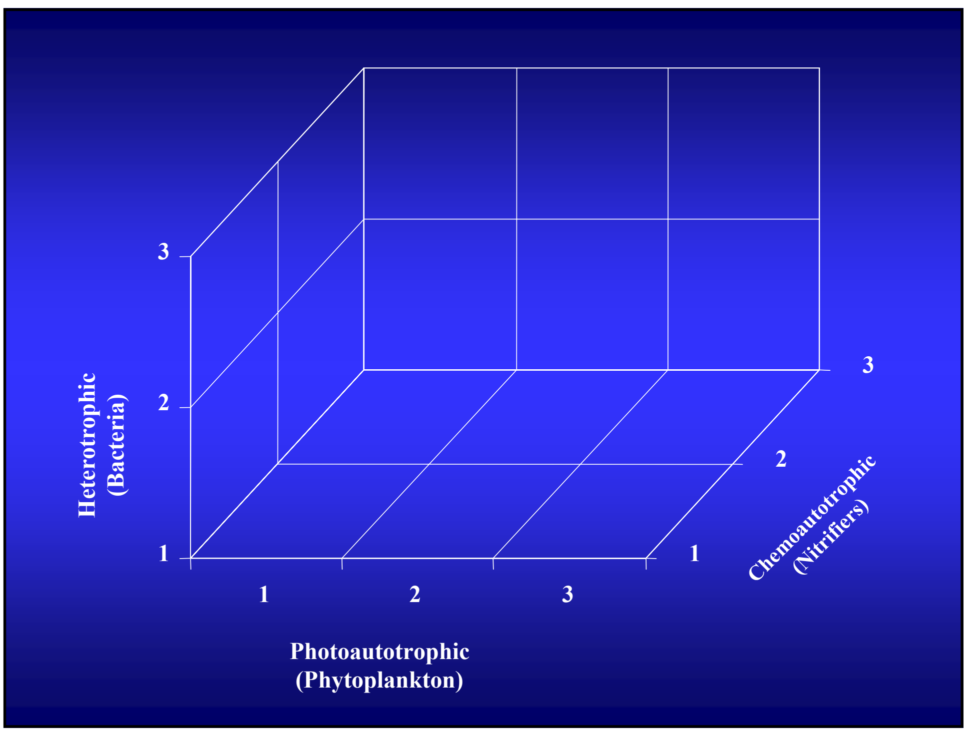
	Filtered water	Mixed water	Raceway water
35% protein			
25% protein			
No feed			

Biomass



Challenges for the Future

- What are the best tools for measuring and describing the complex microbial floc community
- How do we establish a diverse and stable community at start up
- What is the optimal microbial floc community composition
  – For target crop growth
  – For water quality management
- How do we manipulate the community to maintain optimal composition
  – Fertilization - Filtration
  – Sterilization - Inoculation
  – Habitat - Environment



Opportunities for the Future

By understanding and promoting a healthy microbial community:

- New raceway systems are reaching much higher rates of productivity than ever thought possible
- Pond systems are being intensified while reducing effluent environmental impacts
- Stability and production efficiencies can be improved increasing profitability
- Improved crop health and biosecurity
- Marketing of an improved image as a producer of healthy food in eco-friendly systems