ZERO-DISCHARGE BIOFLOC AQUACULTURE

D. E. Brune
Professor of Bioprocess and Bioenergy Engineering
University of Missouri, Columbia, Mo.

WHAT IS BIOFLOC AQUACULTURE?

1) **Aquaculture production[a] in which aquatic animal rearing[b] and water treatment are occurring predominately in same water footprint, as opposed to, separate water treatment operations, such as biofilters (fixed film), or gas exchange .**

2) **Water treatment consisting of suspended cell microbial growth[c] and/or microbially-mediated reactions such as, photosynthesis[d], nitrification, denitrification and/or heterotrophic bacterial growth**

a) Intensive to super-intensive production (8,000 – 45,000 lb/ac-cycle, organic loading of 100-1,000 lbs/acre-day

b) Aquaculture species tolerate of high solids levels of 50-300 mg/l such as shrimp, tilapia, carp, catfish.

c) Brune, D., E., Henrich, C., Kirk, K., and A. G. Eversole, Suspended-Cell Microbial Co-culture for Limited Discharge Aquaculture, International Conference on Recirculating Aquaculture, Roanoke VA. June 2010

d) Stabilized algal cultures, not typically associated with "biofloc"

.

Limited-Discharge / Zero-Discharge and Production Intensification,

1) Physical-chemical solids management; 1-2 system water replacements per growth cycle. Zero discharge possible with sludge dewatering/recycling systems added.

2) Bioprocessing of solids; zero-water discharge possible. Bioprocessing requires animals and systems supporting filter feeding organisms, yielding feed and fuel by products

3) Increased capital and operating cost drives systems intensification to reduce production cost/lb

Why zero-discharge aquaculture?

Animal agriculture recovers only a small fraction of feed-N

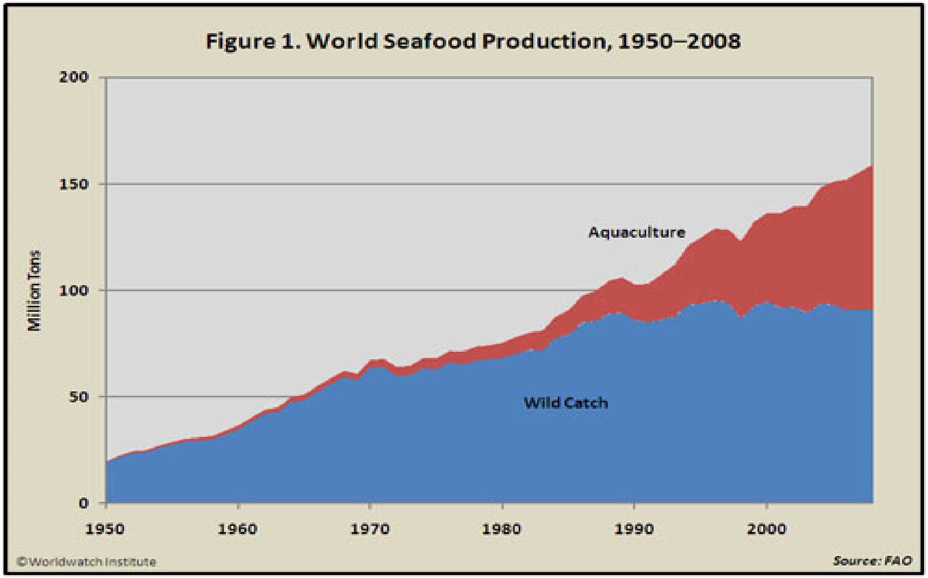
Soy, corn & fish-meal nitrogen inputs

12 – 21% protein nitrogen converted to fish or shrimp

79 – 88% nitrogen discharged as pollutant

Shrimp Production Issues

- Water/waste discharge
- Fish meal importation
- Food transport/food quality
- Shrimp energy footprint



- 1.2 billion lbs/yr shrimp imported to U.S. from Asia; 85% of U.S. consumption.
- 10 X more shrimp wastewater to China's coastal than other industrial wastes
- Shrimp feed 28% of fish meal depleting marine forage fish stocks

In limited or zero-discharge aquaculture , ammonia-N must be treated, recovered , or disposed of using one or more of three techniques;

Algal Photosynthesis (Green Water; Requires Sunlight)

$NH_4 + CO_2 = C_{106}H_{263}O_{110}N_{16}P$ (Algal Biomass) $+ 106\ O_2$

Bacterial Nitrification (Autotrophic Biofloc; Slower Growth)

$NH_4 + O_2 = C_5H_7O_2N$ (Bacterial Biomass) $+ NO_3 + CO_2$

Heterotrophic Bacteria (Brownwater; Requires Carbohydrate)

$NH_4 + C_6H_{12}O_6$ (Sugar) $+ O_2 = C_5H_7O_2N$ (Bacterial Biomass) $+ CO_2$

Algal and heterotrophic = yields large quantities of microbial biomass (~12,000+ lbs/acre dry sludge/cycle)

The solution; recover, convert microbial biomass to food, feed, fuel, and fertilizers

Photosynthetic or Algal System With Bioprocessing of Solids

Feed

Nitrogen Waste

Algal Biomass 300 lb max feed/ac-day

Food and Feed

Bioenergy

Brine shrimp

Slow Release Biofertilizer

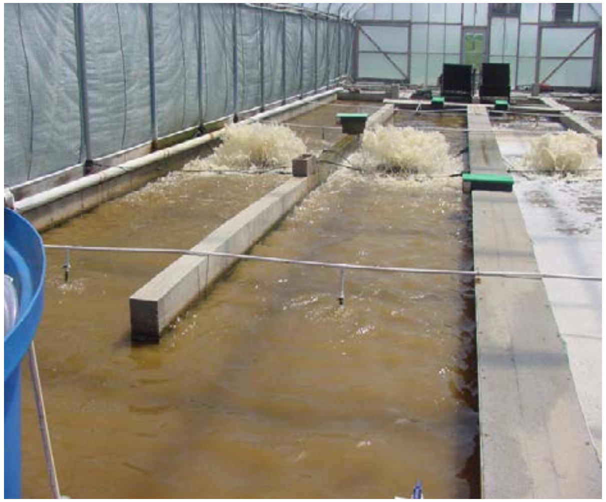
Heterotrophic; Bacterial System With Bioprocessing of Solids

Feed

Carbohydrate addition

Nitrogen Waste

Bacterial Biomass Feed C/N = 12-15/1



Biofloc

Food and Feed

Brine shrimp

Bioenergy

Slow Release Biofertilizer

Nitrifying/Denitrifying (Autotrophic Bacterial) With Bioprocessing of Solids

Feed

Nitrogen Waste

Bacterial Biomass Feed C/N = 9/1; 35%P

Food and Feed

Non Polluting Gases

N_2 & CO_2

Biofloc;10% solids production of heterotrophic

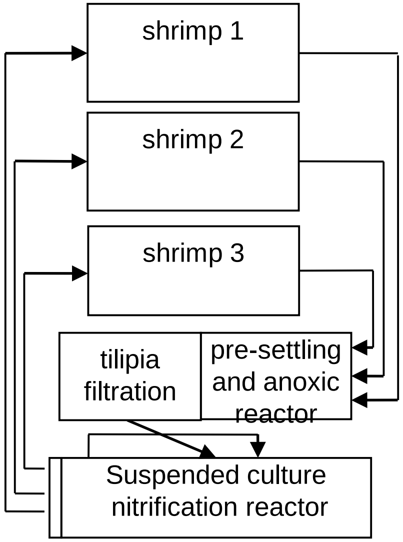
Brine shrimp

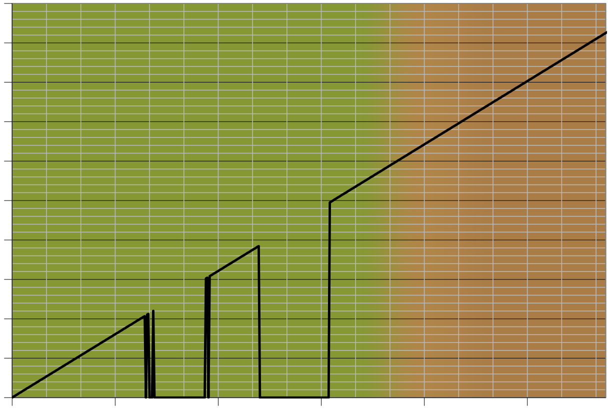
Slow Release Biofertilizer

Clemson; Marine Shrimp 2001- 2008

- 0.25 acre greenhouse
- 33,000 lbs/acre zero-discharge
- Deep tanks for supplemental -N treatment
- Algal floc displaced by bacterial floc at feeding levels of >250-500 lb/ac-day

YR	Yield (lb/ac)	Feed (lb/ac-d) Ave
2003	14,689	155
2004	22,773	378
2005	33,232	608
2007	20,500	700





University of Missouri 2011-2016

- 0.07 acre greenhouse
- Zero-discharge, sustainable seafood, feed and biofuel co-production
- Tilapia and brine shrimp stablized bioprocessing of microbial biomass
- Greenwater and brownwater

MU Bradford Facility 2013

Two - 2,000 liter brine shrimp production reactors

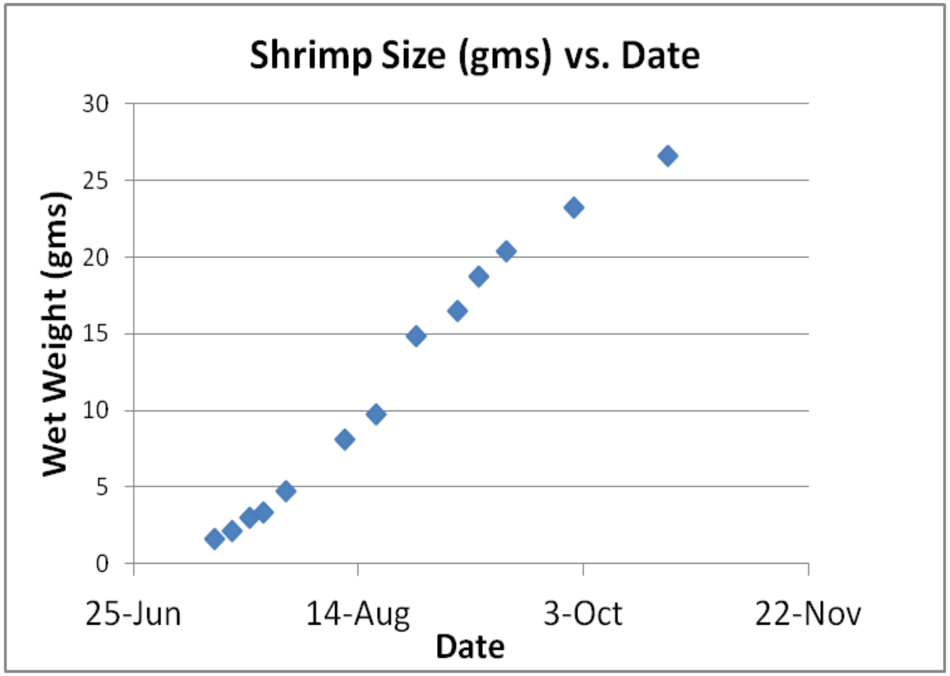
Brine shrimp microbial harvest

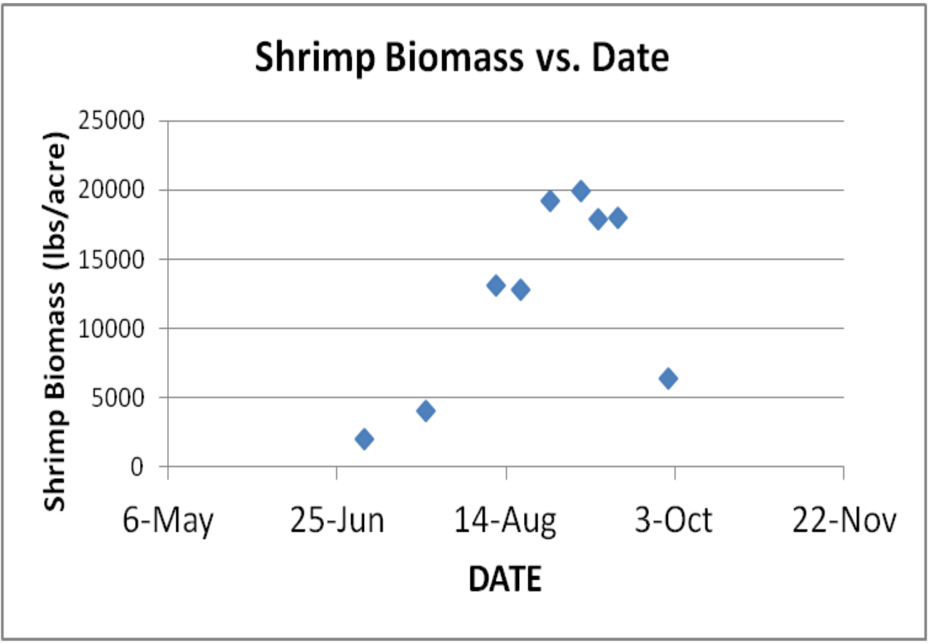
Tilapia Raceway

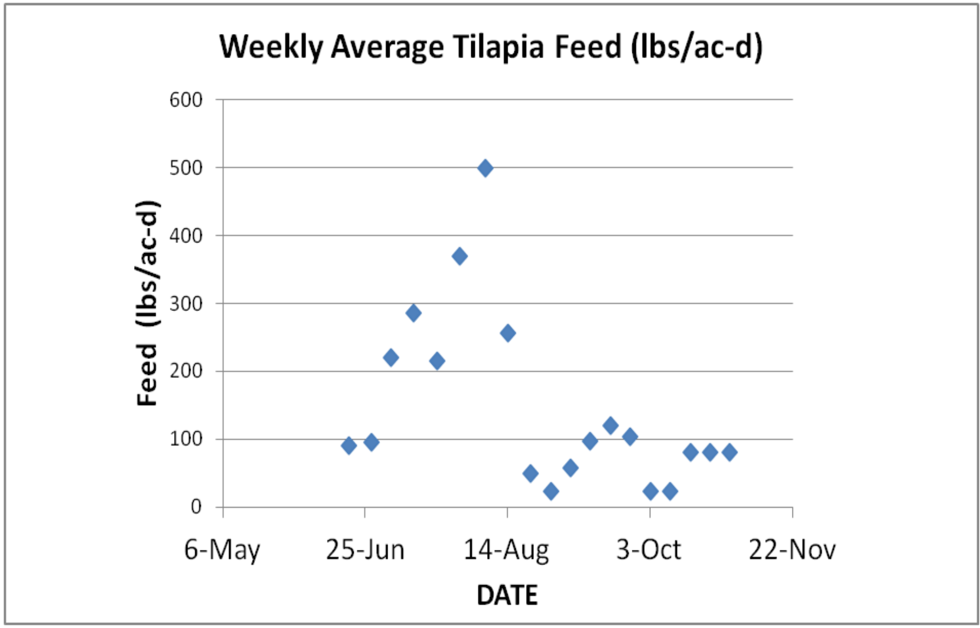
Pacific White Shrimp Raceway

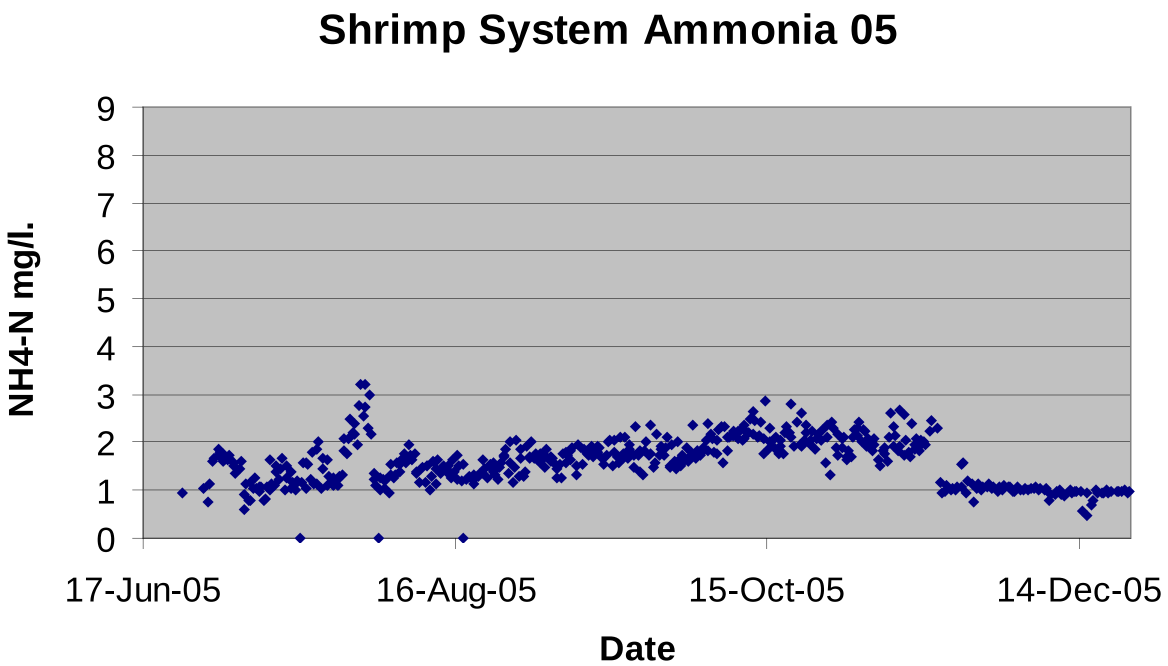
Stocking and Harvest 2013

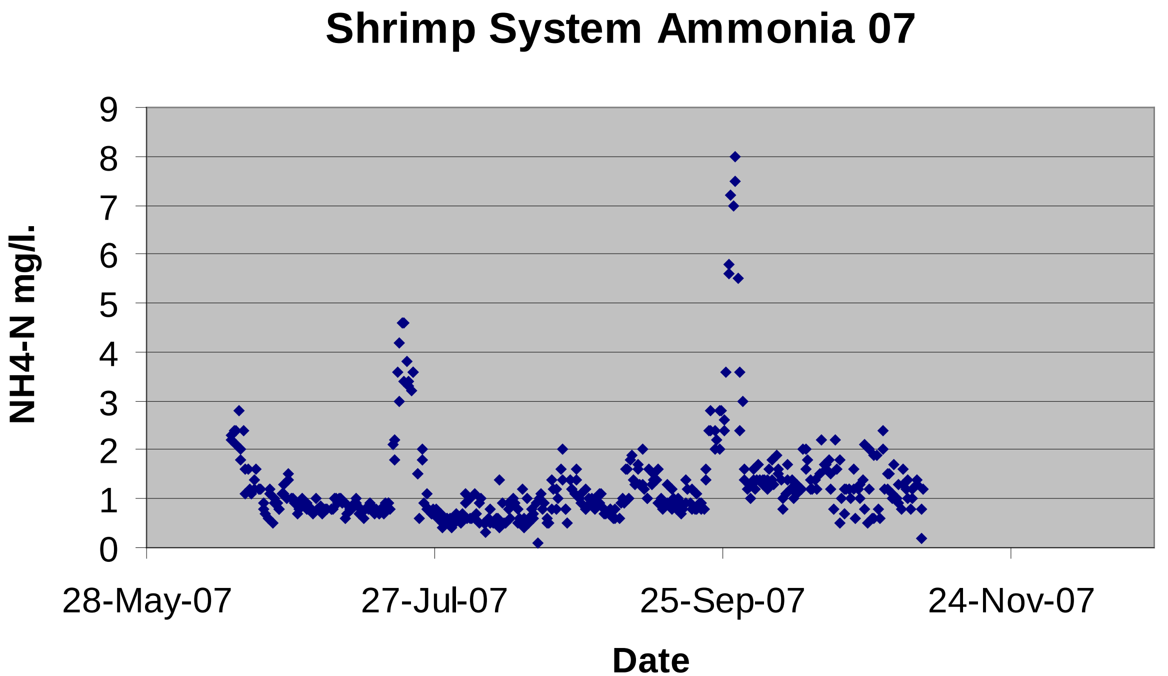
- Stock June 9, PL 8/9 @ 250/m^2
- SPF shrimp from SIS-Florida
- Harvest Aug 20, 19.5 gm (23.3 ct), 101 day grow-out
- Maximum carrying capacity = 499 lbs (19,960 lbs/acre); FCR = 2.12/1
- Purina diet, 35% protein

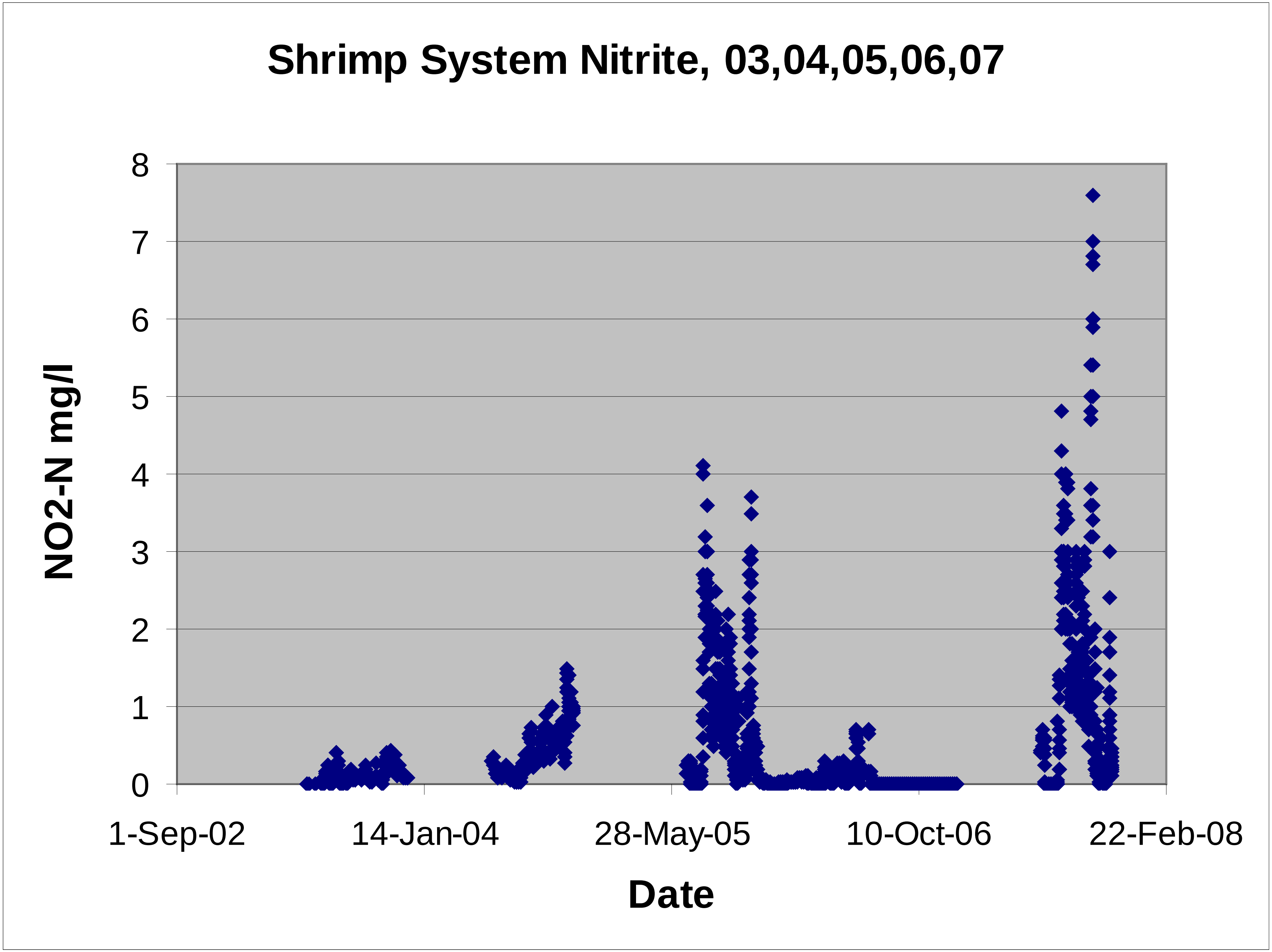







Shrimp System Ammonia 05
NH4-N mg/l.
9
8
7
6
5
4
3
2
1
0
17-Jun-05
16-Aug-05
15-Oct-05
14-Dec-05
Date

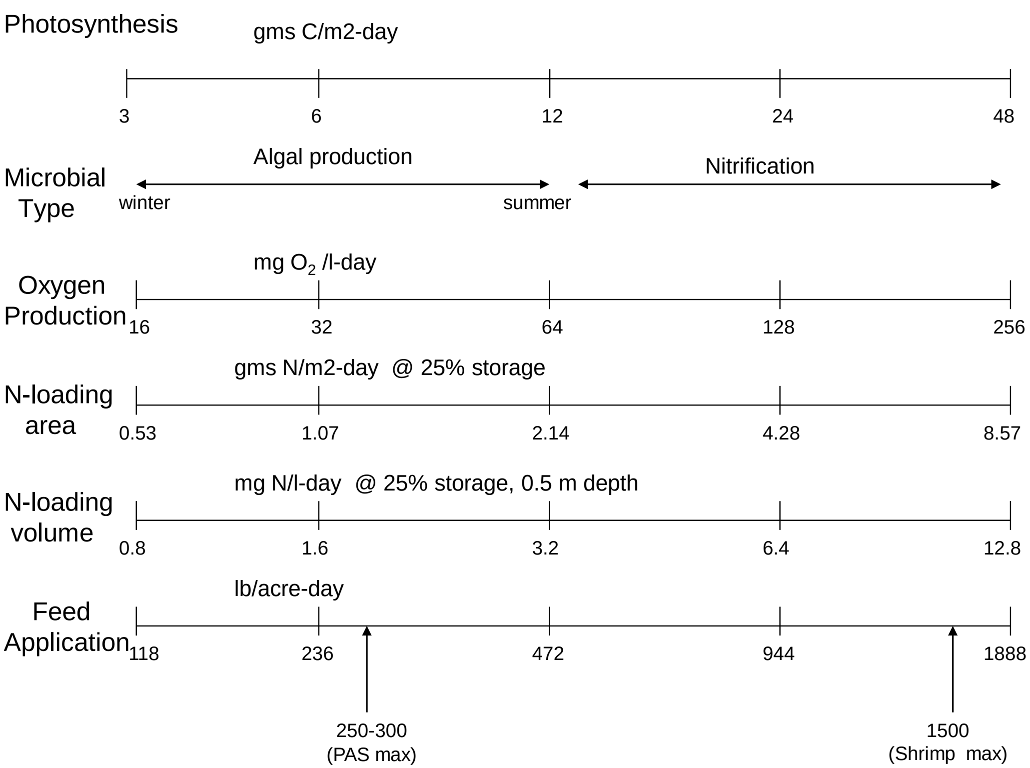

Shrimp System Ammonia 07
NH4-N mg/l.
9
8
7
6
5
4
3
2
1
0
28-May-07
27-Jul-07
25-Sep-07
24-Nov-07
Date

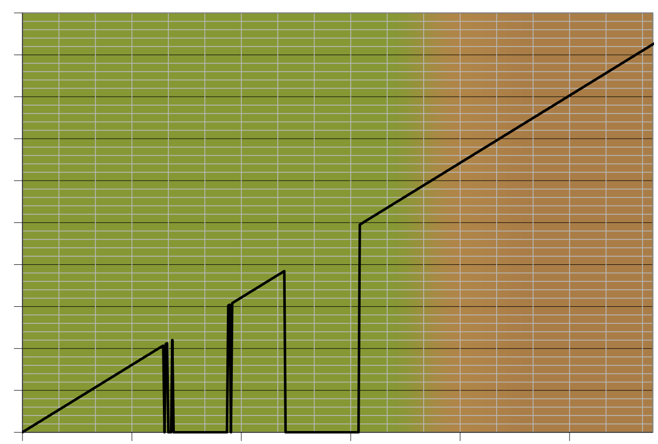


Shrimp System Nitrite, 03,04,05,06,07
NO2-N mg/l
8
7
6
5
4
3
2
1
0
1-Sep-02
14-Jan-04
28-May-05
10-Oct-06
22-Feb-08
Date

Biofloc = Special case of suspended-cell microbial culture

Algal to bacterial water treatment depending on level of external energy input; feed and solar (algal up to 250- 300 lb-feed/ac-d), Nitrifying at C/N of 9/1 (35% protein), Heterotrophic C/N of 12-15/1





Physical Configuration, Stocking, Projected Yields

Ponds, Tanks, Raceway/Hybrid Ponds

Intensive Ponds

Stocking = 100-150/m^2
Yields = 8,000-12,000 lb/acre-100-130 days
Feed/organic rate = 100-200 lb/ac-day
Aeration = 15-30 hp/ac
Capital = \$60,000- \$150,000/acre
Microbial type = algal/heterotrophic or algal/nitrifying
Water depth = 5-6 ft
ADVANTAGES = Lowest cost intensive production
DISAVANTAGES = Marine tropical location needed, water input /discharge or treatment ponds needed, potential environmental impacts, production intensity limited by water mixing and solids sedimentation

Aquasol consultants, FL

Coastal Belize

Marine Shrimp, China

Tanks

Stocking = 200-400/m^2
Yields = 25,000-45,000 lb/acre-100-120 days
Feed/organic rate = 400-1000 lb/ac-day
Aeration = 60-100 hp/ac
Capital = highly variable
Microbial type = heterotrophic or nitrifying (indoor)
ADVANTAGES = Flexible size of operation, control over inventory and harvest schedule, multiple batch production, independent/isolation possible, zero-discharge, good learning platform
DISAVANTAGES = Not hydrodynamically scalable, Low water surface area to enclosure ratio, Not well suited to automation

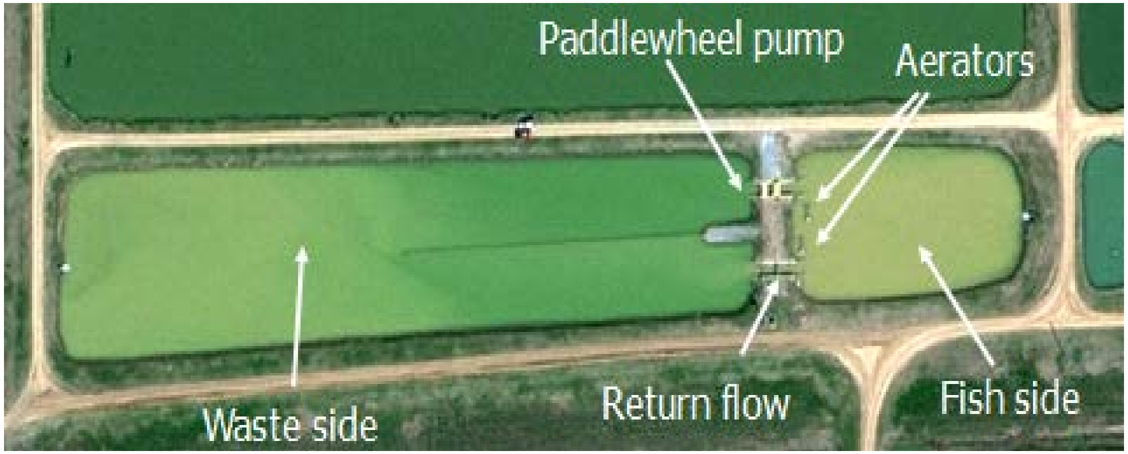
Dairyland Shrimp LLC, Wisconsin, Heterotrophic biofloc, saltwater zero-water exchange, clarifying tanks, 120 day grow-out to 20 gram shrimp

Blue Oasis Shrimp, Las Vegas, Water treatment not described, out of business 2016?

Raceways and Hybrid Ponds

Stocking = 100-400/m^2
Yields = 15,000-45,000 lb/acre-100-120 days
Feed/organic rate = 200-1000 lb/ac-day
Aeration = 30-100 hp/ac
Water depth = 2-5 ft
Water velocity = 0.05- 0.2 fps
Capital/AC = $100,000 (SP), $600,000 (GH) $1,600,000 (IB)
Microbial type = Algal, heterotrophic or nitrifying
ADVANTAGES = Zero discharge possible, solids containment/reuse possible, water footprint 85-90%, Scalable to very large size, suitable for automated feeding and harvest
DISAVANTAGES = Capital intensive, Level topography needed, enclosures subject to storm damage, specialized equipment required

Clemson PAS



Mississippi Split Pond

Raceways and Hybrid Ponds continued

Aquaculture Consultancy & Engineering, Netherlands

Mikolong Aquaventure, Philippines

Mississippi, Paddlewheel oil hydraulic drive

Clemson, Paddlewheel variable frequency drive

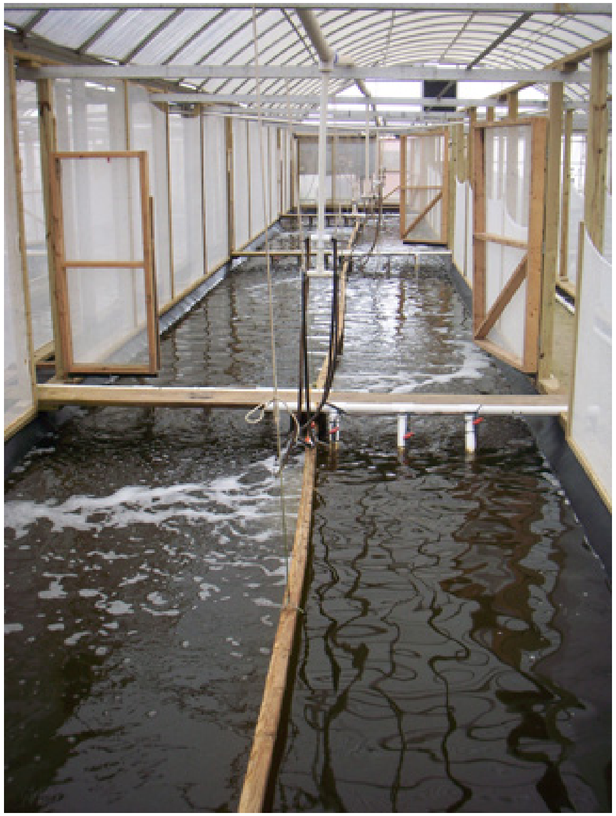
Aeration

Surface aerators = readily available, relatively inexpensive, robust, expandable

Airlifts = inexpensive, requires higher pressure blowers, inefficient gas transfer

O_2 injection = No CO_2 removal, dependable supply of pure O_2 needed

Fountain/paddle = fountain aeration available/low cost, provides good water mixing , paddles must be custom built

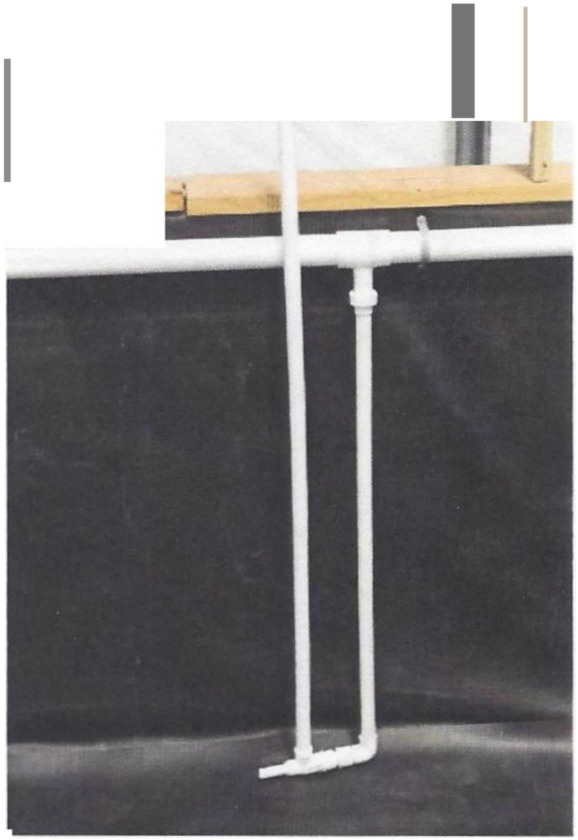


Texas A&M Agrilife Research Mariculture Laboratory - Flour Bluff indoor recirculating shrimp culture raceways equipped with Aero-Tube™ aeration tubing.

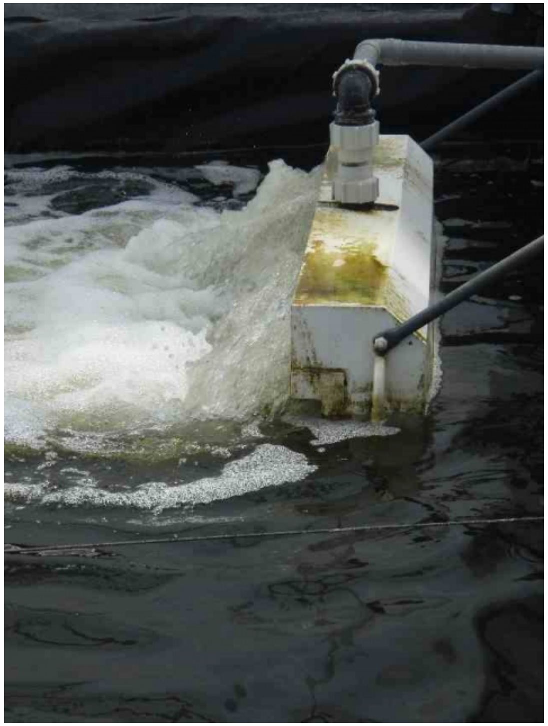
Fountain aeration with paddle driven mixing, MU Bradford Farms 2014.

Surface aerators, Aquacorps, Puerto Rico

Aeration (continued)



Nozzle air injection,
Texas A&M



Airlifts,
Aquaculture Consultancy
Netherlands

Airlifts, MU Bradford farms
First 30-days of culture

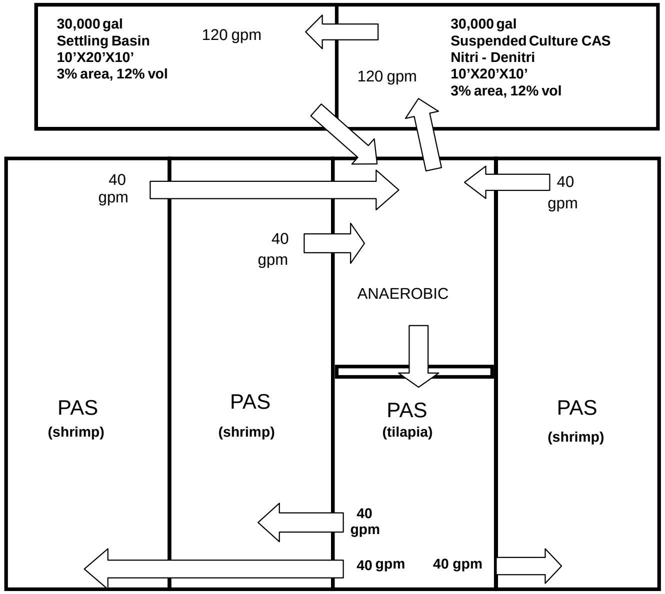
Solids Control

Algal, 50-100 mg/l; filter-feeder needed to control algal species, algal density and zooplankton elimination

Heterotrophic; 200-400 mg/l, floatation, settling tanks, bead filters, sand filters or filter-feeders, Higher solids produces higher system respiration , higher aeration hp, shorter O_2 buffer time

Nitrification reactors; 200-300 mg/l, solids, 10% of solids production compared to heterotrophic or algal

Proposed Configuration for Combined Algal/Bacterial System (CAS)



Clemson, 2008 Supplemental treatment algal/bacterial

MU 2014 Zero-discharge Brine shrimp filter-feeding

Clemson, Excessive solids levels
> 400 mg/l

Clemson, impact of tilapia filtration

Foam Fractionation, Texas A&M; one water replacement per cycle

Bead Filter, Auburn University; two water replacements per cycle

Ammonia and Alkalinity Control

Algal = 20,000 lb feed/120-200 day, 250 lb-feed/day, solids production = 12,000 lb/cycle, aeration =20-30 hp/acre, alkalinity addition = 0 lb/acre-cycle

Heterotrophic = 70,000 - 90,000 lb feed/100-days of which 30,000 - 40,000 lb as carbohydrate, 500-900 lb-feed /day, aeration = 80-100 hp/acre, solids production = 20,000+ lb/cycle, alkalinity addition = 0 lb/acre-cycle

Nitrification = 70,000 - 90,000 lb feed/120-days (35% protein), aeration= 60-80 hp/acre, 500-900 lb/day, aeration = 60 - 80 hp/acre, required alkalinity addition = 12,000 lb/acre-cycle, with denitrification, alkalinity addition = 0 lb/acre-cycle, solids production = 10% of heterotrophic

Algal System (20,000 lbs/cycle yield)

Feed

Nitrogen
Waste

Algal
Biomass

Bioprocessing for solids control
Zero discharge, feed co-production

Foam fractionation for solids control
One water exchange/cycle
Sludge disposal needed

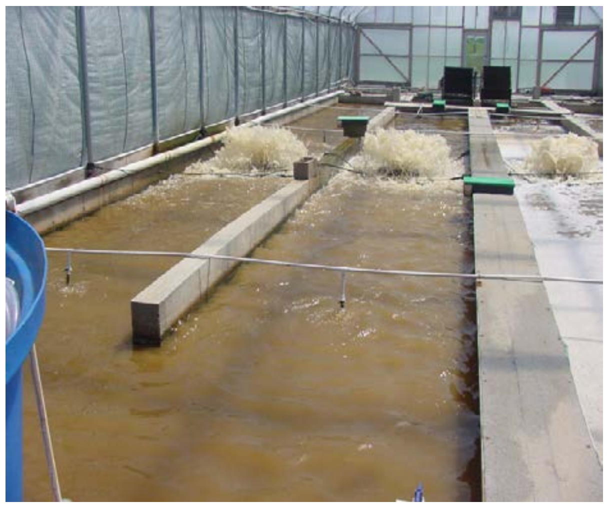
Heterotrophic System (30,000- 45,000 lb/acre yield)

Feed

Carbohydrate addition

Nitrogen Waste

Bacterial Biomass



Bioprocessing for solids control
Zero discharge, feed co-production

Bead filter processing for solids control
Two water exchanges/cycle
Sludge disposal needed

Nitrifying/Denitrifying System (30,000- 45,000 lb/acre yield)

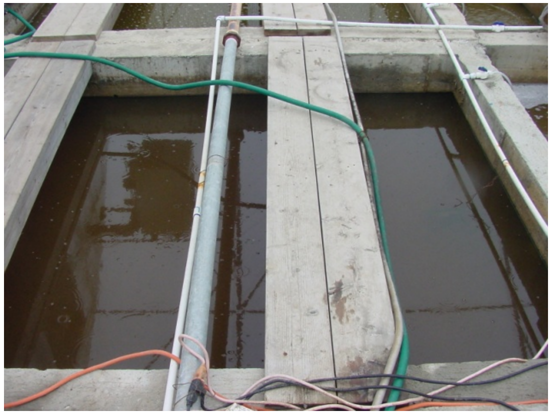
Bioprocessing for solid management
Zero discharge
Non-Polluting gas release N_2 & CO_2

Feed

Nitrogen Waste

Bacterial Biomass

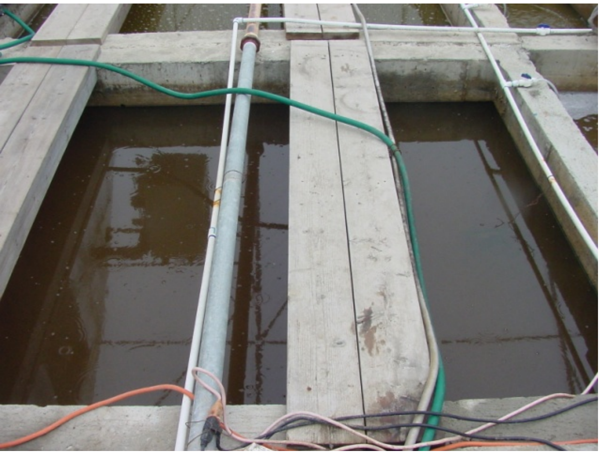
Biofloc



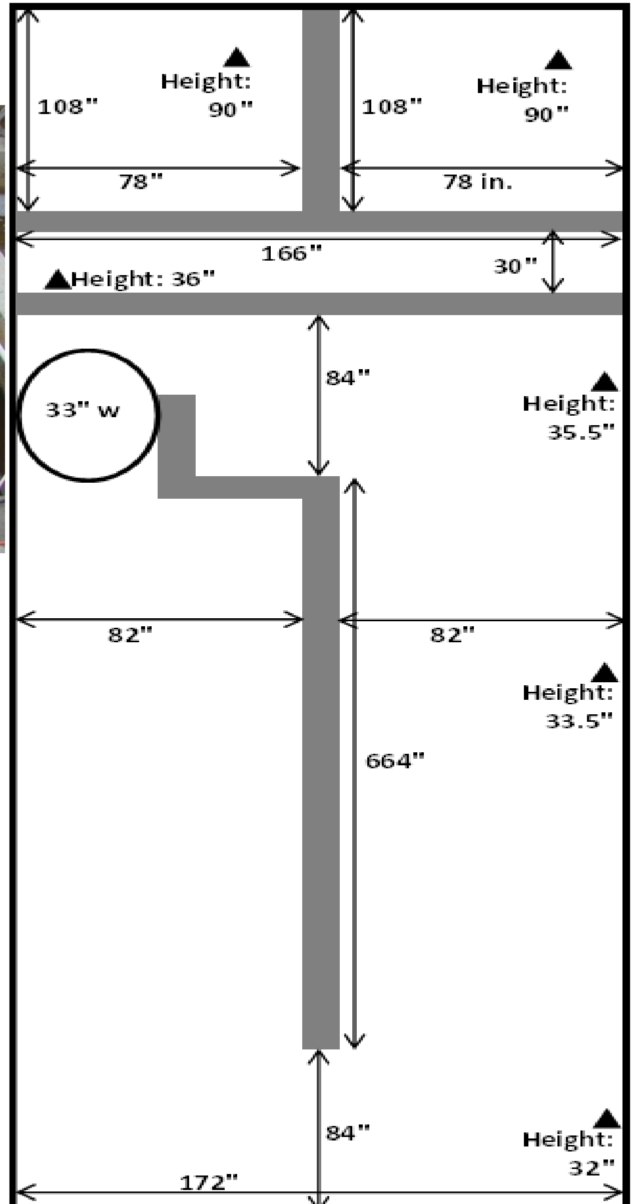
Settling tank, anaerobic digester

MU-Bradford Zero-Discharge Deep Tanks

Two -100 m^2 (1/40 acre) raceways (2-ft water-depth), anaerobic and aerobic reactors (7.5 ft deep); System volume (30,000 gal) exchanged through reactors once/day; Paddlewheels at 0.2 fps water velocity



Anoxic tank; solids & heavy metals removal, denitrification & alkalinity replacement



Aerobic tank; supplemental ammonia oxidation

Enterprise Budgets; Shrimp Culture Comparisons

Carrying capacity; 9,800, 12,570, 27,000 & 45,000 lb/ac-cycle; Operational time; 200, 220, 237 & 365 days/yr, four algal, two nitrifying, six heterotrophic; Two R-30 buildings; Ten-greenhouse enclosures
Heterotrophic = 90-day cycle, Nitrification and algal = 120 day cycle

Carrying capacity; 27,000 lbs/acre*

1) Feed & sugar greenhouse-PAS, 2 crops/yr; FS2(27)
2) Feed & sugar greenhouse-PAS, nursery, 3 crops/yr; FS3(27)
3) Feed & nitrification greenhouse-PAS, 2 crops/yr; FN2(27)
4) Feed & sugar R30-PAS, nursery, 4.6 crops/yr; FS4.6(27)

Carrying capacity; 45,000 lbs/acre+

1) Feed & sugar greenhouse-PAS, 2 crops/yr; FS2(45)
2) Feed & sugar greenhouse-PAS, nursery, 3 crops/yr; FS3(45)
3) Feed & nitrification greenhouse-PAS, 2 crops/yr; FN2(45)
4) Feed & sugar R30-PAS, nursery, 4.6 crops/yr; FS4.6(45)

Carrying capacity; 12,600 lbs/acre-cycle*

1) Fed algal temperate-PAS, 2 crops/yr; FA2(12.6)

Carrying capacity; 9,800 lbs/acre*

1) Fertilized algal temperate-PAS, 2 crops/yr; PAS2(9.8)
2) Fertilized algal tropical-PAS, 3 crops/yr; TPAS3(9.8)
3) Fed lined tropical-pond, 3 crops/yr; TP3(9.8)

Enterprise Budget Summary; Projected Capital & Operating Costs/ac-yr

Carrying capacity; 9,800, 12,570, 27,000 & 45,000 lb/ac-cycle; Operational time; 200, 220, 237 & 365 days/yr, four algal, two nitrifying, six heterotrophic; Two R-30 buildings; Ten-greenhouse enclosures

CAPACITY (lbs/acre-cycle)	27k	27k	27k	27k	45k	45k	45k	45k	12,570	9800	9800	9800
SYSTEM DESCRIPTION	F/S-2	F/S-3	F/N-2	F/S-4.6	F/S-2	F/S-3	F/N-2	F/S-4.6	F/A-2	PAS-2	TPAS-2	TP-3
INPUT												
feed (lb/ac-yr)	97,200	145,800	97,200	223,200	162,000	243,000	162,000	372,600	45,256	0	0	52,963
sugar (lb/ac-yr)	97,200	145,800	0	223,220	162,000	243,000	0	372,600	0	0	0	0
electrical (kw-hr/ac-yr)	243,000	307,150	191,970	473,040	405,000	511,920	319,950	788,400	81,000	89,100	133,650	98,550
heat (kw-hr/ac-yr)	172,685	350,822	390,237	0	111,771	298,032	320,333	0	277,331	387,781	0	0
OUTPUT												
shrimp (lb/ac-yr)	54,000	81,000	54,000	124,200	90,000	135,000	90,000	207,000	25,140	19,600	29,400	29,400
methane (kw-hr/ac-yr)	56,400	75,840	23,463	124,465	94,000	126,321	39,105	207,320	22,600	22,880	37,960	0
brine shrimp (lb/ac-yr)	46,170	69,255	21,870	106,025	76,950	115,425	36,450	176,985	19,324	-19,600	-29,400	0
COSTS & INCOME												
shrimp ($/ac-yr)	295,627	405,888	258,853	675,338	428,881	580,829	356,201	928,929	182,371	162,856	121,476	80,887
energy ($/ac-yr)	1,414	2,156	667	3,532	2,564	3,551	1,112	5,886	567	653	653	0
brine shrimp ($/ac-yr)	34,627	48,594	16,402	79,693	57,710	80,989	25,837	132,738	14,443	0	0	0
cost $/lb	5.47	5.01	4.79	5.44	4.77	4.30	3.96	4.49	7.25	8.31	4.13	2.75
net cost ($/lb - products)	4.81	4.38	4.48	4.77	4.10	3.68	3.66	3.82	6.66	8.28	4.11	2.75
ENERGY												
feed (2.2 kw-hr/lb)	213840	320760	213840	491040	356400	534600	356400	819720	99563	0	0	116519
sugar (1.0 kw-hr/lb)	97200	145800	0	223220	162000	243000	0	372600	0	0	0	0
electrical	243,000	307,150	191,970	473,040	405,000	511,920	319,950	788,400	81,000	89,100	133,650	98,550
heating	172,685	350,822	390,237	0	111,771	298,032	320,333	0	277,331	387,781	0	0
brine shrimp (3.96 kw-hr/lb)	-182833	-274250	-86605	-419859	-304722	-457083	-144342	-700861	-76523	-77616	-116424	0
gas energy (@ 100%)	-1,414	-2,156	-667	-3,532	-2,564	-3,551	-1,112	-5,886	-567	-653	-653	0
NET ENERGY (kw-hr/lb)												
production energy (kw-hr/lb	7.7	8.1	10.8	3.8	5.7	6.0	7.1	3.8	14.3	24.3	4.5	3.4
net energy (feed and sugar)	13.5	13.9	14.7	9.6	11.5	11.8	11.1	9.6	18.2	24.3	4.5	7.3
life cycle energy (-products)	10.0	10.5	13.1	6.2	8.1	8.3	9.5	6.2	15.1	20.3	0.6	7.3
feed replacement (%)	0.86	0.86	0.41	0.86	0.86	0.86	0.41	0.86	0.77	100.00	100.00	0.00
replacement (%-feed cost)	45	42	21	45	45	42	20	45	40	100	100	0.00

Projected Annual Cost Contributions;
% of Annual Income for 12 Systems

SYSTEM	FS2	FS3	FN2	FS4.6	FS2	FS3	FN2	FS4.6	FA2	PAS	TPAS3	TP3
FEED	23	25	23	20	23	25	27	24	15	0	1	39
SUGAR	15	17	0	13	15	17	0	16	0	0	0	0
HEATING	1	2	8	0	1	2	4	0	8	12	0	0
ELECTRICAL	9	9	7	7	9	9	9	8	4	5	11	12
STOCKING	14	18	9	15	14	18	17	18	6	5	11	16
LABOR	8	7	15	9	8	7	11	6	18	22	45	15
DEPRECIATION	21	16	26	24	21	16	22	18	33	37	23	11
INTEREST	9	7	12	12	9	7	10	10	16	18	10	6
Capacity	27K	27K	27K	27K	45K	45K	45K	45K	12K	9.8K	9.8K	9.8K

Carbohydrate~ 2/3 of feed
Depreciation~ feed

Projected Shrimp Cost and Energy Footprint/lb

	System	Season days	Capacity lbs/ac	Production lbs/yr	Capital $1000/acre	Production $/lb	Energy kw-hr/lb
1)	FS2(27)	200	27,000	54,000	613	4.81	7.7/10
2)	FS3(27)	237	27,000	81,000	613	4.34	8.1/10.5
3)	FN2 (27)	237	27,000	54,000	573	4.48	10.8/13.1
4)	FS4.6(27)	365	27,000	124,200	1,522	4.77	3.8/6.2
5)	FS2(45)	200	45,000	90,000	694	4.10	5.7/8.1
6)	FS3(45)	237	45,000	135,000	694	3.63	6.0/8.3
7)	FN2(45)	237	45,000	90,000	629	3.64	7.1/9.5
8)	FS4.6(45)	365	45,000	207,000	1,642	3.82	3.8/6.2
9)	FA2(12.6)	200	12,600	25,200	532	6.65	14.3/15.1
10)	PAS2(9.8)	220	9,800	19,600	531	8.27	24.3/24.3
11)	TPAS3(9.8)	365	9,800	29,400	220	4.11	4.5/0.6
12)	TP3(9.8)	365	9,800	29,400	92	2.75	7.3/7.3

***Brune, D. E., C. Tucker, M. Massingill, and J. Chappell, Partitioned Aquaculture Systems, pp 308-342 in J.H. Tidwell, editor, Aquaculture Production Systems, Wiley-Blackwell, Oxford, UK, 2012.**

+Braga, André, V., Magalhães, T.C., Morris, B. Advent, and Tzachi M. Samocha, Use of a Non Venturi Air Injection System for Producton of *Litopenaeus vannamei* in Biofloc Dominated Zero Exchange Raceways, Aquaculture 2013, Nashville, Tennessee

Asian Shrimp Production Costs* (2014 US-$/lb)

Intensive Systems; 10-15% water exchange/day, 1.6 crops/yr, 2,500 – 9,500 lb/ac-yr

Philippines	4.71/lb
Thailand	4.57/lb
China	3.26/lb
India	4.39/lb
Indonesia	4.30/lb

Average = $4.25/lb

Semi-Intensive; 0-15% water exchange/day,1.6 crops/yr, 760 – 4500 lb/ac-yr

China	2.13/lb
Philippines	4.35/lb
Indonesia	4.53/lb
India	4.82/lb

Average = $3.96/lb

Extensive Systems; No water exchange,1.6 crops/yr, 100 – 650 lb/ac-yr

China	$2.02/lb
Thailand	2.40/lb
Philippines	$4.83/lb
Indonesia	4.54/lb
India	4.77/lb

Average = $3.71/lb

* Ling, B.H., Leung, P.S., Shang, Y.C., Inter country comparison of shrimp farming systems in Asia, World Aquaculture 96, Bangkok Thailand. 1996

2014 Shrimp Retail Value vs. Production Cost (US-$/lb heads-on)

HyVee (on-ice)		Walmart (frozen)	
55 ct, 8 gm, India	$6.50	70 ct, 6.5 gm, India,	$5.87
55 ct, 8 mg, Thailand,	$7.15	35 ct, 12.8 gm, India,	$4.33
18 ct, 25 gm, Thailand,	$9.75	28 ct, 16 gm, India,	$3.58
18 ct, 25 gm, US caught,	$8.45	26 ct, 17 gm, Thailand,	$8.10
		32 gm, 14 ct, Indonesia,	$8.37

Retail price; $3.58 - 9.75/lb, Ave = $6.90/lb

Asian production cost; $2.02 – 4.83/lb, Ave = $3.97

MU Projected Costs;

Bacterial Temperate-PAS	$3.63 - $4.77/lb
Algal Temperate-PAS	$8.27/lb
Algal Tropical PAS	$4.11/lb
Tropical Pond	$2.75/lb

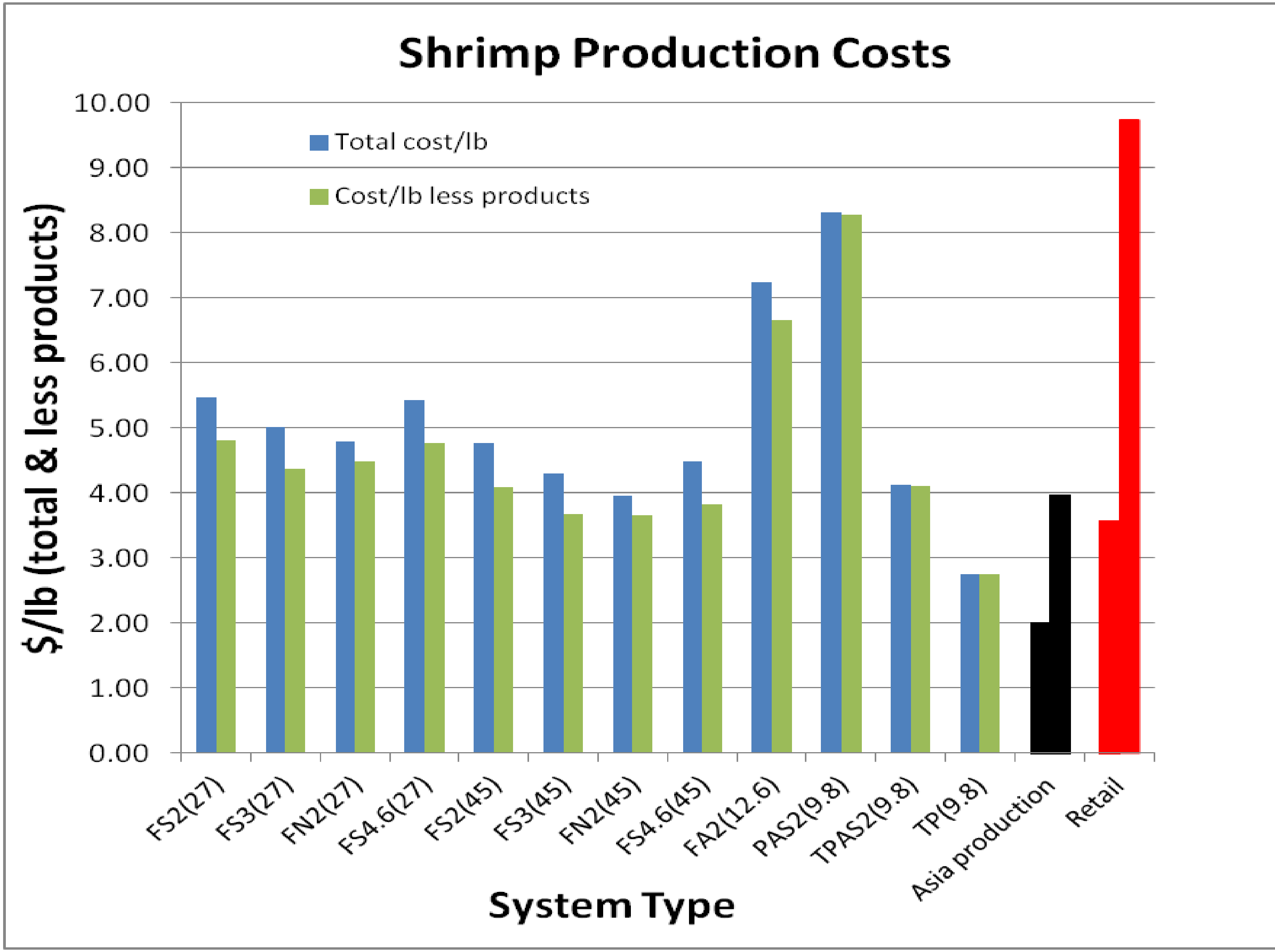
Production Cost 12 systems

Culture cost $/lb (blue)

$/lb less co-product value (green)

Asian intensive pond $/lb high/low (black)

Retail price high/low (red)



Energy Cost
12 systems

Culture energy/lb (dark-blue)

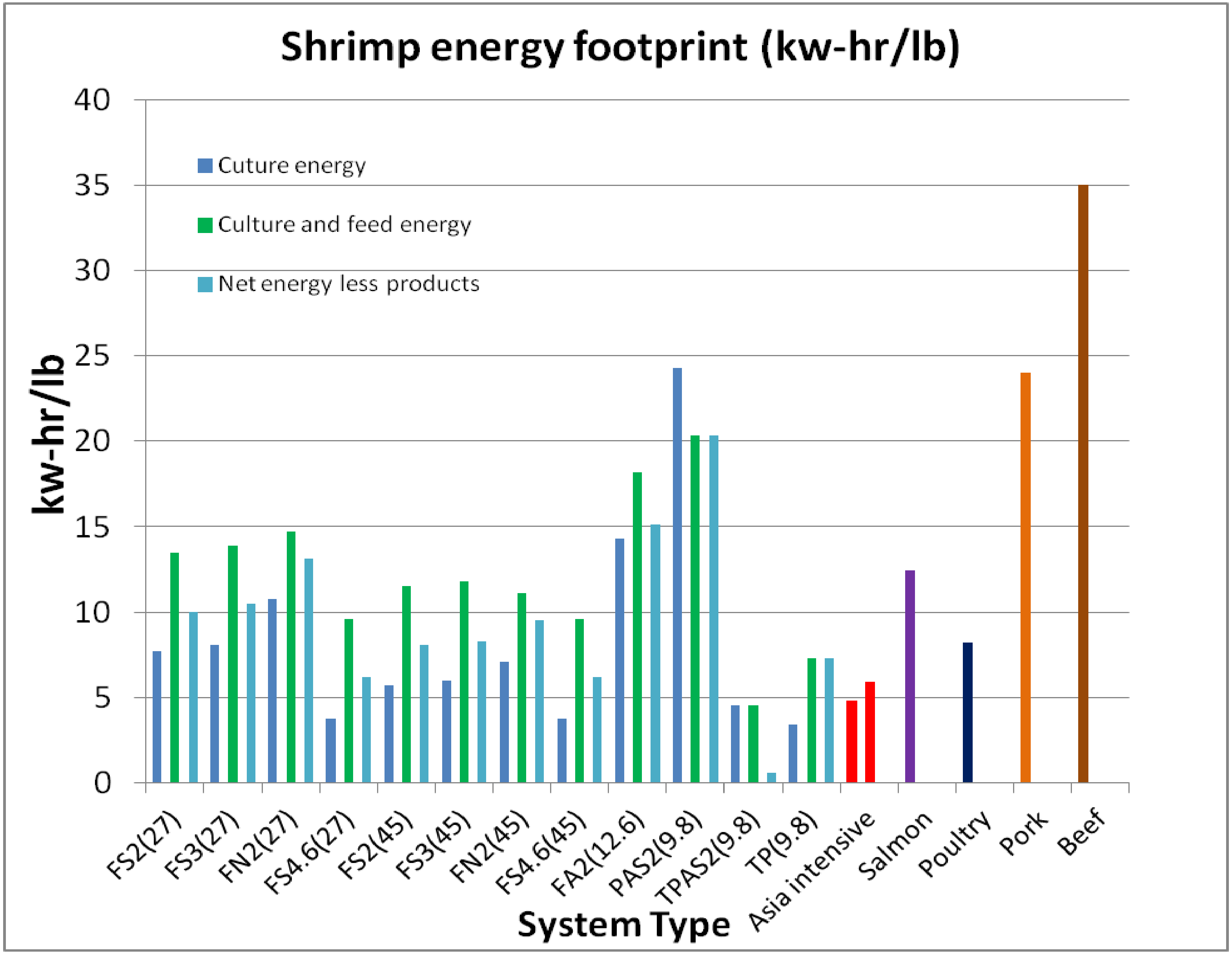
Culture energy + feed and sugar energy (green)

Combined energy less brine shrimp and methane products (light-blue)

Asian intensive shrimp high/low (red)

Cultured salmon (purple)

Beef and poultry (black)



Summary

- Suspended cell culture = water treatment and animal culture in same footprint
- Algal to 300 lb/ac-day, Nitrifying at C/N = 9/1, Heterotrophic = C/N = 12-15/1
- Biofloc = special case of SCC (typically brown water)
- Algal systems must be stabilized with filter-feeders
- Nitrifying solids production = 10% of algal or heterotrophic
- Aeration energy = 30 hp/ac (intensive ponds) to 80-100 hp/ac super intensive
- Mixing of solids and water limiting factor in intensification in ponds
- Capital investment = $100,000/ac ponds to $1.6 million/acre insulated building
- Production = 30,000 lbs/ac-yr ponds to 200,000 lbs/ac-yr super intensive
- Productions costs = $2.00-4.00 / lb ponds to $4.50 / lb super intensive
- Processing, transport, distribution shrimp ~ significant issue

Deployment/Outreach Questions and Challenges

- Small shrimp producers need nursery
- Larger shrimp producers need hatchery
- Tilapia needed in outdoor or green water systems
- Significant capital investment required; Banks not likely to support unproven technology; Who?
- Will U.S. consumers pay more for sustainably produced, locally reared, higher quality fresh seafood? How much more?
- Producers will need network for rapid distribution of unfrozen product; Local stores, farmers markets, restaurants?

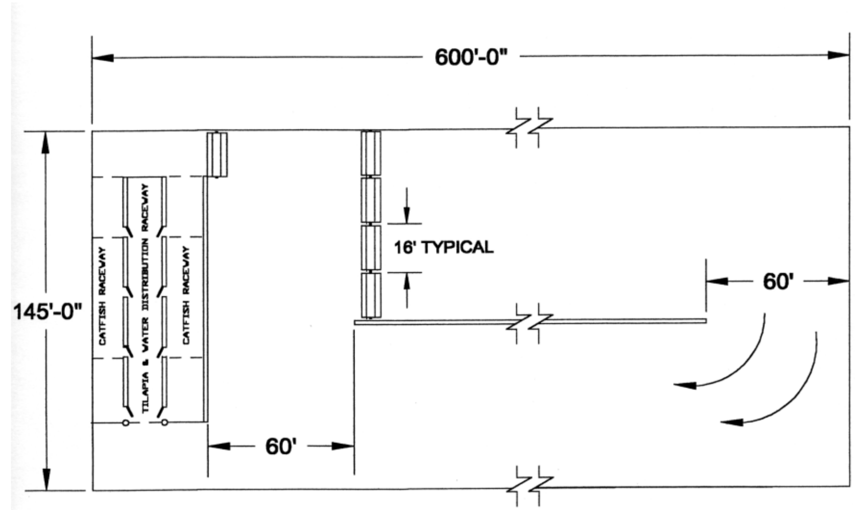
Tilapia in High-Rate Aquaculture Processes

UNIVERSITY OF MISSOURI
Extension

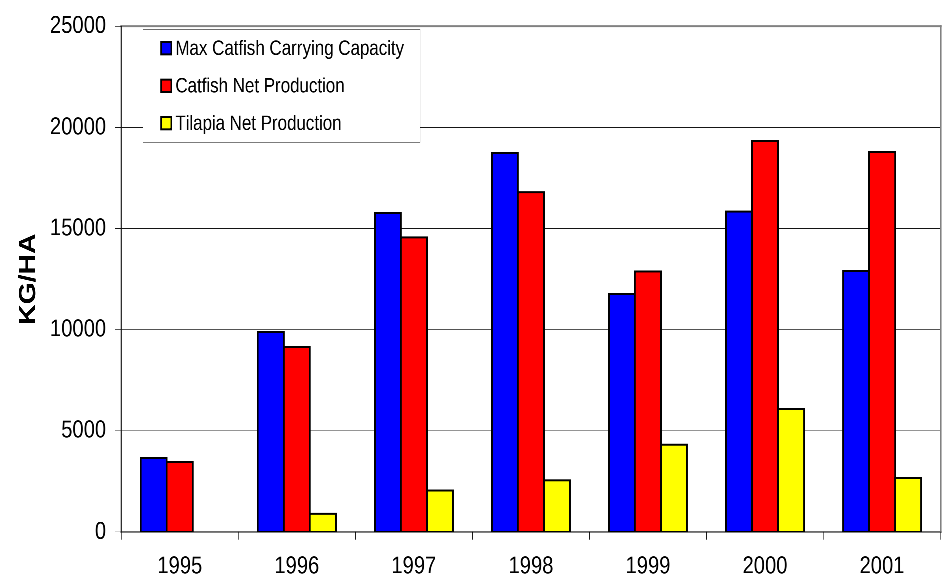
TM

D. E. Brune
Professor, Bioprocess and Bioenergy Engineering
University of Missouri, Columbia, MO. 65211

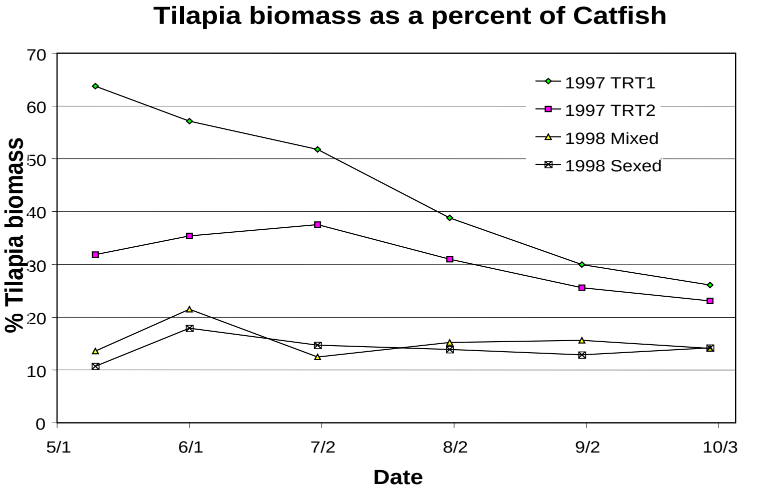
Development of the Partitioned Aquaculture System at Clemson University; 1987-2008 - Green-water for Catfish Production



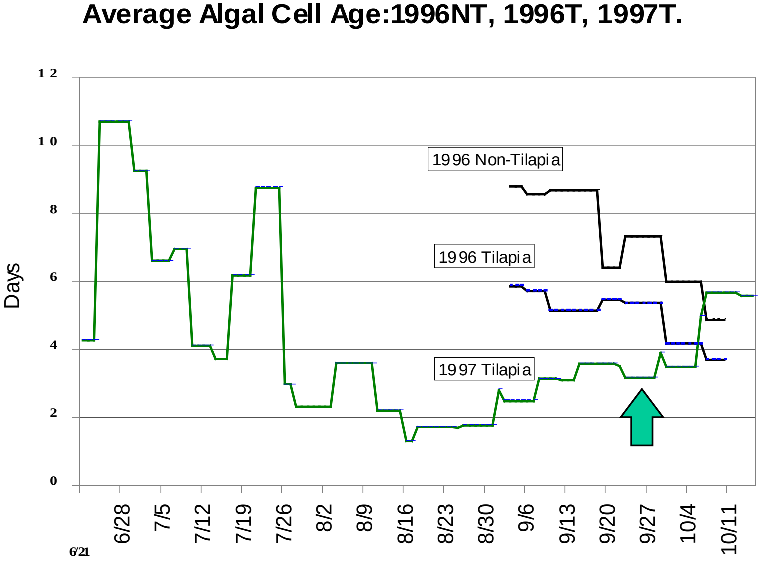
Tilapia co-culture for management of algal production in a "High-Rate Pond" modified for fish production, increasing carry capacity to 19,000 lb/acre



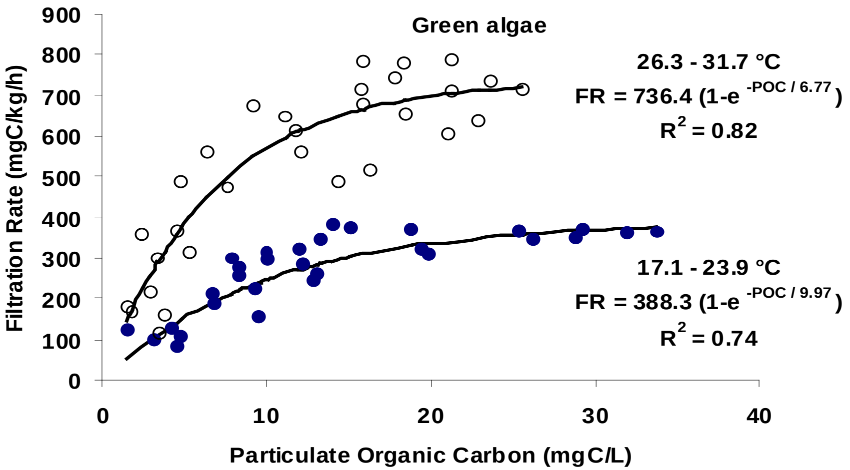
Cyanobacteria elimination and control of algal cell age and algal density

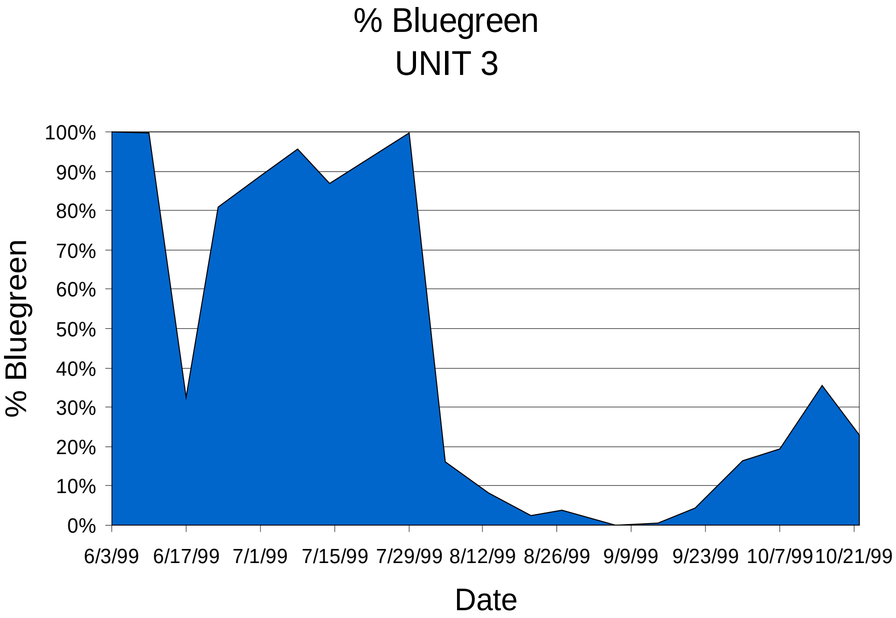


Tilapia assisted biosedimentation of algal biomass providing control of algal density (SD ~ 12-18 cm) and cell age (3-4 days) increasing water treatment capacity and reducing water column



Cyanobacteria and zooplankton reductions



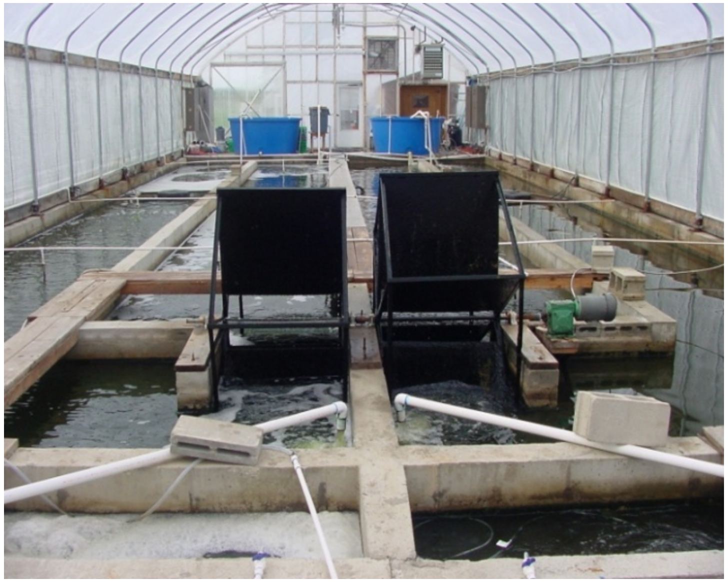


Tilapia filtration reduced Cyanobacteria dominance and zooplankton population, stabilizing culture and reducing fish off-flavor events

Zero-Discharge Sea Food Production

Clemson University 2001-2008; Green and brown-water marine shrimp production at 25,000 to 35,000 lb/acre-120 day cycle

University of Missouri, 2010-2014; Brown-water marine Shrimp production at 35,000+ lb/acre-120 day cycle

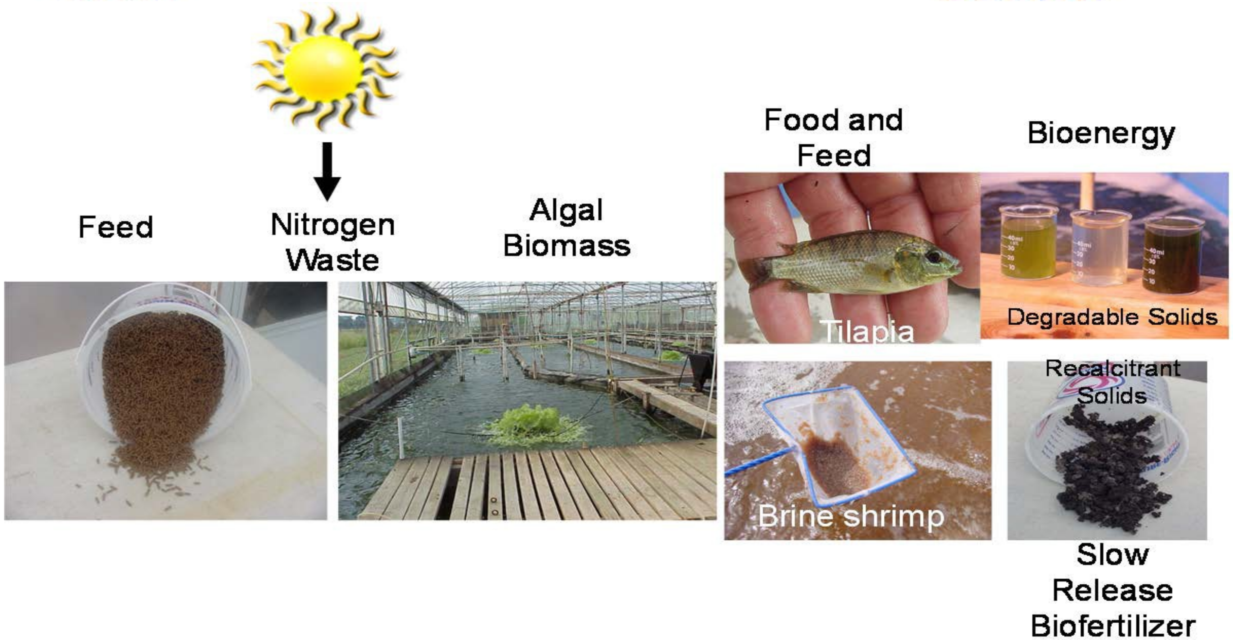


a) **Tilapia filtration unit**
b) **White shrimp culture unit**
c) **Shrimp culture without tilapia filtration**

a) **Brine shrimp culture for fish meal replacement (blue tanks)**
b) **Tilapia raceways (in fore ground)**
c) **Deep tanks (6-ft) for aerobic and anaerobic water treatment**

Zero-discharge; convert algal and bacterial biomass into co-products

Hetertrophic /chemoautotrophic bacterial systems; tilapia, brine shrimp, biofertilizer and bioenergy co-products at 25-35,000 lb/acre marine shrimp,



Algal systems; tilapia, brine shrimp, biofertilizer and bioenergy co-products at 20-25,000 lb/acre marine shrimp

Tilapia in High Rate Aquaculture; Advantages

- Stabilized algal culture, control of algal cell age, density and species
- Zooplankton elimination/reduction
- Net nitrogen and phosphorus removal/recycle
- Net organic removal, pond respiration reduction, net oxygen production
- By-product/bioenergy yield
- Enabler of zero-discharge aquaculture

Disadvantages

- Handling and culture of second fish
- Over-winter of tropical fish
- Mono-sexed tilapia or takeover of culture system
- State permits may be required, state prohibition possible
- Potential reservoir of fish disease

*more detail available in Perschbacher and Stickney

Brune, D. E., Tilapia in High Rate Aquaculture Processes, Chapter 12 in, Tilapia in Intensive, Co-culture, P.W. Perschbacher and R.R. Stickney, Editors, John Wiley & Sons, Inc., In press 2015.