Nitrogen Transformation Rates in a Zero-discharge Suspended-culture Shrimp Production System

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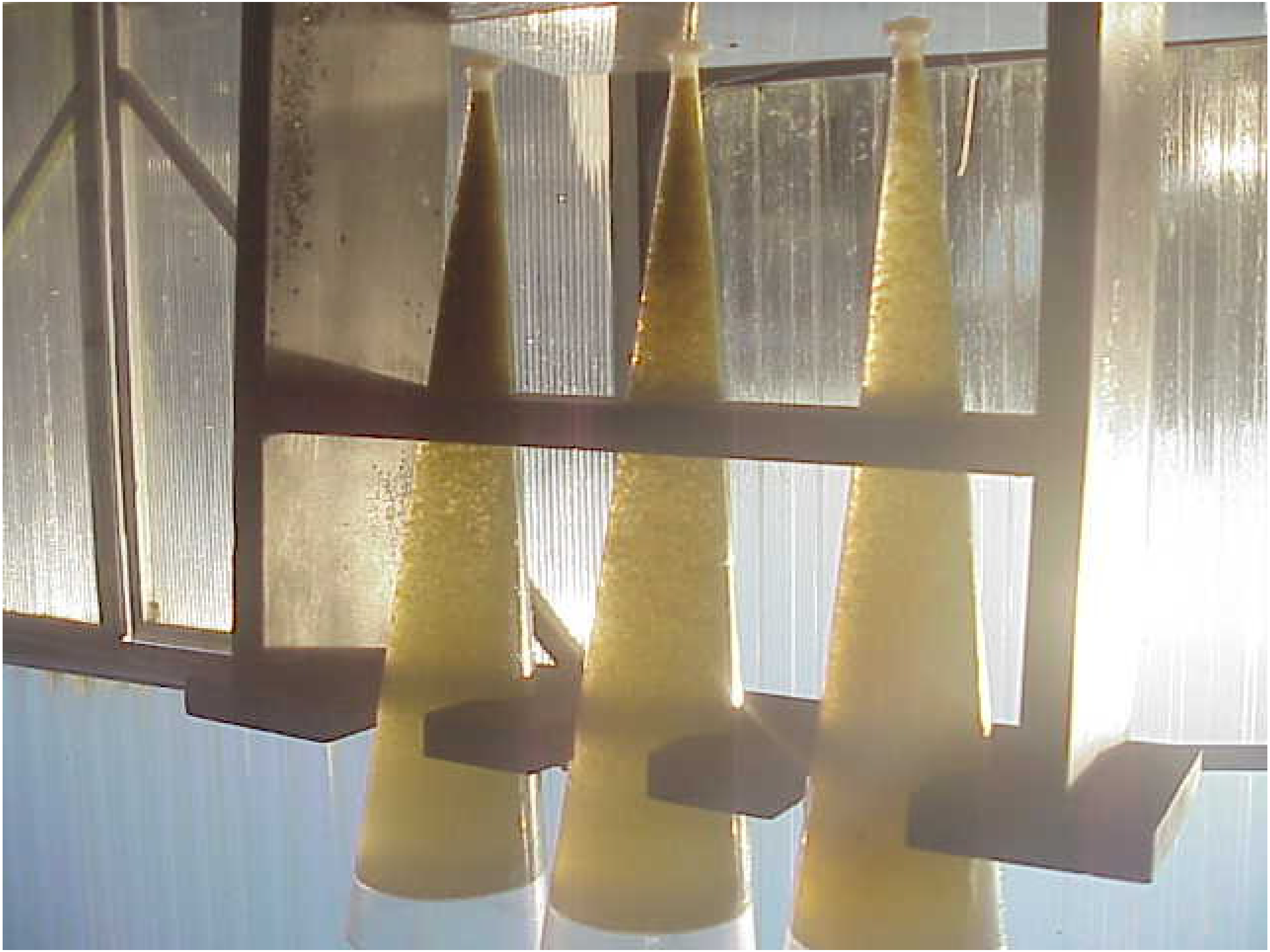
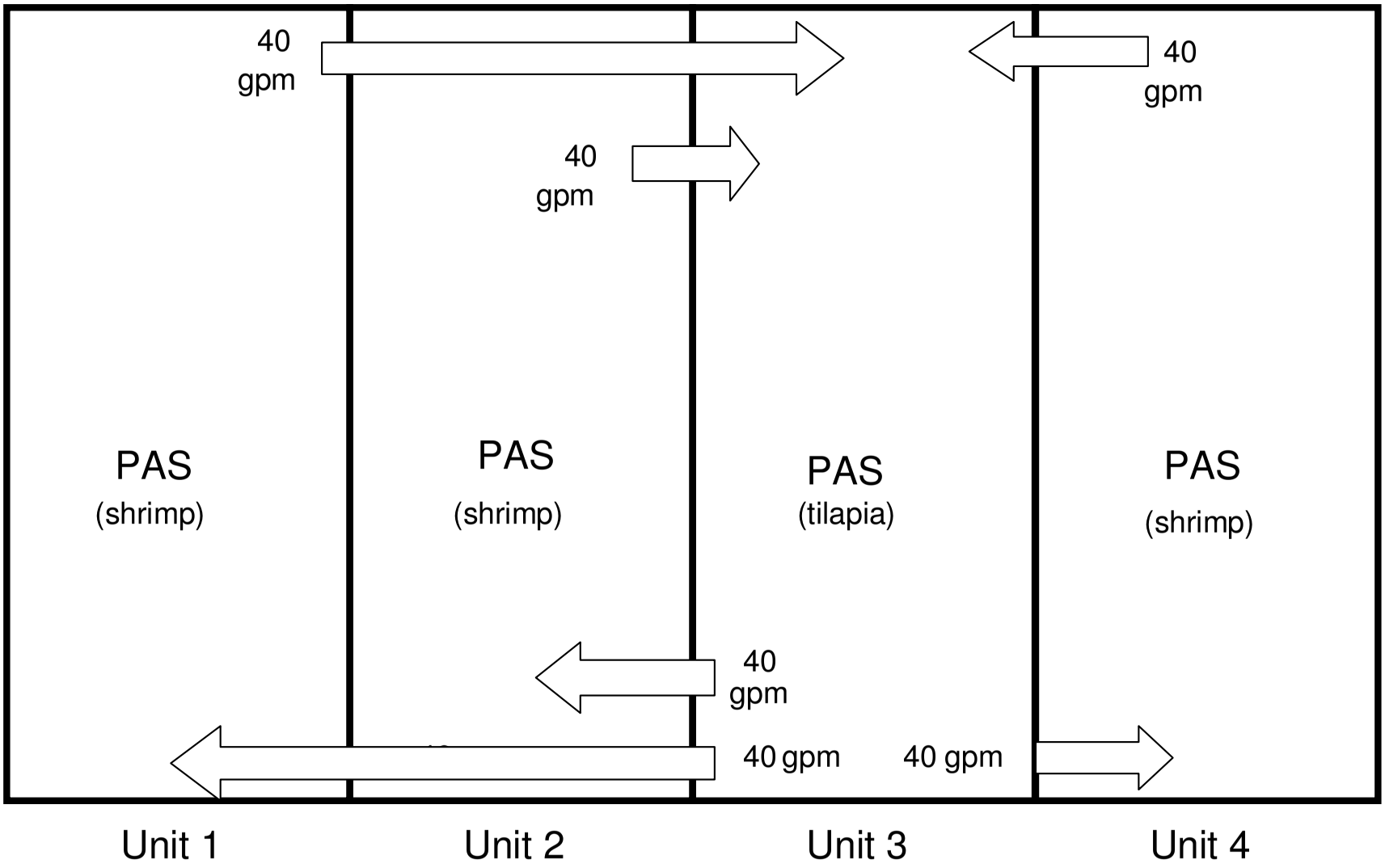
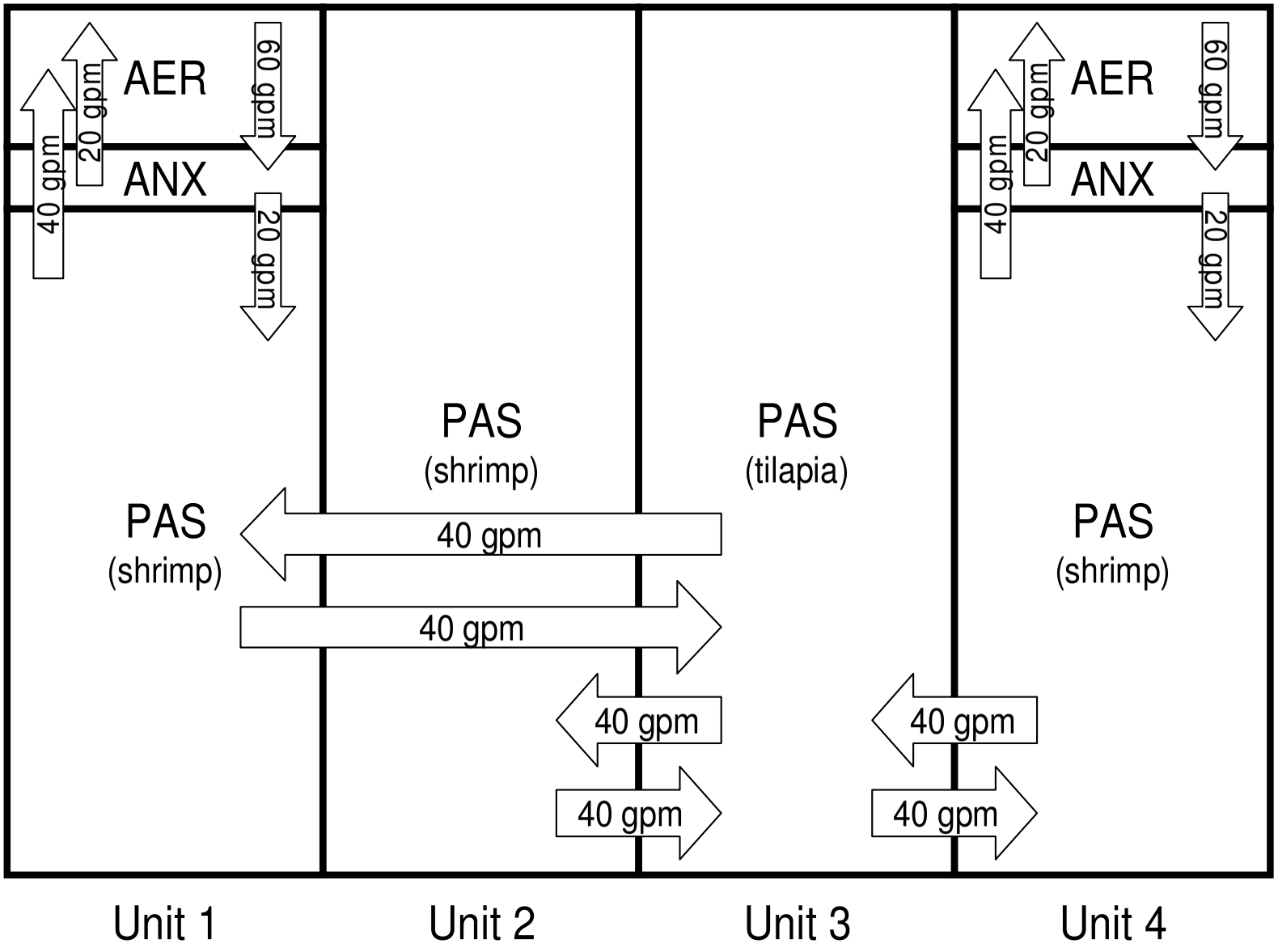
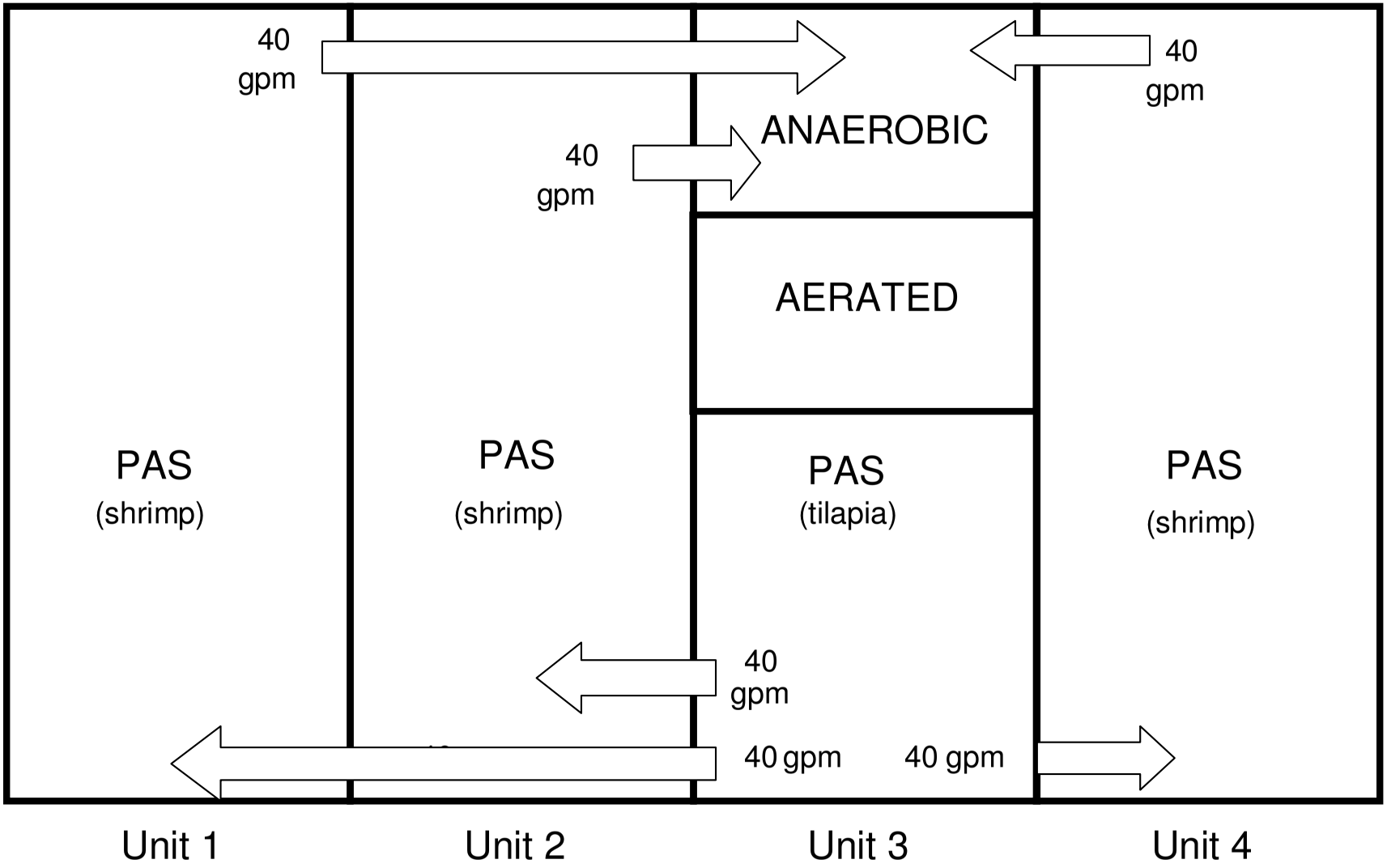




2003 Configuration



2004 Configuration



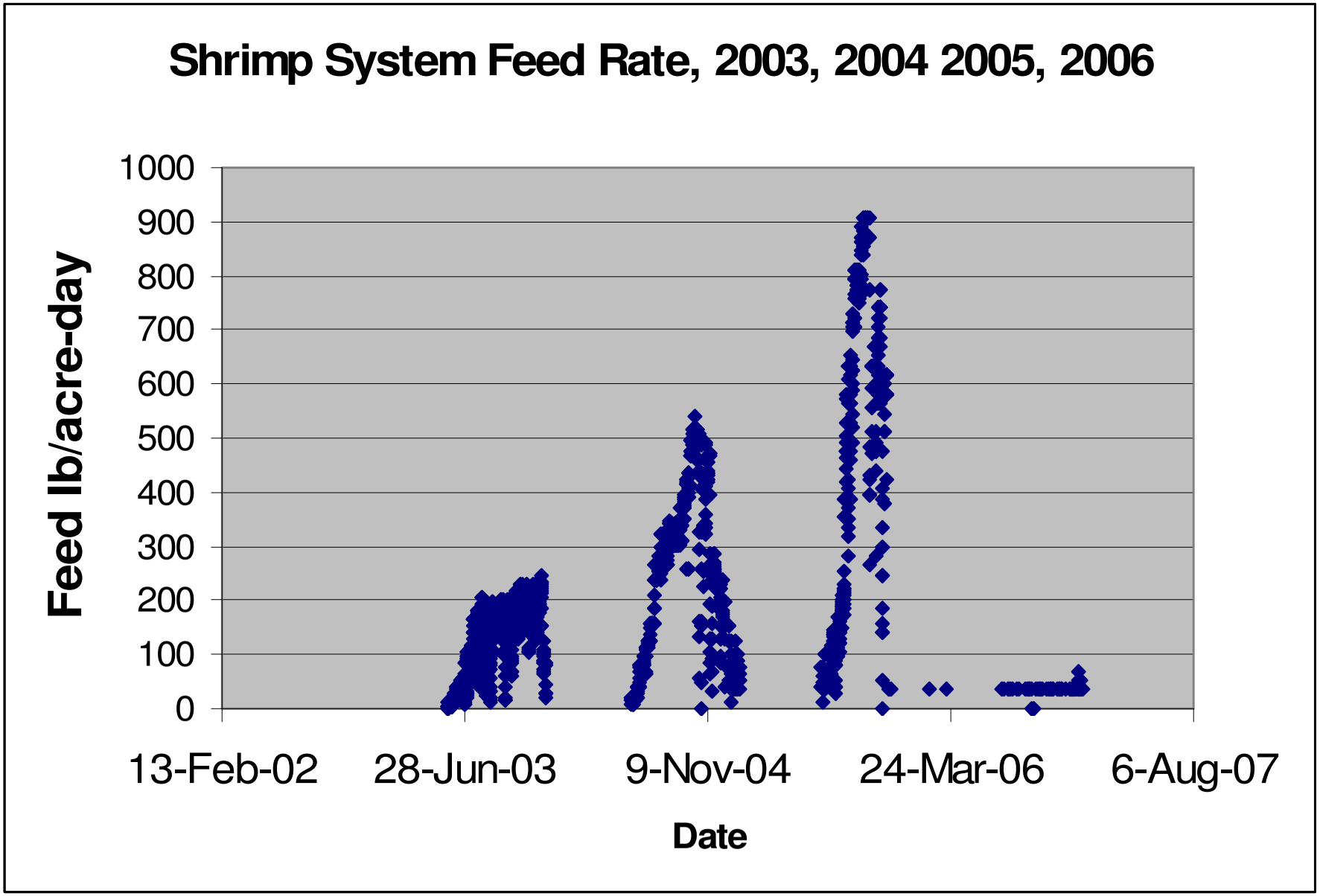
2005 Configuration

Shrimp Yield, Season Length, and Feed Rate

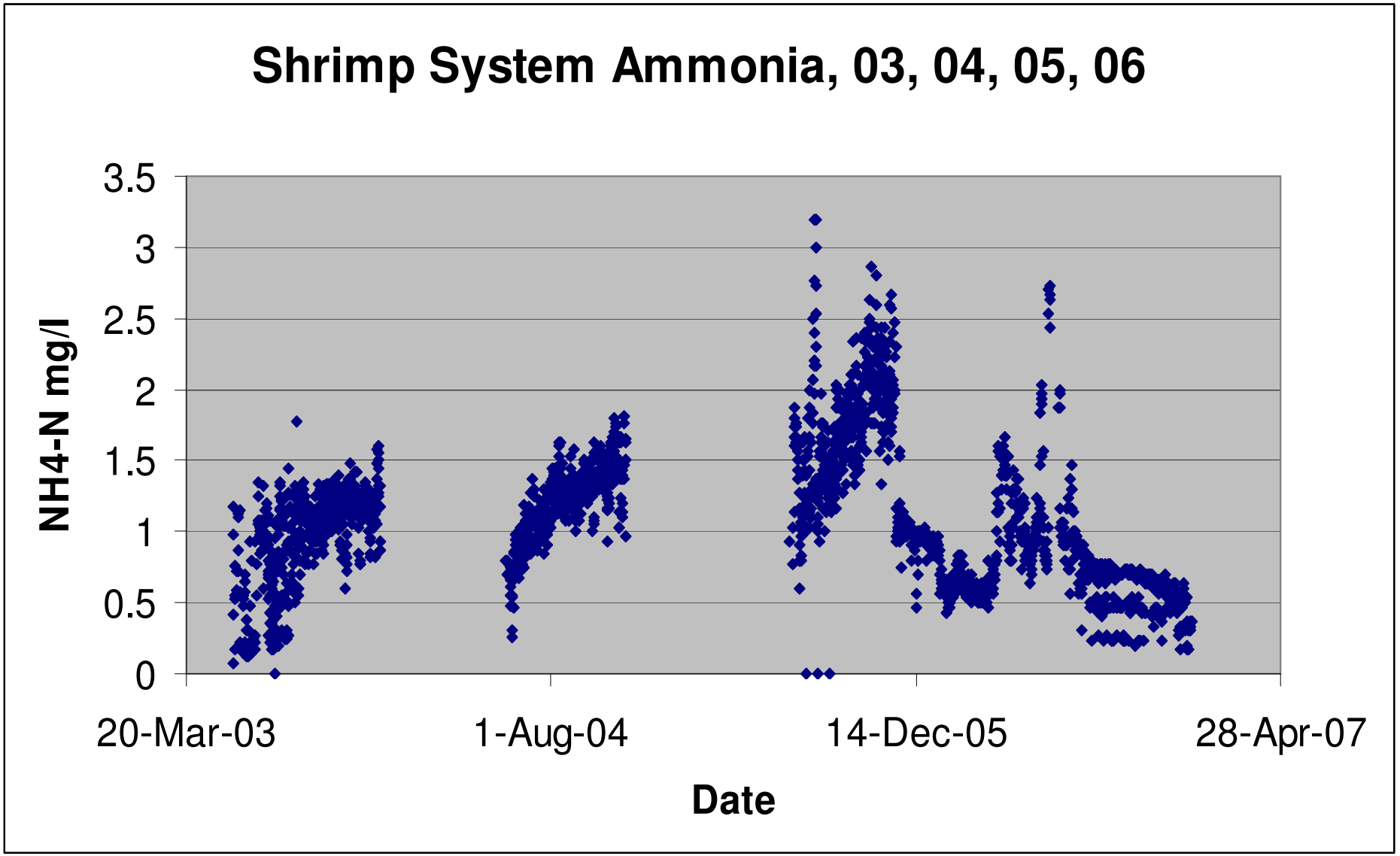
YR	Yield (lb/ac)	Season days	Feed (lb/acre-d) Ave	14d	Peak
2003	14,689	180	155	242	366
2004	22,773	165	378	663	752
2005	33,232	143	608	937	1374

Shrimp Density, % Tilapia, Aeration Energy, Alkalinity, and Volatile Solids

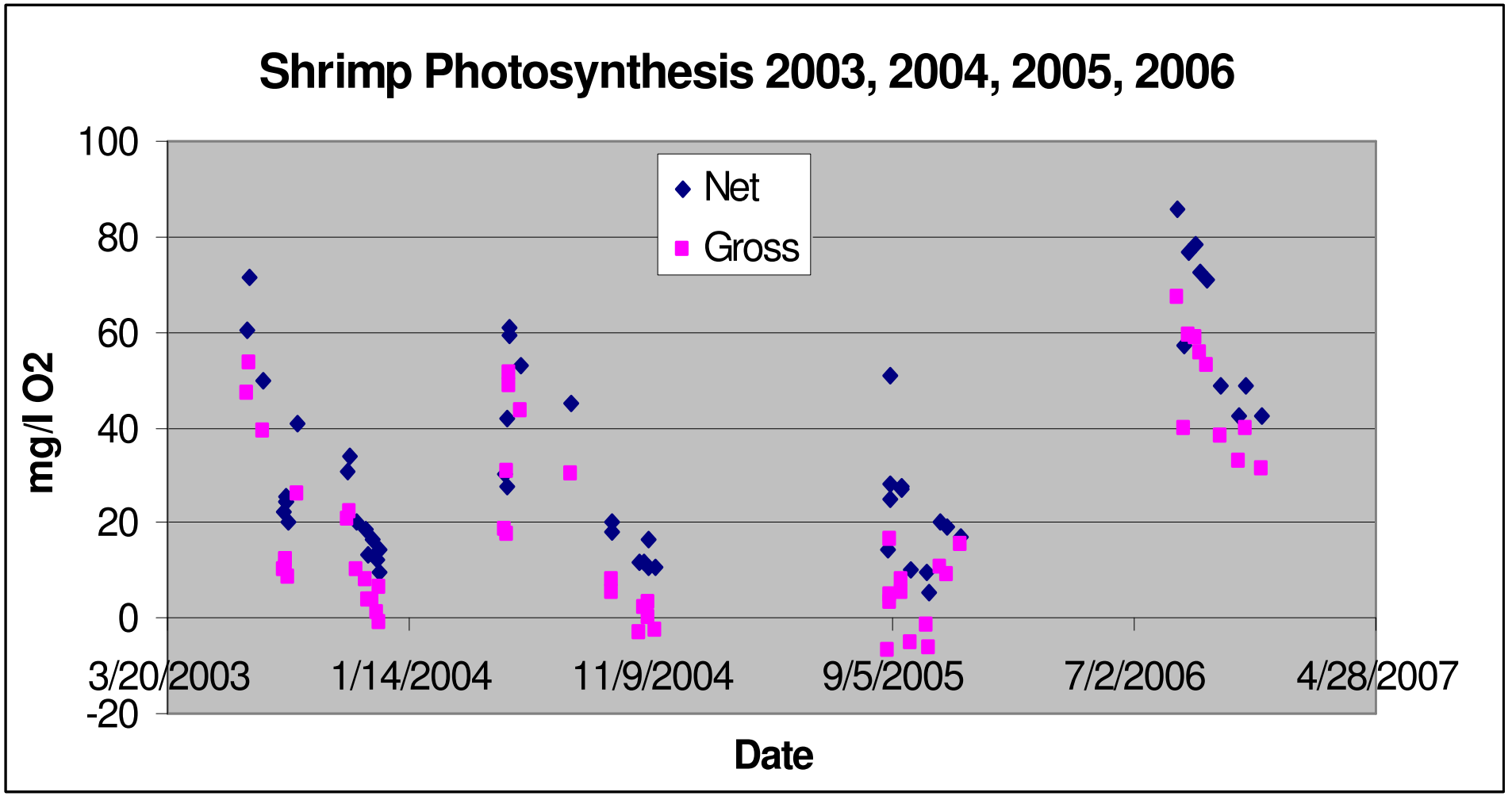
YR	(#/m^2)	Tilapia % mass	hp/ac	Alk (mg/l)	VS(ave/max) (mg/l)
2003	121	29	30	151	140/254
2004	153	24	36	85	155/344
2005	252	16	60	198	226/650

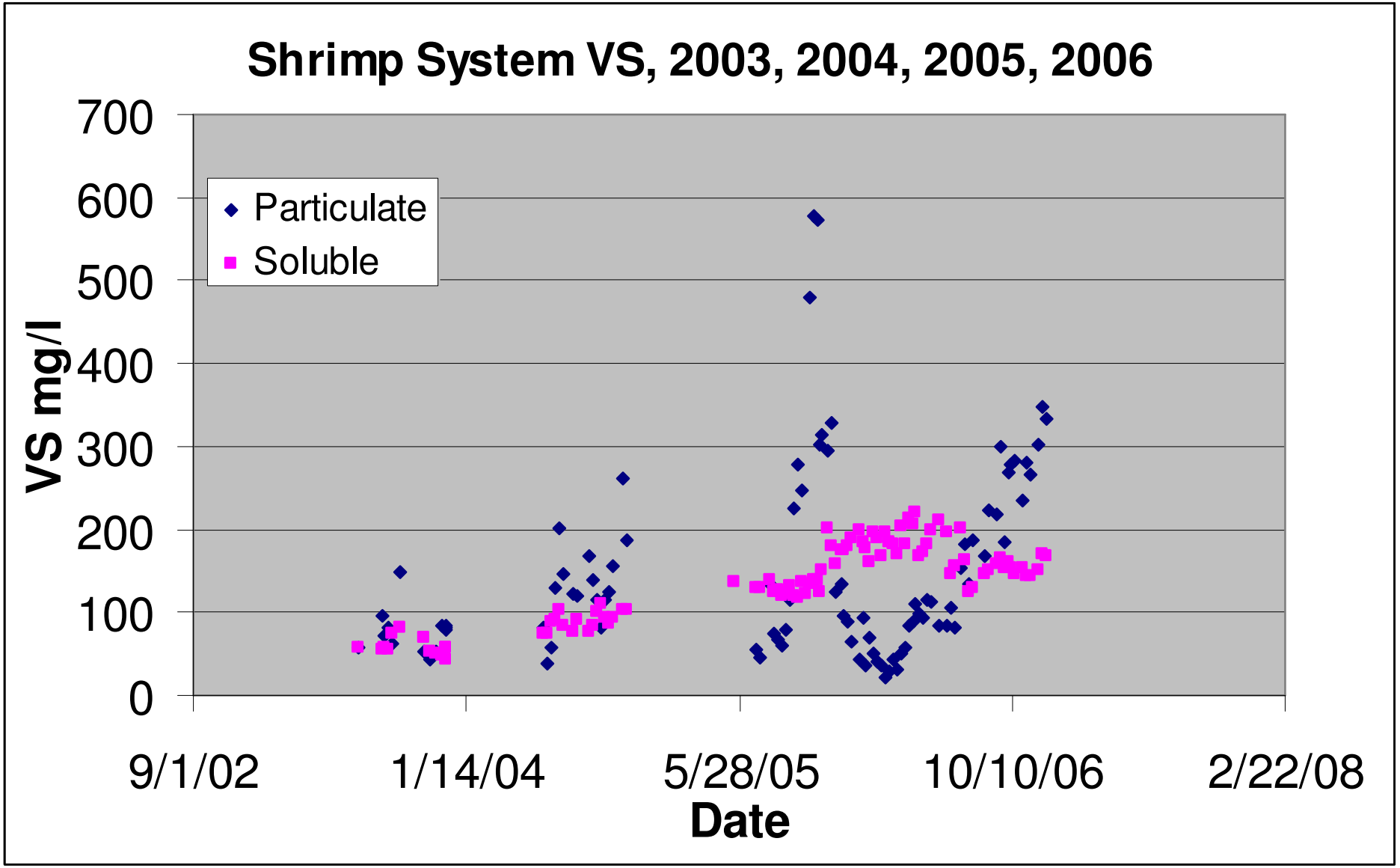


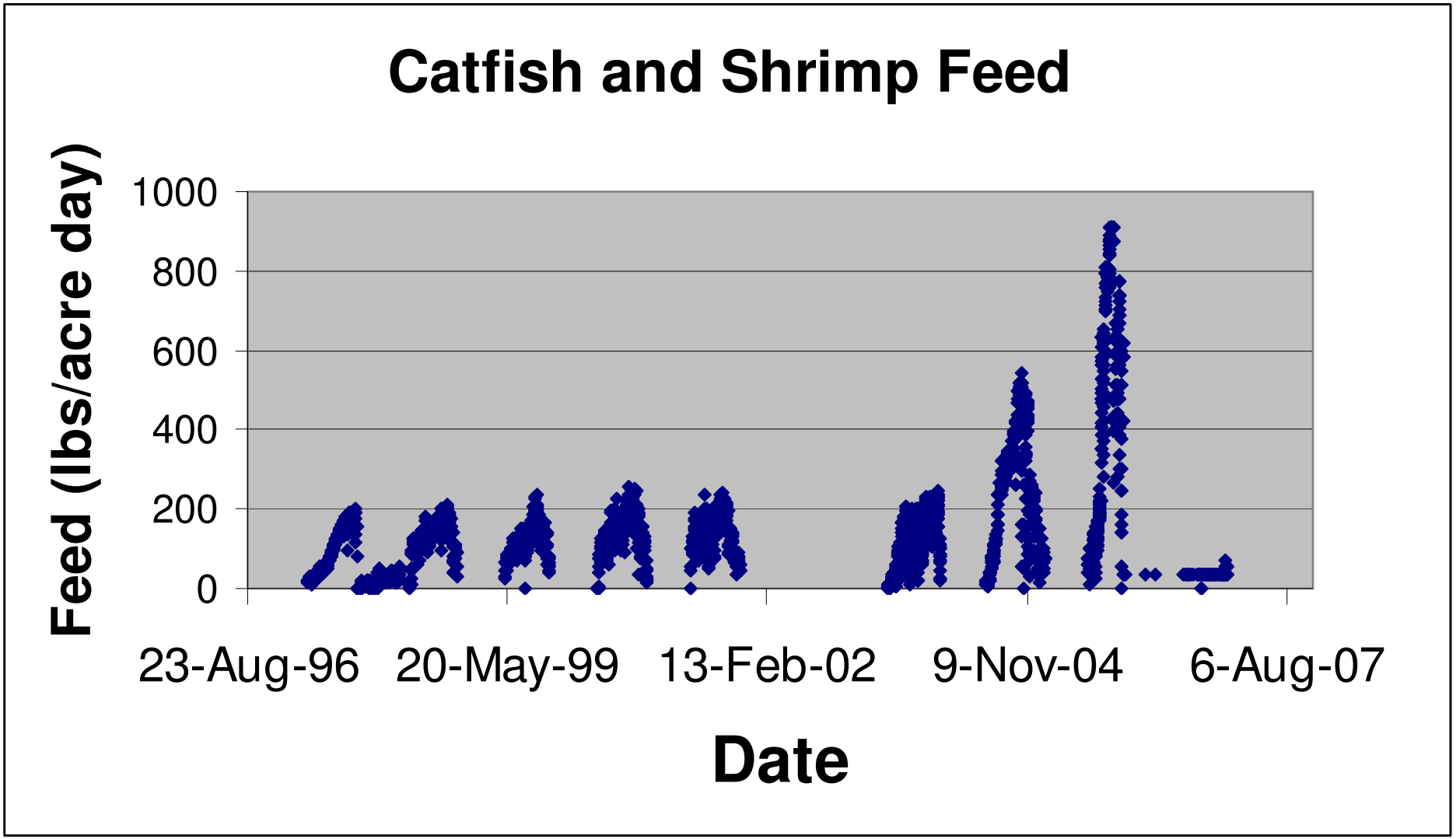
250 to 900 lb/acre day

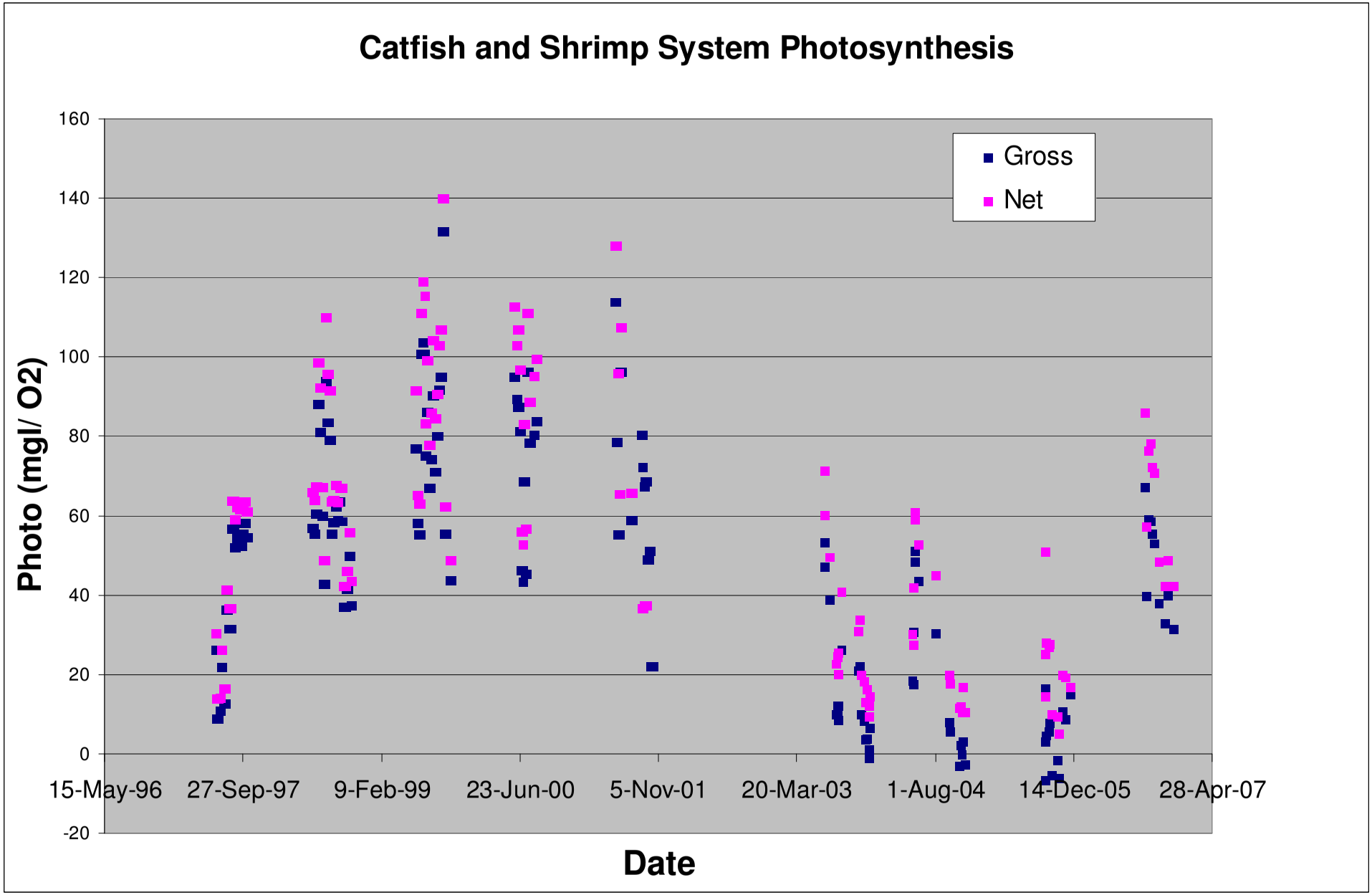

Shrimp System Ammonia, 03, 04, 05, 06
NH4-N mg/l
3.5
3
2.5
2
1.5
1
0.5
0
20-Mar-03
1-Aug-04
14-Dec-05
28-Apr-07
Date

1 to 2 mg/l TAN

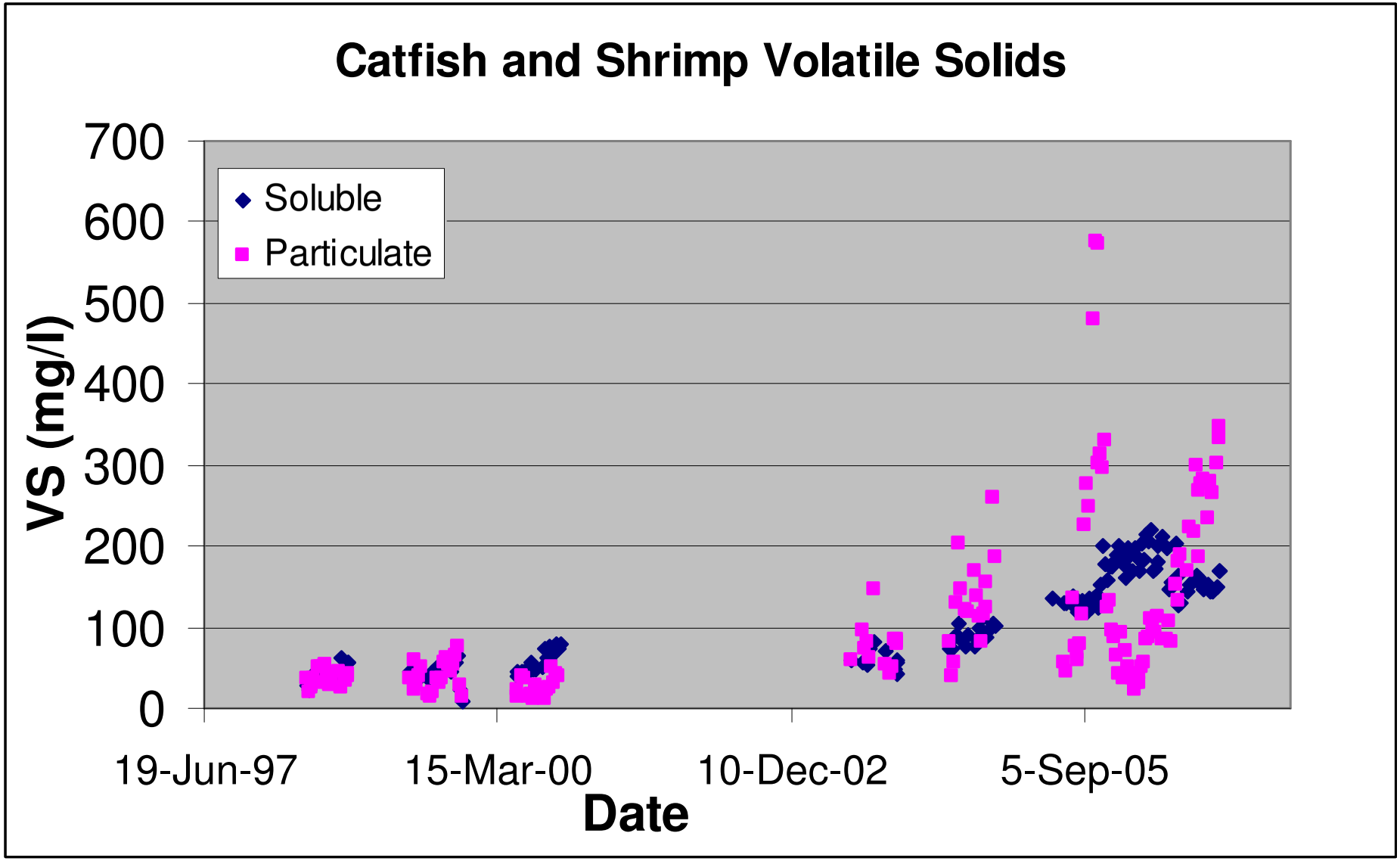

Shrimp Photosynthesis 2003, 2004, 2005, 2006
100
80
60
40
20
0
-20
mg/l O2
Net
Gross
3/20/2003
1/14/2004
11/9/2004
9/5/2005
7/2/2006
4/28/2007
Date


Shrimp System VS, 2003, 2004, 2005, 2006
700
600
500
400
300
200
100
0
VS mg/l
Particulate
Soluble
9/1/02
1/14/04
5/28/05
10/10/06
2/22/08
Date

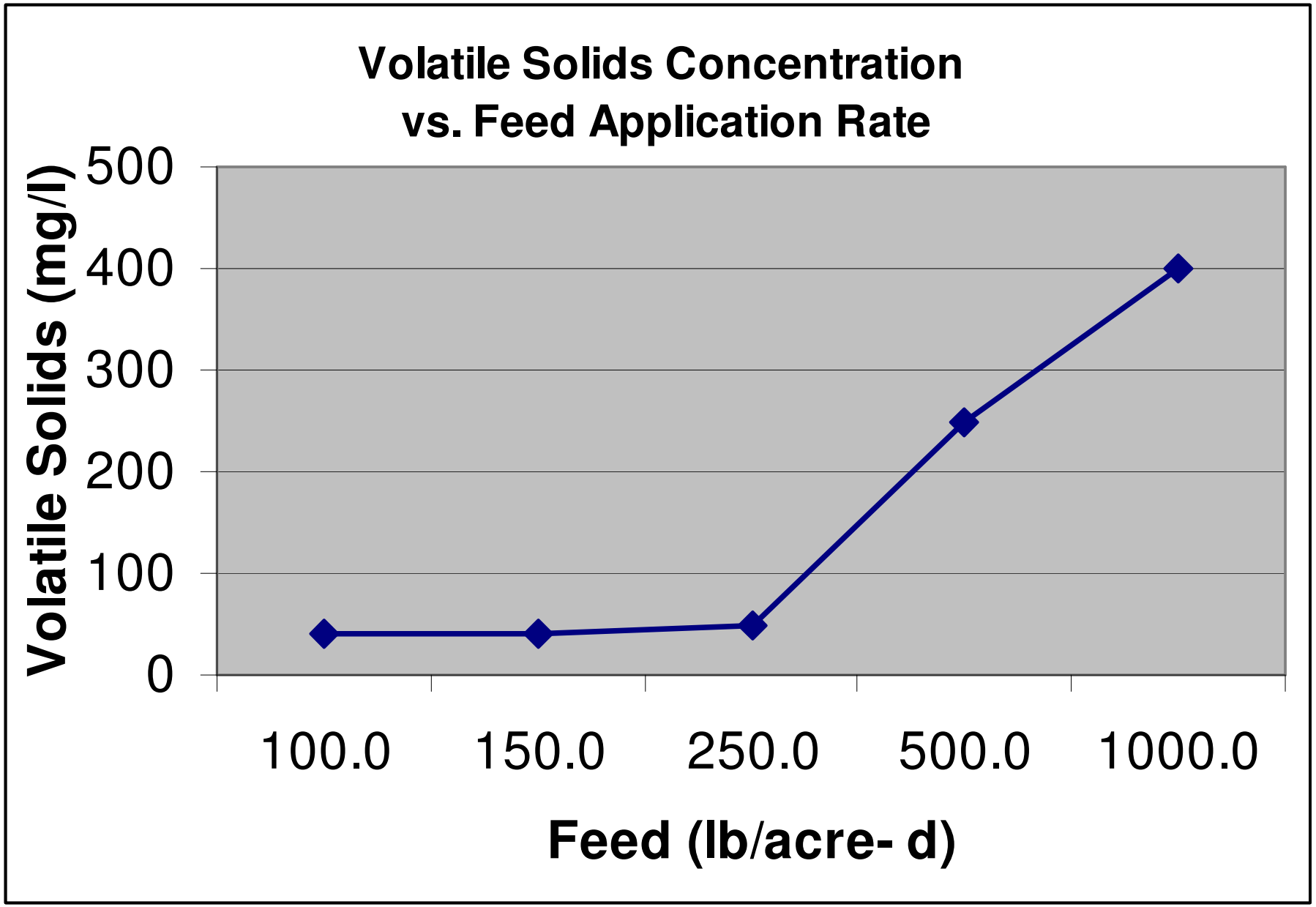

Catfish and Shrimp Feed
Feed (lbs/acre day)
1000
800
600
400
200
0
23-Aug-96
20-May-99
13-Feb-02
9-Nov-04
6-Aug-07
Date



80 to 20 mg O2/l; 60 mg/l unloaded

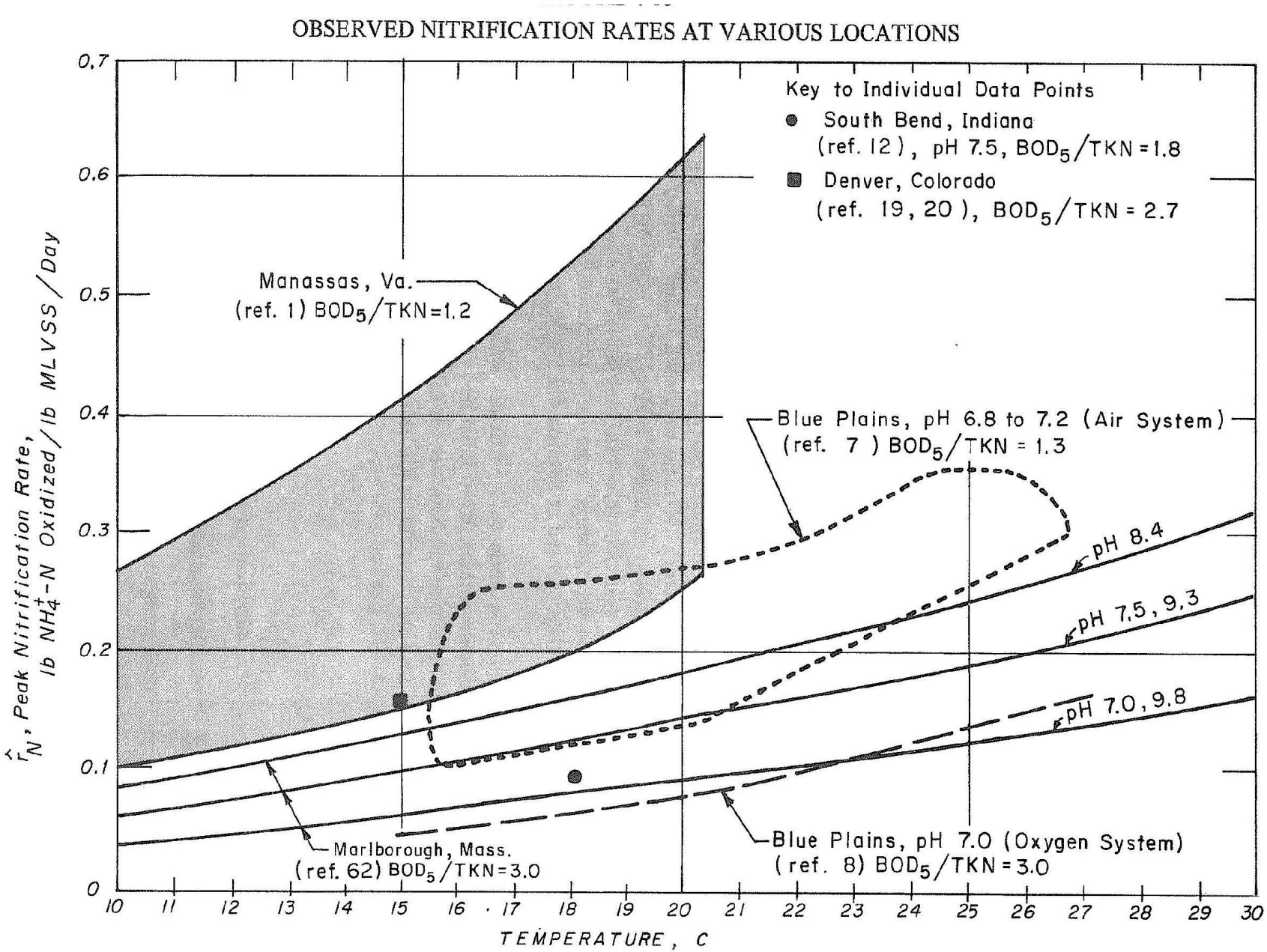


60 To 300 mg/l VS


Volatile Solids Concentration
vs. Feed Application Rate
Volatile Solids (mg/l)
500
400
300
200
100
0
100.0
150.0
250.0
500.0
1000.0
Feed (lb/acre- d)

Water Column Nitrification Rates

- Nitrification @ 0.02 to 0.03 mg-N/mgVS per day in shrimp reactor
- Wastewater rates of 0.05 mg-N/mgVS–d
- 300 to 400 mg/l VS
- Shrimp water column N-loading of 7 to 14 mg-N/l-day

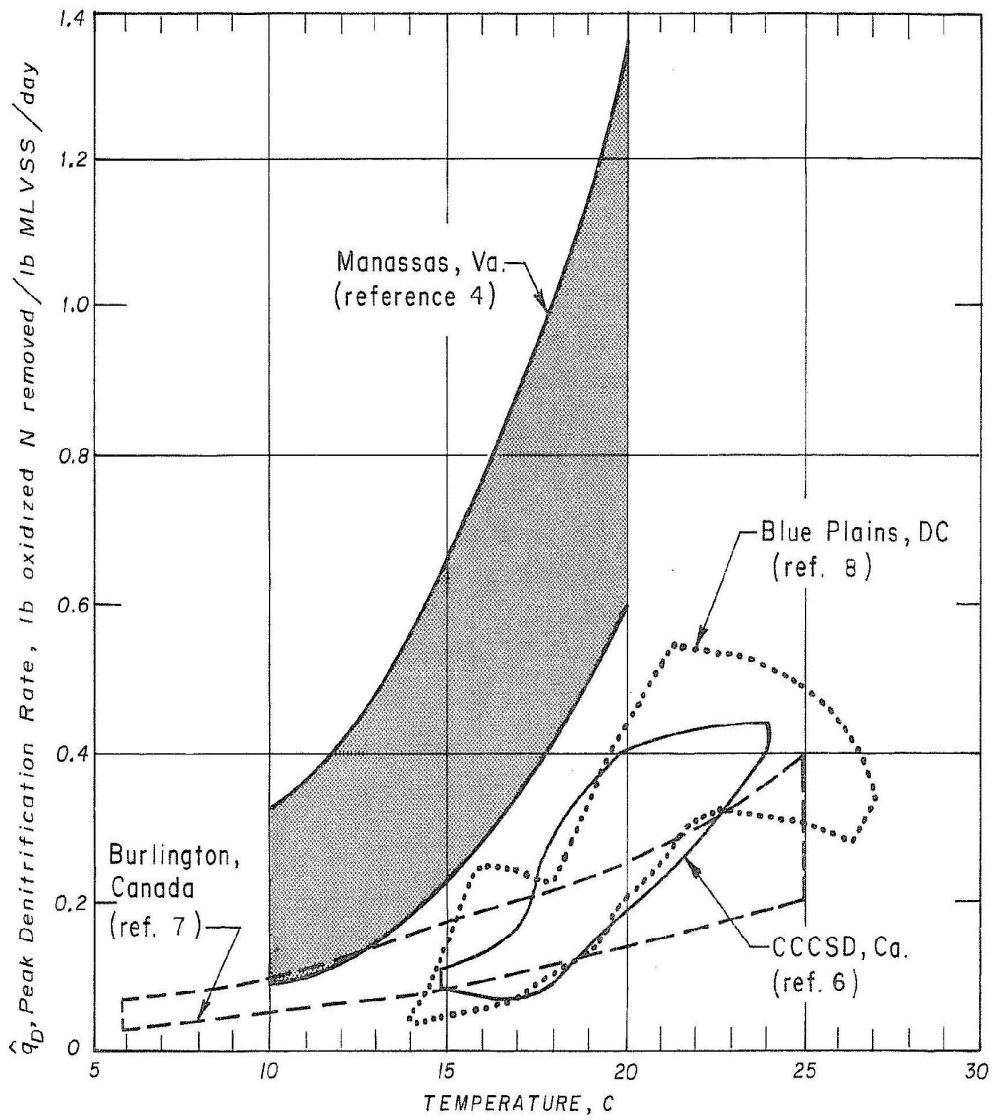


Wastewater rate; 0.05 mg/mg VS-d

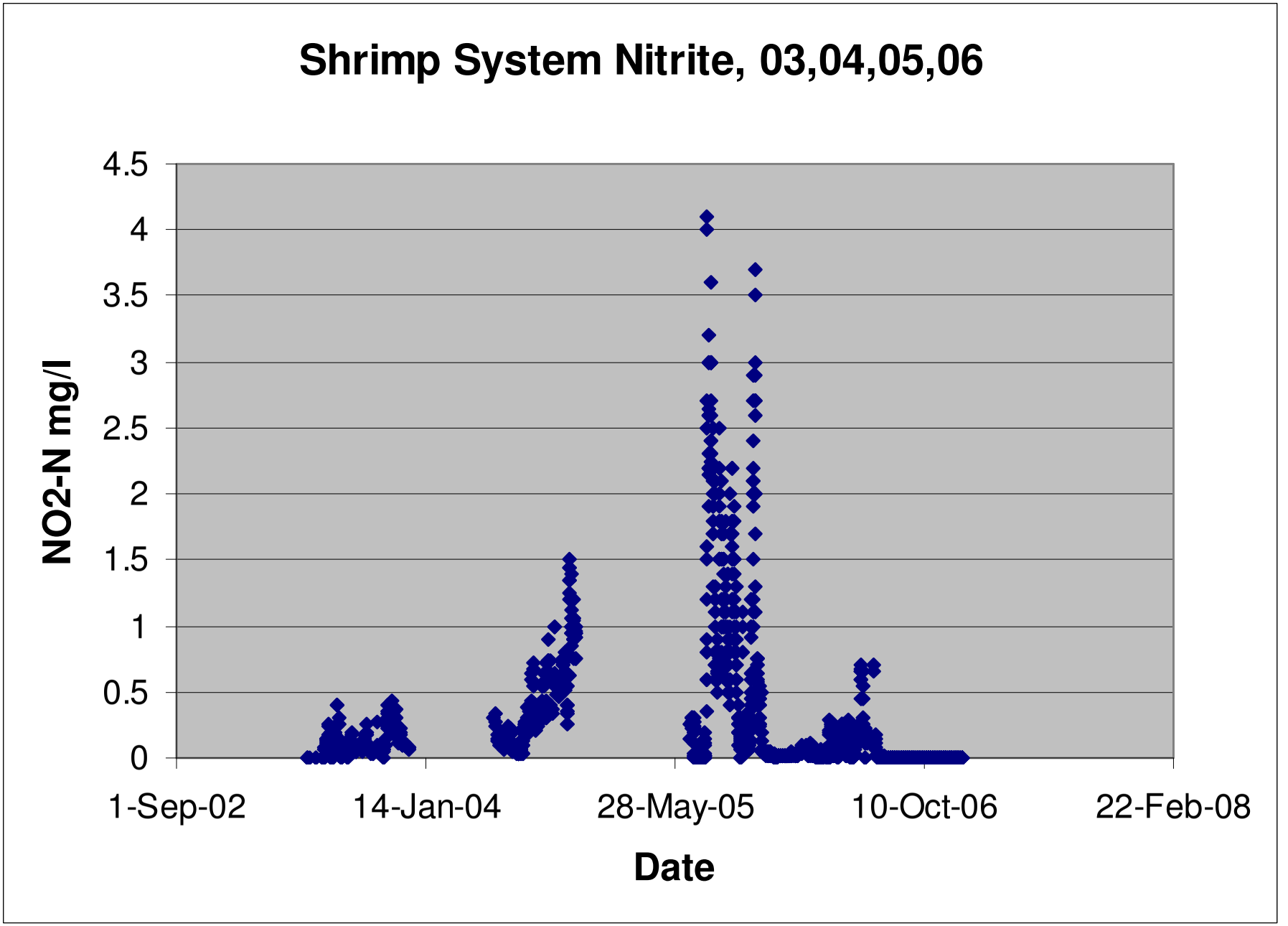
Anoxic Reactor Denitrification Performance

- 50,000 liter volume, 600,000 liter/d flow, = 2 hour detention time
- Denitrification @ 30 – 40 mg-N /liter of anoxic reactor per day
- 0.1 mg/mg VS-day @ 300 to 400 mg/l VS
- Wastewater rate 0.1 to 0.4 mg/mg VS-d

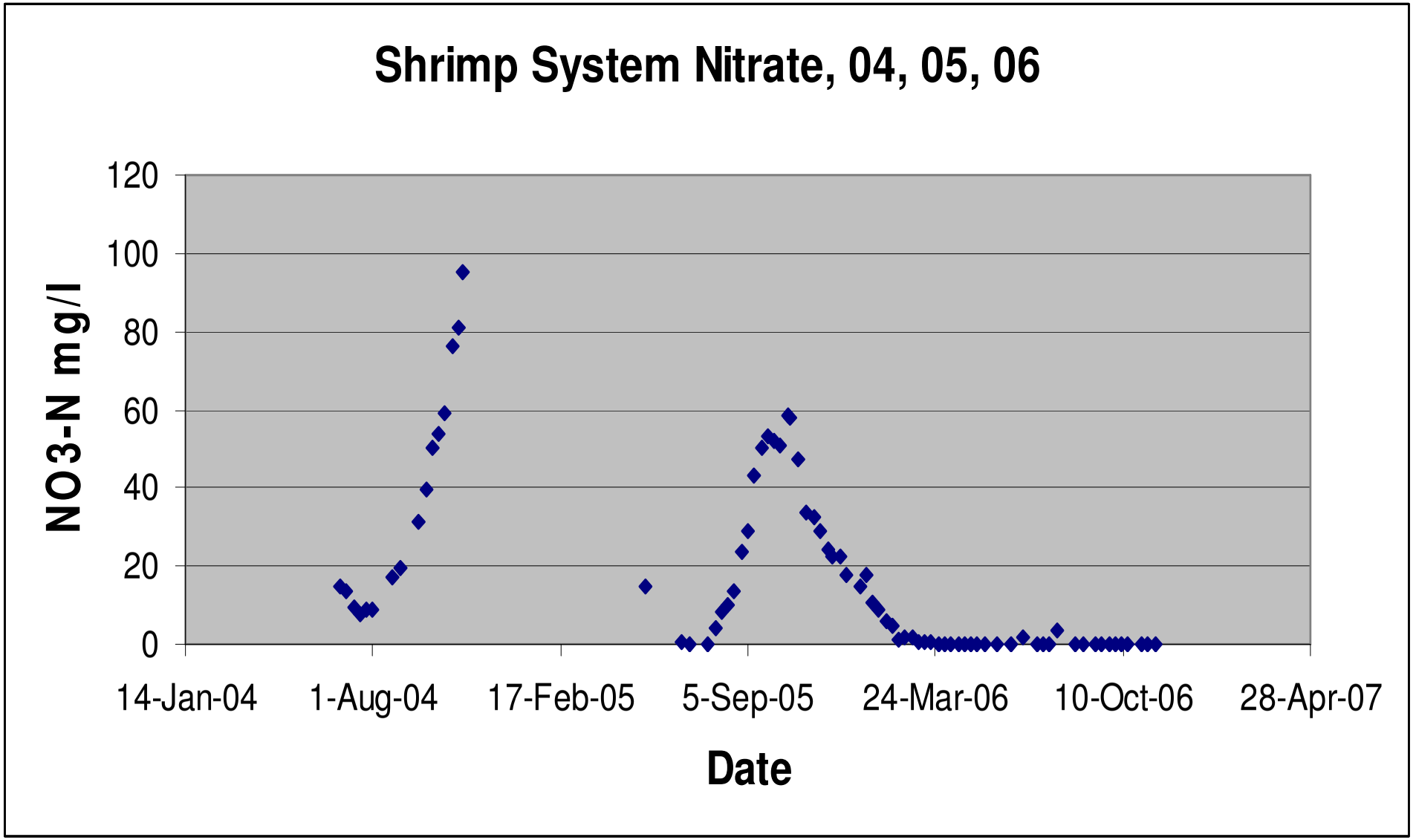
OBSERVED DENITRIFICATION RATES FOR SUSPENDED GROWTH SYSTEMS USING METHANOL



Wastewater rate; 0.1 to 0.4 mg/mg VS-d

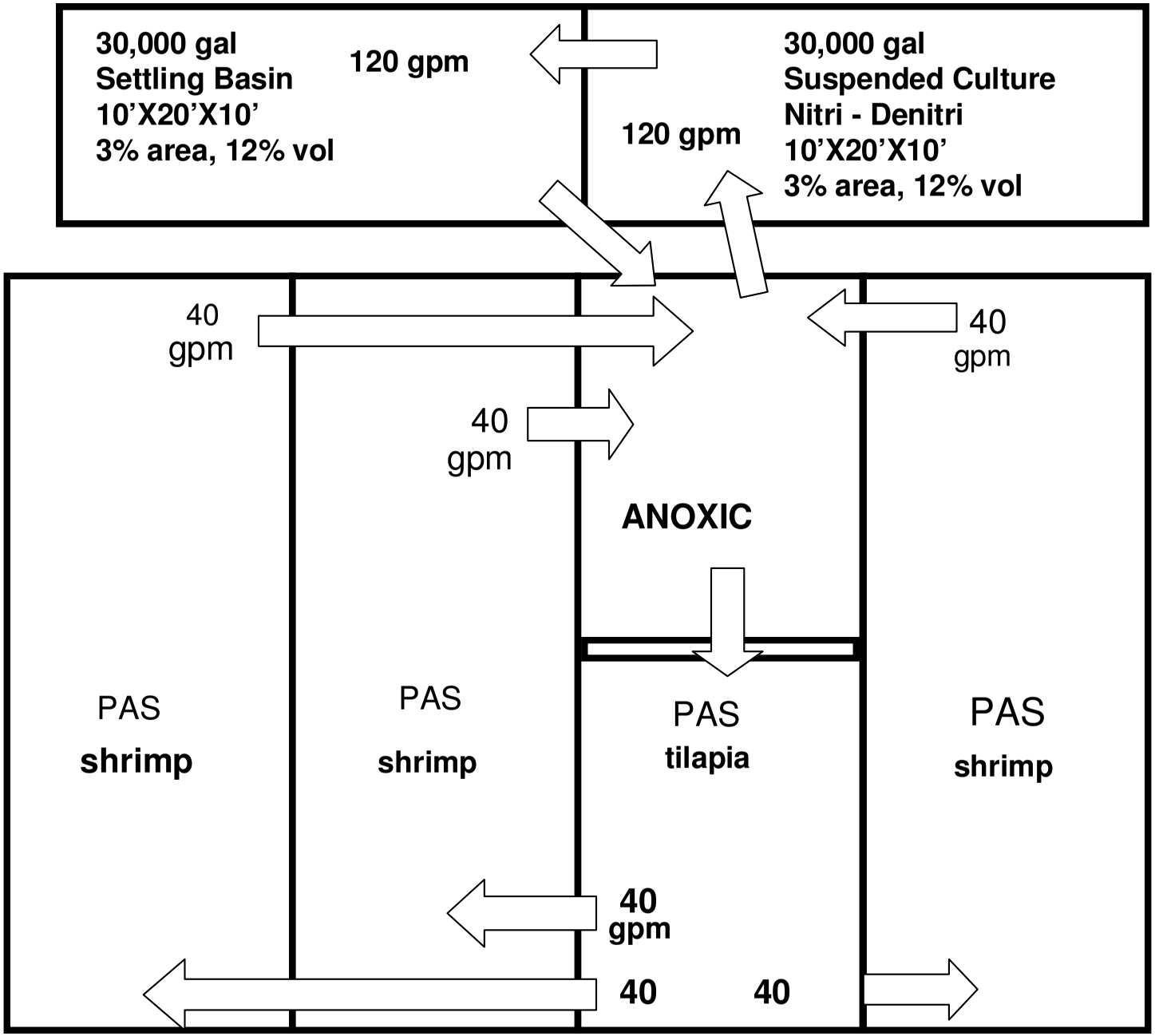


Nitrite up @ higher feeding; higher salt protects



Nitrate accumulation @ high rate feed application

Proposed Algal/Bacterial System

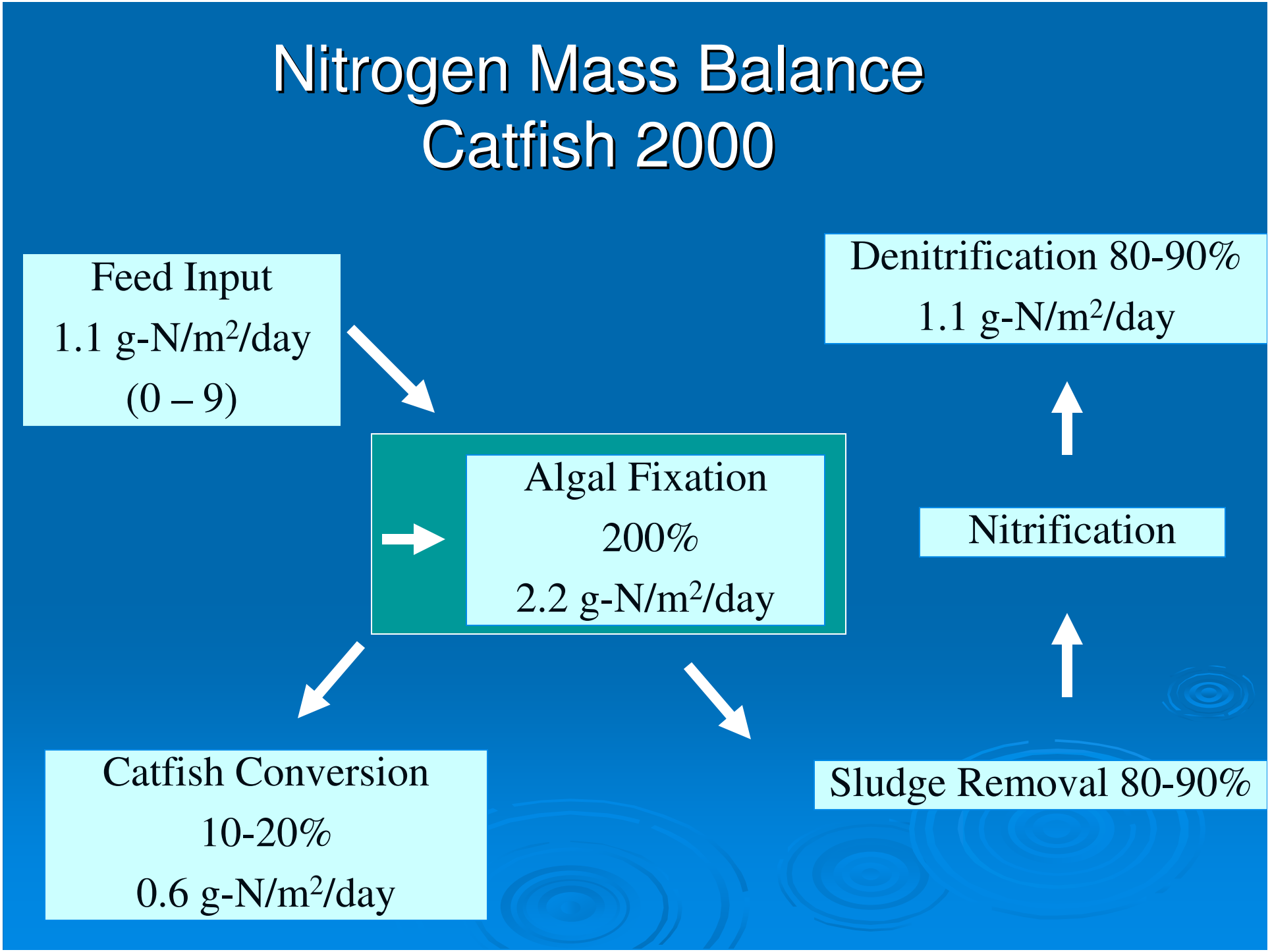


Water Exchange Rates

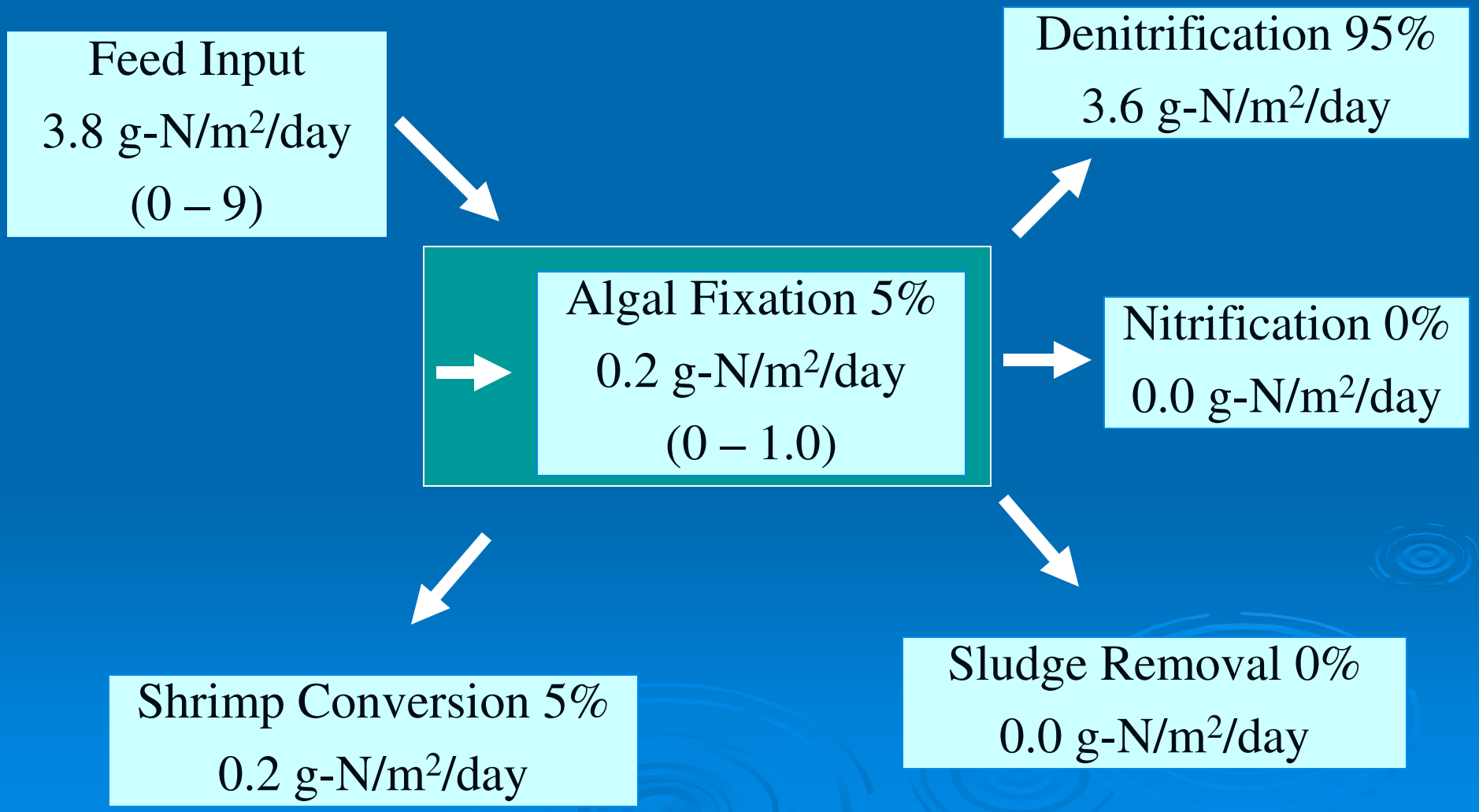
(assuming algae fixation of 10 gm C/m^2 day)

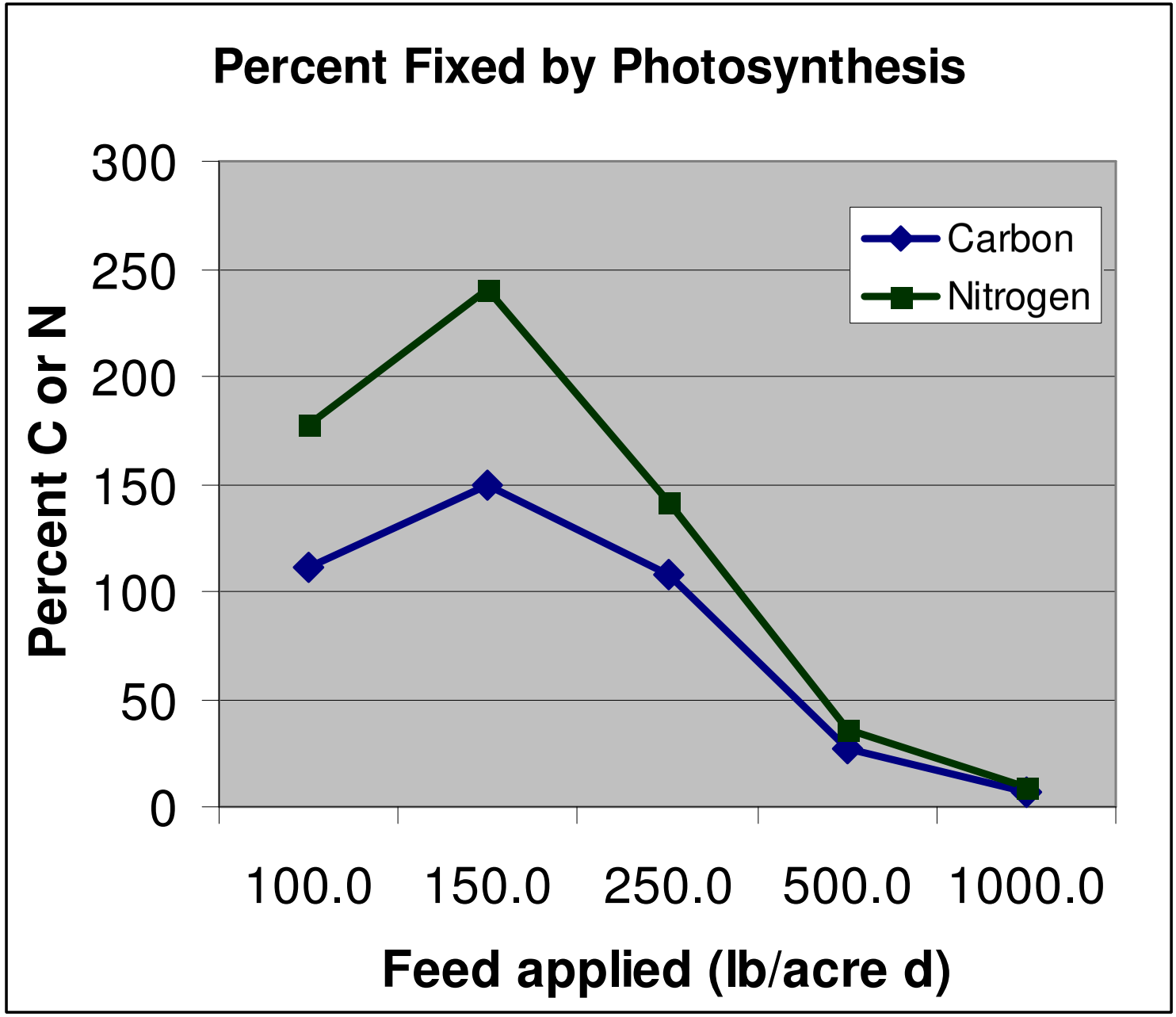
Feed (lb/a-d)	Exchange (per day)	Pumping gpm/acre	Yield (lb/acre)	Nitrogen load (mg N /l d)
250	1.3	640	12,500	2.5
500	1.3	640	25,000	5.0
1000	3.0	1440	50,000	10.0
1500	5.0	2400	75,000	15.0

Nitrogen Mass Balance
Catfish 2000

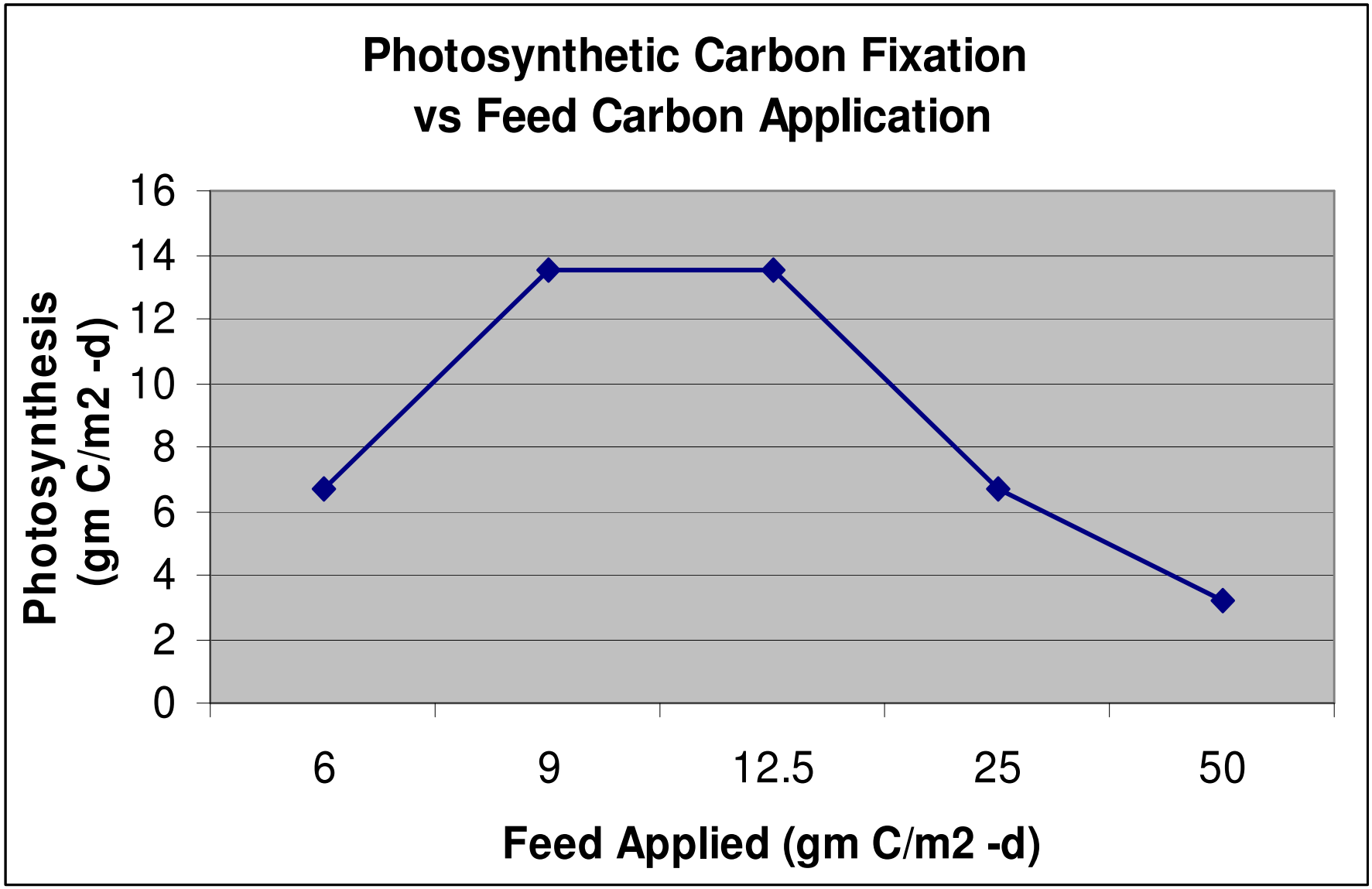


Nitrogen Mass Balance
Shrimp 2005



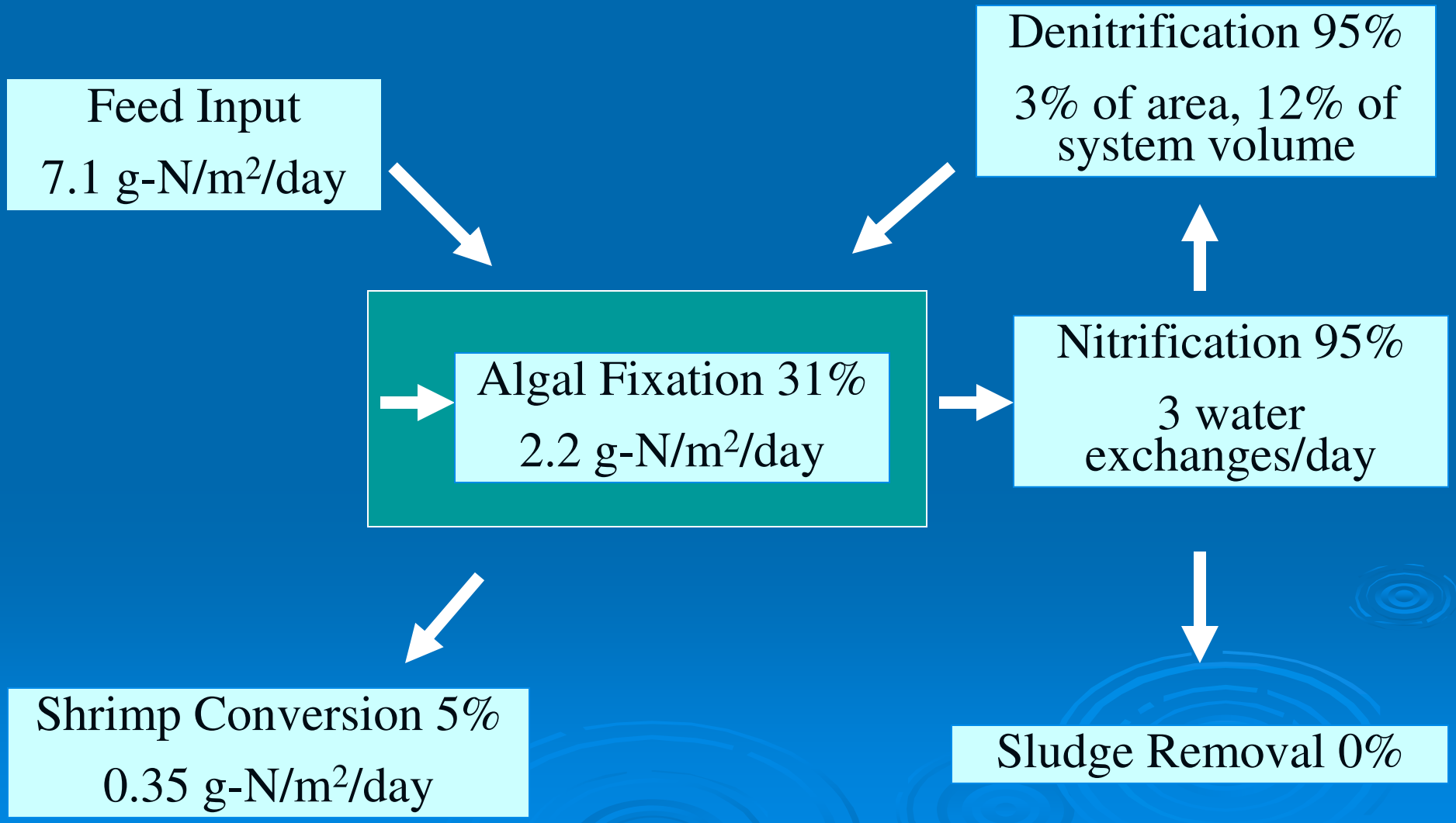


200% Nitrogen Recycle in Catfish



Decline in fixation @ 14 gm C/m^2 day limit

Nitrogen Mass Balance
Shrimp System Proposed



Imposed Constraints

- VS control with sedimentation and tilapia
- Paddlewheel and aeration mixing of 30 to 60 hp/acre
- Feed application ramping; constrained by shrimp survival (NH_4-N of 2- 3 mg/l)
- Anoxic reactor with aerobic flow-path

System Response

- Feed application to 900 lb/acre-d @ nitrifying biomass of 300 mg/l
- Reduced photosynthesis; light shading
- Nitrification of 0.02 mg-N / mg VS-d
- Denitrification of 0.10 mg-N / mg VS- d

ECOLOGICAL SYSTEMS DESIGN:
Self-assembly with operator intervention

Nitrogen loading and photosynthesis at increasing feed application rate

Feed Rate lb/acre-day	Production[1] lb/acre	Nitrogen Loading[2] gm-N/m^2-d	mg-N/l-d	Photosynthesis[3] gm-C/m^2 d	mg O2/l-d
100	3,750 / 5,000	0.5	0.9	3	14
200	7,500 / 10,000	0.9	1.9	5	28
500	18,750 / 25,000	2.4	4.7	13	70
1,000	37,500 / 50,000	4.7	9.4	27[4]	141
1,500	56,250 / 100,000	7.1	14.1	40[4]	211

1) Growing season = 120 or 200 days, CF = 2/1, ave feed = 50% of peak
2) 35% protein, 75% N-release, water column = 0.5 meter
3) Algal C/N = 5.6/1, C/O2 = 1/1 molar
4) Not observed in the field

Predicted photoautotrophic and chemoautotrophic biomass and controlling mechanism

Algal biomass mg/l VS [1,2]	Nitrifying biomass mg/l VS [3]	Control mechanism	Control target
11 – 32	38[4]	paddles / tilapia	production / standing crop
21 – 63	75[4]	paddles / tilapia	production / standing crop
53 – 158	188[4]	paddles / tilapia	production / standing crop
106 – 317[4]	376	paddles / mixing	ramped loading / suspension
158 – 474[4]	564	paddles / mixing	ramped loading / suspension

1) Algal specific uptake = 0.089 mg N/mg VS–day, 100% uptake of N-loading
2) Cell age 1 to 3 days
3) Nitrifying uptake = 0.025 mg N/mg VS-day, 100% oxidation of N-loading
4) Not observed in the field

Acknowledgements

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- SPECIAL THANKS TO; JIM MCVEY