AQUACULTURE INTENSIFICATION:
1) PARTITIONED PONDS, SPLIT-PONDS AND INTENSIVE PONDS
2) IN-POND RACEWAYS & RECIRCULATING SYSTEMS

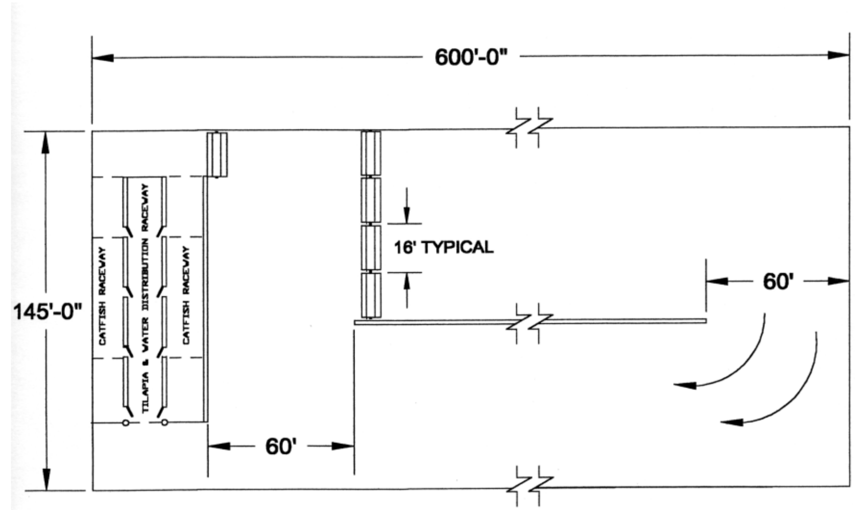
United States Department Of Agriculture
Agricultural Research Service

D. E. Brune[1], Travis W. Brown[2] and Craig S. Tucker[2]

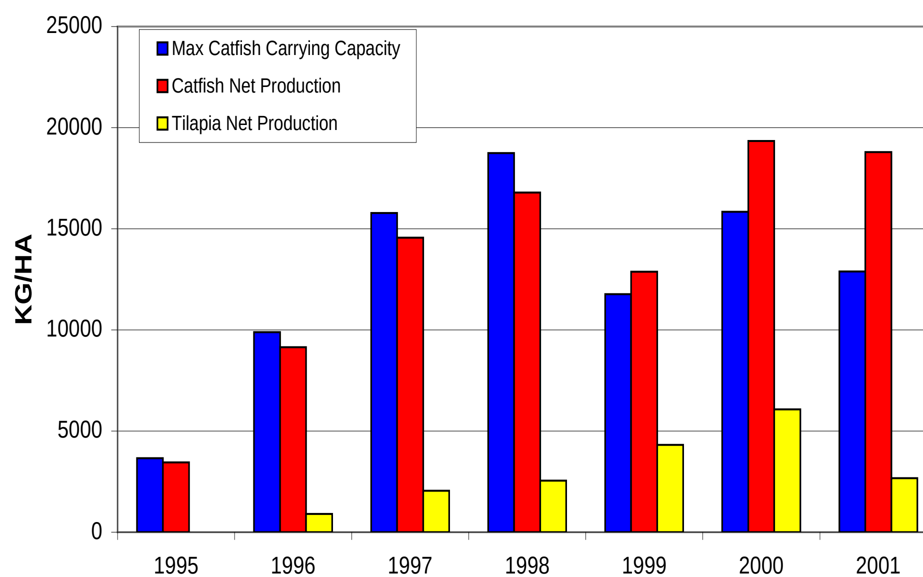
1) University of Missouri, Columbia, MO. 65211

2) National Warmwater Aquaculture Center, Stoneville, MS. 38776

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

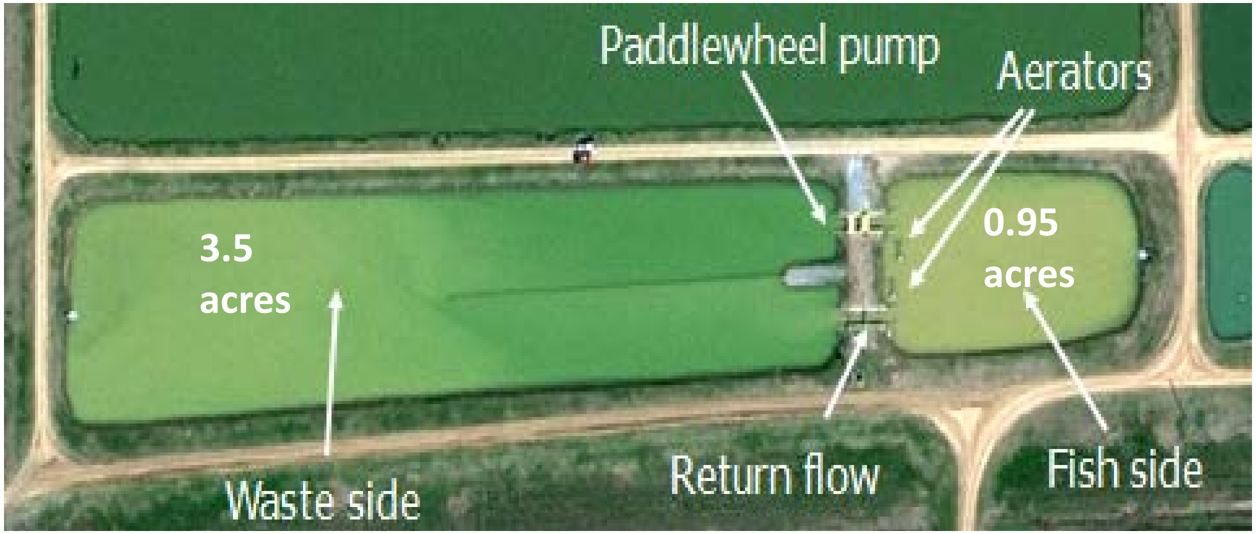


Tilapia co-culture for management of algal production in a "High-Rate Pond" modified for fish production, increasing carry capacity to 19,000 lb/acre



OBJECTIVES; 2014 &2015

Comparisons of Split-Ponds (SP) and Intensive Ponds (IP) at MS-State Delta Branch Experiment Station vs. Conventional Ponds (CP) and Partitioned Aquaculture Systems (PAS) for production of hybrid catfish (*Ictalurus punctatus* x *I. furcatus)*

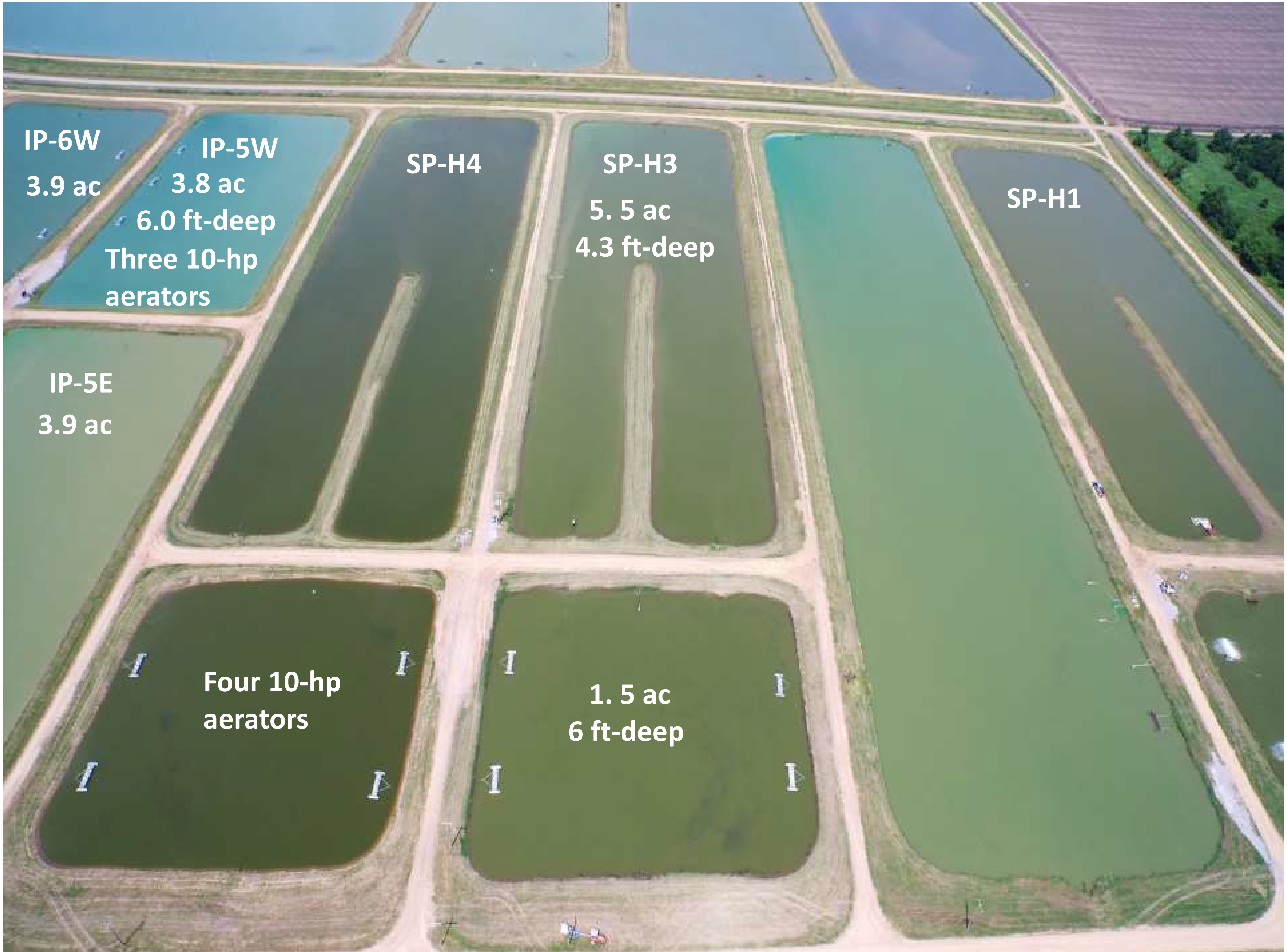


MS Split-Pond ; 2014

1995-2008 Clemson PAS (0.05-2.0 ac)

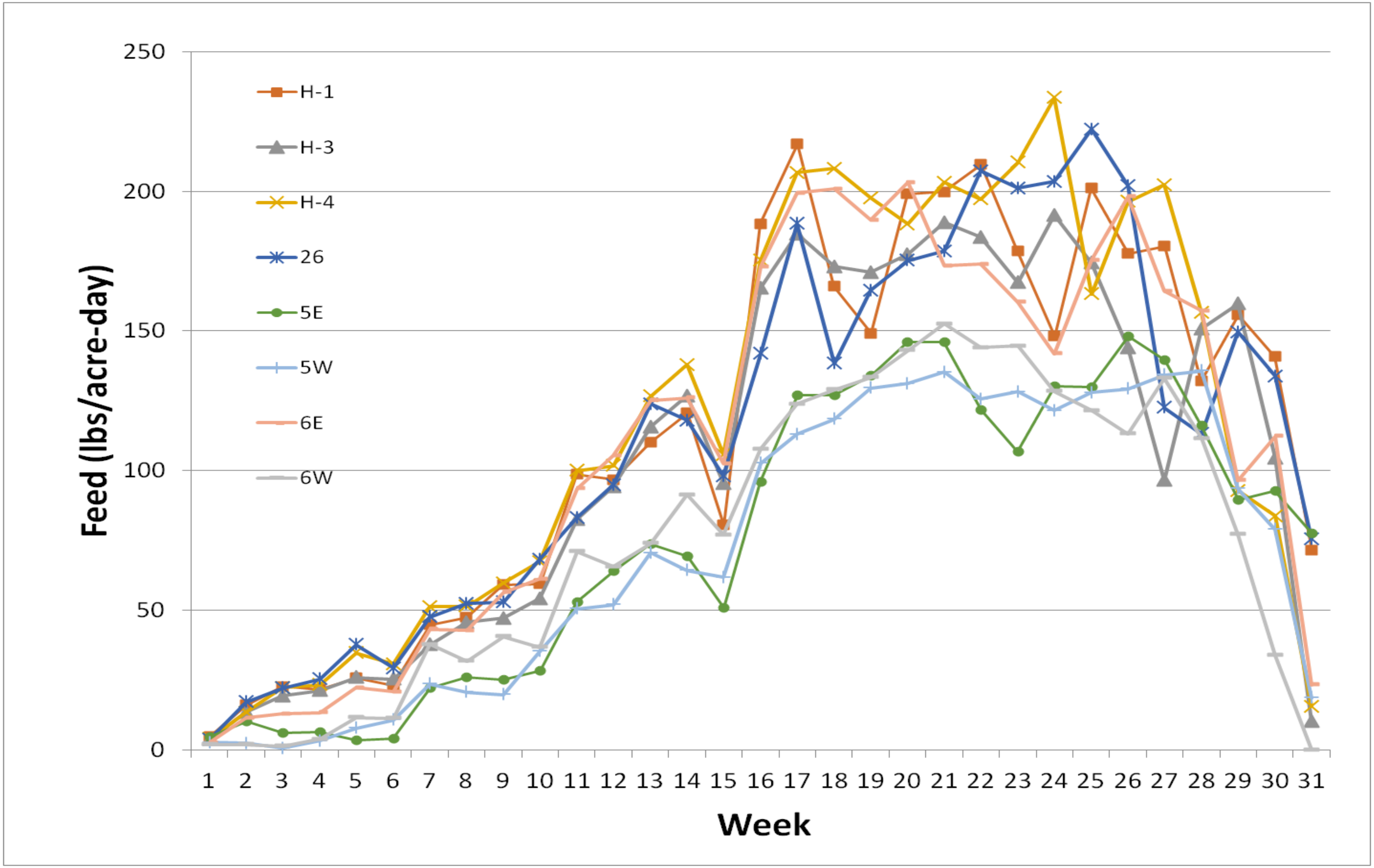
2014 MS Intensive Pond (2.0 ac)

MS Split Ponds and Intensive Ponds; 2015



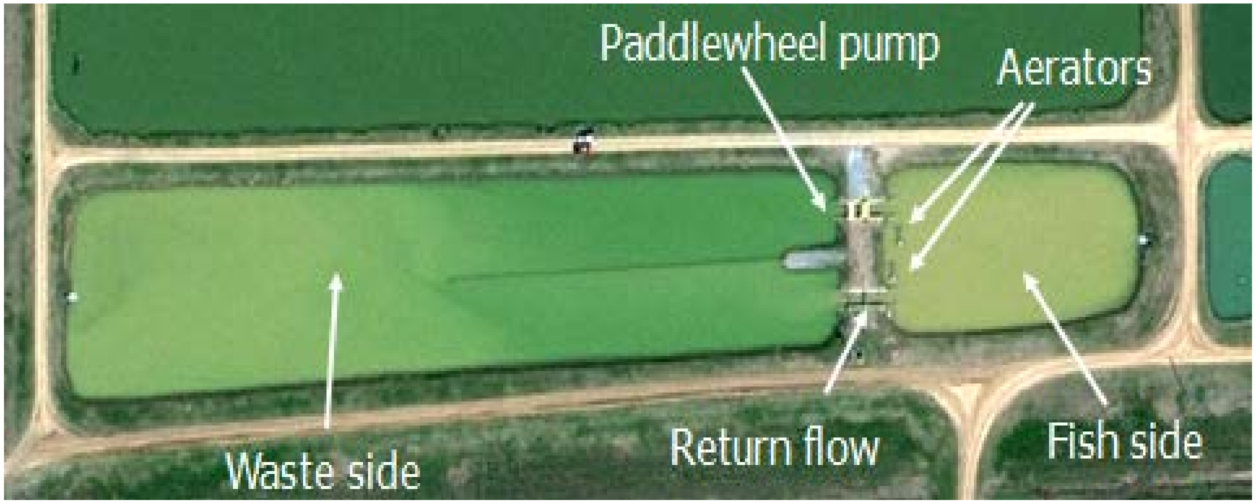
Carrying Capacity and Feeding

Type	Max catfish carrying capacity (lbs/acre)	Feed loading ave/max (lbs/acre-day)	FCR lbs-feed/lbs-fish
		1995-2008	
PAS	15,000-18,000	160/250	1.4-1.6
CP	5,000-7,500	100/150	~2.0
		2014	
SP	14,032	120/280	1.66
IP	18,245	107/270	1.75
		2015	
SP	12,800-14,100	110/216	1.9-2.0
IP	9,200-13,800	84/161	1.8-1.9



SP vs. IP 2015 Feed Rates; Bird losses decreased SP to 70% stocking

Split-Pond Treatment Zones (day-time)



Water Treatment 4.3 ft, (72% of total volume)
Photosynthesis; Top 30%
Aerobic Treatment; Top 65%

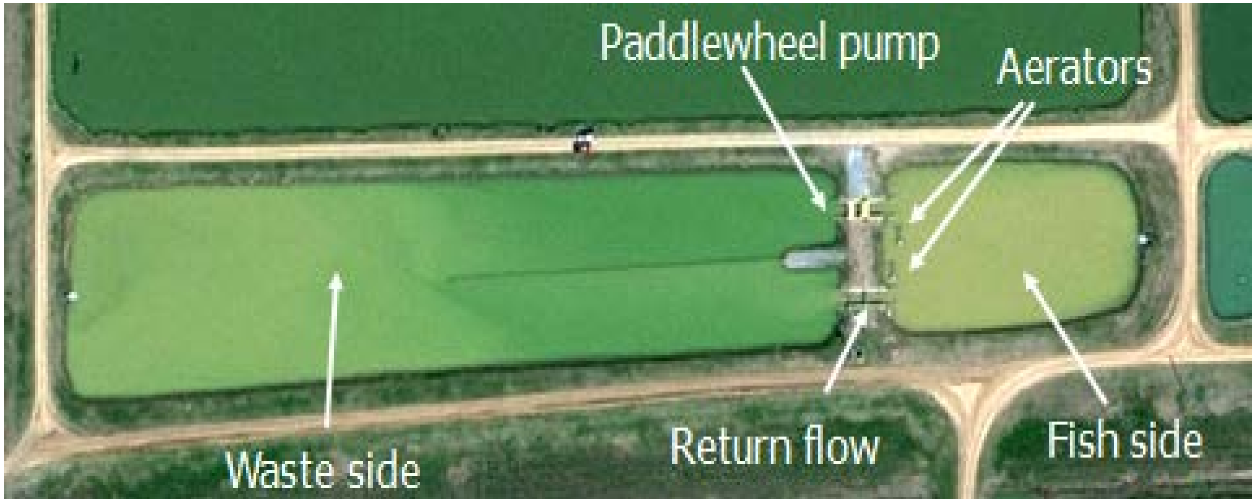
Anoxic Treatment; Variable15%

Anaerobic Treatment; bottom 35%

Fish Culture 6.0 ft,
(28% of total volume)

12,000 gpm
5 fish-zone exchanges/day
Aeration = off

Split-Pond Treatment Zones (night-time)



Water Treatment 4.3 ft, 72% of total volume Anaerobic ~ 100%	Fish Culture 6.0 ft, 28% of total volume Exchange = off Aeration capacity =30 hp/acre

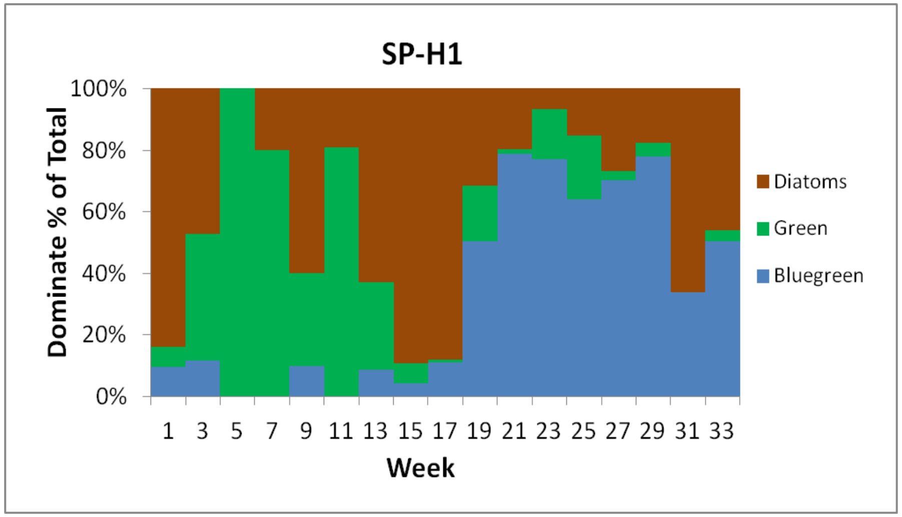
Algal Removal Mechanism, Density and Dominant Algal Species

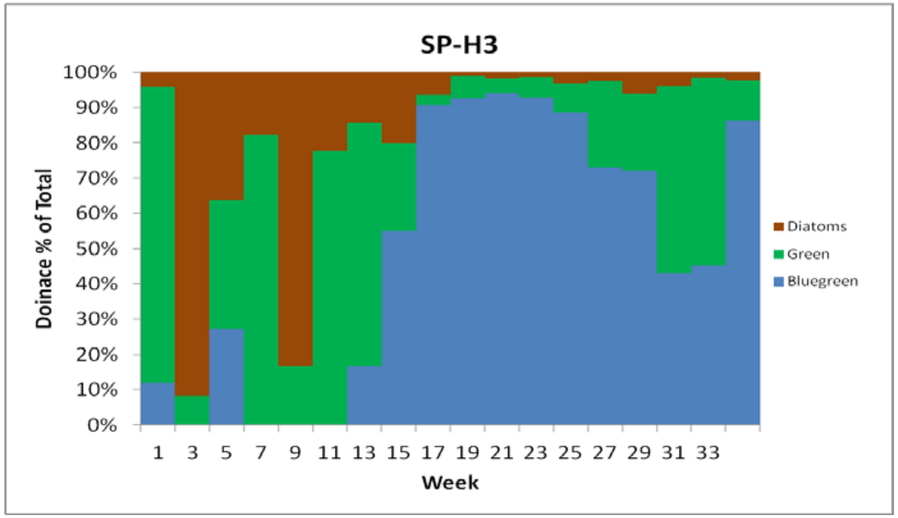
Type	Algal Density Secchi Disk/TSS (cm / mg/l)	Algal removal mechanism (apparent)	Algal genera	Algal cell age (days)
PAS	18 / 80	tilapia/sedimentation	green	3.3
SP	13 /110	zooplankton/sedimentation	bluegreen[1]	4.6
IP	12 / 115	zooplankton/sedimentation	bluegreen[1]	3.8
CP	13 / 110	zooplankton/sedimentation	bluegreen[2]	9.0

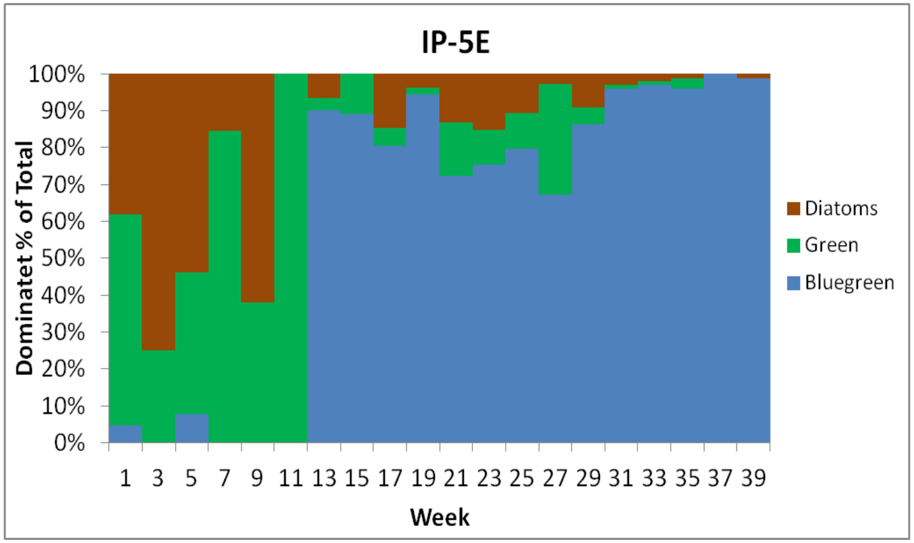
[1] Oscillatoria

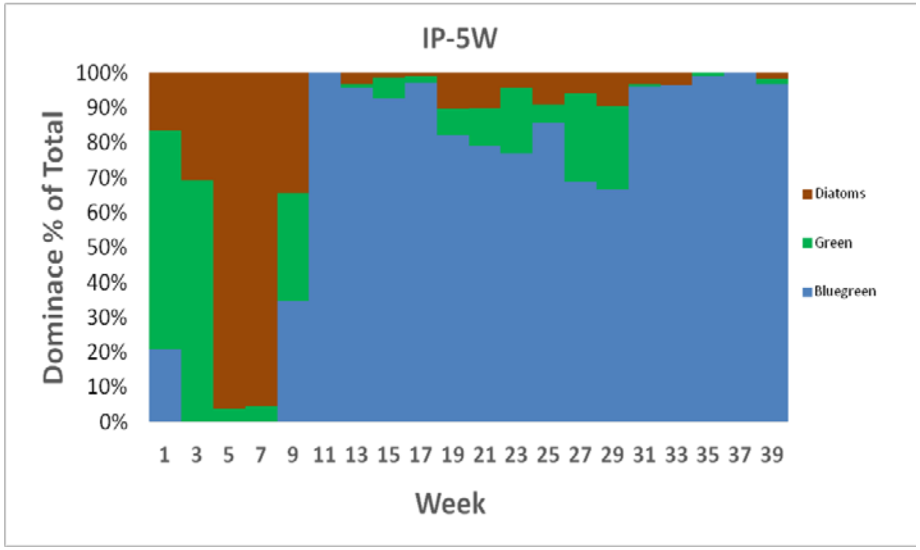
[2] Oscillatoria, Microcystsis Anabaena

Dominate Photosynthetic Organisms
Split Pond vs. Intensive pond; 2015



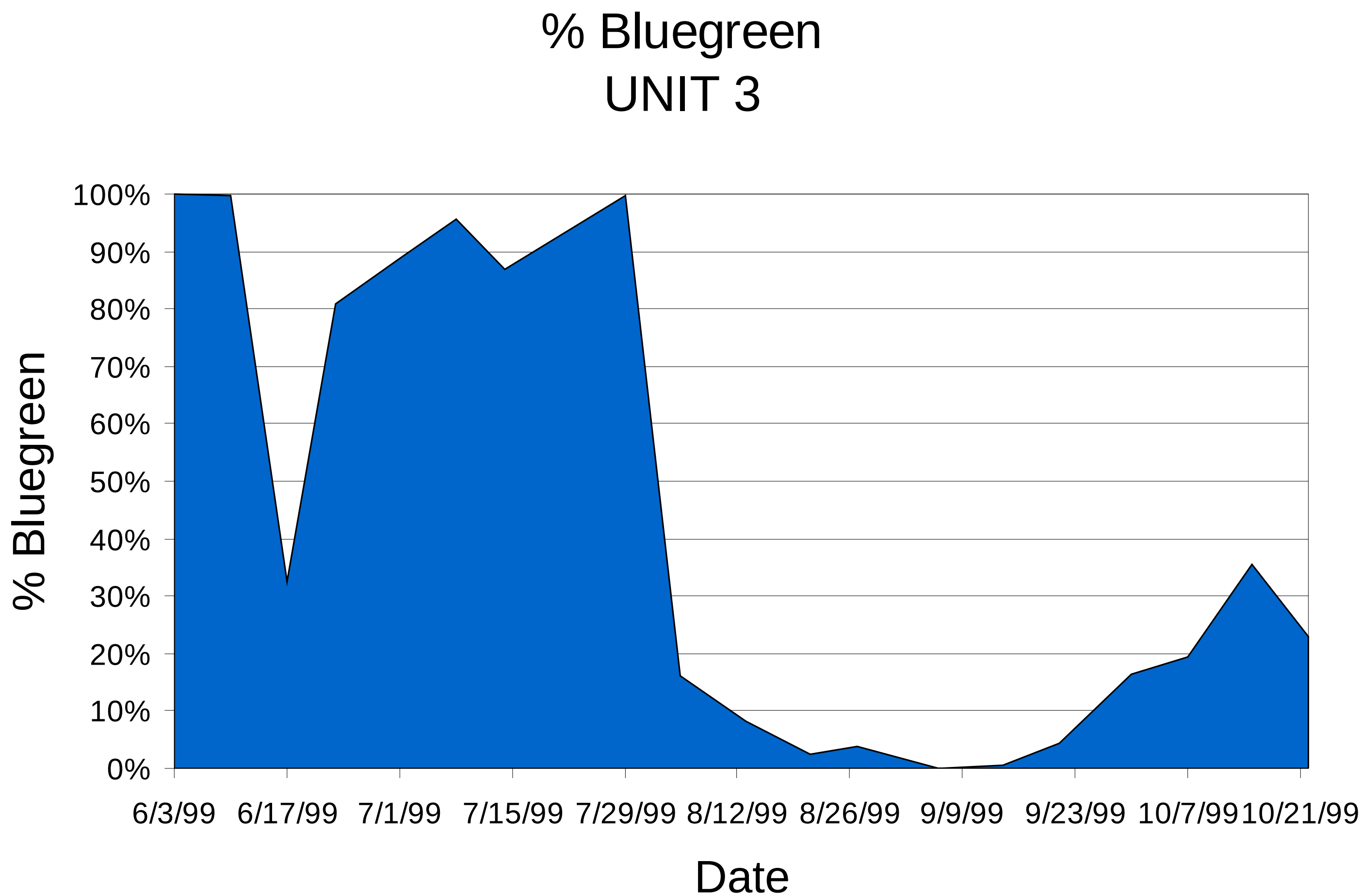






Bluegreen dominance more sustained in Intensive-Pond vs. Split-Pond

PAS Bluegreen Biomass; 1999 (percent of total)



Tilapia filter-feeding (@25% of catfish biomass) reduces bluegreen dominance late season

Zooplankton and Algal Settling (2014)

- High algal settling rates in SP and IP
- Bluegreen algae enmeshed in detritus
- Large zooplankton populations

Summary

Partitioned Aquaculture System

- Continuous paddlewheel mixing, 100% aerobic, 3.0 hp/acre aeration
- 18,000 lb/acre in 5% of system (raceway culture),
- Rapidly growing green algae controlled by tilapia, few zooplankton
- 80 mg/l algal density, 25% algal respiration,
- No nitrification.

Split-Pond

- Daytime mixing with paddle wheels, 80% anaerobic at night, 5.7 hp/acre aeration
- 12,800 - 14,100 lb/acre in 28% of system
- Rapidly growing bluegreen algae, rapid sedimentation, high zooplankton numbers
- 115 mg/l algae density, 50% algal respiration
- Nitrification = 20% of treatment
- More consistent algal bloom, lower bluegreen dominance vs. Intensive-Pond
- Lower capital cost compared to PAS

Summary continued

Intensive Pond

- Night-time mixing and aeration at 7.9 hp/acre, anaerobic % unknown
- 9,200-18,200 lb/acre in 100% of system volume
- Rapidly growing bluegreen algae, rapid sedimentation, high zooplankton numbers
- 110 mg/l algae density, 50% algal respiration,
- No nitrification
- Bird predation harder to control
- Lower capital cost compared to SP

Conventional Pond

- Night-time mixing and aeration at 2.6 hp/acre, anaerobic % unknown
- 7,500 lb/acre in 100% of system volume
- Slowly growing bluegreen algae, sedimentation & zooplankton variable
- 110 mg/l algae density, 50% algal respiration,
- Nitrification unknown
- Lower capital cost compared to IP

Questions

- Raceway culture with higher degree of control over algal population justify higher PAS cost ?
- Reduced cost of SP and IP given lower degree of control with bluegreen dominance justified? Is system behavior reproducible ?
- Reduced cost, lower production, and lower level of control of CP justified? Will variable algal dominance lead to off-flavor issues ?
- PAS control vs. CP low-cost: Systems-wide cost/lb vs. risk comparison ?

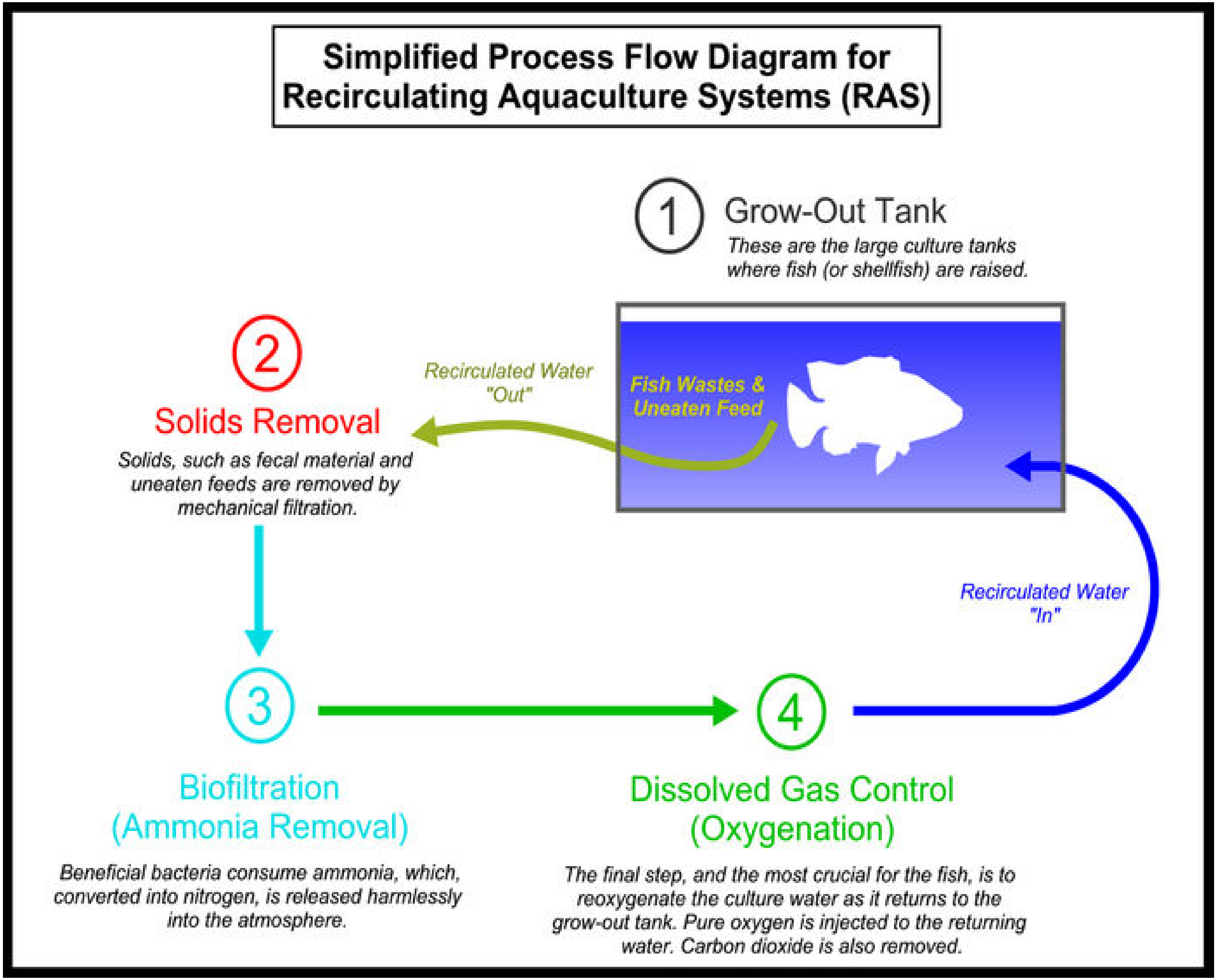
Recirculating Aquaculture Systems

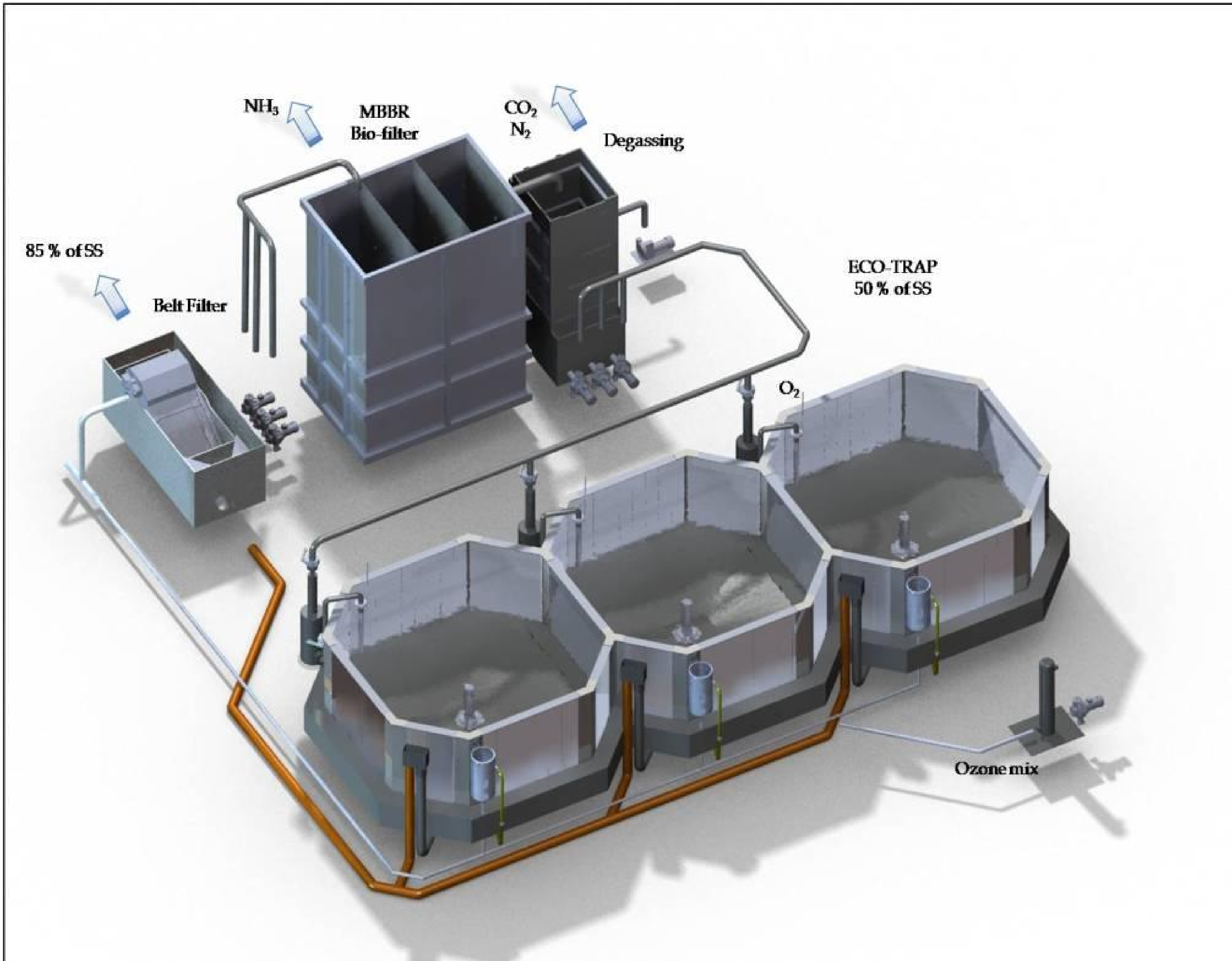
D. E. Brune[1], R. Pierce[2] C. Hicks[3]

[1)]Professor of Bioprocess and Bioenergy Engineering, University of Missouri,

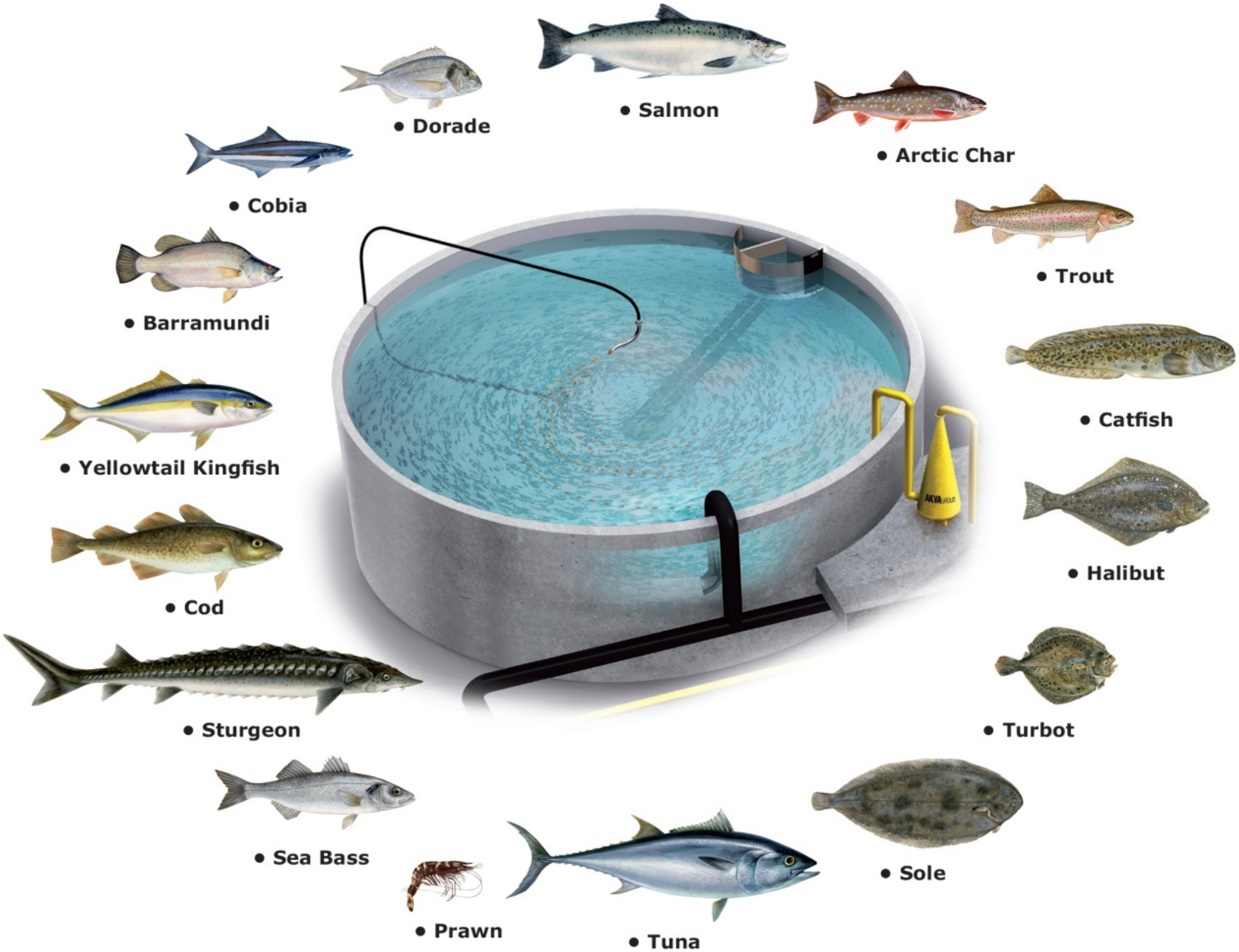
[2)] Fisheries and Wildlife, University of Missouri

[3)] Pinnacle Aquatics LLC, Jamestown, Missouri


Simplified Process Flow Diagram for
Recirculating Aquaculture Systems (RAS)
1
Grow-Out Tank
These are the large culture tanks where fish (or shellfish) are raised.
2
Solids Removal
Solids, such as fecal material and uneaten feeds are removed by mechanical filtration.
Recirculated Water "Out"
Fish Wastes & Uneaten Feed
Recirculated Water "In"
3
Biofiltration (Ammonia Removal)
Beneficial bacteria consume ammonia, which, converted into nitrogen, is released harmlessly into the atmosphere.
4
Dissolved Gas Control (Oxygenation)
The final step, and the most crucial for the fish, is to reoxygenate the culture water as it returns to the grow-out tank. Pure oxygen is injected to the returning water. Carbon dioxide is also removed.


NH$_3$
MBBR
Bio-filter
CO$_2$
N$_2$
Degassing
85 % of SS
Belt Filter
ECO-TRAP
50 % of SS
O$_2$
Ozone mix

RAS typically used for cold-water, clean-water species



AKVA Group, Norway

Hybrid Stripped Bass Production
Kent SeaTech, LLC Temecula, CA 92593

Recirculating System for Largemouth Bass (retrofit of swine facility)

Carrying capacity; 12,000 lbs largemouth bass, FCR = 2.0/1

Aeration: Rotary screw compressor with oxygen separators

Tanks; 4,200 gal grow-out, 300 gal fingering

Biofilters; 1,500 gallon tanks with 12x25 mm plastic media

CO_2 stripping; 4 ft tall x 2 ft diameter columns

Solids removal; 30 micron rotating drum

Capital costs ~ $5.00/gallon, Selling price ~ $6.00/lb

Limited-Discharge Recirculating System;

Biofilters, CO_2 - Stripping, Fingerling Grow-out, Solids removal, Oxygenation

In-Pond Raceways

D. E. Brune[1], R. Pierce[2] C. Hicks[3]

[1] Professor of Bioprocess and Bioenergy Engineering, University of Missouri,

[2] Fisheries and Wildlife, University of Missouri

[3] Pinnacle Aquatics LLC, Jamestown, Missouri

Auburn In-pond Fixed Raceway

Auburn In-pond Floating Raceway

Floating Raceway System

Here is the system in operation. It is easy to observe the water flow in thi
Exchange rate of water through this unit is about every 2.5 minutes.

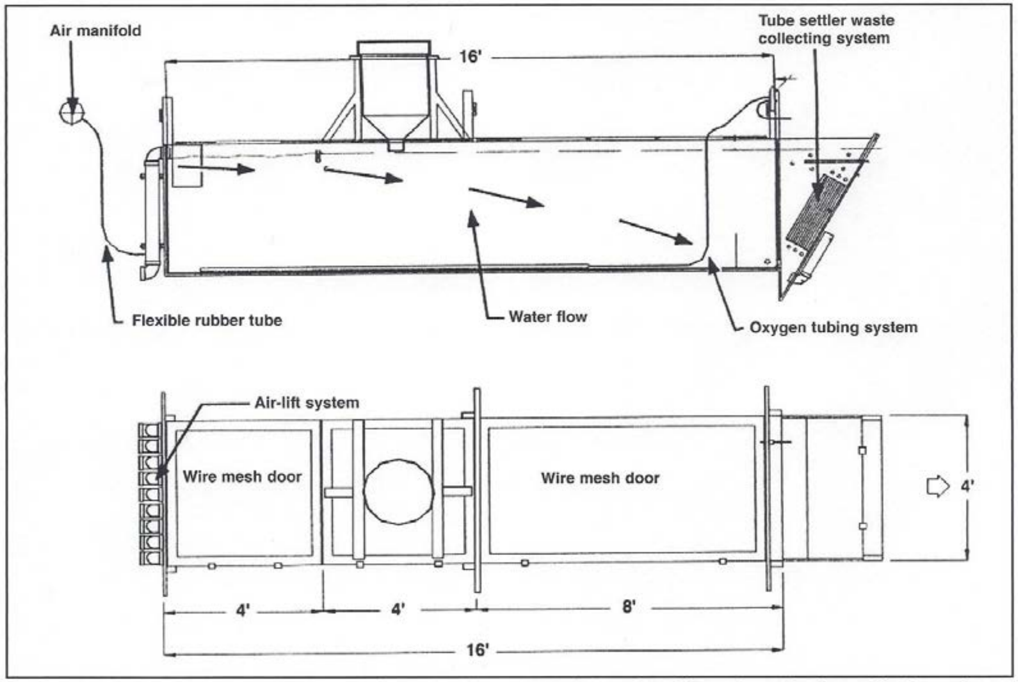


Figure 3c. Drawing of IPR in cross section and top view showing attachment of air-lifts, tube settler, demand feeder, and emergency oxygen tubing system.

Masser and Lazur; In-pond Floating Raceway

Masser and Lazur; In-pond Floating Raceway

ELLENTON, FL Private System reported in Fish Farming News, #4, 2015

In–Pond Raceway[1]

Carrying Capacity; 1,500+ lb fish
Raceway; 20’ x 4’ x 4’
Overall Dimension; 8 ft x 22 ft
Weight; 1,800 lbs
Aeration; Two-1.75 hp blowers
Floatation; 12” x 2’ x 4’ floats
Water Exchange; one vol/30min
Air-lift: 3 inch PVC pipes
Capital cost ~ $12,000/unit
Sale price ~ $6.00/lb
(live haulers ~1.5 lb fish)

[1)] Pinnacle Aquatics LLC

In–Pond Raceway (0.67 fpm velocity); Water Inlet (9-airlift tubes), Outlet for Solids Capture/Removal (80 gpm) and Blowers (1.75 hp)

TABLE 1. Economic comparisons between the IPR, cages and open-pond catfish culture (1-acre pond).[1]

	Open-pond[2]	Cage	IPR
Assumptions			
yield (lbs)	3,806	2,830	5,352
death loss (%)	6	10	10
feed conversion	1.8	1.6	1.45
% protein feed	32	36	36
Economic parameters (dollars)			
variable costs	3,135.63	2,391.27	4,160.25
fixed costs	787.72	850.16	1,111.26
total costs	3,923.35	3,241.43	5,271.51
breakeven price (cents per pound)			
to cover variable costs	82.39	84.50	77.73
to cover total costs	103.08	114.54	98.50

[1]Pond construction and management costs have not been included in the budgets.

[2]Open-pond production yields are based on actual average production values observed in the catfish industry in Alabama.

Masser and Lazur; Economic Comparisons IPR Ponds and Cages