Aquaculture in the Midwest;
Split-Ponds, Intensive Ponds, In-Pond Raceways & Recirculating Systems

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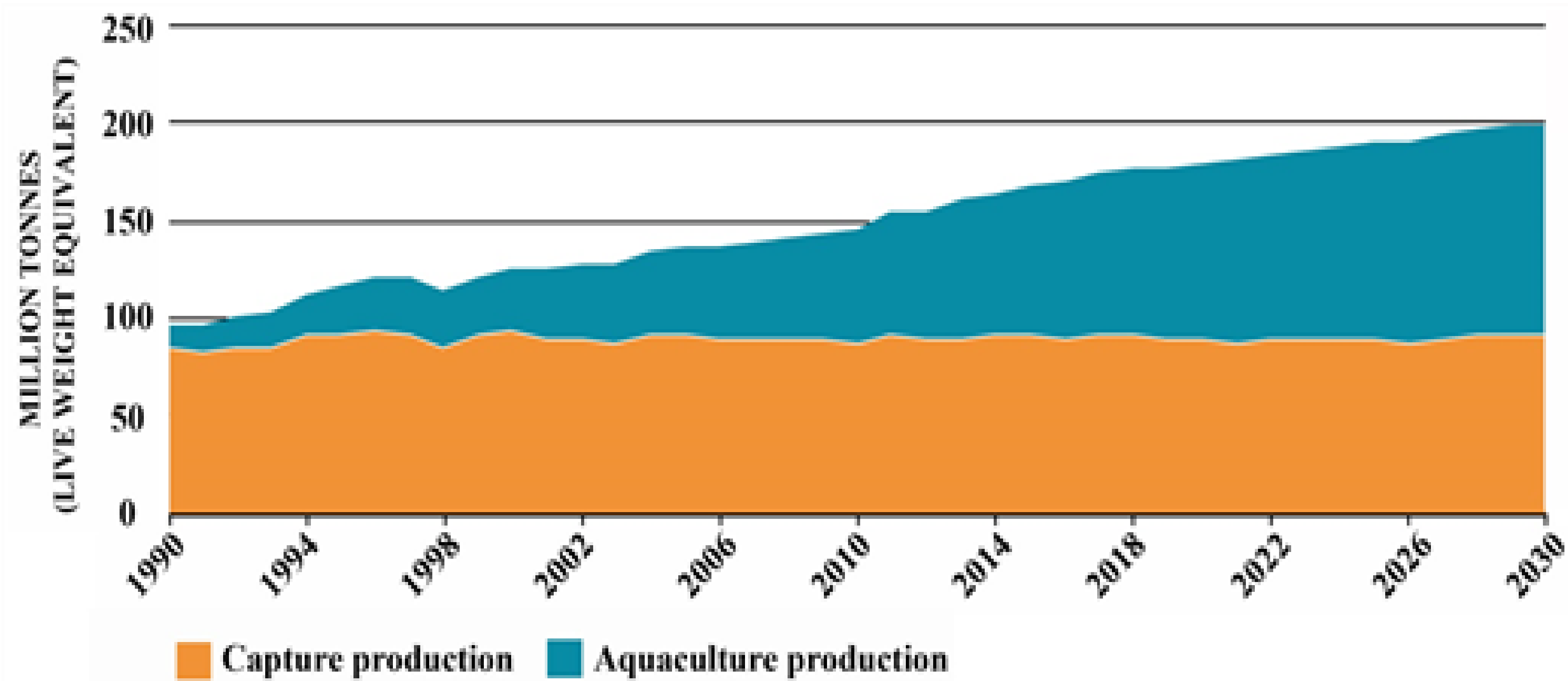
Midwestern farmers read discussions concerning aquaculture and ask if this technology could expand their farm production and income.

Marine Shrimp and Stripped Bass

Global Marine and Freshwater Seafood Production Projected to 2030;
Global Aquaculture Currently Supplies 50%



Within the last 30 years, aquaculture production of marine and freshwater fish/shellfish has grown from 5% to 50% of global seafood supply and is expected to continue to expand.

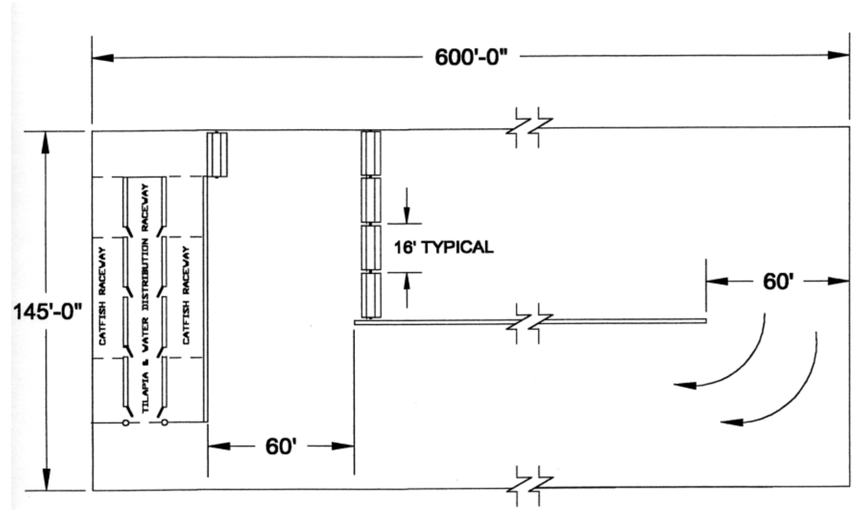
Intensification in Aquaculture Productivity from 1960 to 2020

From 1,000-2,000 lb/acre to 45,000 + lb/acre

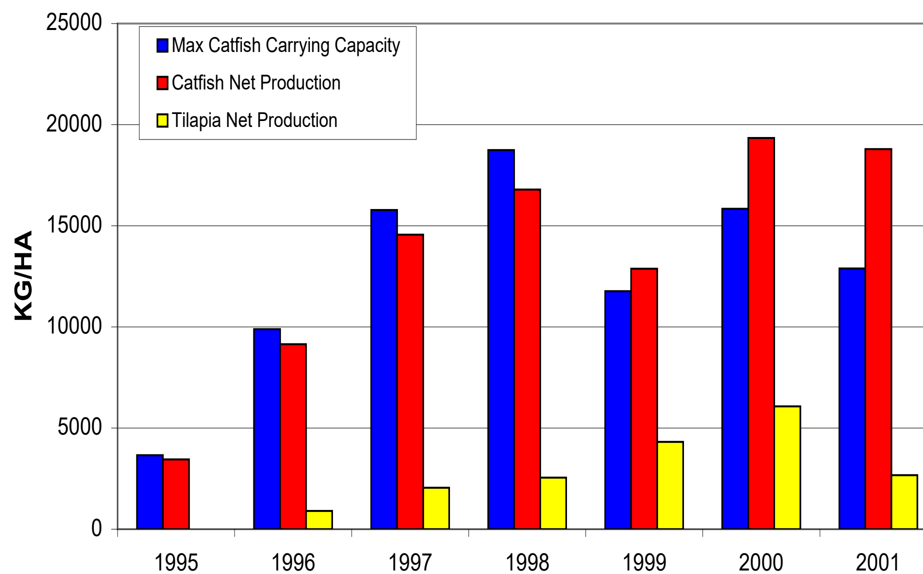
SYSTEM	Yield kg/ha	Feed kg/ha-d	Aeration KW/ha	Type (g-C/m^2 d)	VSS mg/l	Timeline
Extensive	1,124-2,247	11-34	Wind	Algal (0.5-1)	10-20	1960
Semi- Intensive	4,494-6,742	56-112	1.8-3.7	Algal (2-3)	50-100	1980
Intensive pond	11,235-13,483	112-168	11-22	Mixed (3-4)	100+	1990
PAS/SP	16,854-21,348	225-280	13--18	Algal (6-12)	50-100	2000
Super nitrifying	44,943+	1,123	92-111	Nitrification	300-400	2006
Super heterotrophic	44,943+	1,123/674	111-148	Heterotrophic	300-400	2006
Rapid Removal	34,000-50,000	1,685	123-140	Intensive Nitrification	70-80	2020

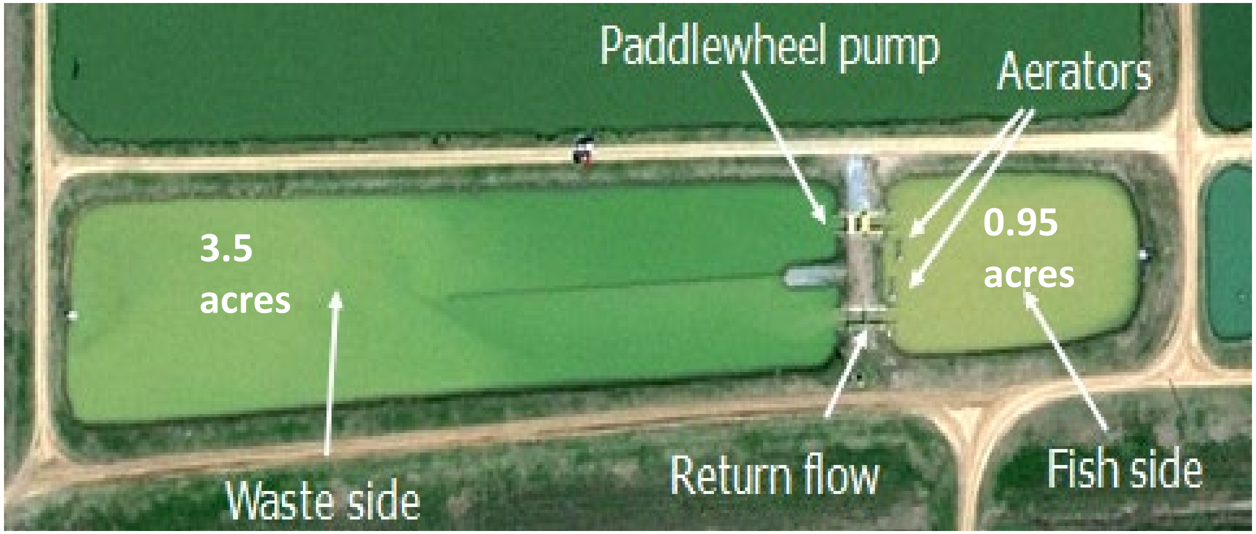
Aquaculture technology has advanced substantially; Fish/shellfish yields increased from farm-pond production of 1,000 to 2,000 lbs/acre-year to 40,000 to 50,000 lbs/acre-year in, year-round, climate-controlled, zero-discharge recirculating aquaculture systems (RAS).

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



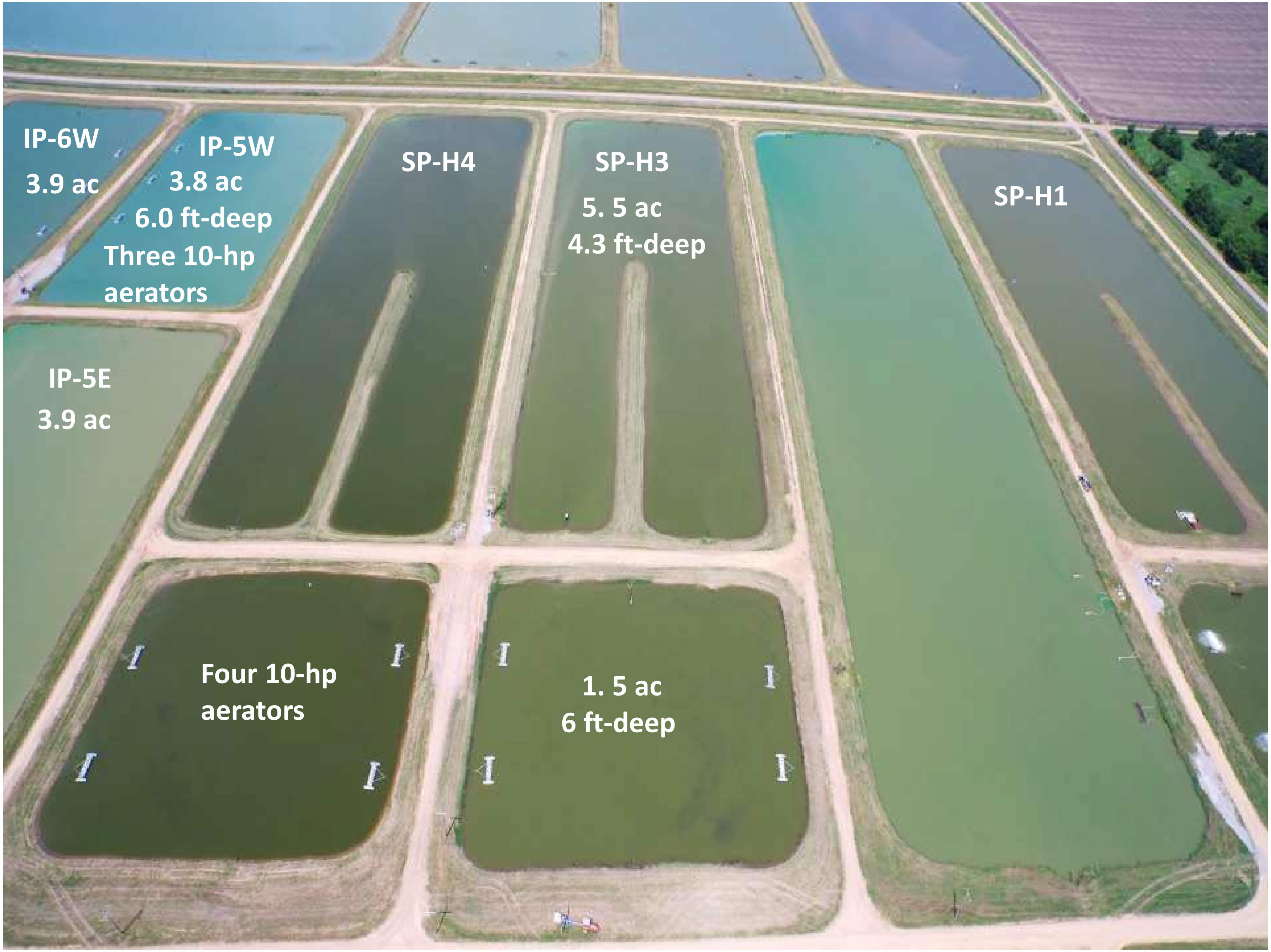


MS Split-Pond ; 2014

1995-2008 Clemson PAS (0.05-2.0 ac)

2014 MS Intensive Pond (2.0 ac)

MS Split Ponds and Intensive Ponds; 2015



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

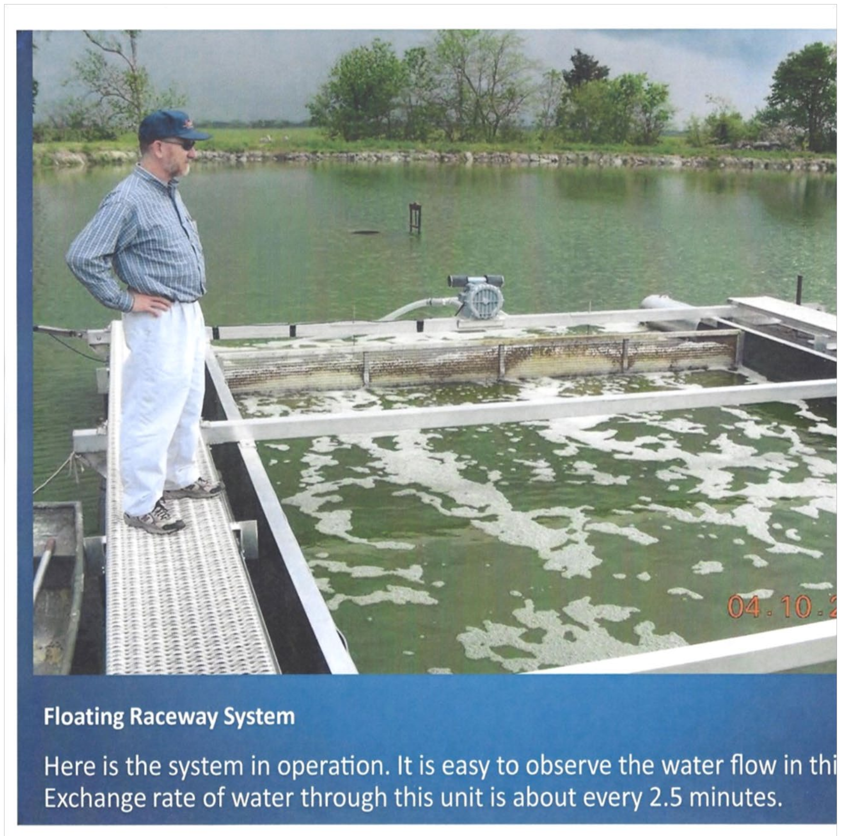
- Night-time mixing and aeration at 7.9 hp/acre, anaerobic % unknown
- 9,200-18,200 lb/acre in 100% of system volume
- Rapidly growing bluegreen algae, rapid sedimentation, high zooplankton numbers
- 110 mg/l algae density, 50% algal respiration,
- No nitrification
- Bird predation harder to control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

Auburn In-pond Fixed Raceway

Auburn In-pond Floating Raceway



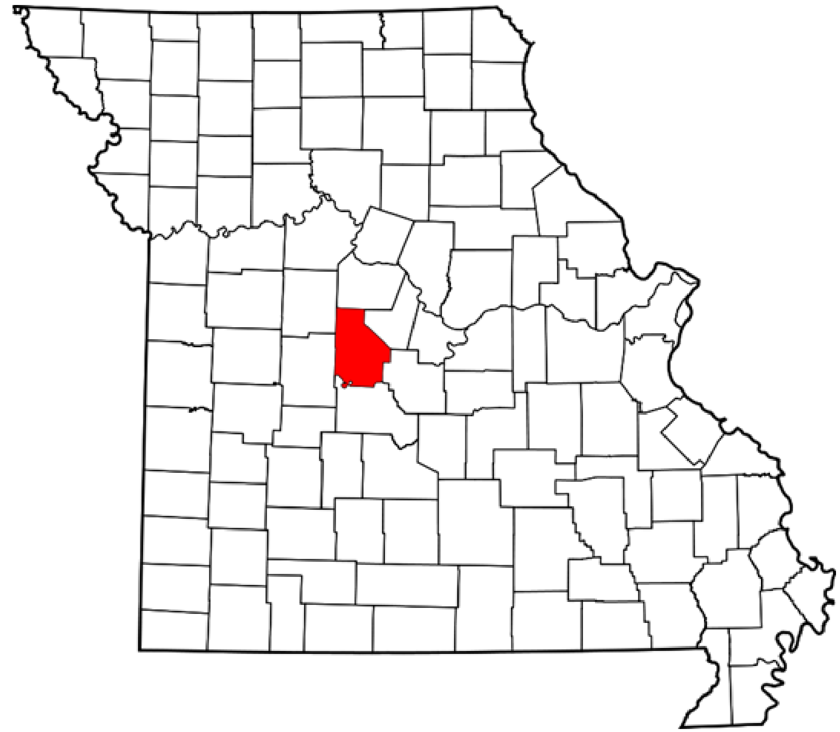
Representative Catfish Production, Break-Even Costs, Aeration/Mixing Energy and Area of Alternative Systems*

	Area (acres)	Production (lb/acre)	Energy (hp/acre)	BEC
IPR	6.0	8,800 -14,300	2.0	$1.32/lb
IA	5.0-7.5	7,500 – 21,300	5-10	$0.93/lb
SP	10.0	7,500 – 27,000	3.0	$0.92/lb

IPR = In Pond Raceway, IA = Intensively Aerated Ponds, SP = Split Ponds
Production data from MS, AL and AR
Break-even cost for Midwest production ~ 1.5 -2.0 x Southern cost
Break-even cost for Bass ~ 1.5 -2.0 Catfish

*Kumar, G., Engle C., Hanson, T., Tucker, C., Brown, T., Bott, L., Roy, L., Boyd, C., Recsetar, M., Park, J., and E. Torrans, Economics of Alternative Catfish Production Technologies, World Aquaculture Society, 2018: 49: 1039-1059

Economics of Prototype, Zero-Discharge, Temperature-Controlled, Recirculating Aquaculture System At Private Farm in Morgan County Missouri



Site Preparation in Morgan County, Missouri;
0.28 Acres; Cost = $3,500

Building Construction; Cost = \$120,000 + electrical (\$10,000) + site preparation (\$3,500), Total cost = \$133,500 or \$22.25/ft^2)

“Sukup” Building; 100 x 60 ft = 6,000 ft^2

Insulated walls and roof on 6-inch concrete pad

Prototype Raceways and Water Collection Sump

30-Mil HDPE Liner Inserted into ¾ Inch plywood containment, providing 2,800 gallons; Liner cost = $700, plywood containment = $4,200 Total cost = $1.75/gallon

½-Inch Welded PVC Sheets Inserted into ¾ Inch plywood;
PVC liner cost = $1,000, plywood containment =$4,200 Total cost = $1.86/gallon

Commercially-available, glass-coated steel raceway, anchor-bolted to concrete; Cost = $24,380 for 8,600 gallons, Total cost = $2.83/gallon

Concrete-filled, prefabricated PVC (7,200 gallons)
PVC Forms ($3,000) + concrete ($2,000) + lumber ($1,500)
Total cost = $0.90/gallon

Supporting equipment; Rotary-compressor ($5,600), Oxygen-separator ($7,000), Bead-filter ($4,400), Blowers/Ozone-generator ($2,700), Machine room ($6,500)

Water Supply

25-gpm well ($6,600) + plumbing ($4,000)

Shrimp vs Finfish (Bass) Carrying Capacity
Concrete-filled PVC; Resource Inputs vs Outputs

	Bass	Auto-Shrimp	Hetero-Shrimp
Harvest size	1.5 lb	22 gm (jumbo)	
Carrying Capacity			
Volumetric (1-meter deep)	0.5 lb/gallon	0.0458 lb/gallon	
Areal	60 kg/m^2	250/m^2 @ 22 gm = 5.5 kg/m^2	
Crops/yr	1	3	4
Yield/m2-yr	60 kg/m^2-yr	16.5 kg/m^2-yr	22.0 kg/m^2-yr
Breakeven income	$604.07/$m^2$-yr	$351.49/$m^2$-yr	$453.50/$m^2$-yr
BI +15%	$695.62/$m^2$-yr	$404.22/$m^2$-yr	$521.53/$m^2$-yr
Input (energy)	5 kwh/lb	15.2 kwh/lb	11.4 kwh/lb
Input (protein)	0.75 lb/lb	0.54 lb/lb	0.54 lb/lb
Input (sugar)	0	0	1.28 lb/lb
Waste lb-VS/lb production)	0.31 lb/lb	0.33 lb/lb	0.94 lb/lb

Production Cost (Fish vs Shrimp) $/lb in Concrete-Filled PVC

Capital Costs ($/lb)	Bass	Shrimp (Auto)	Shrimp(Hetero)
Building	0.232	0.617	0.463
Heat Pump	0.111	0.296	0.222
Generator	0.035	0.093	0.069
Raceways	0.181	0.604	0.453
Filters	0.124	0.156	0.117
Aerators	0.082	0.272	0.204
Pumps	0.013	0.042	0.031
Total Capital	**0.778**	**2.080**	**1.557**
Steel tanks	+0.433	+1.796	+1.357
Operating Costs ($/lb)			
Feed	1.500	1.080	1.080
Sugar	0	0	1.032
Animals	0.784	2.428	2.428
Aeration KWH	0.213	0.760	0.570
H/C KWH	0.286	0.760	0.570
Labor	0.638	2.122	1.592
Total Operating	**3.421**	**7.150**	**7.272**
TOTAL COSTS	**$4.20/lb**	**$9.23/lb**	**$8.83/lb**

Aquaculture Production Costs; Pond vs RAS

Estimated Costs/Prices* ($/lb) for Whole/Processed Pond and RAS Products

TYPE/YIELD	Break-Even (whole)	Farm-gate (whole)	Wholesale (processed)	Retail (processed)
POND				
Catfish (0.32 lb fillet)	0.80-1.00/lb	0.85-1.25/lb	5.00-6.00/lb	8.00-11.00/lb
Shrimp (0.6 lb tails)	1.50-1.90/lb	2.00-3.00/lb	5.00-6.00/lb	5.00-12.00/lb
RAS				
Shrimp (0.6 lb tails)	4.00-8.25/lb			13.00-18.00/lb whole
Bass (0.32 lb fillet)	4.00-6.00/lb	5.00-6.00/lb	15.00-18.00/lb	20.00-28.00/lb

Recirculating Systems Production Costs; Marine shrimp = $4.00-8.25/lb, Freshwater large-mouth bass = $4.00-6.00/lb

Typical Commodity Farm-Gate Prices; Catfish = $1.00/lb, Largemouth Bass = $6.00/lb, Shrimp = $3.00/lb

Small Volume Niche Market Shrimp Prices; Shrimp =$13-18/lb

Recirculating System Costs = 1-6X commodity price, 45-65% of niche market price

* Break-even costs dependent on scale, species, and system productivity. RAS cost/sales highly variable based on small sample size

Recirculating aquaculture production costs cannot compete with Southern U.S. pond production costs or seafood commodity costs; RAS production cost = 1 to 6 fold over farm-gate or dock-side prices. However, retail seafood prices range from 45 to 65% of RAS costs

Summary

- Zero-discharge, controlled-climate, RAS production costs range from $4.20/lb (fish) to $9.23/lb (marine shrimp)
- Production energy requirements range from 5.0 kwh/lb (fish) to 15 kwh/lb (shrimp) as opposed to 8 kwh/lb (chicken), 24 kwh (pork) and 35 kwh/lb (beef).
- Profitability of zero-discharge RAS will require retail sales
- Growers must bear costs of seafood holding, processing, transportation, packaging, and advertising/marketing to sell product directly to consumers
- Begin small, consider markets before addressing technology and investment issues; Which marketable species? What product to provide (whole or processed)? Where to sell?

Fingering Production in PAS

Fingering Production in PAS
80-100 gms vs 30-40 gms from ponds

Presentations/Resources

MU Extension Aquaculture;
Detailed technical and economic presentations

https://extension.missouri.edu/programs/aquaculture-extension

Short Video Presentations

1) Importance of Aquaculture; Impact on US Seafood Supply and Economy

2) Aquaculture in the Midwest; Economic Opportunity for Missouri Farmers?

3) Aquaculture Technology; Ponds to Super-Intensive Production