Advancements in Aquaculture: Economic Opportunity for Midwest Farmers?

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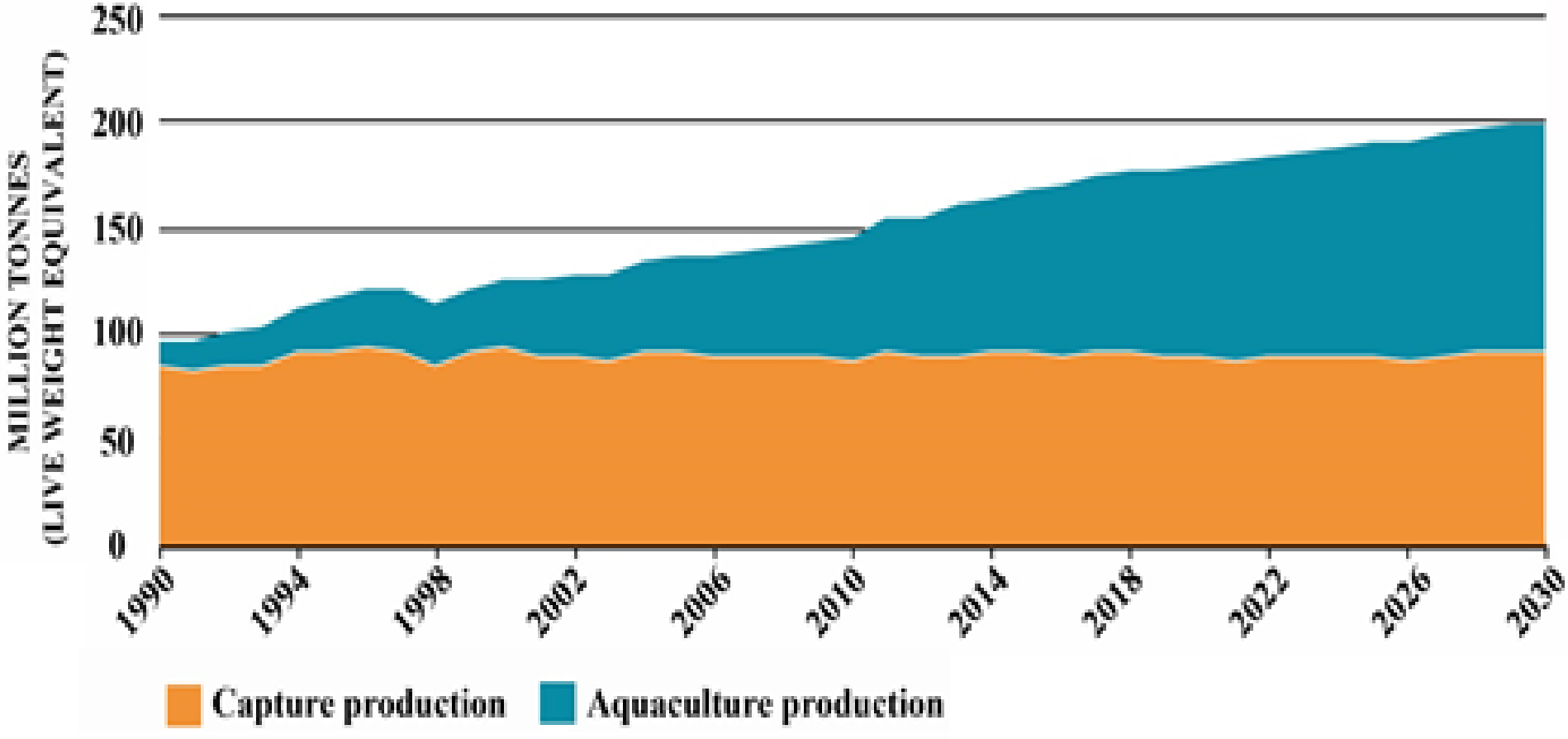
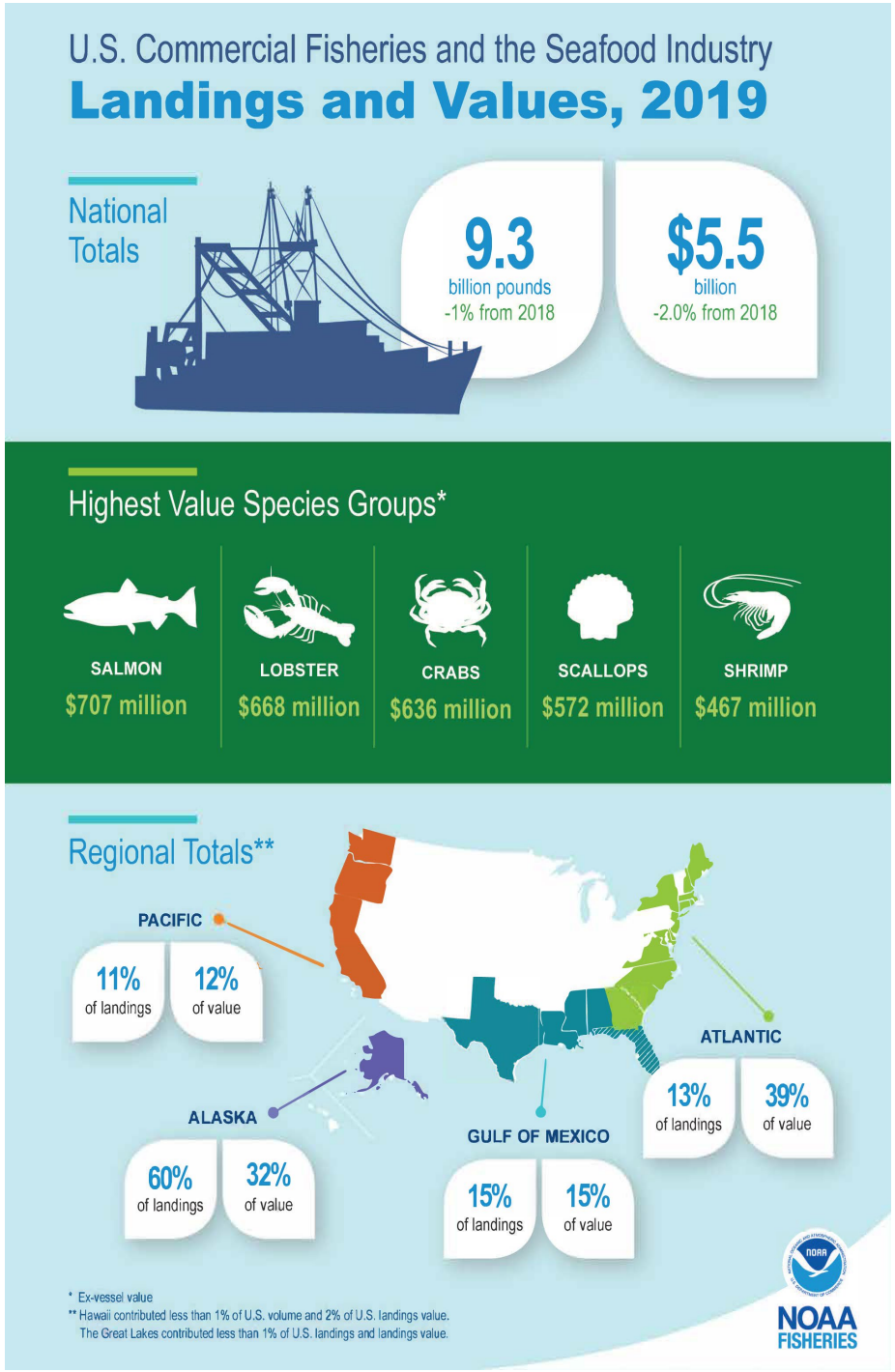
Global Marine and Freshwater Seafood Production

Global Aquaculture Currently Supplies 50%



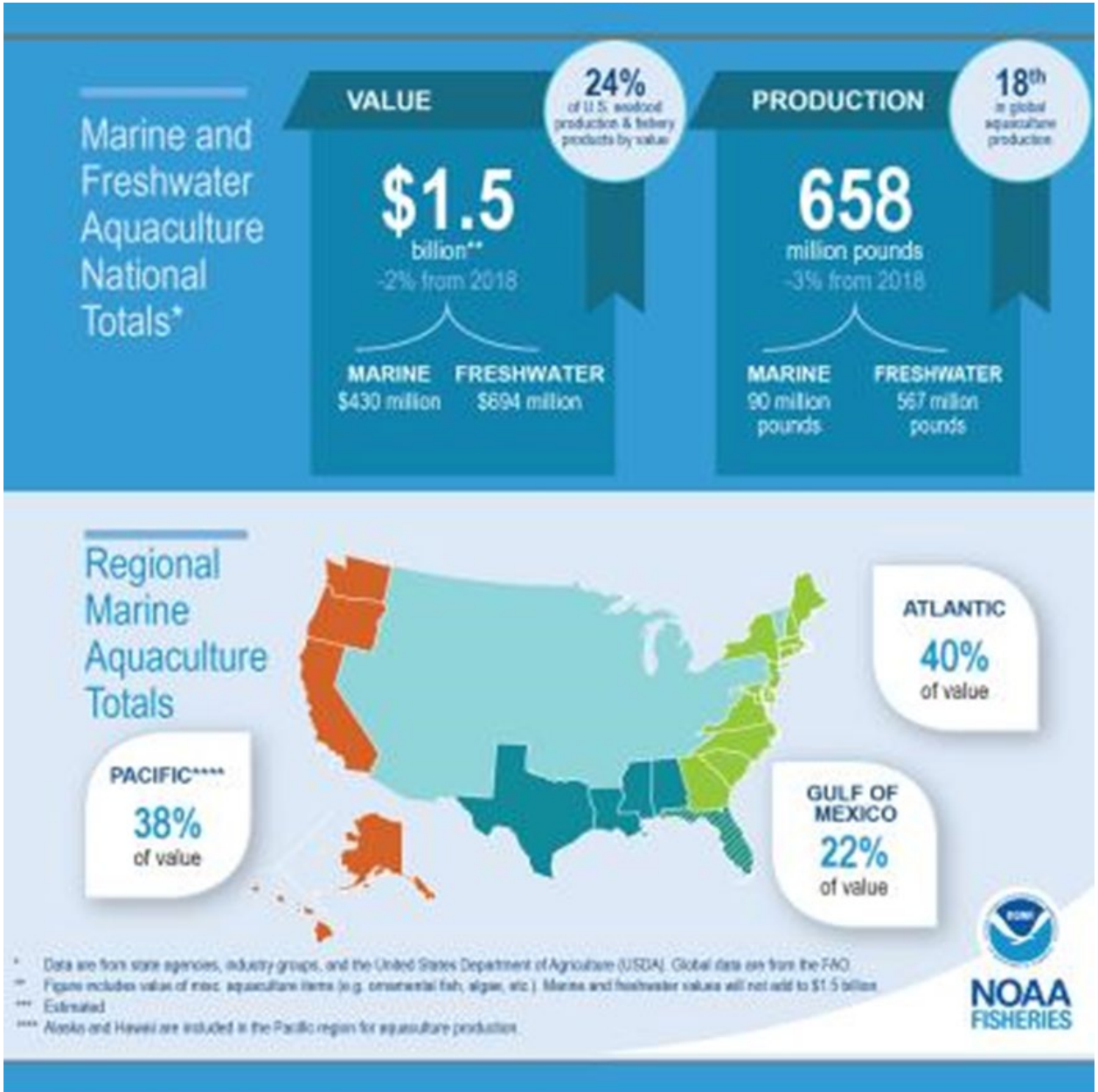
In last 30 years, aquaculture production of marine and freshwater fish/shellfish has grown from 5% to 50% of global seafood supply and is expected to expand. Wild caught fish production cannot be expanded.



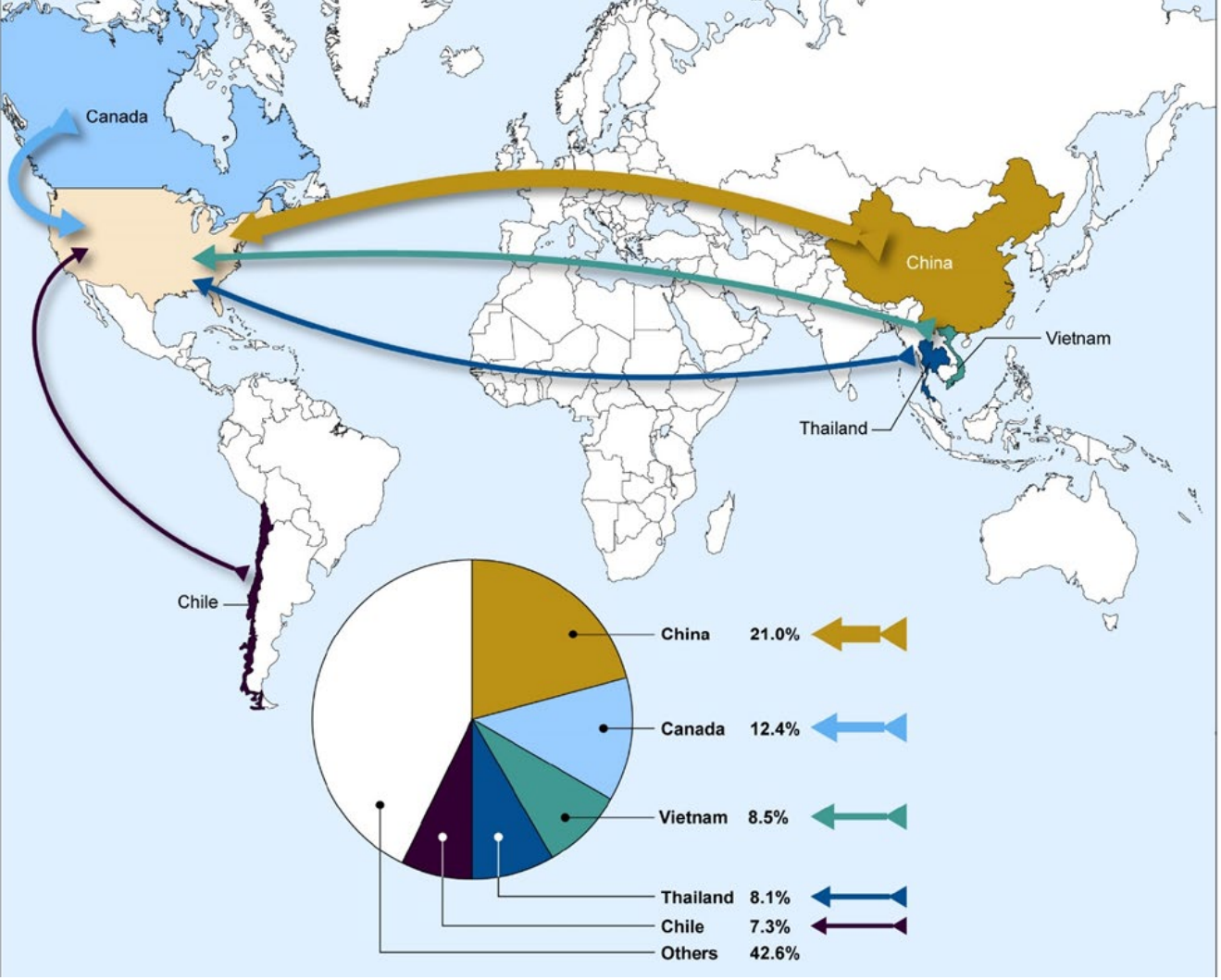
Global Seafood Production; 392 billion lb/yr (2020) of which 192 billion lb/yr was provided by aquaculture (NOAA, 2022).

U.S. Seafood Catch; 9.3 billion lb/yr, with an additional 5.5 billion lb/yr (2019) of seafood product imported.

U.S. Aquaculture Production; Estimated at 658 million lb/yr (7.1% of catch), with U.S. trout at 36 million lbs/yr and U.S. catfish at 307 million lbs/yr (NOAA 2020). Small, but of growing importance



Bulk of U.S. seafood supply is imported



85% of seafood imported
65% caught/grown overseas
25% of US wild caught processed overseas and re-imported to US

85% of U.S. seafood supply is imported, most coming from Asia

U.S. Seafood Trade deficit 2021-2023 = $20.3-24.8 billion

Catfish Dominates U.S. Aquaculture Production

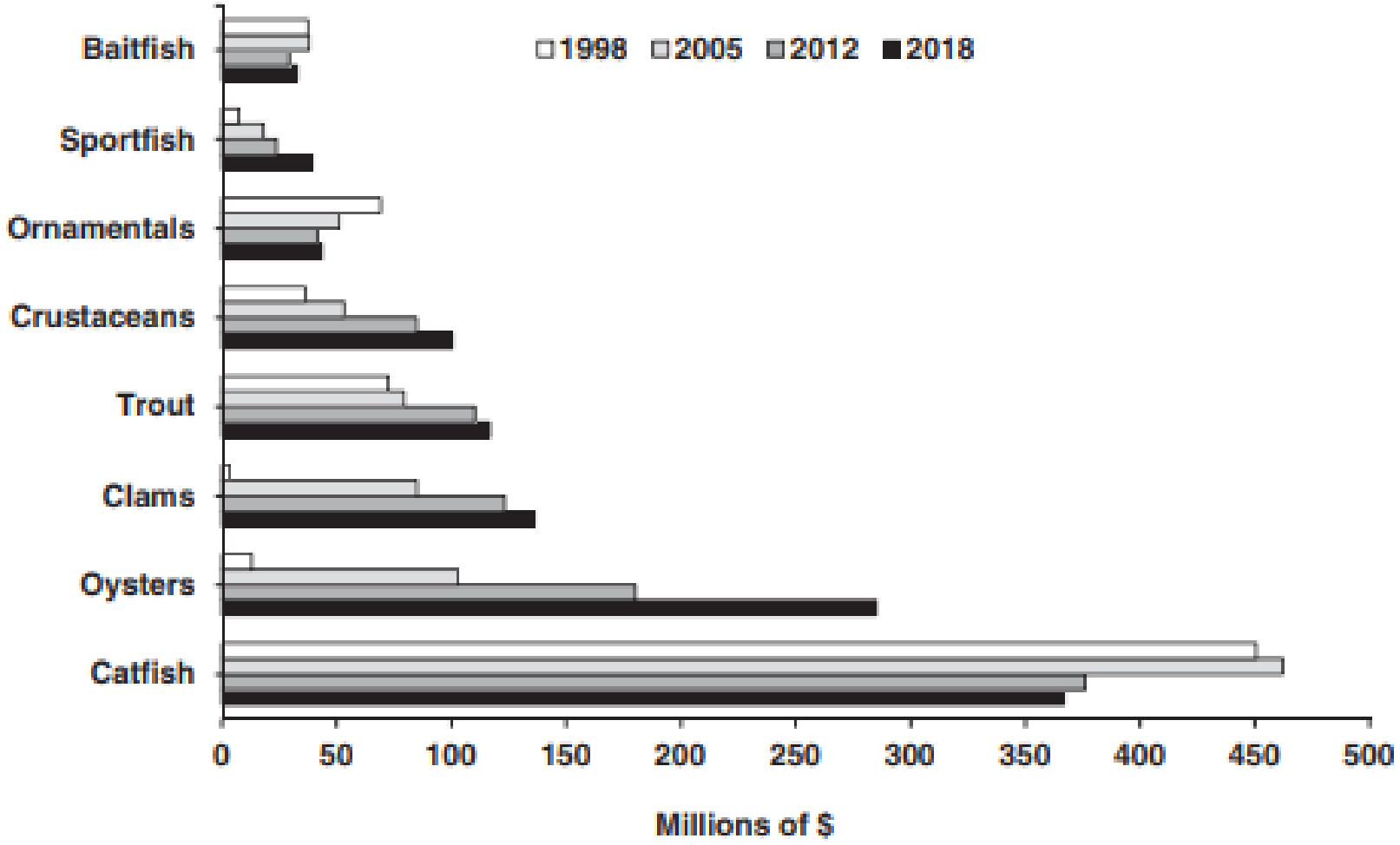


Figure 1. U.S. aquaculture, seven major species categories, by volume of sales, 1998, 2005, 2012, and 2018. Sources: Census of Aquaculture, USDA-NASS.

U.S. Catfish Industry Emerges in 1960's

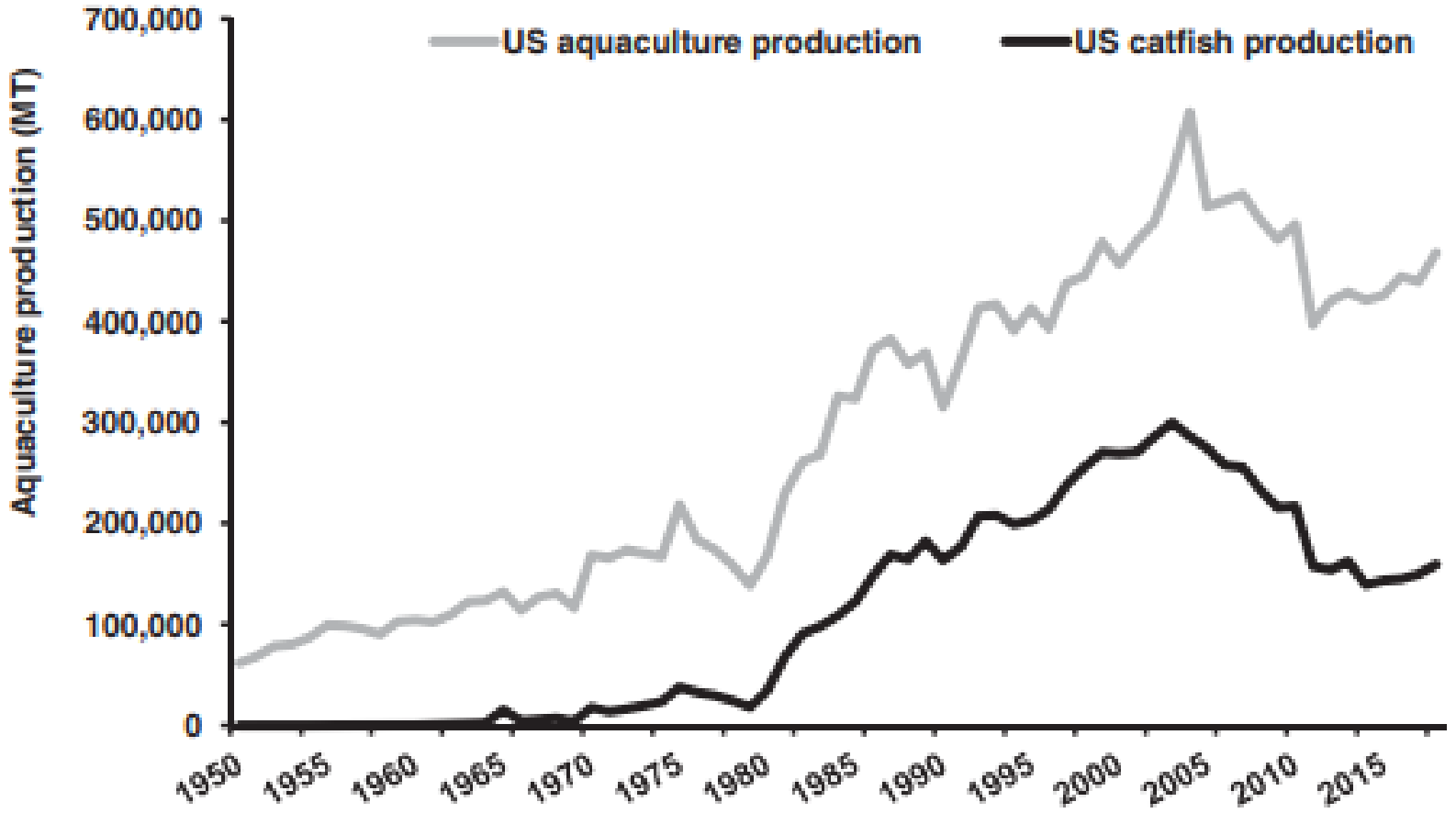


Figure 2. U.S. catfish and total U.S. aquaculture production, 1950–2018 (in metric tons). Source: FAO (2020).

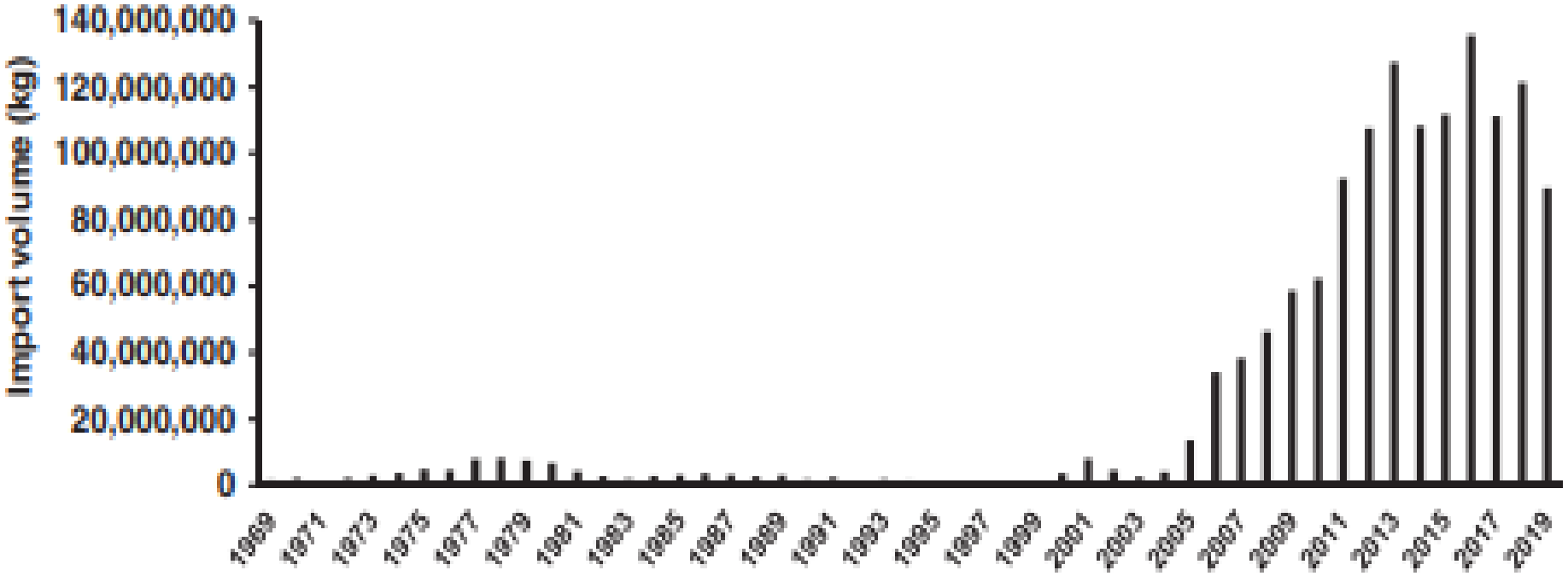
- Seafood consumption downturn beginning in 2001
- Due to NY terror attack, rising feed prices, import competition

Catfish Institute promotion and public relations campaigns (1986-2019) establish U.S. consumer demand for catfish

Campaigns	1986-88	1989-91	1992-94	1995-97	1998-00	2001-03	2004-06	2007-09	2010-12	2013-15	2016-18
Deliciously versatile	■		■				■				
Raised w/known inputs on farms that produce a safe product	■										
Nutritious source of healthy protein	■										
Grain fed a natural grain diet	■										
Raised in man-made ponds, pure water	■										
Finest quality catfish available		■			■						
Unexpected great taste		■	■	■							
Farm-raised for great taste				■							
Providing great dishes from great chefs				■							
You don't have to fry it to love it					■	■					
U.S. Farm-Raised Catfish						■	■	■	■	■	■
Catfish American Style						■					
Grilled in the U.S.A.						■					
Cooking Light on the Move						■					
Catfish Road Show						■					
Spice It Up						■	■				
America's Fish							■				
Red, White, and Good							■				
Lightly Fried, Deeply Southern							■				
Fit to be Fried							■				
Who Ever Heard of Northern-Fried?							■				
Collateral branding							■	■	■	■	■
Partnership programs							■	■	■	■	■
U.S. Farm-Raised Catfish: You Can Count On It							■				
U.S. Farm-Raised Catfish: Safety You Can Trust								■	■	■	■
A Great Catch for Food Service								■			
Farmer and the Chef								■			
Introducing the Whole Grain Fish								■			
Catfish Farmers of the Year									■	■	■
Fresh Ideas for Catfish									■	■	■
Where Does Your Catfish Come From?										■	
Co-marketing programs										■	■
U.S. Farm-Raised Catfish: 100% American										■	■
Sports marketing										■	■
Social media										■	■
Catfish is Life											■
Digital media											■

Catfish Imports Increase After 2005*

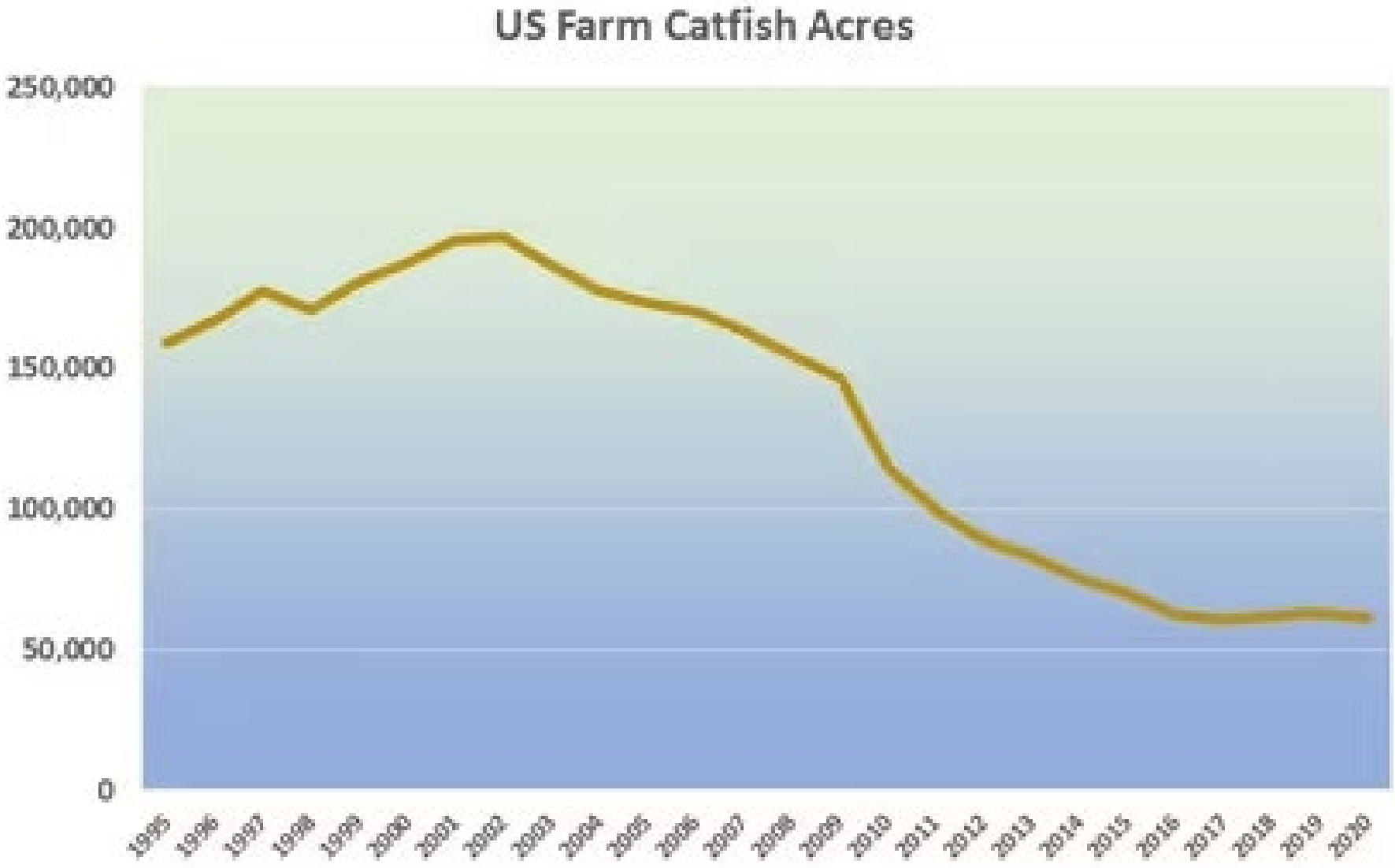
Asian catfish prices 38-55% lower than U.S. catfish



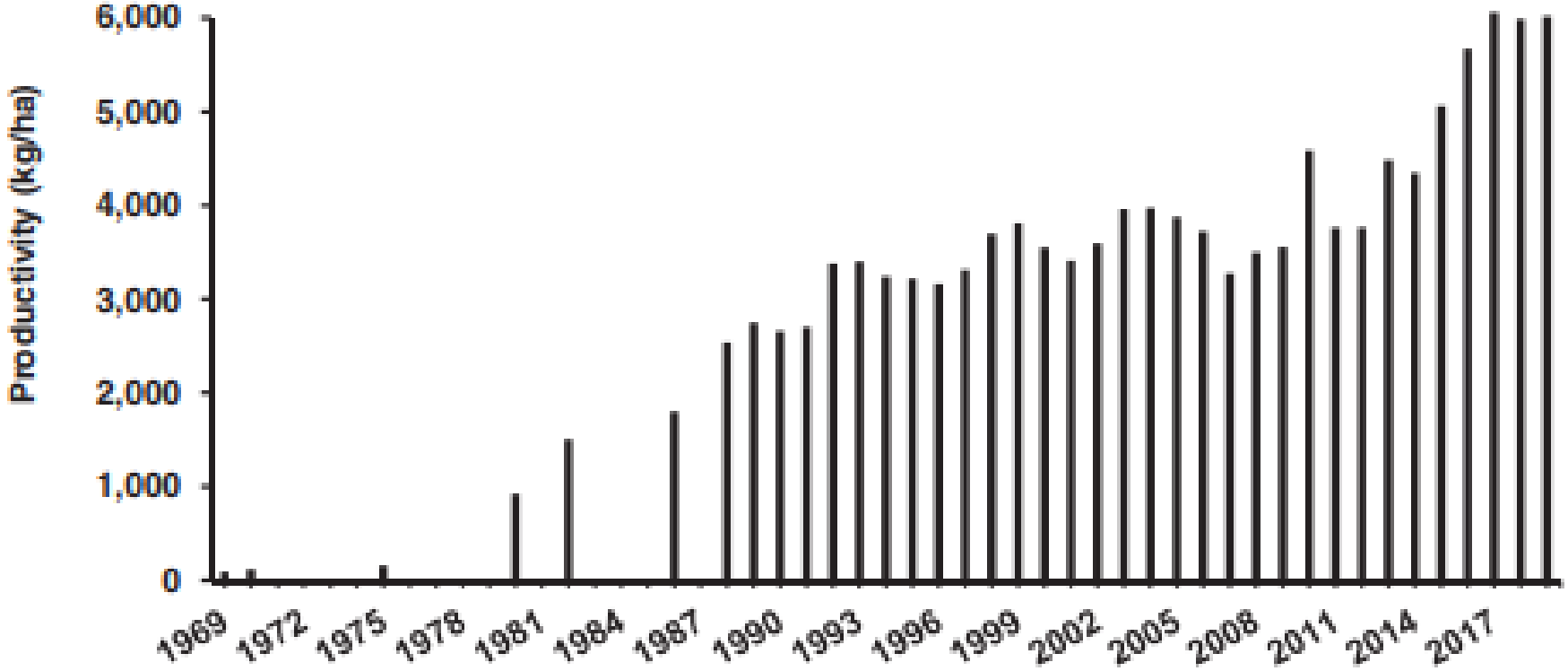
The growth of catfish sales in America did not go unnoticed. Free-riding on U.S. fish farmer's promotional efforts and market opportunities, foreign competitors target newly developed catfish markets in United States*

*Engle, C., T. Hanson and G Kumar, Economic history of U.S. catfish farming; Lessons for growth and development of aquaculture, Aquaculture Economics and Management, 2022.

Catfish Acres Decline After 2001



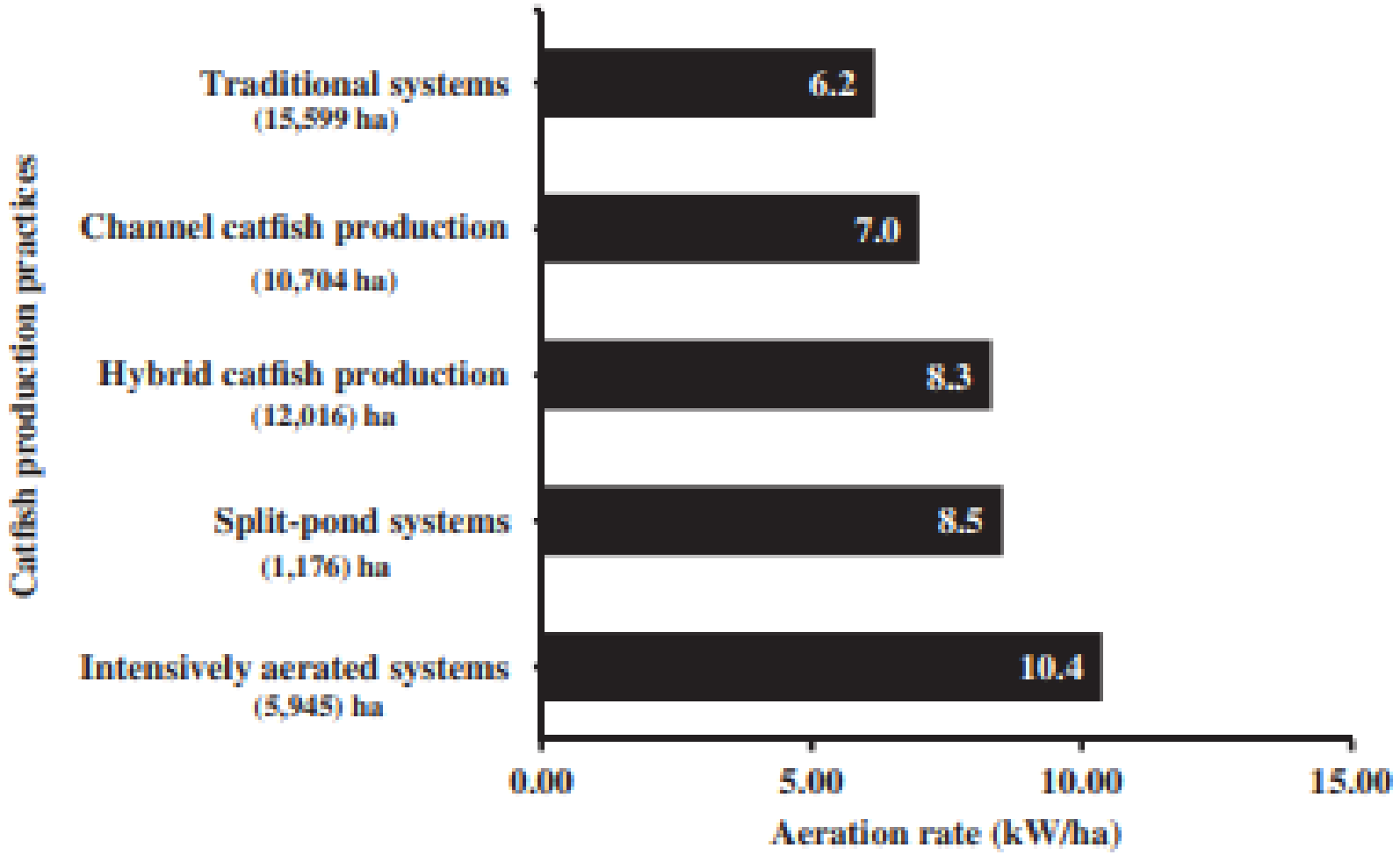
Catfish Productivity (kg/acre) Increases*



*Engle, C., T. Hanson and G Kumar, Economic history of U.S. catfish farming; Lessons for growth and development of aquaculture, Aquaculture Economics and Management, 2022.

Increased Energy in Catfish Culture*

10 kW/ha = 5.4 hp/acre



*Hegda, Kumar, Engle, et. al., Technological Progress in the U.S. Catfish Industry, World Aquaculture Society, 2021.

Overview of Aquaculture Intensification *

Name, Yield, Feed, Aeration, Solids, Microbial Type, Solids, Inception date

SYSTEM	Yield lb/ac	Feed lb/ac-d	Aeration hp/ac	Type g-C/m^2-d	VSS mg/l	Timeline
Extensive	1,000-2,000	10-30	Wind	Algal (0.5-1)	10-20	1960
Semi- Intensive	4,000-6,000	50-100	1-2	Algal (2-3)	50-100	1980
Intensive pond	10,000-12,000	100-150	6-20	Mixed (3-4)	100+	1990
PAS/SP	15,000-19,000	200-300	7-10	Algal (6-12)	50-100	2000
Super heterotrophic	40,000+	1,000/600	60-80	Heterotrophic	300-400	2006
Super nitrifying	40,000+	1,000	50-60	Nitrification	300-400	2006
Rapid Removal	30,000-44,639	1,500	67-76	Intense Nitrification	70-80	2020

Aquaculture technology advancements over 60 years; Fish/shellfish yields increased from 1,000 to 2,000 lbs/acre-year to 40,000 to 50,000 lbs/acre-year, year-round, climate-controlled, zero-discharge, recirculating aquaculture systems (RAS).

*Brune, D. E., Autotrophic and Heterotrophic Water Treatment in Semi-Intensive, Intensive and Super-Intensive Fish and Shrimp Culture, *The Shrimp Book II*, Victoria Alday-Sanz, Editor, 5M Press, 2022.

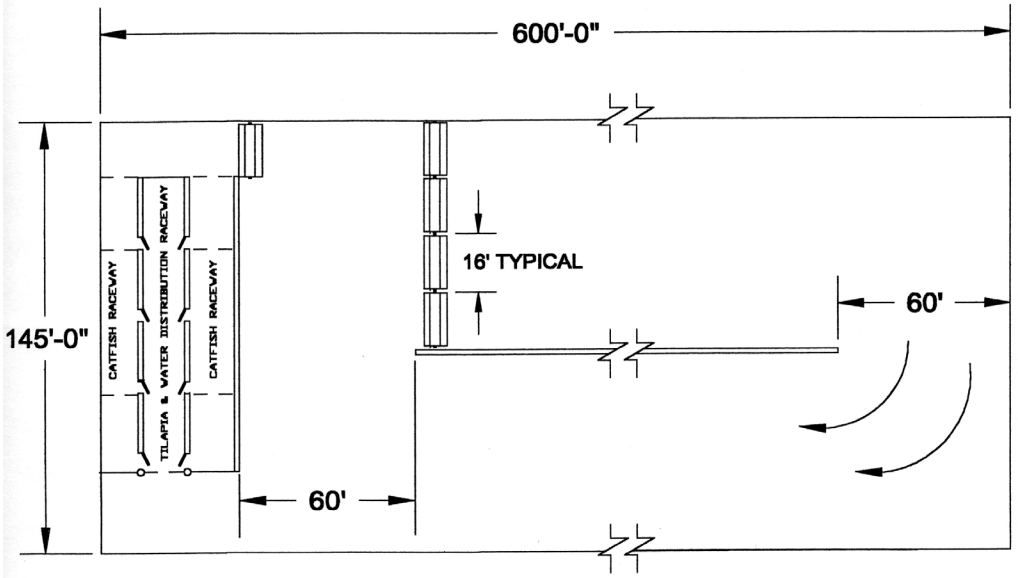
Advances in Aquaculture Technology

- Partitioned aquaculture (Clemson)
- Split-ponds (Mississippi)
- Intensive aeration (Mississippi)
- In-pond raceway (Auburn)
- Biofloc marine shrimp production (Clemson/MO)

Development of the Partitioned Aquaculture System at Clemson University; 1987-2008 – Enhanced Algal Treatment for Catfish Production

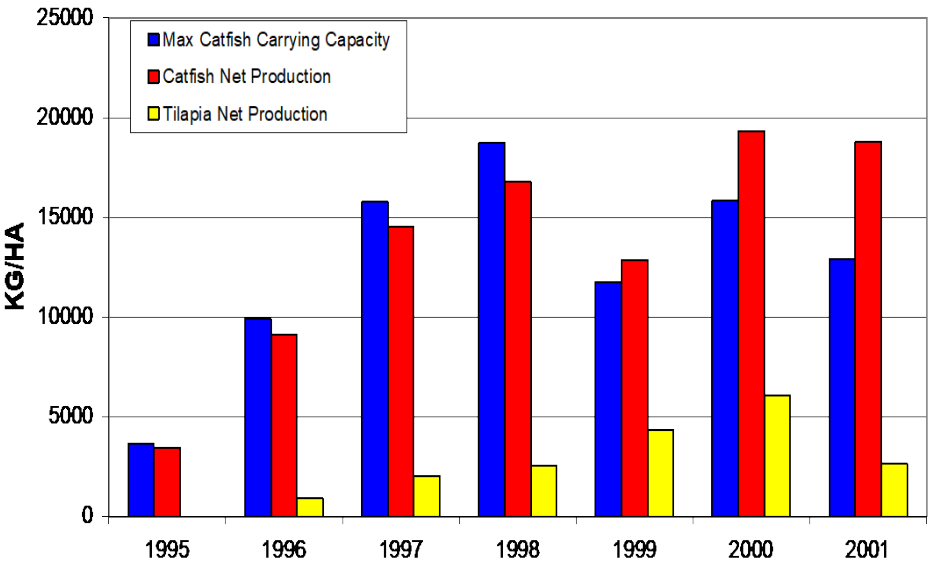
Converting pond fish culture to raceway culture

Two acres total with fish confined to 5% of area,



95% of pond area converted to high-rate algal pond for water treatment

Two-acre Partitioned Aquaculture System (PAS); Paddlewheels provide uniform water mixing promoting increased photosynthesis with fish in high-density raceways.

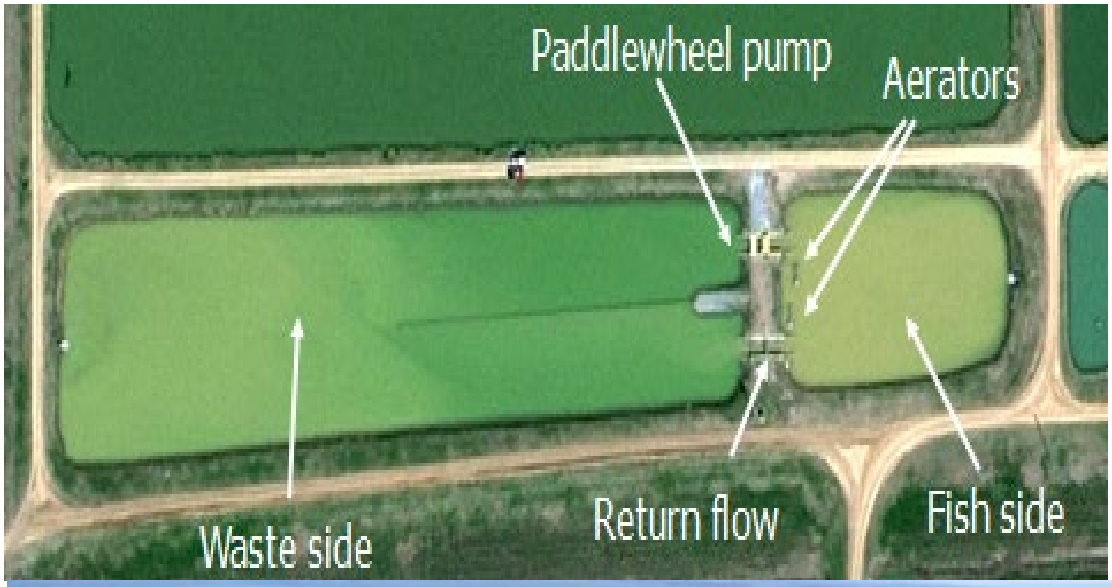


Clemson Two-Acre PAS
0.4 ft/sec water velocity

Catfish Yields in PAS ~18,000 lbs/acre
Tilapia co-culture for management of algae in a "High-Rate Pond," adapted for fish production


Catfish Culture in Raceways
Bird predation eliminated
Improved feed conversion
1.5/1 vs 2.2/1
Ease of harvest/fish treatment

Split-ponds at Warmwater Aquaculture Center, Stoneville Mississippi



Lower-cost version of the PAS, the split-pond, at Mississippi demonstrates catfish production at 12,000 to 17,000 lbs/acre

Production in 5.0-7.0 acre split-ponds divided into water treatment and fish culture, fish confined to 25% of pond area

Enhanced Photosynthetic Catfish Production in Intensively Aerated Ponds

Intensively aerated ponds at NWAC/MS demonstrated 7,000–17,000 lb/acre-yr production in 1.0-4.0-acre ponds with fish confined to 100% of pond area

Enhanced Photosynthetic Catfish Production; In-Pond Fixed Raceways

In-pond raceways at Auburn University demonstrated maximum production of 16,000 lb/acre in 6.0-acre pond. Fish confined to 2.0% of pond area

Fish Culture Footprint, Aeration Energy, and Yield of Enhanced Catfish Production

System	Fish Culture	Typical Acres	Aeration energy hp/ac	Ave yield lb/ac
PAS	5%	2.0	6.0	17,000-18,000
SP	20%	7-10	6-10	13,000-17,000
IP	100%	5 -7	6-10	7,000-17,000
IPR	2%	6	3.0	13,400
CP	100%	5-10	3.3	4,000-5,000

Maximum production similar in PAS, SP and IP

Production in IP more variable than in PAS and SP

SP/IP lowest cost. PAS and IPR most expensive

Advantages of Aquaculture Intensification

Increased efficiency of water, land and equipment/lb-production
Reduced cost/lb-production
Reduced labor needs/automation possible
Reduced fish predation
Improved fish health management and feed conversion

Limitations/Disadvantage of Aquaculture Intensification

Maintaining control of water quality; nitrogen/ammonia concentrations
Increased dependency on electrical supply (backup generators)
Increased level of technology and training of labor
Capital intensive, increased investment

Marine Shrimp Production

University of Missouri Zero-Discharge Marine Shrimp Production

Biofloc expands production to 40,000 lb/acre

High levels of microbial solids (250-300 mg/l) within culture water

Types of Biofloc Water Treatment

Autotrophic Nitrification (Slow growth, low sludge production)

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

Heterotrophic Bacteria (Rapid growth, requires carbohydrate)

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

Catfish and Shrimp Culture in Ponds in Warm Climates

Intensive aeration allowing U.S. catfish production to expand from 2,000 to 10,000 lbs/acre in captive water

Intensive aeration with water discharge allowing Asian shrimp production to expand from 1,000 to 10,000 lbs/acre

The Drive to Zero-Discharge Aquaculture

Animal agriculture recovers only a small fraction of feed-N

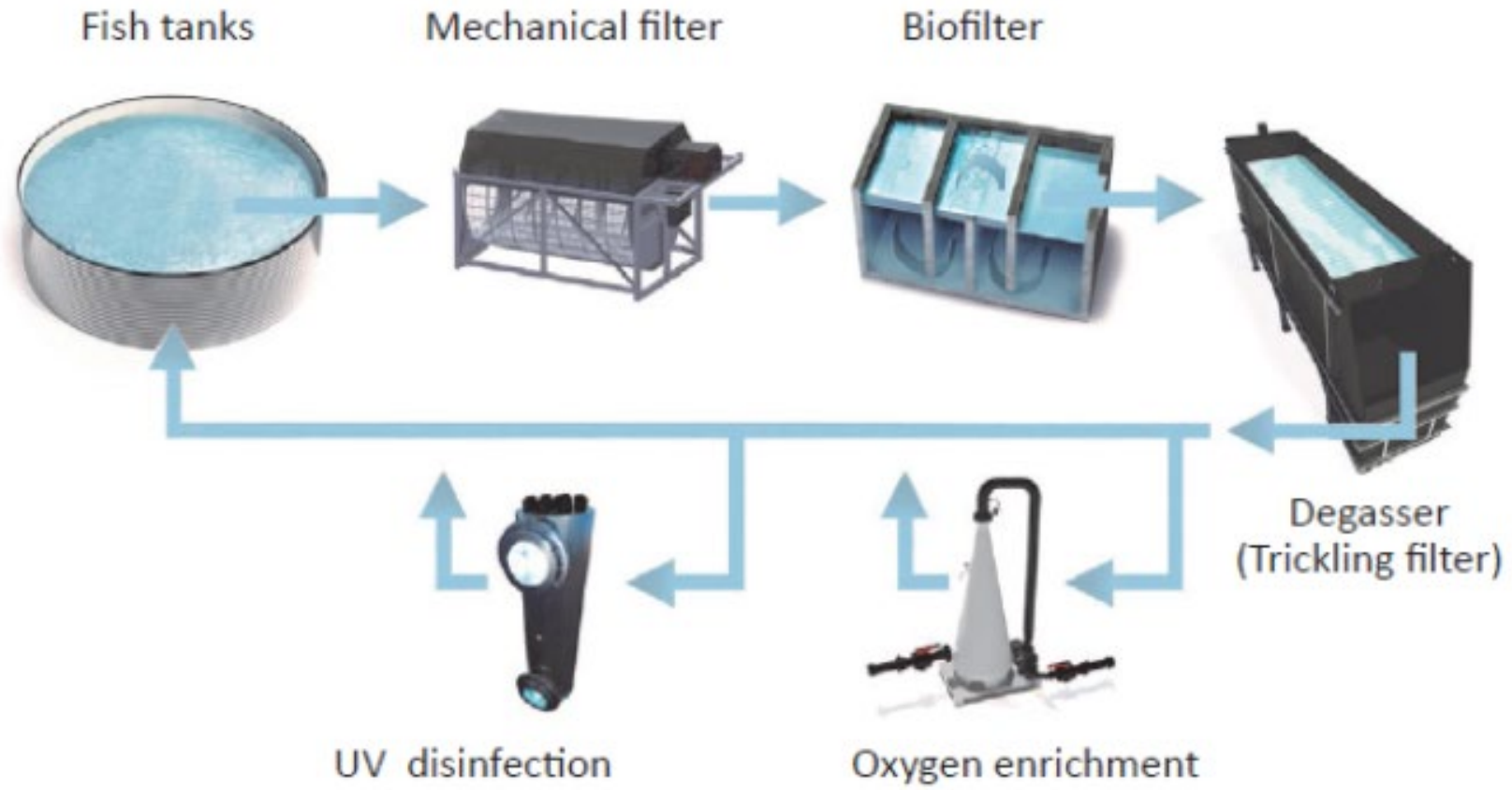
Soy, corn & fish-meal nitrogen inputs

12 - 21% protein nitrogen converted to fish or shrimp

79 - 88% nitrogen discharged as pollutant

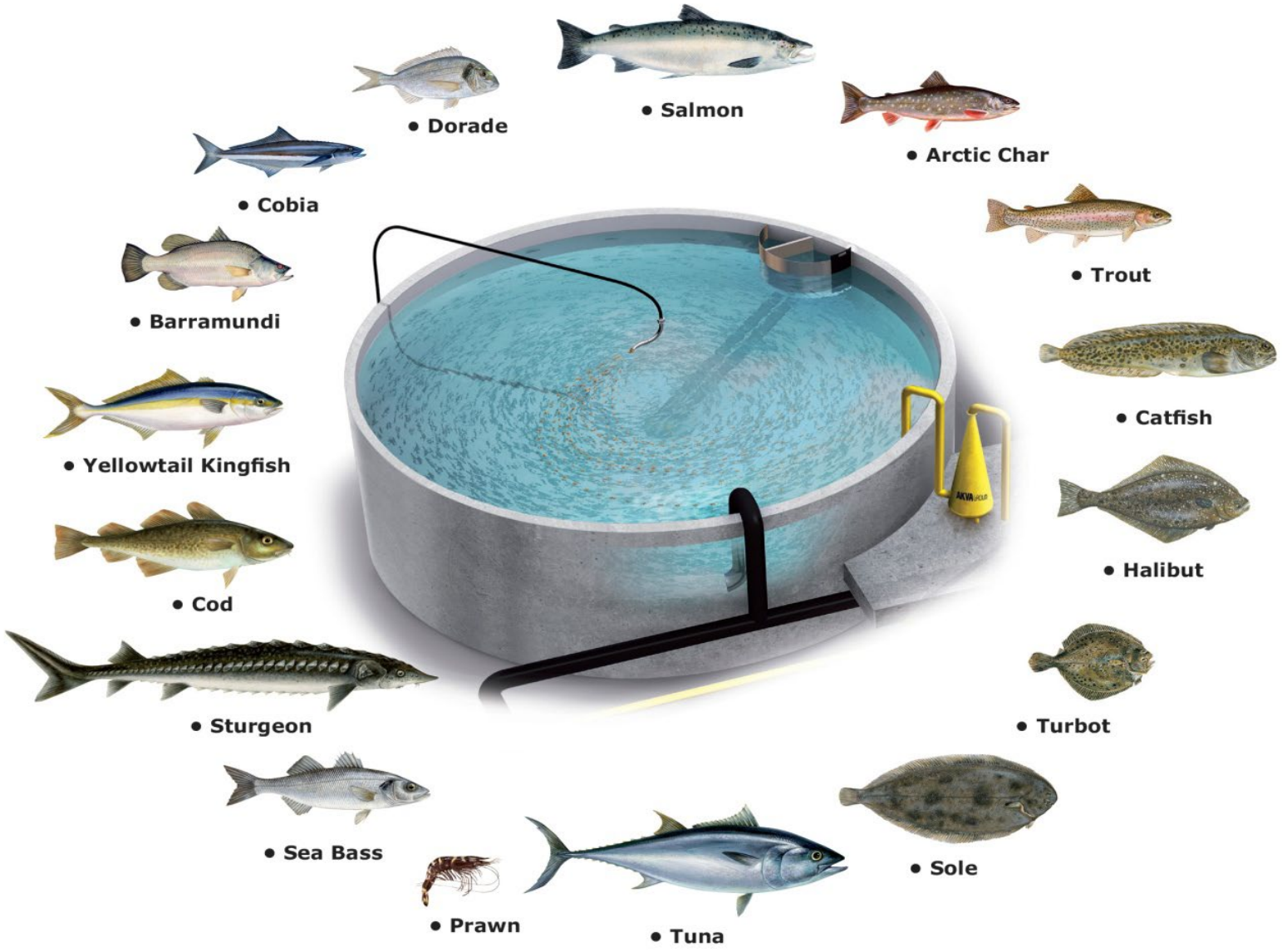
Recirculating Aquaculture Systems (RAS)

Water Treatment Components



In cooler zones, or where water discharge is restricted, RAS units provide continuous water treatment, using mechanical filtration, microbial treatment and aeration/stripping, oxygen enrichment and UV disinfection

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



Hybrid Stripped Bass Production at Kent SeaTech Corporation in California

Recirculating System for Largemouth Bass in Missouri

4,200 gal grow-out tanks, 1,500-gallon biofilters with plastic media

Capital costs ~ $5.00/gallon, Fish selling price ~ $6.00/lb

Carrying capacity; 12,000 lbs largemouth bass

Missouri Farmers Ask,
Can Aquaculture Expand Farm Production and Income?

Marine Shrimp and Stripped Bass

ADVANCING AQUACULTURE IN THE MIDWESTERN REGION
(NCRAC Funded Project - $177,158, 2024-2025)

Extension
University of Missouri

PI: David Brune Professor, University of Missouri

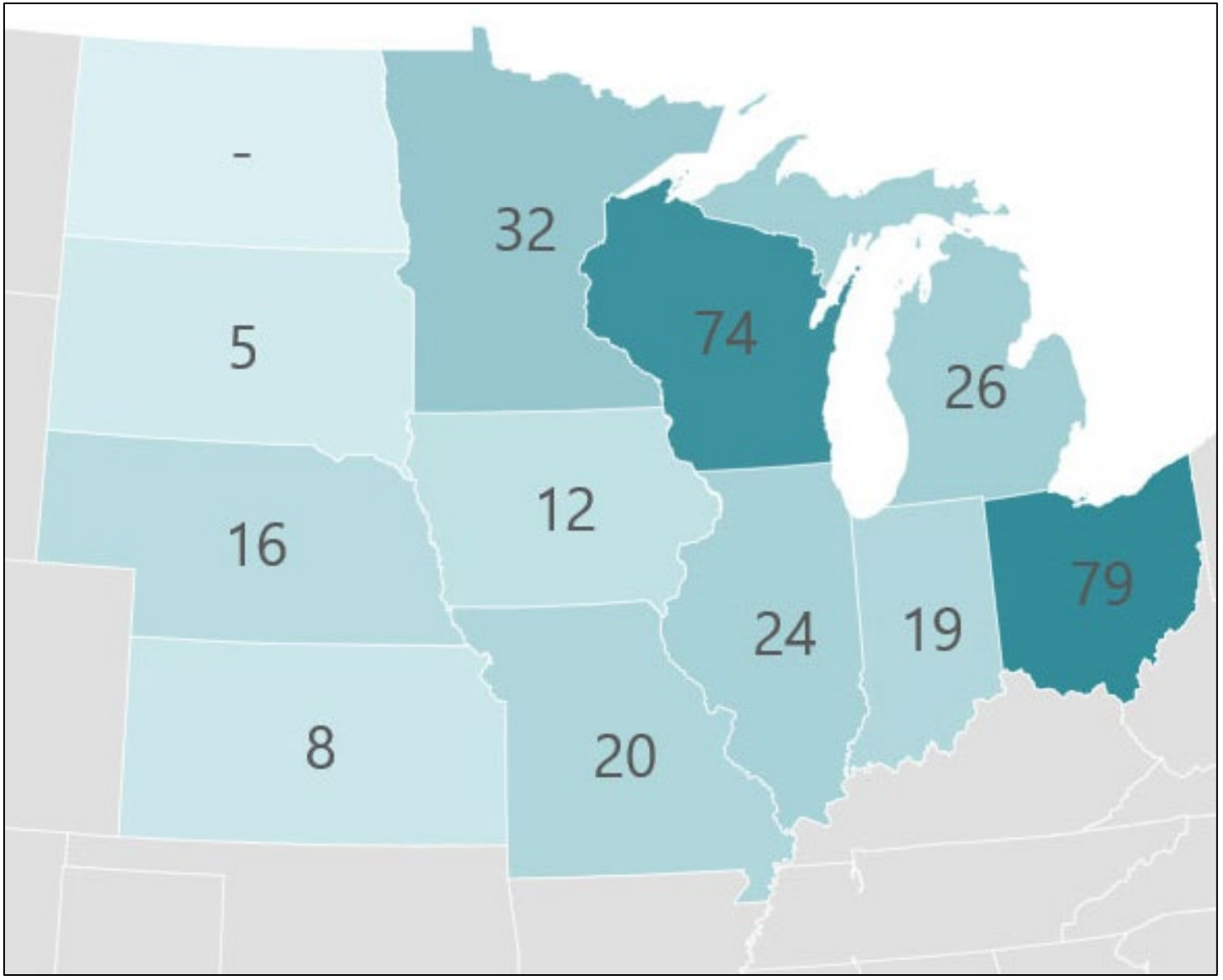
Co-PI(s): Paul Brown and Kwamena Quagrainie Purdue University, Dong Fang Deng, University of Wisconsin, Simone Valle de Souza, Michigan State University, Ryan Milhollin, Mallory Rahe, Adauto Roacha, and Robert Pierce, University of Missouri.

Justification

For Midwestern aquaculture to grow, we must understand how to expand into new markets and how to design efficient and cost-effective systems capable of maximizing business performance and economic success.

Project Objectives

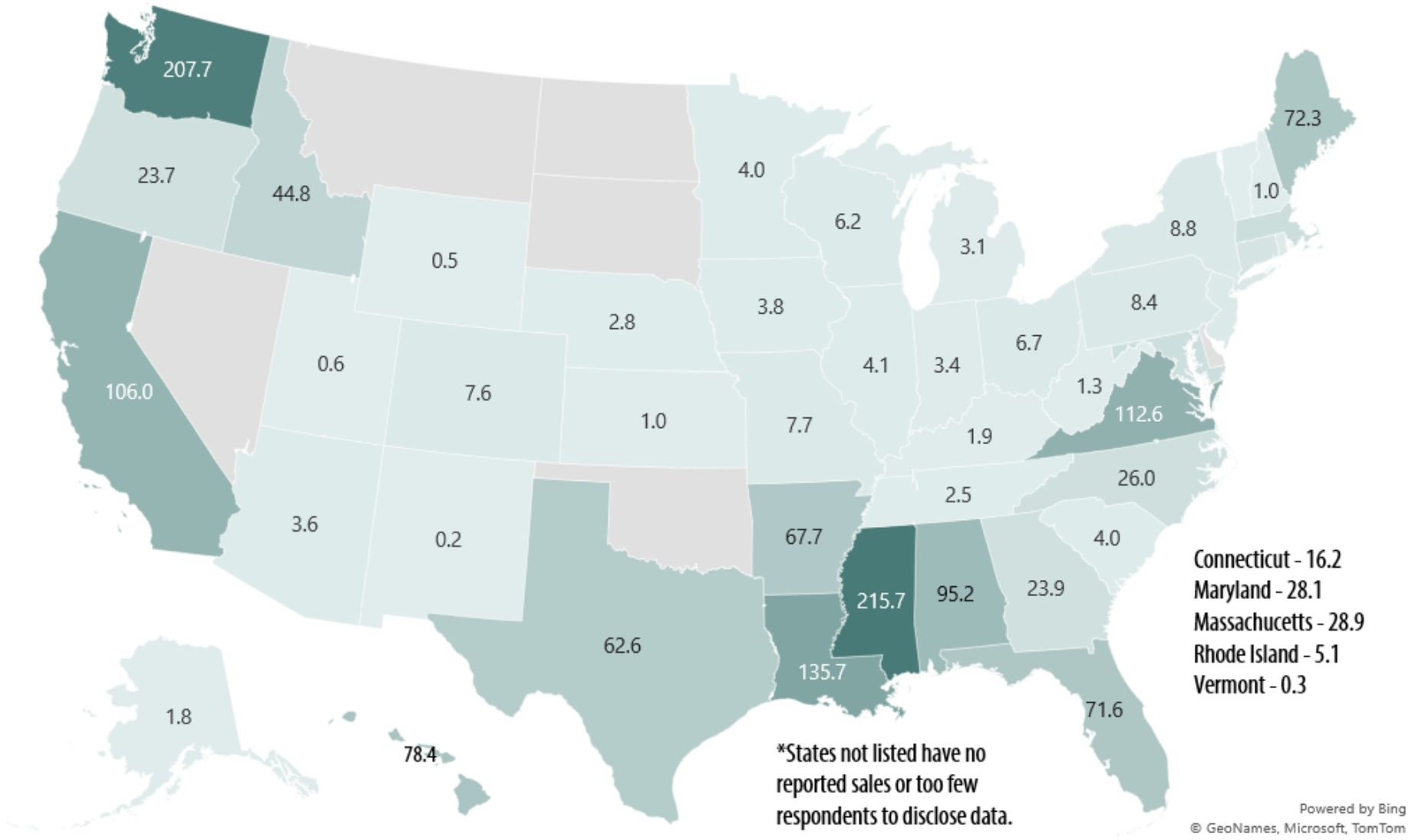
- Objective 1 – Summarize trends and outlook for U.S. and Midwestern aquaculture.
- Objective 2 – Conduct site visits supporting a needs assessment of existing Midwestern aquaculture producers.
- Objective 3 – Conduct consumer survey via distributed questionnaires to determines north central regional aquaculture needs and potentials.
- Objective 4 – Provide business model/enterprise budgets for most promising Midwestern aquaculture species and cultural operations.
- Objective 5 – Develop aquaculture educational materials, provide training sessions, webpages and symposium presentations.



Aquaculture Farms in North Central Region, 2023

Wisconsin and Ohio largest number of farms

Aquaculture in the U.S.: Major Production Areas



U.S. Aquaculture Sales, in Million Dollars: USDA 2018

Mississippi (catfish) and Washington (mollusks) dominate sales

Aquaculture Site Visits in North Central Region

Hanilu Farms (Barramundi), Cutler Indiana

Tippco Fish Inc (Tilapia), Romney Indiana

Freshwater Farms of Ohio (Trout), Urbana Ohio

Harrietta Hills Trout Farm (Trout), Harrietta Michigan

Millcreek Perch Farm (Yellow Perch), Maryville Ohio

Ozark Fisheries (Ornamental Fish), Stoutland Missouri

Gollon Brothers International, Ltd (Bait), Stevens Point Wisconsin

Superior Raceway Systems, Stevens Point Wisconsin

RDM Aquaculture LLC (Shrimp), Fowler Indiana

Rushing Waters Fisheries (Trout), Palmyra Wisconsin

Site Visits to Date

Ozark Fisheries in Missouri. 300 acres of pond-reared goldfish. Selling to wholesale markets and direct on-line consumer sales

RDM Shrimp in Indiana. Pacific White Shrimp in biofloc RAS tanks. Selling seed shrimp to growers and heads-on shrimp direct to consumers

Hanilu Grow-out tanks

Hanilu Farms in Indiana. Barramundi in 1,600 gallons of RAS tanks. Selling live fish to wholesale market

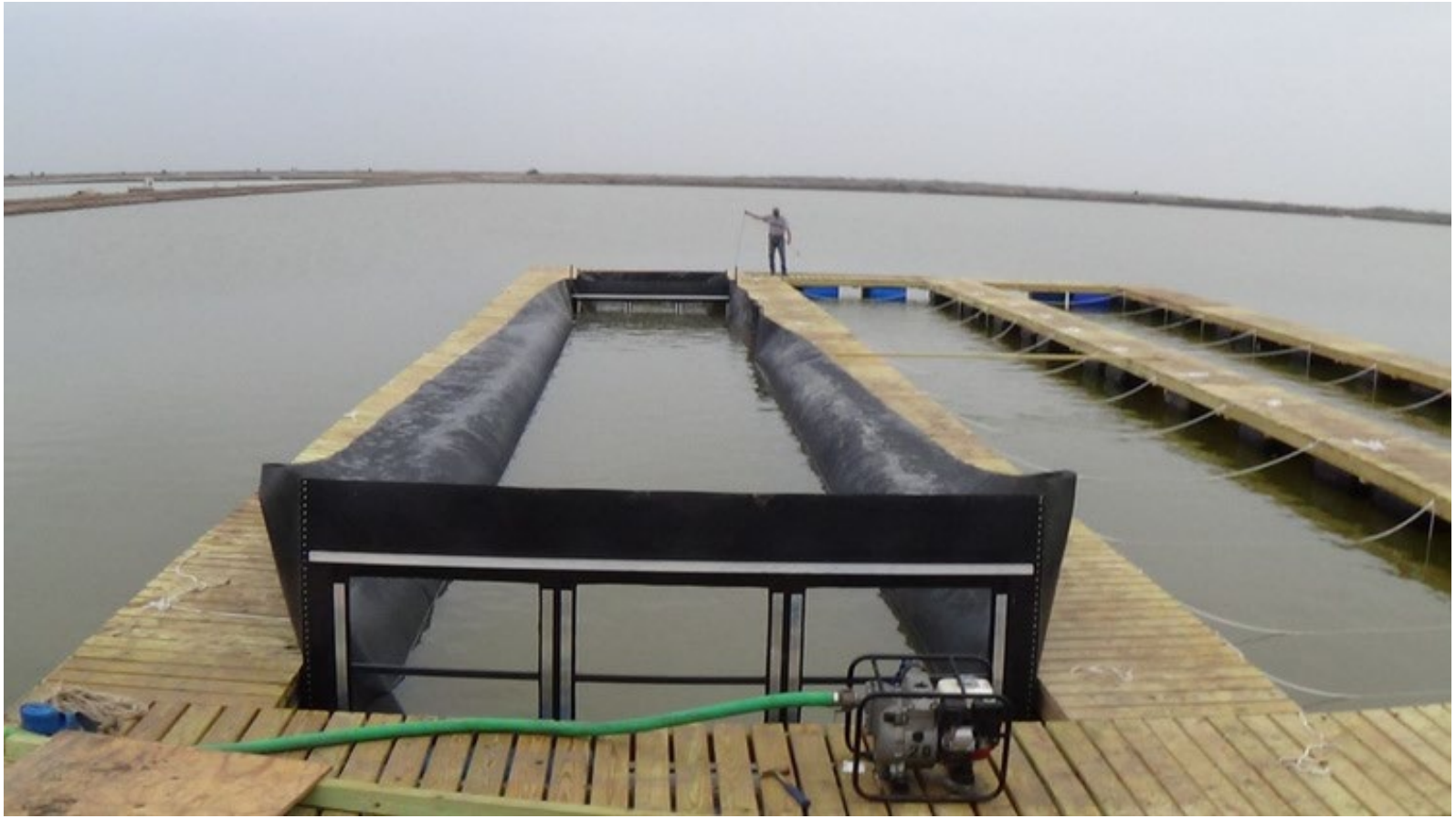
Freshwater Farms Smoked Trout and Trout Filets

Freshwater Farms of Ohio. Trout production in RAS and ponds.
Selling smoked trout and processed fish-fillets direct to consumers

Aerial View of Big House Fish Farm

Big House Fish Farm of Illinois. 10 acres of pond reared large mouth bass. Selling to wholesale live markets.

Superior Aquaculture selling in-pond raceways to companies in U.S., Africa, and Canada Raceways containing 48,000 gallons of water. Water flow provided via air-lift pumps powered by regenerative blowers. Raceways typically placed in 2-to-4-acre ponds.



Superior Aquaculture LLC in Wisconsin, Selling In-Pond Raceways

2024/2025 OUTCOMES/BENEFITS

Midwestern aquaculture trends and outlook summary

Report documenting consumer demand/willingness to pay, and identification of buyers/preferences for a variety of aquaculture products

Aquaculture business models/enterprise budgets supporting cost-effective expansion of existing aquaculture operations and establishment of new enterprises.

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Evaluation of Prototype, Zero-Discharge, Temperature-Controlled, Recirculating Aquaculture System 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

Water Supply

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

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

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 (32% fillet)	0.80-1.00/lb	0.85-1.25/lb	5.00-6.00/lb	8.0-11.00/lb
Shrimp (60% heads)	1.50-1.90/lb	2.00-3.00/lb	5.00-6.00/lb	6.00-11.00/lb
RAS				
Shrimp (60% heads)	8.00-9.00/lb			15.00-18.00/lb whole
Bass (32% fillet)	4.00-6.00/lb	5.00-6.00/lb	15.00-18.00/lb	20.00-28.00/lb

Recirculating System Production Costs, Marine shrimp = 8.00-9.00/lb, Bass = 4.00-6.00/lb

Typical Commodity Farm-Gate Price, Catfish = 1.25/lb, Bass = 6.00/lb, shrimp =3.00/lb

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

Break-even cost dependent on scale, species, productivity, RAS costs 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 = 4 to 6-fold over farm-gate or dock-side prices. However, retail seafood prices allow 10-20% profit margins

Summary

- Zero-discharge, controlled-climate, RAS production costs range from $4.20/lb (fish) to $9.23/lb (marine shrimp)
- 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?

Potential Global Impacts of Aquaculture

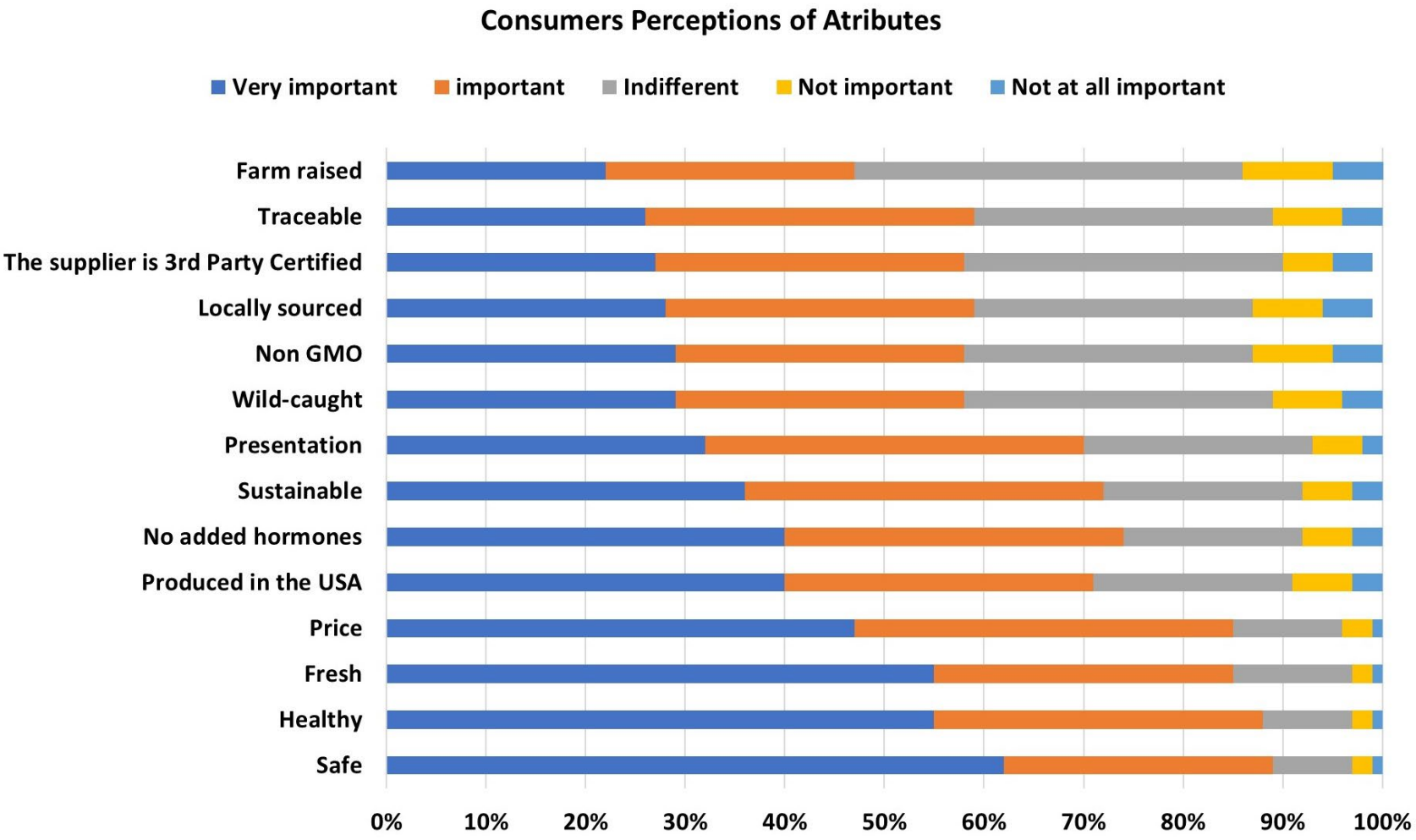
Threats (external costs)

Wild-caught fish used in fish meal
Pesticides, heavy metals in water/product
Nutrient enrichment/eutrophication of water
Wild seed-stock harvest
Habitat modification/destruction
Aquatic disease, pathogens, parasites

Remedies (direct costs)

Fish-meal replacement/substitutes
Regulatory system to mitigate impact
Hatchery for seed production
Proper siting
Zero-discharge RAS

U.S. consumption of lower-cost (imported) seafood enables global impacts while restricting U.S. aquaculture development



Consumers are more interested in safety and healthfulness of seafood than sustainability

De Souza, S., Quagrainie, K., Knudson. W., and April Athno, Go FISH: U.S. Seafood Consumers Seek Freshness, Information, Safety, and Health Benefits, Agricultural & Applied Economics Association V 36, # 4, 2021

In 2015, FDA examined 2.2 percent of imported seafood entry for a variety of food safety issues. FDA tested 0.1 percent of 1 million seafood samples to detect unsafe residues. Imported seafood that tested positive included, 9% of catfish, 12% of shrimp, 11% of tilapia 11% and 7% of other*

2010 -2015, FDA refused entry into U.S. of 1,726 seafood products for drug-related violations. Majority were exports from four countries: China (37 percent), Malaysia (28 percent), Indonesia (12 percent), and Vietnam (11 percent). Of refusals, shrimp represented 54%, tilapia 32%, and catfish 7%,

Will 10-12 % contamination level in imported seafood encourage U.S. consumers to shift to safe local products?

*IMPORTED SEAFOOD SAFETY United States Government Accountability Office, U.S. Senate September 2017

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