ECONOMIC IMPACT ASSESSMENT AND MONITORING PROGRESS OF TECHNOLOGY ADOPTION IN THE U.S. CATFISH INDUSTRY

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PROJECT OBJECTIVES

Objective 1.	Determine the economic impact of the U.S. catfish industry
Objective 2.	Monitor the adoption of production-enhancing technologies in the U.S. catfish industry

ANTICIPATED BENEFITS

The catfish industry is the largest aquaculture segment of U.S. aquaculture contributing significantly to local employment, economic activity, food production, and poverty alleviation. It is vital to measure the current economic contribution of this industry at the state and regional levels, given the recent changes in economic structures of the industry and the recent adoption of productivity-enhancing technologies. Researchers from three institutions collaborated to quantify the economic contribution of the catfish industry in the three major catfish-producing states (Alabama, Arkansas, and Mississippi). An analysis-by-part approach using input-output modeling techniques was employed to detail the contribution of the catfish industry to the three state and tristate regional economies, as well as the specific contribution of farms and supply-chain partners (processing plants and feed mills) to the regional economy for the year 2019. The results provide vital insights into those sectors of local economies that are most influenced and supported by the catfish industry. The project also provides inferences into the ongoing technological progress on catfish farms by measuring the on-farm adoption of alternative catfish production technologies (split-ponds, intensively aerated ponds, in-pond raceway systems) and complementary technologies (i.e., fixed paddlewheel aeration, hybrid catfish, and oxygen monitoring systems). This study captured recent trends and dynamics of sales, cost structures, and farming methods in the catfish industry, and provides the most comprehensive and current estimates of the economic contribution of the industry along with the progress of on-farm adoption of productivity-enhancing technologies. This extensive survey-based approach that resulted in detailed information at the farm, processor, and feed mill levels, paves the way for future input-output modeling studies for other U.S. aquaculture industries.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS

Objective 1. Determine the economic impact of the U.S. catfish industry

(Mississippi State University/Virginia Tech/Auburn University)

The catfish industry continues to be the leading U.S. aquaculture sector constituting about 35% of total U.S. aquaculture sales in 2018. The economic impact/contribution[1] of an industry such as the U.S. catfish industry to regional economies is much greater than just the direct farm gate sales as the industry supply chain involves several diverse value chain actors. Prior studies found that the catfish industry had complex interactions in the economy contributing significantly towards local employment, rural income generation, poverty alleviation, and food production. Such industries are vital for the economic development of southern U.S. economies, which are characteristically rural with economic challenges that include relatively low living standards, low per capita income, and high rates of unemployment. Documenting the economic impact of the catfish industry within the three major catfish producing states of Arkansas, Alabama, and Mississippi informs policy-making agencies of the overall economic contributions and the number of other economic sectors supported by the industry. This study was specifically aimed at quantifying the economic contribution of the catfish industry in the three major production states (Alabama, Arkansas, and Mississippi) in terms of generation of revenue, jobs, income, and tax revenue generated in each respective state and to the region.

Survey and data collection

A survey of catfish farms and their related supply-chain partners (feed mills and processing plants) was conducted during 2019-2020 to collect data on specific revenue and spending patterns in these segments of the catfish industry. Three separate questionnaires were prepared for interviewing catfish farms, feed mills, and processing plants as their cost structures differed substantially from each other. The surveys were designed as a census of all catfish farms (catfish hatcheries and foodfish farms) and related supply-chain partners (feed mills and processing plants) in the tristate region. Extension specialists in respective states sent out a notice of the survey to the catfish farmers in their respective states for which they had mailing addresses. The informational notice was followed by telephone calls to request personal interviews. Of the 291 farms listed in the tristate region, there were 68 completed responses, for a response rate of 23% and a 66% coverage rate of the total production area (Table 1). Fourteen of the 16 supply-chain partners responded (88% response rate) to the survey. Figure 1 depicts the geographical spread of the catfish farm survey responses in the tristate region. The farm survey was conducted with in-person interviews, and the supply-chain survey was conducted by telephone. The length of interviews varied from 0.75 to 3.5 hrs. (mean ~1.5 hrs.).

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[1]There is a technical difference in the economics discipline between economic “impact” and “contribution” . Although, the lay person and most used term “economic impact” is used throughout this work, what is being requested is, technically, an analysis of the “economic contribution” of the catfish industry. The distinction is that an economic contribution analysis does not account for what alternative contributions might be made to the economy in the absence of the industry in question. An economic contribution analysis traces expenditures as they flow through the economy and quantifies the resultant economic linkages.

Table 1. List frame, responses, and coverage rate of the survey conducted in the tristate region of the U.S. catfish industry.

Industry components	List frame	Completed	Rate (%)
Farms			
Number of responses	291	68	23%
Area coverage (acres)	56,800	37,613	66%
Supply-chain partners			
Feed mills, number	6	5	83%
Processing plants, number	10	9	90%

Note: Arkansas did not have any feed mills or processing plants while Alabama did not have catfish hatcheries.

Catfish farms have forward linkages[2] with processing plants and backward linkages with feed mills whereas processors have backward linkages with farms, while a feed mill has a forward linkage to catfish farms. The four actors in the catfish industry (i.e., catfish hatcheries, foodfish farms, feed mills, and processing plants) were modeled together in the state-specific and tristate regional models. However, separate models estimated the impacts of "*farms*" and "*supply-chain partners*" individually in the tristate region. For this purpose, the economic contributions of the hatchery and foodfish farms were combined and referred to as "*farms"* to protect their confidentiality. Similarly, the economic contributions of feed mills and processing plants were also combined and reported as "*supply-chain partners*".

AL = Alabama
AR= Arkansas
MS = Mississippi

Figure 1. Tristate regional map highlighting the approximate location of the 68 farms surveyed, 2019-2020. The 14 responding supply-chain partners are not shown to preserve confidentiality of responses.

[2]A forward linkage in an economy occurs when economic activity in a particular sector boosts economic activities in subsequent stages of production while a backward linkage arises when investment in one sector creates demand for goods and services that are purchased as inputs in another sector.

Accounting for non-responses

To estimate the economic impact/contribution of the entire industry requires accounting for the revenue and expenses from farms and supply-chain partners that did not participate in the surveys. Revenue values for non-respondents were estimated by adjusting for the total volume of production and sales in 2019 for each state following USDA-NASS reports as well as the latest USDA Census of Aquaculture. Expenses on non-responding farms (76% of the farms and 33% of the farmed area) were estimated accounting for the cost structure of the average farm size of the non-responding area[3] and the number of non-respondents in that state (Table 2). Farm non-respondents were mostly smaller farms ranging between 57 to 94 acres. The spending patterns per acre on similar small-sized farms (60 to 100 acres) in each state were used to estimate weighted averages of the respective expenditures of non-responding farms. A similar approach was adopted to estimate expenditures of the few non-responding supply-chain partners.

Economic impact of the U.S. catfish industry

The economic impact of the U.S. catfish industry for 2019 was determined in a two-step process. Step 1 collected basic descriptive summaries of the U.S. catfish industry at the national, tristate regional (tristate region of Alabama, Arkansas, and Mississippi), and individual state (Alabama, Arkansas, and Mississippi) levels. This summary described the current status of the catfish industry and included data on farms (both foodfish and hatcheries), feed mills, and processing plants (Table 2). Data collected included the number of entities in each category, volumes of production, and water surface acres of farms in the three states as well as the tristate region.

Table 2. Basic production metrics of the catfish industry at regional and state levels.

Description	Alabama	Arkansas	Mississippi	Tristate
Number of farms[a]	96	34	161	291
Number of farms surveyed	24	12	32	68
Area under catfish production (acres)[b]	16,800	4,300	35,700	56,800
Area surveyed (acres)	10,926	3,053	23,634	37,613
Non-responding area (acres)	5,874	1,247	12,066	19,187
Average size of non-responding farm (acres)	82	57	94	86
Catfish production (million lb)[c]	102.5	18.6	203.5	324.6
Catfish feed production (tons)[c]	*nd*	*nd*	*nd*	450,438
Processed product volume (million lb)[c]	*nd*	*nd*	*nd*	167.5

[a]Census of Aquaculture, 2018, USDA- NASS, Agricultural Statistics Board.
[b]Catfish production, 2020, USDA- NASS, Agricultural Statistics Board.
[c]Hanson, T. R., 2019. Catfish processing feed deliveries reports, Monthly reports for The Catfish Institute, 2019.
nd= values are not disclosed to preserve confidentiality in responding and non-responding values of supply-chain partners owing to the limited number of members in the industry relative to the number of catfish farm operations.

[3] Obtained by dividing the non-responding area in that state by the number of non-responding farms in that state.

Step 2 of the project quantified the economic linkages of the catfish industry in the three study states (Alabama, Arkansas, and Mississippi) by constructing input-output (I-O) economic models. Models were created separately for the tristate region as well as for the three states. These state and regional models incorporated the sales and expenses from catfish farms (foodfish farms and hatcheries) and off-farm supply-chain partners (feed mills and processing plants). Additional models were created to separately quantify the economic impacts of catfish farms and supply-chain partners in the tristate region.

An IMPLAN-based (Impact Analysis for Planning, MIG, Inc., North Carolina 1997) input-output approach was used for this purpose employing the 2018 IMPLAN database. The databases consisted of matrices of technical coefficients that account for the backward and forward linkages related to all economic activity in the geographic regions selected for analysis.

Input-output models have the advantage of measuring linkages throughout local and regional economies. Although it requires exhaustive data to arrive at realistic estimates, it was selected over other models[4] as it 1) explicitly measures the interdependencies of various industries through the flows of goods and services throughout the local, state, and regional economies of interest; 2) the IMPLAN framework is the most commonly used type of economic impact analysis, and its choice allows results to be directly compared to those obtained for other sectors; 3) the IMPLAN Pro® database is updated annually primarily on data from several U.S. federal agencies[5] and avoids the necessity of the extremely high cost to develop such a dataset; and 4) advanced users of IMPLAN can incorporate user-supplied data for sectors such as catfish that are not disaggregated from other animal and fishing industries in the economic datasets compiled across the U.S. Additionally, the IMPLAN-based approach was best suited to provide the type of results identified as most important (jobs, sales, tax revenue, and economic impact) by the Industry Advisory Council of the Southern Regional Aquaculture Center (SRAC).

IMPLAN models generate linear production functions that relate outputs from a particular industry to the inputs required for that level of output. The modeling approach begins with the linear relationship between the total output q from sector i, expressed through a generalized I-O model framework as the sum of goods and services sold to other sectors, z_{ij}, and to that is sold to the final demand sector, f_i and functionally expressed as:

$$q_i = \sum_{1}^{N} (z_{ij} + f_i)$$

where i and j can take values from 1 to N. The variable z_{ij} is a unique linear function of output q_j; which when divided by q_j results in a matrix of the technical coefficients of the input-output model. Inversion of the matrix allows for representation of the input-output model:

$$q = [I - A]^{-1} * F = \begin{pmatrix} m_{ij} & \cdots & m_{ij} \\ \vdots & \ddots & \vdots \\ m_{ij} & \cdots & m_{ij} \end{pmatrix} * F \ = M * F$$

[4]Alternative approaches to economic impact analysis include economic simulation models, computable general equilibrium models, econometric modeling, REMI (Regional Economic Modeling, Inc.) and LM3 (Local Multiplier 3) models, etc.
[5] U.S. Bureau of Economic Analysis, U.S. Bureau of Labor Statistics, U.S. Census Bureau, U.S. Department of Agriculture, and US Geological Survey

where I is an identity matrix, A is the matrix obtained by dividing z_{ij} by q_j, and m_{ij} are the supply chain interaction coefficients in the matrix M. Therefore, the output multiplier for each sector j, can be obtained by dividing M by i. These multipliers capture the economic effects (rates of change) resulting from basic level production (farm-level or supply-chain level) and allow for estimation of the direct, indirect, and induced effects of spending activity in the catfish industry within each of the three states and the tristate region. Direct effects express the economic impacts within the sector where the expenditures are first incurred. For example, catfish firms employ local and regional labor and incur other input expenses in the process of producing catfish products that generate revenue. Indirect effects result from activities of the suppliers of the goods and services that are the inputs needed to produce the catfish products that meet the demand for catfish. Catfish farms purchase key inputs such as feed, fingerlings, and make expenditures for labor and other key services such as custom harvesting and live hauling, electricians, and vehicle repair mechanics from other companies. These businesses rely to varying degrees on catfish production for their viability. Induced effects arise from household spending of wages by the employees in the catfish industry and in those secondary businesses that supply inputs and services to the catfish industry. Similar to obtaining the multiplier for output, multipliers for employment, labor income, and value addition depicted the rate of changes of those variables in the economy due to their economic effect in basic level production (farm-level or supply-chain level).

County-level IMPLAN datasets were purchased from The IMPLAN Group (MIG, Inc., North Carolina) for Alabama, Arkansas, and Mississippi for the year 2018. IMPLAN does not contain a dedicated sector for aquaculture; instead, aquaculture is grouped with other forms of animal production (excluding cattle, poultry, and eggs). Given that the dataset does not disaggregate the catfish sector, an "Analysis-By-Parts" (ABP) technique was employed to create a customized industry sector, thereby delineating an industry that is not well represented in the IMPLAN database. The Analysis-By-Parts technique is a process of parsing an impact analysis into more specific parts and details their budget expenditures and income. It is the most appropriate and accurate approach for modeling an industry that is a subset of a current IMPLAN sector, the case for the catfish industry. This allows for greater flexibility and model customization and allows for the specification of commodity inputs, the proportion of local labor income, local purchases, and for the use of IMPLAN's special spending patterns.

Successful employment of the ABP approach would first require the determination of the direct economic effects of the catfish industry. These direct effects (revenue generated or direct employee compensation) were obtained from the industry survey data and adjusted for non-response, as described previously. To calculate the indirect effects, an industry spending pattern was created to reflect industry spending activity. The expenses made by primary sectors of the catfish industry in business that provide inputs and services to the catfish industry were recorded as expenses. These service and input suppliers included equipment manufacturers and dealers, custom harvesters, transportation services, banks, pond builders, vehicle repair shops, shipping services, insurance companies, accounting firms, and other secondary suppliers. A spending coefficient for each expense category was obtained as a ratio of the individual expense of categories of secondary industries over the revenue generated by the catfish industry actors. The coefficients calculated from the standardized enterprise budget were then assigned to the respective NAICS sector codes. Such an industry spending pattern was created for each model viz: tristate model, state model, farm model, and supply-chain partner model. The induced effect of the catfish aquaculture industry in the three respective states was calculated by adding a labor income change to the model to account for employee compensation (EC). Again, labor income change is specific for each model (farms and supply-chain partners) and represents the employee wages and proprietor income. All models were run without any scale modification.

Six IMPLAN models were created each outlining the contribution of 1) tristate region (Alabama, Arkansas, Mississippi), 2) Alabama, 3) Arkansas, 4) Mississippi, 5) catfish farms and 6) catfish supply-chain partners. Customized expenditure patterns were created for each of these models in Microsoft Excel® from the survey data. Enterprise budgets, adjusted for non-response, were utilized to calculate the coefficients of the different expenditures resulting from catfish industry activities. These coefficients were used to develop the IMPLAN industry spending pattern for the catfish production area in each of the three states. Standardized enterprise budgeting techniques were used with uniform valuation methods and a standardized cost structure for aggregation across the three states. Each line item from the survey responses was summed to create customized expenditure patterns for each catfish-related business. The expenditures ($) were converted into spending coefficients (fractions of expenditure over revenue) and coded by the appropriate NAICS (North American Industry Classification System) sector codes. The calculation of the expenditure coefficient ε is shown as

$$\epsilon_\theta = \frac{\sum_{i=1}^{n} C_i - \sum_{i=1}^{n} W_i - \sum_{k=1}^{n} Z_k}{\sum_{i=1}^{n} (W_i + X_i)} + \frac{\sum_{j=1}^{n} C_j - \sum_{i=1}^{n} X_i}{\sum_{j=1}^{n} Y_j} + \frac{\sum_{k=1}^{n} C_k}{\sum_{k=1}^{n} Z_k}$$

where, ϵ_θ is the expenditure coefficient, on i^{th} farm or j^{th} processing plant or k^{th} feed mill with *i, j, k* taking integer values between 1 and *n*; *W is the r*evenue from fingerlings sales; *X* is the revenue from foodfish sales; *Y* is the revenue from fish processing; *Z* is the revenue from feed mills; *C* is the cost item in respective catfish industry actors.

The coded expenditure patterns were later imported into IMPLAN. This helped in identifying the sector in IMPLAN which includes the data for relevant line items under an existing non-basic industry. On identifying the industry, a new catfish industry spending pattern and labor-income change were created to disaggregate the economic contributions of the specific basic industry under consideration. Appendix 1 provides an example of calculating the respective expenditure coefficient (ϵ_θ) from the details of quantities, prices, revenue, and expenses generated for ABP purposes and their respective links to IMPLAN sectors, specified for a typical catfish farm producing foodfish.

The IMPLAN analysis also identified the sectors of state and regional economies that benefit the most from the business activity generated by the catfish industry in the tristate and individual state economies. Further, the IMPLAN output generates the resultant jobs, labor income, and economic value addition into direct, indirect, and induced economic effects. The labor income effect is a summation of the labor spending and proprietor income. Value addition in an economy is the sum of labor income and taxes on production/imports and income from all other properties (Figure 2). Local state and federal taxes generated by the catfish industry actors in the respective states and tristate region were generated.

Prior economic impact assessment in the catfish industry accessed the backward linkage of the industry direct output effect at the top of the supply chain, i.e., economic activity at catfish processing plants and their associated backward linkages in the supply chain. However, such approaches do not completely capture neither the specific economic activities (expenditure patterns and revenue generation) occurring at various actor levels of the industry actor such as feed mills, hatcheries, and foodfish operation, nor the diversity in production strategies associated with various production phases. A distinct advantage of the ABP approach adopted in this work was to delineate the economic contribution of all actors of the catfish production process which included farms and supply-chain partners. This allowed for the complete capturing of revenue generation by various catfish industry actors without double counting output in forward linkages. Thus, this model captured actual revenue generation at each industry actor level while avoiding double counting the sales generated at each level by counting it only once as ex-gate revenue and not again as an expense in the respective forward linkages. For example, the revenue generated in catfish feed mills was accounted as sales output (direct effect) of feed mills and not counted as a feed expense in hatchery and foodfish operations. Similarly, the revenue generated from the sale of fingerlings was counted as sales output (direct effect) in catfish hatcheries only and not as a fingerling expense on foodfish operations (See Appendix 1). Fish sales from foodfish farm operations were counted as their sales output (direct effect) and not as fish expenses in processing plants (Figure 3).

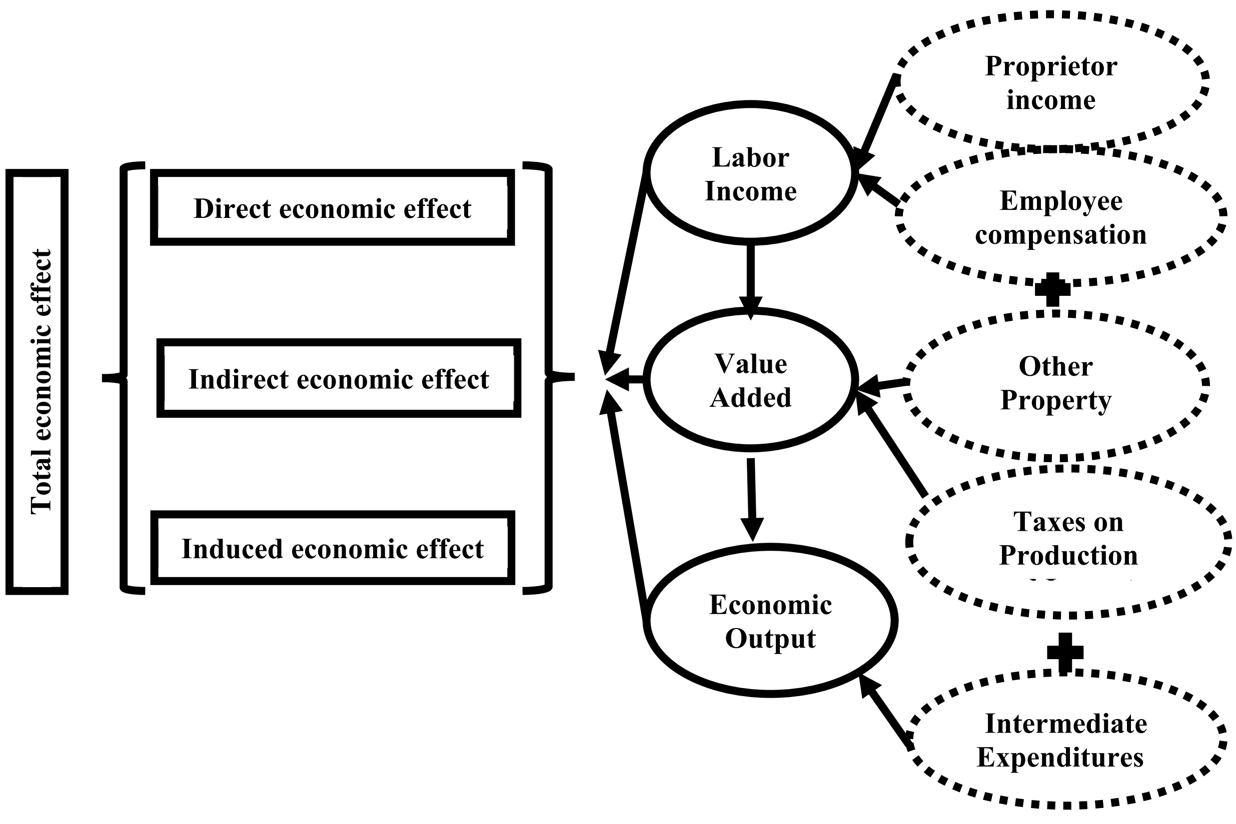

Figure 2: Conceptual diagram of labor income and value addition calculation done by IMPLAN.

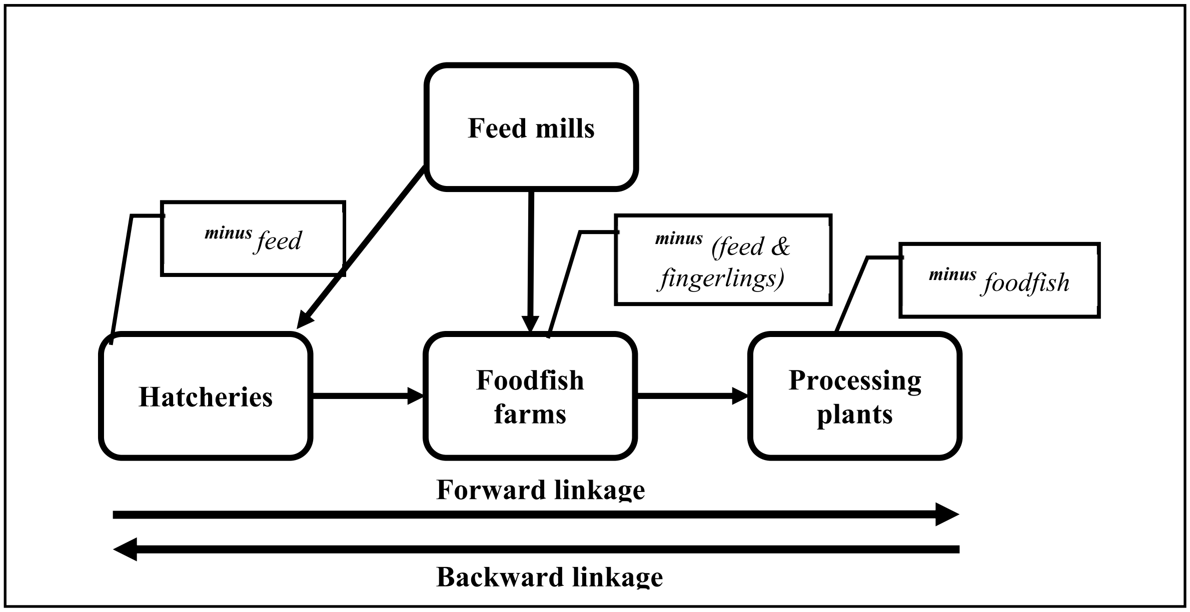

Figure 3. Conceptual diagram of forward and backward linkages of the catfish industry actors. Revenues generated from outputs at one level were not added to expenditures in subsequent forward links.

Additionally, a separate ABP analysis was performed to analyze the economic impact of the catfish industry in the tristate region in recent years preceding 2019 (2016-2018) by creating separate expenditure patterns using prices and quantities of foodfish sold, round weight processed, feed produced, and fingerling sold in the tristate region, *ceretis paribas*[6]. The effect of these changes on the regional economy was recorded in terms of total economic impact, jobs created, and taxes generated for the period from 2016 to 2019.

RESULTS

Description of the study area characteristics

The tristate region of Alabama, Arkansas, and Mississippi was home to ~11 million residents and had a gross regional product of $475 billion, housed 521 different economic industries as identified by IMPLAN, and employed over 3.7 million workers in 2019 (Table 3). The relatively lower population density, per capita income, relatively higher per capita income gaps from the U.S. national average, and high poverty rate depicted the rural and economic challenges of these three Southern states.

[6] keeping all other variables constant.

Table 3. State and regional characteristics of the study area, 2019.

Characteristics	Units	Alabama	Arkansas	Mississippi	Tristate
Gross regional product[a]	$billion	$228	$131	$116	$475
Total employment	nos.	1,053,453	1,758,609	958,126	3,770,188
Number of industries[b]	nos.	509	474	463	521
Land area	sq. mile	50,645	52,036	46, 923	149,604
Population	nos.	4,903,185	3,017,804	2,976,149	10,897,138
Population density	nos./sq. mile	97	58	63	73
Total households	nos.	1,867,893	1,158,071	1,104,394	4,130,358
Persons per household	nos.	2.55	2.52	2.62	2.56
Civilian labor force	%	57%	58%	57%	57%
Mean household income	$	$50,536	$47,597	$45,081	$47,738
Per capita income	$	$27,928	$26,577	$24,369	$26,291
Difference in per capita income from U.S. average	$	-$6,175	-$7,526	-$9,734	-$7,812
Population below poverty	%	15%	15%	19%	16%

[a] U.S. Bureau of Economic Analysis, 2019.

[b] IMPLAN MIG Inc. 2019. All other metrics are sourced from the U.S. census 2019.

An abridged summary of the economic base of the tristate region is provided in Table 4. Housing, petroleum refineries, real estate, poultry processing, electric power transmission, banking, health services, and transportation are some of the top contributors to economic output in the tristate region.

Table 4. Top ten economic bases in the tristate region of Alabama, Arkansas, and Mississippi sorted by output, 2019.

Economic sectors	Employment	Labor Income	Output
Owner-occupied dwellings	$0	$0	$37,688,530,000
Petroleum refineries	3,262	$633,865,900	$26,054,740,000
Other real estate	147,388	$2,686,342,000	$24,337,140,000
Poultry processing	72,031	$3,064,914,000	$21,379,400,000
Electric power transmission and distribution	16,796	$2,239,932,000	$21,271,090,000
Monetary authorities & credit intermediaries	63,649	$4,905,028,000	$20,331,160,000
Hospitals	119,200	$7,853,673,000	$19,358,500,000
Automobile manufacturing	11,159	$1,083,931,000	$17,617,740,000
Offices of physicians	96,600	$9,303,956,000	$16,643,660,000
Truck transportation	105,462	$5,888,804,000	$16,584,560,000

Source: IMPLAN MIG Inc. 2019

Economic contribution of the catfish industry to the tristate region

The catfish industry contributes substantially to the economy of the tristate region with over 95% share of the U.S. catfish production, catfish processing, and feed production. Results from the tristate economic impact model estimated a total economic impact of $1.9 billion for 2019. The direct, indirect, and induced economic effects were $1.1 billion, $553 million, and 255 million, respectively. The industry generated a total of 9,180 jobs with a direct effect of 4,298 jobs, an indirect effect of 3,078 jobs, and an induced effect of 1,804 jobs. The total labor income generated was $418 million, while the total value added was $587 million. A summary of the types and values of economic impacts generated by catfish industry elements in the tristate economy is provided in Table 5.

Table 5. Economic impact of catfish industry in the tristate region of Alabama, Arkansas, and Mississippi, 2019.

Type of impact	Employment	Labor Income	Value Added	Output
Direct economic impact	4,298	$192,678,334	$216,124,324	$1,102,136,449
Indirect economic impact	3,078	$151,834,974	$231,954,487	$553,435,208
Induced economic impact	1,804	$73,075,547	$139,077,293	$254,850,980
Total economic impact	9,180	$417,588,855	$587,156,104	$1,910,422,637

The economic multiplier effect[7] of the catfish industry elements was 1.73 indicating that every $1.00 spent in the industry generated an additional $0.73 in the tristate economy in 2019. The employment multiplier and labor income multipliers were 2.14 and 2.17, respectively. This suggested the generation of 1.14 additional jobs in the tristate economy for every one job created in the catfish industry and an additional $1.17 generated for every dollar of labor wage paid in the industry. Similarly, the value-added multiplier (2.72) suggested that every dollar generated from the catfish industry further generated an economic value of $1.72 in the form of labor income, other property incomes, and taxes on production and imports in the regional economy.

Results revealed several complex, yet significant economic linkages of the catfish industry elements and recognized economic sectors that benefit most from the business activity generated by the catfish industry in the tristate economy (Table 6). Grain farming, banks, truck transportation, electric power generation, and equipment manufacturers were some of the leading industries supported by the catfish industry in the tristate region.
Although the catfish industry does not make direct expenses toward purchasing inputs from sectors such as housing, hospitals, and doctors' offices, the high induced effect generated within these sectors shows the economic relevance of the catfish industry in rural economies. The catfish industry was found to affect 97% (506) of the total 521 IMPLAN listed industries in the tristate region in 2019. The top 10 sectors affected by the catfish industry in the tristate region varied based on employment, labor income, and economic value addition (Table 7). These are the additional jobs, labor income, and value addition generated in the tristate region due to the direct spending in catfish business activities, specifically the indirect and induced effects due to the economic activities in the catfish businesses. Grain farming was the most affected sector based on employment, with an estimated 457 jobs created due to catfish industry activities. This was followed by services to buildings (300 jobs) and non-depository credit intermediaries or banks (273 jobs). Grain farming, truck transportation, and banking sectors were the top three industries affected in terms of labor income generation with impacts of $22 million, $15 million, and $15 million, respectively. In terms of value addition, grain farming, owner-occupied

[7] SAM multiplier = Total economic impact ÷ direct economic impact

dwelling, and banking sectors were the top three industries affected with $25 million, $24 million, and $20 million, respectively.

Table 6. Effect of catfish industry on the economic output of the top 15 industries supported in the tristate region of Alabama, Arkansas, and Mississippi, 2019.

Economic sectors	Direct	Indirect	Induced	Total
Grain farming	$89,993,538	$75,787,971	$82,749	$165,864,258
Non depository credit intermediaries	$48,300,226	$39,216,071	$2,104,715	$89,621,013
Truck transportation	$38,022,836	$39,962,888	$2,704,761	$80,690,484
Electric power generation	$36,448,013	$24,729,107	$852,142	$62,029,262
Farm machinery manufacturers	$23,824,937	$21,624,343	$1,921	$45,451,201
Insurance carriers	$11,827,572	$15,443,205	$6,029,217	$33,299,994
Owner-occupied dwellings	$0	$0	$30,876,781	$30,876,781
Industrial equipment repair	$14,563,804	$15,594,727	$504,937	$30,663,468
Other real estate	$708,551	$17,504,823	$8,197,734	$26,411,107
Automotive repair	$10,358,735	$12,327,468	$2,192,025	$24,878,228
Building repair and maintenance	$9,467,458	$12,516,055	$1,115,898	$23,099,411
Depository credit intermediaries	$0	$13,173,398	$9,109,833	$22,283,231
Insurance agencies & brokerages	$0	$11,443,647	$4,319,518	$15,763,165
Hospitals	$0	$0	$15,141,459	$15,141,459
Electric power distribution	$0	$9,895,626	$3,517,881	$13,413,507
All other industries (491)	$818,620,779	$244,215,879	$168,099,411	$1,230,936,069
Total economic impact (521)	$1,102,136,449	$553,435,208	$254,850,980	$1,910,422,637

Table 7. Top 10 industries affected by catfish industry activities in the tristate region based on the contribution to employment (jobs), labor income ($), and value addition ($), 2019.

Industry description	Employment	Industry description	Labor Income	Industry description	Value Added
Grain farming	457	Grain farming	$22,366,252	Grain farming	$25,490,093
Services to buildings	300	Truck transportation	$15,139,231	Owner-occupied dwellings	$24,332,748
Non depository credit intermediation	273	Non depository credit intermediation	$14,823,776	Non depository credit intermediation	$19,508,698
Truck transportation	268	Industrial equipment repair	$7,901,494	Truck transportation	$18,564,349
Other real estate	154	Automotive repair	$6,817,624	Depository credit intermediation	$12,020,727
Automotive repair	149	Offices of physicians	$6,668,937	Power generation-Fossil fuel	$10,078,626
Support activities for Ag. and forestry	139	Hospitals	$6,154,933	Industrial equipment repair	$9,943,144
Industrial equipment repair	124	Support activities for Ag. and forestry	$6,022,341	Automotive repair	$9,693,676
Full-service restaurants	120	Services to buildings	$5,674,395	Insurance carriers, except direct life	$8,618,115
Employment services	115	Depository credit intermediation	$5,439,327	Offices of physicians	$7,864,892
Limited-service restaurants	106	Insurance agencies & brokerages	$4,052,375	Other real estate	$7,789,256
Hospitals	92	Building repair/maintenance	$3,738,526	Hospitals	$7,473,878
Retail-Gasoline stores	89	Management of companies/enterprises	$3,715,345	Tenant-occupied housing	$6,497,941
Religious organizations	77	Employment services	$3,676,491	Services to buildings	$5,919,639
Building repair/maintenance	76	Religious organizations	$3,394,678	Support activities for Ag. and forestry	$5,866,924
All other industries	2,344	All other industries	$109,324,795	All other industries	$191,369,072
Indirect & induced impact	4,882	Indirect & induced impact	$224,910,522	Indirect & induced impact	$371,031,780

Economic contribution of the catfish industry to the three major catfish producing states

Alabama

Catfish industry actors in Alabama included foodfish-producing farms, processing plants, and feed mills. Results from the Alabama state economic impact model estimated a total economic impact of $496 million for 2019 (Table 8). The direct, indirect, and induced economic effects were $277 million, $134 million, and 85 million, respectively. The Alabama catfish industry actors (farms and supply-chain partners) generated a total of 2,109 jobs with a direct effect of 794 jobs, an indirect effect of 711 jobs, and an induced effect of 604 jobs. The total labor income and economic value addition were $143 million and $173 million, respectively.

Table 8. Economic impact of catfish industry in Alabama, 2019.

Type of impact	Employment	Labor Income	Value Added	Output
Direct economic impact	794	$69,833,729	$56,082,508	$276,931,427
Indirect economic impact	711	$47,613,205	$69,915,440	$133,866,120
Induced economic impact	604	$25,311,130	$47,363,565	$85,517,250
Total economic impact	2,109	$142,758,063	$173,361,513	$496,314,797

Every dollar expended in the Alabama catfish industry generated an additional $0.79 in the state economy. A job created in the catfish industry in the state of Alabama generated an additional 1.66 jobs in the state economy. Similarly, every dollar of labor wage paid in the Alabama catfish industry generated an additional $1.04 in the state economy. The value-added multiplier (3.09) suggested that every dollar generated from the Alabama catfish industry further generated an economic value of $2.09 in the form of labor income, other property incomes, and taxes on production and imports in the state economy.

Arkansas

Catfish industry actors in Arkansas included only foodfish-producing farms and catfish hatcheries. There were no catfish supply-chain partners (processing plants or feed mills) in Arkansas. Results from the Arkansas state economic impact model estimated a total output effect of $49 million from catfish farms for 2019 (Table 9). The direct, indirect, and induced economic effects were $23 million, $19 million, and $7 million, respectively. The catfish farms generated a total of 261 jobs in the state of Arkansas with a direct effect of 115 jobs, an indirect effect of 99 jobs, and an induced effect of 47 jobs. The total labor income and the total value addition were $11 million and $16 million, respectively.

Table 9. Economic impact of catfish industry in Arkansas, 2019.

Impact	Employment	Labor Income	Value Added	Output
Direct economic impact	115	$4,065,456	$4,851,938	$23,135,400
Indirect economic impact	99	$5,145,557	$7,978,177	$19,194,215
Induced economic impact	47	$1,907,792	$3,602,327	$6,599,900
Total economic impact	261	$11,118,805	$16,432,442	$48,929,515

Every dollar spent on Arkansas catfish farms generated an additional $1.11 in the state economy. A job created in the catfish industry in the state of Arkansas generated an additional 1.27 jobs in the state economy. Similarly, every dollar of labor wage paid on Arkansas catfish farms generated an additional $1.73 in the state economy. The value-added multiplier (3.39) suggested that every dollar generated from the catfish industry further generated an economic value of $2.39 in the form of labor income, other property incomes, and taxes on production and imports in the state economy.

Mississippi

Mississippi is the largest catfish-producing state in the U.S. having all four catfish industry actors (hatcheries/foodfish farms/processing plants/feed mills) within the state. Results from the Mississippi state economic impact model estimated a total output effect of $1.29 billion for 2019 (Table 10). The direct, indirect, and induced economic effects were $802 million, $361 million, and 125 million, respectively. The catfish industry segments (farms and supply-chain partners) generated a total of 6,390 jobs in the state of Mississippi with a direct effect of 3,390 jobs, indirect effect of 2,095 jobs, and induced effect of 905 jobs. The total labor income and economic value added were $215 million and $361 million, respectively.

Table 10. Economic impact of catfish industry in Mississippi, 2019.

Type of impact	Employment	Labor Income	Value Added	Output
Direct economic impact	3,390	$93,057,189	$149,010,827	$802,069,622
Indirect economic impact	2,095	$88,040,890	$144,351,967	$361,477,573
Induced economic impact	905	$33,780,933	$67,799,492	$124,514,004
Total economic impact	6,390	$214,879,011	$361,162,287	$1,288,061,199

Each dollar spent in the Mississippi catfish industry generated an additional $0.61 in the Mississippi state economy. A job created in the Mississippi catfish industry generated an additional 0.88 jobs in the state economy. Similarly, every dollar labor wage paid in the Mississippi catfish industry generated an additional $1.31 in the state economy. The value-added multiplier (2.42) suggested that every dollar generated from the catfish industry further generated an economic value of $1.42 in the form of labor income, other property income, and tax revenue on production and imports in the state economy.

Tax revenue generated by the catfish industry in the state and regional economies, 2019.

The catfish industry generated $78 million in federal, state, and local taxes in the tristate region (Table 11). Forty-four percent ($34 million) of this was in state/local tax revenue while the rest 56% ($44 million) was in federal taxes. The total tax revenue generation in the states of Alabama, Arkansas, and Mississippi were, respectively, $21 million, $3 million, and $46 million. The specific breakdown of the tax revenue generated at the state/local and federal levels from catfish industry activities were $7 million and $13 million in Alabama, $1.2 and $1.5 million, in Arkansas, and $22 million and $24 million in Mississippi.

Table 11. Tax revenue generation by the catfish industry in the three states and regional economy, 2019.

Tax categories	Alabama	Arkansas	Mississippi	Tristate
State and local tax	$7,420,781	$1,270,427	$21,750,540	$34,065,897
Federal tax	$13,105,248	$1,467,867	$24,235,993	$43,922,105
Total tax generated	$20,526,029	$2,738,294	$45,986,533	$77,988,002

Results of the individual state analyses revealed that the catfish industry affected 494, 458, and 448 IMPLAN-listed industries in the states Alabama, Arkansas, and Mississippi, respectively. This represented 97% of the total industries listed in the respective state economies. The individual state models also identified the economic sectors that benefited the most from the indirect and induced business activities generated by the catfish industry (Table 12). Grain farming, banks, truck transportation, electric power generation (fossil fuel), and equipment manufacturers were the leading industries affected by the catfish industry in terms of economic output in Alabama and Mississippi. Truck transportation, electric power generation (nuclear), banks, and religious organizations were the greatest beneficiaries in terms of economic output in Arkansas. These differences in the industries supported by the catfish industry arose primarily as a result of the absence of feed mills and processing plants in Arkansas.

Table 12. Top 15 industries supported by the catfish industry in the states of Alabama, Arkansas, and Mississippi, 2019.

Alabama		Arkansas		Mississippi	
Industry description	Output	Industry description	Output	Industry description	Output
Grain farming	$72,410,680	Truck transportation	$3,656,896	Grain farming	$86,356,784
Non depository credit intermediation	$21,510,469	Power generation - Nuclear	$2,876,766	Non depository credit intermediation	$67,174,014
Truck transportation	$17,616,570	Non depository credit intermediation	$2,584,782	Truck transportation	$56,912,717
Farm machinery/equipment makers	$11,048,353	Religious organizations	$2,472,467	Power generation-Fossil fuel	$49,907,682
Power generation-Fossil fuel	$10,745,745	Industrial equipment repair	$2,016,557	Farm machinery/equipment makers	$28,641,619
Owner-occupied dwellings	$10,674,418	Farm machinery/equipment makers	$1,950,875	Paperboard container manufacturing	$20,658,992
Insurance carriers, except direct life	$9,811,753	Motor vehicle and parts dealers	$1,020,841	Insurance carriers, except direct life	$19,832,992
Building repair/maintenance	$8,681,432	Retail - Gasoline stores	$982,893	Automotive repair and maintenance	$17,519,239
Industrial equipment repair	$8,524,269	Power generation - Fossil fuel	$954,200	Owner-occupied dwellings	$16,888,756
Automotive repair and maintenance	$6,878,491	Other real estate	$892,283	Services to buildings	$16,763,464
Depository credit intermediation	$6,168,844	Owner-occupied dwellings	$760,147	Other real estate	$13,665,714
Other real estate	$6,001,792	Insurance carriers, except direct life	$736,007	Depository credit intermediation	$12,743,354
Hospitals	$4,491,702	Depository credit intermediation	$695,840	Industrial equipment repair	$10,466,985
Insurance agencies/brokerages	$4,290,678	Construction machinery manufacturing	$671,184	Power distribution	$9,857,362
Offices of physicians	$3,944,647	Power distribution	$639,903	Power generation - Nuclear	$9,708,197
All other industries (479)	$293,514,956	All other industries (443)	$26,017,876	All other industries (433)	$850,963,329
Total economic impact (494)	$496,314,797	Total economic impact (458)	$48,929,515	Total economic impact (448)	$1,288,061,199

Economic contribution of the catfish farms to the tristate region

The IMPLAN analysis was also able to estimate the economic impact of catfish hatchery and foodfish farms separately from that of supply-chain partners. The economic impact of the catfish farms in the tristate economy amounted to $713 million in 2019 (Table 13). The direct, indirect, and induced economic effects were $383 million, $243 million, and $87 million, respectively. The catfish farms generated a total of 2,987 jobs in the tristate regional economy. The 1,259 catfish farm jobs further created an additional 1,728 jobs in the tristate economy with 1,117 jobs being indirect, and 611 jobs resulting from induced household spending. The total labor income generated from farms amounted to $142 million aiding a total of $211 million in value addition in the tristate economy.

Table 13. Economic impact of catfish farms in the tristate region states of Alabama, Arkansas, and Mississippi, 2019.

Types of impacts	Employment	Labor Income	Value Added	Output
Direct economic impact	1,259	$56,443,763	$63,312,102	$383,337,336
Indirect economic impact	1,117	$60,494,003	$100,309,595	$242,924,878
Induced economic impact	611	$24,763,388	$47,143,165	$86,380,652
Total economic impact	2,987	$141,701,155	$210,764,862	$712,642,866

A dollar spent on catfish farms generated an additional $0.86 in the tristate economy. The addition of a single job on catfish farms would create an additional 1.37 jobs in the major catfish-producing states. Similarly, every dollar of labor wage paid on catfish-producing farms further generated $1.51 in the tristate economy. The value-added multiplier (3.33) suggested that every dollar generated from catfish farms further generated an economic value of $2.33 in the form of labor income, other property incomes, and taxes on production and imports in the tristate economy. Catfish farms in the tristate region generated $34 million in state/local and federal taxes.

Economic contribution of the catfish supply-chain partners to the tristate region

Similar to separating the economic effects of catfish farms, the analysis also teased out the economic impact of two major catfish supply-chain partners - feed mills and processing plants, in the regional economy. The total economic impact of the catfish supply-chain partners in the tristate economy was $1.2 billion in 2019 (Table 14). The direct, indirect, and induced economic effects were $719 million, $311 million, and $168 million, respectively. The catfish processing plants and feed mills substantially contributed to employment in the tristate economy generating a total of 6,192 jobs. The 3,039 off-farm jobs in processing and feed mills further generated an additional 3,153 jobs in the tristate economy, of which 1,961 were indirect jobs created in secondary sectors and 1,192 jobs resulted from induced household spending. The total labor income generated from farms amounted to $276 million and the total economic value addition was $376 million in the tristate economy.

Table 14. Economic impact of catfish supply-chain partners in the tristate region states of Alabama, Arkansas, and Mississippi, 2019.

Types of impacts	Employment	Labor Income	Value Added	Output
Direct economic impact	3,039	$136,234,570	$152,812,223	$718,799,113
Indirect economic impact	1,961	$91,073,976	$131,233,872	$310,623,661
Induced economic impact	1,192	$48,255,622	$91,826,533	$168,273,164
Total	6,192	$275,564,169	$375,872,628	$1,197,695,938

A single dollar spent in the catfish processing plants and feed mills generated an additional $0.67 in the tristate economy. One job added to a catfish supply-chain company, such as a feed mill or a processing plant created an additional 1.04 jobs in the major catfish-producing states. Similarly, every dollar of labor wage paid on catfish processing plants and feed mills generated an additional $1.02 in the tristate economy. The value-added multiplier (2.46) suggested that every dollar generated from catfish processing plants and feed mills further generated an economic value of $1.46 in the form of labor income, other property incomes, and tax revenues on production and imports in the tristate economy. Catfish processing plants and feed mills in the tristate region generated $44 million in state/local and federal taxes.

Sensitivity analysis of varying volumes and prices of outputs generated by the catfish industry in the tristate region during 2016 to 2019 suggested a sustained economic contribution to the regional economy. The economic impact ranged from $1.87 to $1.93 billion during this period (Figure 4). The total jobs supported by the industry during this period ranged from 9,180 to 9,245 and tax revenue generated (state/local/federal) ranged from $75 to $78 million.

Tristate output	2016	2017	2018	2019
Feed delivered (tons)	466,897	489,315	459,052	450,438
Foodfish produced (million lbs)	297	310	315	325
Processed fish volume (million lbs)	153	160	163	168

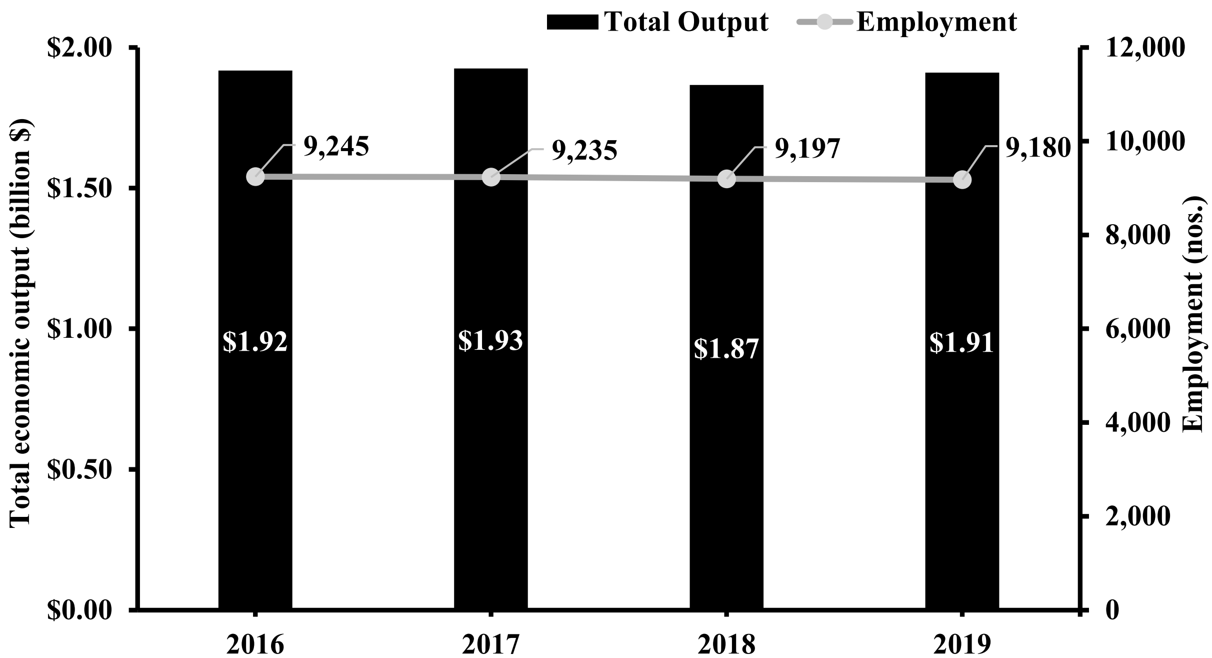

Figure 4. Sensitivity analysis of the total economic impact of the catfish industry in the tristate region, 2016-2019.

Objective 2. Monitor the adoption of production-enhancing technologies in the U.S. catfish industry (Mississippi State University/Virginia Tech/Auburn University)

The second objective of this project was to quantify the current trends in the adoption of productivity-enhancing and complementary technologies in the U.S. catfish industry. Although the farmed area has contracted from its peak in 2003, the productivity of the catfish farms has improved due to the adoption of improved technologies. Alternative catfish production technologies such as split ponds and intensive aeration (aeration rate >5 hp/acre) have been increasingly adopted in the catfish industry. The advent of these intensive catfish production systems has led to increased adoption of complementary technologies like hybrid catfish fingerlings, fixed-paddlewheel aerators, and oxygen-monitoring systems on farms. Additionally, catfish fingerling operations have increasingly adopted vaccination as a strategy to mitigate Enteric Septicemia of Catfish (ESC; causative agent - *Edwardsiella ictaluri*), possibly the most prevalent disease in the industry. The most recent estimates of the number of farms and the acres of production under different technologies were collected during the early adoption phase (2010 to 2013) of these technologies. The adoption of alternative systems has expanded considerably of late. It is critical to determine the extent to which adoption of the new technologies has continued and at what rate it has continued, to clearly understand industry trends behind the adoption of these new technologies. Monitoring the technological progress of alternative production technologies and the use of complementary technologies in the industry will guide researchers and Extension specialists on the nature and direction of technological progress within the catfish industry.

Survey and data collection

The survey of catfish farms (n=68) described in Objective 1 also captured the acreage in production of catfish with traditional and alternative-production systems. Adopters (producers who had adopted at least one of three alternative-catfish production systems (split-ponds, intensively aerated ponds, in-pond raceway systems) were asked to specify the area under production for each production system. All respondents were asked for information on farm size, the area under complementary technologies such as hybrid catfish fingerlings, and whether they had adopted automated oxygen-monitoring systems. Information on stocking practices (single batch, multiple batch, or modular type), average farm aeration rate (hp/ac), average stocking density (nos./ac), average feeding rate, and feed conversion ratios (FCR) were also inquired. Fingerling producers were asked whether they have adopted vaccination against ESC and the area of fingerling production stocked with vaccinated fish. Adoption of alternative catfish production technologies on non-responding farms (n=223) of the catfish industry was adjusted for the number of adopters and areas under adoption, based on inputs from Extension specialists and researchers working in the respective states. This post-2013 data were combined with those of a previous study (Kumar 2015[8]) that collected adoption data from 2010-2013 to assess the technology progress across the catfish industry.

RESULTS

Key production parameters of catfish farms are shown in Table 15. The average stocking density, feeding rate, and FCR on catfish farms were 9,179 fish/acre, 9 tons/acre, and 2.4, respectively. Seventy-nine percent of the survey respondents followed multiple-batch cropping systems on their farms. Single-batch cropping system was followed on 59% of the surveyed farms.

Table 15. Production practices of catfish farmers in the tristate region, 2019 (n=68).

Parameters	Units	Mean ± SD
Stocking density[1]	(no./acre/yr)	9,179 ± 1,774
FCR[1]	(ratio)	2.4 ± 0.26
Feeding rate[1]	(tons/acre/yr)	9.0 ± 2.8
Percentage of farms following different management practices n=68		
Multiple batch[2]	(%)	79%
Single batch[2]	(%)	59%
Modular three-stage systems[2]	(%)	9%

[1]Stocking density, FCR, and feeding rate were reported only from farms that generate revenue primarily from sales of foodfish (n=60). The above parameters were found to be different on fingerling operations and not disclosed to preserve confidentiality.
[2]Events are not mutually exclusive as farms adopt multiple stocking strategies at any given time.

[8] Kumar 2015. Economics and adoption of alternative-catfish production technologies. Ph.D. dissertation. University of Arkansas at Pine Bluff, June 2015

The industry survey also revealed important information on trends in the adoption of alternative catfish production technologies. Two of the three alternative technologies (split ponds, intensive aeration) are increasingly being adopted on catfish farms (Figure 5). The area under intensive-aeration systems has outpaced that of split ponds since 2016. As of 2019, 89 of the listed 291 farms had adopted intensive aeration (>5 hp/acre) on their farms (Table 16). The number of farms adopting intensive aeration was 61, 22, and six respectively in Mississippi, Alabama, and Arkansas. The area under intensively aerated ponds was 14,863 acres with 71% in Mississippi, 25% in Alabama, and 4% in Arkansas. Split-pond systems were adopted on 17 catfish farms (Table 16). The corresponding number of farms adopting split-pond systems in Mississippi and Arkansas were 13 and three, respectively. Alabama had one split-pond adopter as of 2019. The majority (89%) of the area in split ponds were in Mississippi (2,619 acres) with Arkansas (10%) having 288 acres (Table 16).

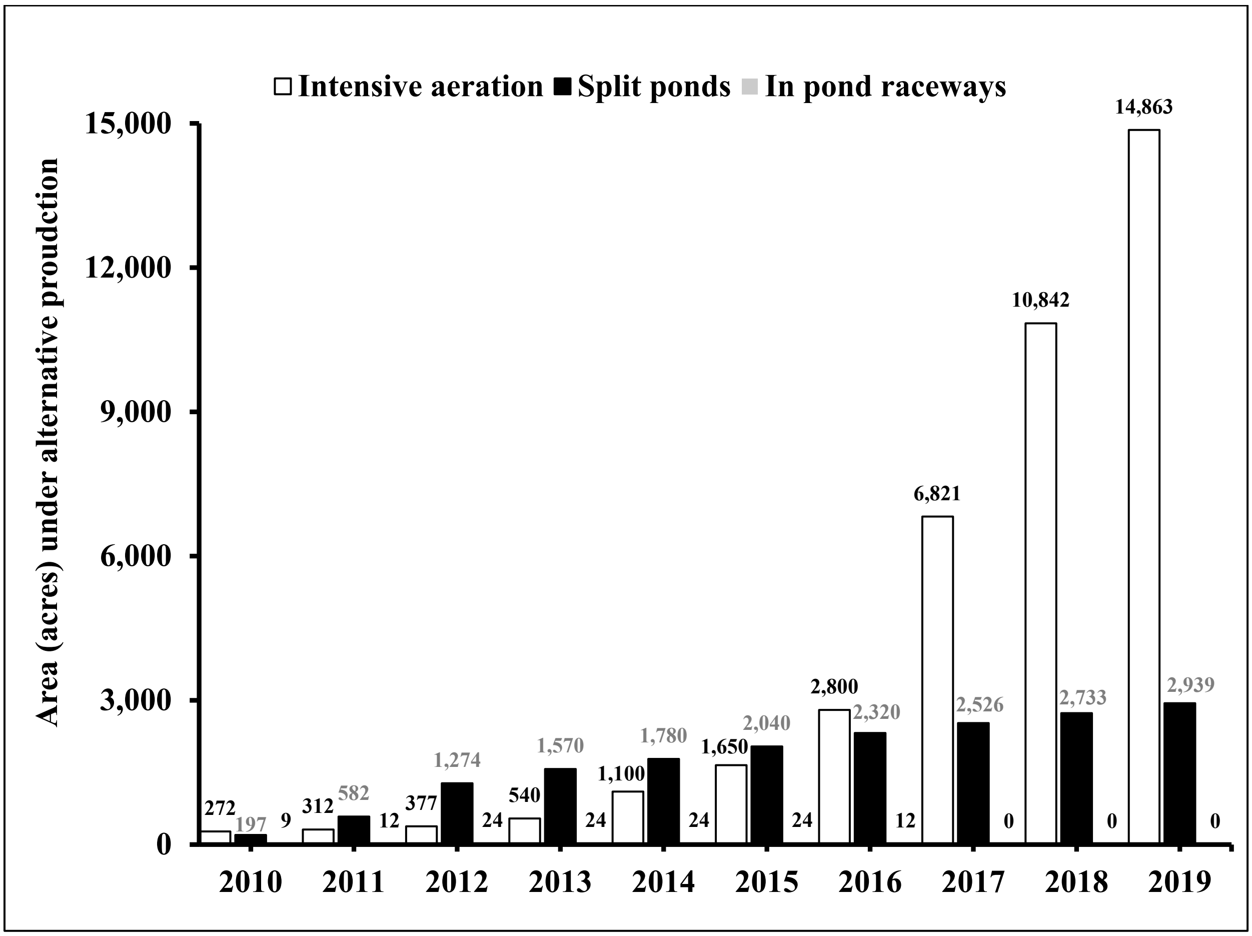

Figure 5. Adoption of split ponds, intensively aerated ponds, and in-pond raceways in the U.S. catfish industry.

Table 16. Adoption of alternative catfish production technologies in the U.S. catfish industry, 2020.

	Intensively aerated ponds		….Split ponds…		..Intensive systems...	
Regions	Area (acres)	Number of adopters (#)	Area (acres)	Number of adopters (#)	Area (acres)	Number of adopters (#)
Alabama	3,971	22	32	1	4,003	23
Arkansas	636	6	288	3	924	6
Mississippi	10,256	61	2,619	13	12,875	67
Tristate total	14,863	89	2,939	17	17,802	96

The survey also revealed the rate at which alternative productivity-enhancing intensive technologies were adopted by the catfish industry. About 31% of the catfish production area has adopted them with the majority being intensively aerated ponds (Figure 6). Much of this growth is no longer from the early adopters, but from the early-majority and late-majority adopters, who began to adopt mostly intensive-aeration systems and some additional split-pond systems in recent years. Over the last 10 years, intensively aerated ponds were adopted at an annual rate of 1,780 acres/year while split-pond systems were adopted at an annual rate of 294 acres/year. In-pond raceways, previously used for catfish production during 2010-2016, were no longer in use in catfish production at the time of the survey.

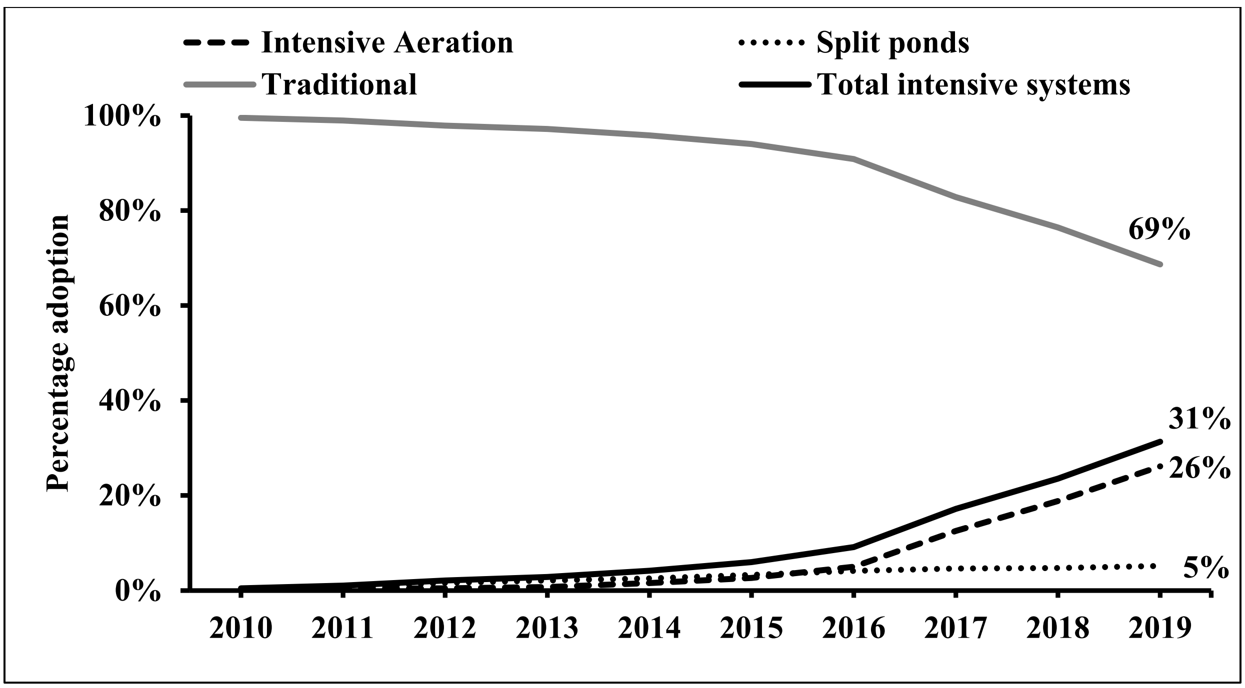

Figure 6. Percentage adoption of intensive and traditional catfish production systems from 2010-2019.

Subsequent to the adoption of intensive systems, the catfish industry also had increased adoption of fixed paddlewheel aeration. The weighted average paddlewheel aeration rates in Alabama, Arkansas, and Mississippi were 4.0, 3.7, and 4.4 hp/acre, respectively, resulting in an industry weighted average aeration rate of 4.2 hp/acre (Table 17).

Table 17. Weighted average aeration rate in the catfish industry in the tristate area, 2019.

Regions	Aeration rate (hp/acre)
Alabama	3.97
Arkansas	3.72
Mississippi	4.35
Tristate average	4.16

The adoption of intensive farming practices that increases aeration rate has resulted in a 68% increase in average paddlewheel aeration rate in the last decade (Figure 7). The increased adoption of intensive systems and increased aeration rates in the industry also resulted in greater adoption of automatic oxygen monitoring systems. Ninety-six percent of the surveyed catfish farms had adopted automated oxygen monitoring systems as a complementary technology to manage pond dissolved oxygen levels (Figure 8).

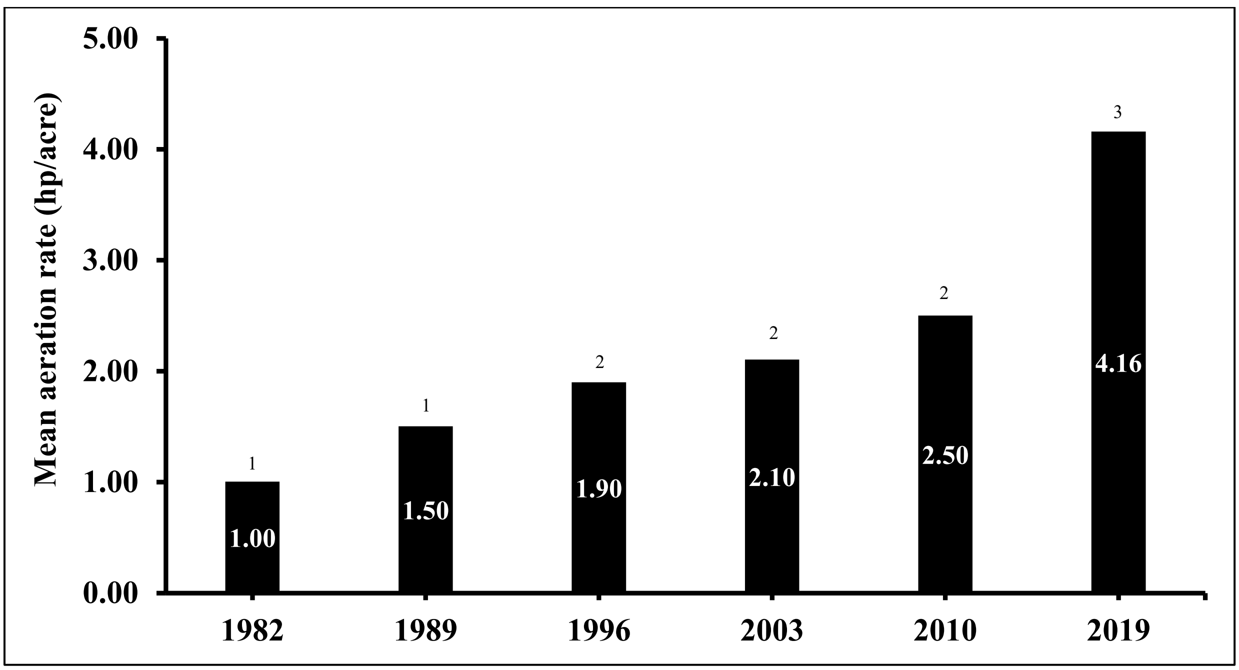

Figure 7. Trends of average paddle-wheel aeration rate in the catfish industry, 1982-2019. Sources: [1]Boyd (1998); [2]USDA (2010); [3]current study.

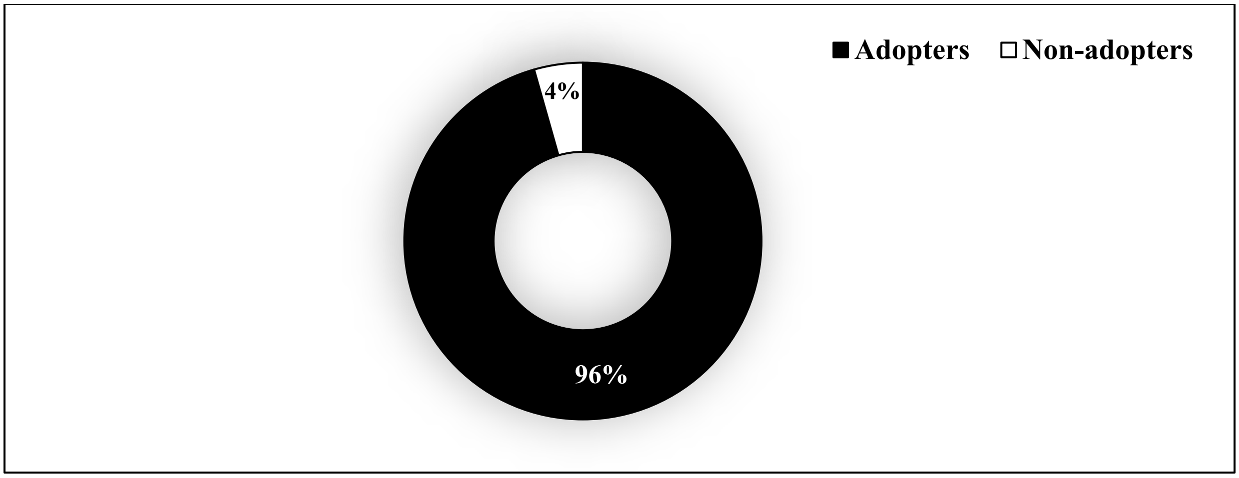

Figure 8. Adoption of automated oxygen monitors in the U.S. catfish industry, 2020. (n= 68)

Hybrid catfish are considered as a complementary input in intensive catfish production systems. The increased adoption of intensive catfish production systems has been accompanied by a substantial increase in the adoption of hybrid catfish. Fifty-three percent of the catfish production area used hybrid catfish at the time of the survey (Table 18). Mississippi had the highest adoption with 69% of the catfish production area stocking hybrid catfish. Alabama and Arkansas had 24% and 32% of their catfish production area under hybrid catfish, respectively. The survey of fingerling producers found that about 60% of the catfish fingerlings produced in the industry were hybrid catfish (Table 19). An alternative metric of adoption of hybrid catfish obtained from catfish processing plants suggested that 58% of the roundweight processed were hybrid catfish. All three measurements found increased adoption of hybrid catfish in the catfish industry with adoption ranging from 53% to 60% depending on the metrics.

Table 18. Area under hybrid and channel catfish in the tristate region, 2019.

Area	Hybrids (acres)	Channels (acres)	Hybrids (%)	Channel (%)
Alabama	4,088	12,712	24%	76%
Arkansas	1,378	2,922	32%	68%
Mississippi	24,575	11,125	69%	31%
Total	30,041	26,759	53%	47%

Table 19. Share of hybrid and channel catfish based on the number of fingerlings produced and volume of fish processed, 2019.

Industry metrics	Hybrids	Channels	Hybrids (%)	Channel (%)
Fingerlings produced (million)	315	209	60%	40%
Roundweight processed (million lbs)	188	137	58%	42%

The U.S. catfish industry also witnessed technological progress on the disease management front. About 3,448 acres or 66% of the fingerling production area have currently adopted vaccination against ESC as a means of disease management (Figure 9). Ten of the 12 (83%)

catfish fingerling operations had various degrees of vaccination of their fingerling production area in 2020.

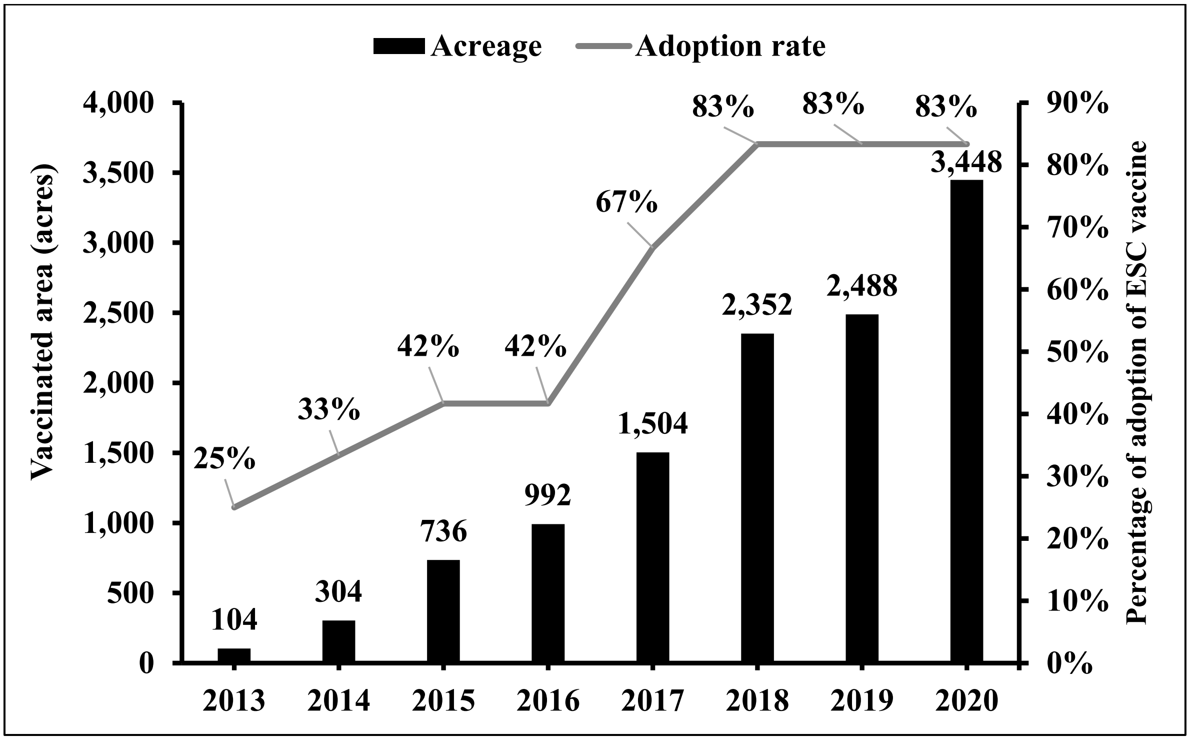

Figure 9. Fingerling area under ESC vaccine in the tristate region.

IMPACTS

This project has captured recent trends and dynamics of sales, cost structures, and farming methods in the catfish industry, provided comprehensive and current estimates of the economic contribution of the industry, and documented the progress of on-farm adoption of productivity-enhancing technologies. These findings are of value to policymakers, Extension specialists, and researchers working with the U.S. catfish industry and U.S. aquaculture in general.

The first objective of this study provided documentation of the regional economic contribution of the catfish industry covering the three major producing states of Alabama, Arkansas, and Mississippi. The study explicitly accounted for all major segments of the catfish industry (hatcheries, farms, feed mills, and processors) and employed a novel Analysis-By-Parts approach to model the contribution of individual industry sectors as well as the total contribution of the industry. The U.S. catfish industry is a significant economic contributor to the tristate region with an economic impact of $1.9 billion. The catfish farms contributed $713 million while the supply-chain partners contributed $1.2 billion to the regional economy. Mississippi leads the states in economic contribution followed by Alabama and Arkansas. The industry provided employment for more than 9,100 people in the tristate region and generated over $78 million in federal and state/local income taxes. Grain farming, banking, power generation, and transportation sectors were some of the industries that were supported to the greatest extent by the U.S. catfish industry. An industry that generates such high and steady economic contributions remains especially vital for the tristate region that is characteristically rural and economically challenged in terms of employment and income levels.

In the second objective, this project quantified trends in the adoption of productivity-enhancing technologies in the U.S. catfish industry and found a trend of increasing intensification in the U.S. catfish industry. Alternative catfish production technologies such as intensively aerated ponds and split ponds have been increasingly adopted by the catfish industry. About 31% of the catfish production area had adopted intensive systems at the time of the survey. The advent of these intensive catfish production systems has led to increased adoption of complementary technologies such as hybrid catfish fingerlings, fixed-paddlewheel aerators, and oxygen-monitoring systems on farms. Hybrid catfish are raised on 53% of the farmed area while the average paddlewheel aeration rates have risen to 4.2 hp/acre. Automated oxygen monitoring systems are managing dissolved oxygen on 96% of the surveyed farms. The study also found that vaccination against ESC was adopted on over 83% of fingerling operations.

RESULTS AT A GLANCE

- **The catfish industry continues to be the leading and sustained economic segment with significant economic contribution in the tristate regional economies of Alabama, Arkansas, and Mississippi.**
- **The economic contribution of the catfish industry to the tristate region in 2019 amounted to $1.9 billion.**
- **The industry contributed over 9,100 jobs to the regional economy and generated over $78 million in taxes.**
- **The state of Mississippi which has all the catfish industry actors (farms/feed mills/processing plants) was the major contributor to the regional economy ($1.3 billion) followed by the state of Alabama ($0.5 billion).**
- **The catfish industry supports over 97% of the industries listed by IMPLAN in the regional economy.**
- **The U.S. catfish industry is witnessing increased adoption of intensive productivity-enhancing technologies such as intensively aerated ponds and split-pond systems.**
- **Over 33% of the catfish production area adopted intensive production systems in 2019.**
- **The average aeration rate across the catfish industry in 2019 was 4.2 hp/acre.**
- **Over 96% of the surveyed farms adopted automated oxygen monitoring systems.**
- **About 53% of the catfish production area used hybrid catfish.**

Appendix 1. Pro forma detailing the farm expenditure patterns on a typical foodfish-producing farm in the tristate region. for IMPLAN modeling.

Gross Receipts	P_f	Q_f	R		
Description	Prices (P_n)	Quantity (Q_n)	Expenditure (C_n)	IMPLAN Coefficients, ϵ_θ	IMPLAN Sector Codes (3XXX)
Feed	-	-	-	-	-
Fingerling	-	-	-	-	-
Electricity	P_1	Q_1	C_1	R/C_1	*3039*
Water (office/labor housing)	P_2	Q_2	C_2	R/C_2	*3049*
Fingerling transport	P_3	Q_3	C_3	R/C_3	*3417*
Permanent labor	P_4	Q_4	C_4	R/C_4	*EC*
Seasonal labor/part-time	P_5	Q_5	C_5	R/C_5	*EC*
Fish health testing	P_6	Q_6	C_6	R/C_6	*3467*
Chemicals	P_7	Q_7	C_7	R/C_7	*3170*
Fuel	P_8	Q_8	C_8	R/C_8	*3408*
Heating gas	P_9	Q_9	C_9	R/C_9	*3048*
Bird supplies	P_{10}	Q_{10}	C_{10}	R/C_{10}	*3256*
Office supplies	P_{11}	Q_{11}	C_{11}	R/C_{11}	*3149*
Gravel	P_{12}	Q_{12}	C_{12}	R/C_{12}	*3029*
Internet	P_{13}	Q_{13}	C_{13}	R/C_{13}	*3434*
Service fees (pest control)	P_{14}	Q_{14}	C_{14}	R/C_{14}	*3476*
Water quality	P_{15}	Q_{15}	C_{15}	R/C_{15}	*3185*
Sanitation	P_{16}	Q_{16}	C_{16}	R/C_{16}	*3049*
Subscriptions	P_{17}	Q_{17}	C_{17}	R/C_{17}	*3523*
Donations	P_{18}	Q_{18}	C_{18}	R/C_{18}	*3521*
Security services	P_{19}	Q_{19}	C_{19}	R/C_{19}	*3475*
Telephone	P_{20}	Q_{20}	C_{20}	R/C_{20}	*3433*
Seining	P_{21}	Q_{21}	C_{21}	R/C_{21}	*EC*
Hauling	P_{22}	Q_{22}	C_{22}	R/C_{22}	*3417*
Equipment repair and maintenance	P_{23}	Q_{23}	C_{23}	R/C_{23}	*3515*
Payroll taxes	P_{24}	Q_{24}	C_{24}	R/C_{24}	*EC*
Workers' comp	P_{25}	Q_{25}	C_{25}	R/C_{25}	*3444*
Property taxes	P_{26}	Q_{26}	C_{26}	R/C_{26}	*3534*
Legal	P_{27}	Q_{27}	C_{27}	R/C_{27}	*3455*
Accounting	P_{28}	Q_{28}	C_{28}	R/C_{28}	*3456*
Farm Insurance/auto insurance	P_{29}	Q_{29}	C_{29}	R/C_{29}	*3444*
Lease	P_{30}	Q_{30}	C_{30}	R/C_{30}	*3447*
Permits/License/decal	P_{31}	Q_{31}	C_{31}	R/C_{31}	*3531*
Health insurance	P_{32}	Q_{32}	C_{32}	R/C_{32}	*3444*
Benefits (401k)	P_{33}	Q_{33}	C_{33}	R/C_{33}	*3446*
Postal services	P_{34}	Q_{34}	C_{34}	R/C_{34}	*3526*
Bap certification (one time)	P_{35}	Q_{35}	C_{35}	R/C_{35}	*3531*
Payroll software	P_{36}	Q_{36}	C_{36}	R/C_{36}	*3456*
Vaccination cost	P_{37}	Q_{37}	C_{37}	R/C_{37}	*3172*
Hormone cost	P_{38}	Q_{38}	C_{38}	R/C_{38}	*3185*
Short term interest	P_{39}	Q_{39}	C_{39}	R/C_{39}	*3439*
Advertising	P_{40}	Q_{40}	C_{40}	R/C_{40}	*3465*
Miscellaneous supplies	P_{41}	Q_{41}	C_{41}	R/C_{41}	*3412*
Feed transport	P_{42}	Q_{42}	C_{42}	R/C_{42}	*3417*
Depreciation					-
Computer	P_{44}	Q_{43}	C_{43}	R/C_{43}	*3404*
Small tools	P_{45}	Q_{44}	C_{44}	R/C_{44}	*3234*
Trucks	P_{45}	Q_{45}	C_{45}	R/C_{45}	*3402*

Tractors	P_{46}	Q_{46}	C_{46}	R/C_{46}	*3260*
Buildings	P_{47}	Q_{47}	C_{47}	R/C_{47}	*3055*
Office furnishings	P_{48}	Q_{48}	C_{48}	R/C_{48}	*3055*
Equipment	P_{49}	Q_{49}	C_{49}	R/C_{49}	*3055*
Pond Construction	P_{50}	Q_{50}	C_{50}	R/C_{50}	*3403*
Wells	P_{51}	Q_{51}	C_{51}	R/C_{51}	*3260*
Long term interest	P_{52}	Q_{52}	C_{52}	R/C_{52}	*3262*
Total Cost	-	-	Σ	Σ	-

Note: *R* is the revenue or sales value from sales of foodfish, P_f is the price of the fish produced, Q_f is the quantity of fish produced, $R=P_f * Q_f$ while C_n is the cost of individual expenses based on the price of the input (P_n) and quantity of input (Q_n) used and *n* can take any positive integer value. Employee compensation is denoted as *EC*. The expenditure coefficient ϵ_θ is calculated for each expenditure line item as a fraction of the respective expenses over revenue. Expenditure coefficients having the same IMPLAN code (four-digit numbers) were summed up before importing to IMPLAN.

Publications, manuscripts, or papers presented:

Journal articles (published)

Kumar, G., C. R. Engle, J. L. Avery, L. Dorman, G. H. Whitis, L A. Roy, and L. Xie. 2020. Characteristics of early adoption and non-adoption of alternative catfish production technologies in the U.S. Aquaculture Economics & Management. Aquaculture Economics & Management, 25:1, 70-88, DOI: 10.1080/13657305.2020.1803446

Presentations and posters

Kumar, G., 2019. Factors affecting the adoption of aquaculture technologies. Asia Pacific Aquaculture Chennai, India. May 2019.

Kumar, G., C. R. Engle, *S. Hegde, J. van Senten, S. Aarattuthodiyil, J. L. Avery. 2019. Assessment of economic impact and cost of regulations on catfish farms. Fall seminar, Mississippi State University, Stoneville, MS. Nov 2019.

Kumar, G., L. A. Roy, and T. R. Hanson. 2019. Cost of regulations, technological advances, and Economic impact: Research planned for the catfish industry. Annual producer meeting of West Alabama catfish farmers. Greensboro, AL. Dec 2019.

Kumar, G., and J. Avery. 2018. Effective communication portals for technology transfer. 2018 Delta Research and Extension Center Annual Report.

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