Received: 18 March 2022 | Revised: 25 May 2022 | Accepted: 21 June 2022

DOI: 10.1111/jwas.12917

APPLIED RESEARCH

Journal of the World Aquaculture Society Open Access | WORLD AQUACULTURE Society | WILEY

Cost of regulations on US catfish farms

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Funding information
Arkansas Catfish Promotion Board; USDA-NIFA Hatch Project, Grant/Award Number: 1013160; Mississippi Agriculture and Forestry Experiment Station Special Research Initiative, Grant/Award Number: MAFES-SRI-Grant#MIS-371240; United States Department of Agriculture-National Institute of Food and Agriculture, Grant/Award Numbers: #1017200, #2018-70007-28827

Abstract

Understanding the economic effects of regulations on US aquaculture farms provides insights into which compliance costs create the greatest compliance burden on farms. This can further guide strategies to improve the efficiency of regulatory frameworks and potentially reduce on-farm compliance costs while maintaining adequate oversight. This study estimated the regulatory compliance burden on US catfish farms as part of a national effort to quantify the cost of regulations on US aquaculture farms. Completed survey interviews of catfish farms in the major catfish-producing states covered 63% of the total US catfish production area. Total regulatory costs of the US catfish industry were estimated at $45 million annually. Lost farm revenues (measured as the value of lost production, the value of markets lost from regulations, and the value of business opportunities lost because of regulations) were estimated to be $35 million per annum. Catfish-producing states outside the Alabama/Arkansas/Mississippi region had the highest ($2856/ha) and Alabama the lowest ($1127/ha) regulatory costs per hectare among the surveyed states. The greatest regulatory cost burden on catfish farms ($18 million) was caused by environmental regulations related mostly to the management of federally protected piscivorous migratory birds, followed by labor regulations ($12 million), and taxes/insurance ($7 million). Regulatory costs ($/kg) were 2.6 times higher on smaller (<80 ha) farms relative to larger

(>300 ha) farms. Attention is needed to identify alternative regulatory frameworks that provide the same degree of regulatory oversight but are more cost-efficient.

KEYWORDS
catfish, economics, regulations, regulatory cost, US aquaculture

1 | INTRODUCTION

Regulations are necessary to maintain a balance between social welfare and the economic interests of citizens. Although most regulations improve overall social conditions, redundant, complex, expensive, and excessively stringent regulations inflict an unnecessary burden on concerned firms and sectors of an economy (Hahn, 1996; Lockwood, 2017; van Senten, 2016). Prescriptive regulations negatively affect the ability of businesses to adopt rapidly evolving technologies necessary for growth (Oster & Quiglay, 1977).

Studies have shown the US regulatory environment to have inhibited industry development (Abate et al., 2016, 2018; Farquhar et al., 2017; Kite-Powell et al., 2013; Knapp & Rubino, 2016). Sluggish and often negative aquaculture growth in Japan, the European Union, and the United States was found to result from stringent regulatory environments (Abate et al., 2016). When the balance of power among regulatory agencies favors pro-environment schemes, aquaculture growth is affected negatively (Abate et al., 2018). Osmundsen et al. (2017) highlighted the dynamic nature of aquaculture and the importance of governing aquaculture through more flexible and cost-efficient regulations. The slow development of a pragmatic regulatory framework for US aquaculture was reported by Anderson et al. (2019).

Stringent aquaculture regulations were cited as the major reason for business closures and foregone investment in US aquaculture (Lockwood, 2017). Engle and Stone (2013) identified more than 1300 US regulations categorized as follows: (1) bird depredation and other environmental regulations; (2) labor regulations; (3) food safety regulations; (4) fish health regulations, (5) interstate transport regulations, and (6) taxes and insurances (Table 1).

Studies quantifying the regulatory costs on aquaculture farms are relatively new but increasingly important as they create a better understanding of the types and extent of the regulatory burden on farms. Such studies in baitfish, salmonids, shellfish, and ornamental industries have demonstrated that the effect of regulations on aquaculture farms stretches beyond the simple costs of permits and licenses (Boldt et al., 2022; Engle et al., 2019; van Senten & Engle, 2017, 2020). Increased production costs resulting from compliance, time spent on record keeping, and foregone revenue in the form of lost production, the value of markets lost from regulations, or the value of lost business opportunities—all contribute to reduction in producer surplus and negatively affect total societal welfare.

In one of the first studies in the US aquaculture sector, van Senten and Engle (2017) found regulatory costs to contribute 25% to the total cost of production in the US baitfish and sportfish industry. Regulatory costs contributed 12% of the total production and marketing costs on salmonid farms (Engle et al., 2019), 29% on Pacific coast shellfish farms (van Senten et al., 2020), and 26% on ornamental fish farms in Florida (Boldt et al., 2022). Per-farm regulatory costs were $148,554/farm on baitfish/sportfish, $150,506/farm on salmonid, $240,621/farm on Pacific coast shellfish, and $173,135/farm on Florida ornamental farms (Boldt et al., 2022; Engle et al., 2019; van Senten et al., 2020; van Senten & Engle, 2017).

Revenues lost were much higher than the direct cost of regulations in all but the baitfish/sportfish industry. In the salmonid industry, lost revenue of $490,797/farm originated from lost markets, lost production, and lost opportunity from thwarted expansion attempts as a result of the regulatory framework (Engle et al., 2019). On Pacific coast shellfish farms, revenue losses ranged from $112,000 to $3.2 million per farm across different states (van Senten et al., 2020). Ornamental fish farms in Florida lost production value at $774,063/farm from regulations (Boldt

TABLE 1 Major regulations contributing to costs under different regulatory categories

Regulatory categories	Regulations
Bird depredation and other environmental regulations	Migratory bird treaty act (MBTA), Effluent discharge regulations, Aquatic Nuisance Species regulations (ANS), Application and management of agricultural chemicals, Water usage regulations, Toxic Substances Control Act (TSCA)
Labor	Immigrant labor regulations, State minimum wages, Occupational Safety and Health Administration (OSHA)
Food safety	Chemical tolerance limits under Federal Food Drug and Cosmetic Act (FFDCA), United States Department of Agriculture Food Safety Inspection Service (USDA FSIS)
Fish health	Veterinary Client Patient Relationship (VCPR), Veterinary Feed Directive (VFD), Investigative New Animal Drug (INAD)
Interstate transport regulations	Lacey act, Commercial vehicle registration regulations, International Fuel Tax Agreement
Taxes and insurance	Federal, state, and county taxes including payroll taxes, farm insurance, vehicle insurance, workers' compensation insurance
All other regulations	State and county regulations, third-party certification

et al., 2022). The lowest revenue losses ($85,039/farm) across these studies were on baitfish/sportfish farms (van Senten & Engle, 2017).

Prescriptive regulatory requirements can reduce farm-level efficiencies. For example, in the baitfish/sportfish farms, a 10% reduction in the cost of manpower spent on regulatory compliance alone could increase the technical efficiency of farms from 77% to 78% (van Senten, Dey, & Engle, 2018; van Senten, Engle, et al., 2018). Fish health testing costs required for sales into other states could be reduced through risk-based approaches as compared with current practices (Engle, van Senten, et al., 2021). Adopting uniform health standards for aquaculture was estimated to save $6.6 million annually to the US baitfish/sportfish industry (van Senten, Dey, & Engle, 2018; van Senten, Engle, et al., 2018).

The US catfish industry is the leader in US aquaculture (Hegde et al., 2022), contributing $1.9 billion to the regional economy of Alabama, Arkansas, and Mississippi (Hegde et al., 2021). Understanding the extent and effects of regulatory costs on US catfish farms is critical given the competition with low-priced imported products from countries with less effective governance structures than those in the United States (Engle et al., 2022). This study is the first to estimate the regulatory costs on US catfish farms.

The goal of this study was to identify and quantify the economic effects of regulations on US catfish farms. The specific objectives of this study were to (1) identify the number and types of regulations affecting catfish farms, (2) estimate the average cost of regulations on catfish farms on a per-farm ($/farm), per-hectare ($/ha), per-kilogram ($/kg) and industry basis ($/state; total $), (3) estimate the effect of regulations on farm revenue in terms of lost revenue and lost business opportunities, and (4) compare the regulatory cost burden across different farm sizes.

2 | METHODS

2.1 | Data collection

A national survey of US catfish farms was conducted during 2019–2020. The 2018 Census of Aquaculture (USDA, 2018) was the reference point for the number and area under production in various catfish-producing states. The survey was conducted as a census, with every attempt made to contact all producers. A notice requesting participation in the survey was sent out to catfish producers in all states through state Extension Specialists followed by

TABLE 2 List frame and summary of the survey responses

States/regions	List frame (nos.)	Completed interviews (nos.)	Response rate (%)	Total area (ha)	Production area covered (ha)	Coverage rate (%)
Alabama	95	24	25	6720	4370	65
Arkansas	29	12	41	1720	1221	71
Mississippi	157	32	20	14,280	9454	66
Other catfish-producing states	55	10	18	1440	942	65
Total United States	469	78	17	25,328	15,987	63

phone calls to schedule an in-person or telephone survey. Each detailed in-person survey interview involved a conversation with the producers regarding regulatory compliance requirements and associated costs.

A survey instrument was developed to understand the various regulations affecting catfish farms. The questionnaire measured the extent of regulatory actions on farm costs and revenue through qualitative questions on regulations and detailed quantitative questions on specific regulatory costs. Additional questions enquired into the most problematic regulations confronted by farms, frequency of reminders received by farmers regarding permit renewals and regulatory changes, markets and opportunities lost because of regulations, and unexpected changes on farms because of regulatory compliance. Quantitative information included the number of regulations affecting each farm, itemized direct and indirect costs associated with on-farm compliance with various regulations, and compared the relative magnitude of on-farm costs of six regulatory categories identified by Engle and Stone (2013) (bird depredation and other environmental, labor, food safety, fish health, interstate transport, and taxes and insurance).

2.2 | Coverage, participation rate, and accounting for nonresponses

Of the 469 catfish farms identified in the 2018 Census of Aquaculture (USDA NASS, 2018), 78 interviews were completed with a response rate of 17% (of total US producers) nationally and a coverage rate (of total US area) of 63% of the total production area (Table 2). Given the major production clusters in Alabama, Arkansas, and Mississippi, results were reported separately for these three states, with the remaining observations combined into an "other catfish-producing states" category to protect the confidentiality of individual respondents. Study results were adjusted for coverage to estimate national effects.

2.3 | Analysis

Regulatory costs were calculated for each observation and were disaggregated into (1) regulatory categories identified in previous studies; and (2) type of regulatory cost (manpower spent on regulation, farm-level changes, permits and licenses, all other direct costs, interest costs, and depreciation). Results were calculated per farm, per hectare, per kilogram of fish produced, per state (where there were sufficient observations to do so without violating confidentiality), and nationally as well as a percentage of total costs.

Lost revenue (the value of lost production, the value of markets lost because of regulations, and the value of lost business opportunities) was estimated for each observation and aggregated by type of regulation. Lost revenue was calculated per farm, per hectare, per kilogram of fish produced, per state (where there were sufficient observations to do so without violating confidentiality), and nationally.

Farm size effects of regulations were estimated by categorizing observations into small (<80 ha), medium (81–300 ha), and large-sized (>300 ha) farms. Results were expressed per farm, per hectare, per kilogram of fish

produced, per state (where there were sufficient observations to do so without violating confidentiality), and nationally as well as a percentage of total costs.

3 | RESULTS

3.1 | Top five problems on catfish farms

When asked to identify the top five problems on catfish farms, diseases, marketing, regulations, and labor were the major problems cited (Figure 1). Forty-seven percent of the respondents cited diseases as the biggest issue on their farm, while 21% cited issues with marketing as their biggest problem. Another 14% listed regulations as the top problem on their farm. Regulations were cited as the second and third largest problems on catfish farms by 27% and 26% of the respondents, respectively.

3.2 | Problematic regulations on catfish farms

Respondents also listed the most problematic regulations on their farms. The problems of fish lost to federally protected migratory birds (under The Migratory Bird Treaty Act, MBTA) were cited as the most problematic regulation (Figure 2). Twenty-three percent of respondents ranked this environmental regulation as the most problematic regulation, while 32% cited this as either the most or the second most problematic regulation. The MBTA was enacted in 1918 with the goal of ensuring the sustainability of populations of migratory bird species. At the time, there was growing concern over declining bird populations that had resulted from over-hunting and poaching for their feathers. The construction of flood control systems in the Mississippi River drainage reduced wetland areas for migratory birds that have turned to commercial fish ponds for feeding. The second most problematic regulations were reported by respondents to be labor laws, specifically immigration laws surrounding the hiring of H2A workers, and payroll tax regulations. Labor shortages in the United States have forced catfish farmers to seek temporary agricultural workers from other countries, which requires attorneys to navigate the visa process and substantial paperwork. H2A workers are required to be paid wages that exceed the federal minimum wage requirements by 28%–50%. Other problematic regulations mentioned included the Veterinary Feed Directive (VFD) issued by the US Food and Drug Administration (FDA), which requires a veterinary–client relationship for access to antibiotic use, EPA regulations in general, taxes, insurance, state, and local environmental laws, and USDA-FSIS regulations.

3.3 | Lost markets and business opportunities

Twelve percent of respondents indicated that they knew of catfish farms that had gone out of business or never started up because of regulations (Table 3). Almost all these farms were in the Mississippi River Delta, which experience greater problems from migratory birds. Another 85% mentioned that they had to make unexpected changes in the farm operations, most of which was because of the management of federally protected birds. Farmers reported spending increasingly more time chasing birds away from farms rather than being involved in productive activities. Several fingerling farmers consolidated their fingerling production ponds to more centralized locations away from the farm periphery where bird activity was high. Another 15% mentioned that they had lost opportunities because of various regulations. Interstate transport regulations, specifically the Lacey Act, have eliminated the live transport of Asian carps to ethnic markets. Secondary businesses run by catfish farmers, such as hauling fish across state borders, also closed down because of stringent interstate transport regulations. Renovation of some existing ponds was delayed or never occurred because of the need for wetland surveys and the absence of wetland surveyors. The

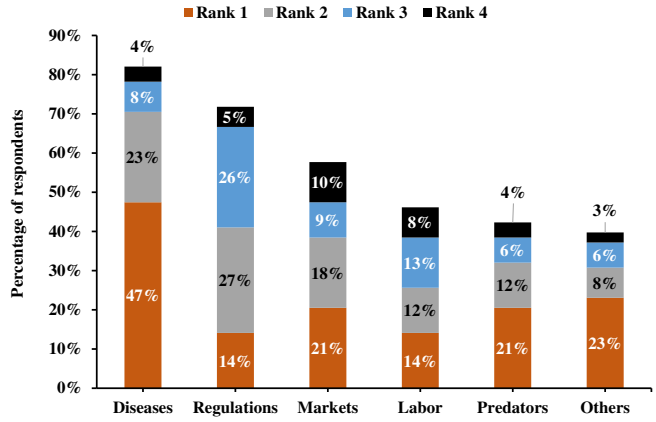

FIGURE 1 Ranking of top five problems on US catfish farms by the respondents, 2019–2020 ($N = 78$)

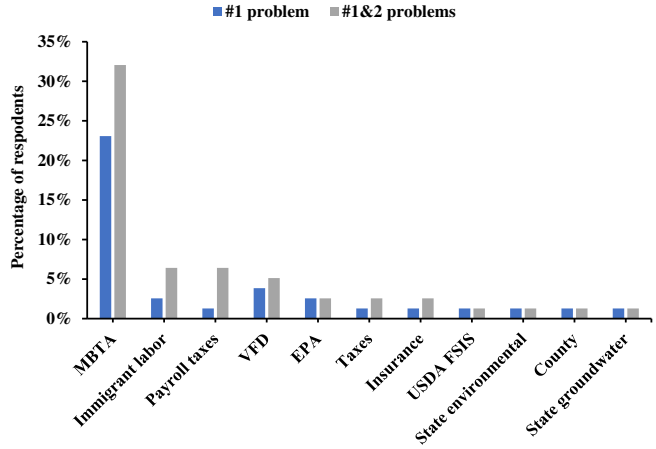

FIGURE 2 Most problematic regulations on catfish farms based on producer responses, 2019–2020 ($N = 78$). EPA, Environmental Protection Agency; FSIS, United States Department of Agriculture Food Safety and Inspection Service; MBTA, Migratory Bird Treaty Act; VFD, Veterinary Feed Directive

culture of alternative fish species such as red drum, barramundi, largemouth bass, and hybrid striped bass was restricted in other catfish-producing states resulting in lost opportunities for sales and business expansion.

3.4 | Regulations, regulatory filings, and regulatory reminders

The total numbers of distinct regulations identified by respondents in surveyed states were 28, 31, 30, and 31 in Alabama, Arkansas, Mississippi, and other catfish-producing states (Table 4), respectively, with total regulatory filings (sum of all the filings by individual farmers across all states) of 2314. Nearly a third of the respondents (29%) mentioned that regulatory agencies always provided reminders of permit renewals, while 6% of respondents mentioned never receiving renewal notices. The nonresponse rate suggests that the question was either skipped by the respondents or was answered as "I don't know" (Table 5). However, almost all respondents mentioned that the state Land Grant University Extension specialists were proactive in reminding them about permit renewals and in providing periodic mandatory training.

TABLE 3 Farms that have gone out of business, or have experienced lost markets, unexpected changes, and other lost opportunities ($n = 78$)

Survey questions	Yes (%)
Do you know of farms that have either closed down or never started up due to regulations?	12
Are there states and/or countries/regions you used to sell catfish to or would like to sell catfish to, but do not due to the regulatory environment?	3
Have there been unexpected changes in the farm business as a result of having to comply with all regulations?	85
Are there any other opportunities that were lost due to regulations?	15

TABLE 4 Number of regulations and regulatory filings identified by the respondents in catfish-producing states

States/regions	Number of distinct regulations				Regulatory filings[a]
	Federal	State	Local	Total	Total number
Alabama	15	8	5	28	672
Arkansas	15	10	6	31	372
Mississippi	15	9	6	30	960
Other catfish-producing states	15	12	4	31	310
Total regulatory filings	-	-	-	-	2314

Note: Federal regulations identified were the same across catfish-producing states, whereas state and local regulations differed among the surveyed states.
[a]Number of regulatory filings is calculated by multiplying the number of regulations by the number of respondents in each state.

TABLE 5 Notification of annual renewals and changes in regulations ($n = 78$)

Survey rating (0 = never; 5 = always)	Do you receive annual reminders of permit renewals? (% of respondents)	Do you receive timely notification from regulatory agencies of any changes to comply and avoid penalties? (% of respondents)
0	6	3
1	0	1
2	0	0
3	12	12
4	1	0
5	29	23
No response	51	62

3.5 | Total regulatory costs

National total annual regulatory costs on catfish farms amounted to $45.4 million per year (Table 6). Cost of regulations represented an average of 8.4% of the total cost of production on catfish farms, with the lowest percentage in Alabama (5.4%). Mississippi, the largest catfish-producing state, had the greatest total state-wide regulatory costs

TABLE 6 Total regulatory costs by state

Regions	$/state	$/farm	$/ha	$/kg	Regulatory costs as a % of total costs
Alabama	$7,571,387	$205,171	$1127	$0.13	5.4
Arkansas	$3,596,217	$212,776	$2091	$0.23	9.2
Mississippi	$26,807,473	$571,888	$1877	$0.21	8.7
Other catfish-producing states	$7,447,357	$172,425	$2856	$0.40	9.2
National	$45,422,434	$352,591	$1793	$0.21	8.4

Note: All values were adjusted for coverage at the state and national levels.

($27 million). The national mean regulatory cost per farm was $352,591. The national annual regulatory cost averaged $1793/ha, with the highest cost per hectare in other catfish-producing states ($2856/ha). The average regulatory costs in Alabama, Arkansas, and Mississippi on a per-hectare basis were $1127/ha, $2091/ha, and $1877/ha, respectively. Nationally, regulatory costs contributed an average of $0.21/kg, with costs ranging from $0.13 to $0.40/kg of the total production cost across different states.

Of the regulatory costs incurred on catfish farms, 39% were fixed costs. Taxes and insurance, depreciation, legal charges, permits and licenses, and several of the farm-level changes were fixed costs that occurred regardless of the volume of production. Labor spent on federally protected birds and labor regulations (H2A and state minimum wage laws) contributed the bulk of the variable regulatory costs.

3.6 | Cost of regulations by regulatory category

Regulatory costs were sorted by type of regulation, including migratory bird and other environmental, labor, food safety, fish health, interstate transport, taxes and insurance, and all other regulations (Table 7). Of these, migratory birds and other environmental regulations composed 39% of total regulatory costs. Over 90% of costs in this regulatory category were incurred for complying with the MBTA. The permits and licenses involved in the management of migratory birds on farms contributed <1% of this regulatory cost category (Figure 3a), while labor required for regulatory compliance constituted 36% of this regulatory cost. This was followed by other direct costs (21%), costs of farm-level changes (17%), depreciation on assets employed in complying with regulations (17%), and interest incurred (8%) on regulatory expenditures on farms. Figure 3b shows that 46% of the bird management cost on catfish farms was dedicated to labor used for bird patrolling activities. This was followed by expenditures on trucks used for bird patrolling (25%). One-eighth of the bird management cost was expended on levee upkeep for patrolling birds. Costs of firearms and ammunition used for lethal control constituted 4%, while exclusion and scaring devices used to keep birds away from ponds contributed 5% of the total bird management cost and interest on operating expenses accounting for 8% of this regulatory cost category.

The next major regulatory cost category affecting catfish farms was labor regulations comprising 27% of total regulatory costs (Table 7). Most of the costs associated with labor regulations were directly spent on labor (62%; Figure 4a). Farm-level changes are needed for compliance because labor regulations comprised 11% of the total labor regulatory costs. Permits and licenses associated with labor regulations accounted for 4% of the labor regulatory costs. About three-fourths of the labor regulatory costs stemmed from the cost of hiring H2A farmworkers from foreign countries (Figure 4b). Additional costs for compliance to pay higher prevailing wages to H2A farmworkers as required by the Department of Labor ($11.81 in MS to $11.88/h in AR) had a major share in this increased cost on farms from employing an H2A labor force. The domestic workers on farms employing H2A laborers cannot be discriminated against and must be paid the same rate or greater regardless of the federal minimum wage requirement

TABLE 7 Regulatory costs by category and by state (total $), and as share (%)[a] of the total regulatory costs

	Alabama		Arkansas		Mississippi		Other catfish-producing states		National	
Regulatory categories	**$**	**%**	**$**	**%**	**$**	**%**	**$**	**%**	**$**	**%**
Bird depredation and other environmental regulations	4,132,148	55	1,728,111	48	10,366,026	39	1,691,545	23	17,917,830	39
Labor regulations	655,986	9.0	971,127	27	9,650,942	36	914,726	12	12,192,781	27
Food safety regulations	796,610	11	203,622	6.0	886,166	3.0	91,197	1.0	1,977,595	4.0
Fish health regulations	7214	0.1	29,478	0.8	68,329	0.3	5077	0.1	110,097	0.2
Interstate transport regulations	499,407	7.0	85,302	2.0	725,671	3.0	88,010	1.0	1,398,389	3.0
Taxes/insurance	1,078,416	14	412,430	11	4,730,872	18	757,735	10	6,979,454	15
All other regulations	401,607	5.0	166,146	5.0	379,467	1.0	3,899,067	52	4,846,288	11
Total regulatory costs	7,571,387	100	3,596,217	100	26,807,473	100	7,447,357	100	45,422,434	100

Note: All values have been adjusted for coverage at the state as well as national level.

[a]Percentages represent the share of each regulatory category in total regulatory cost for each state. These values are calculated by column.

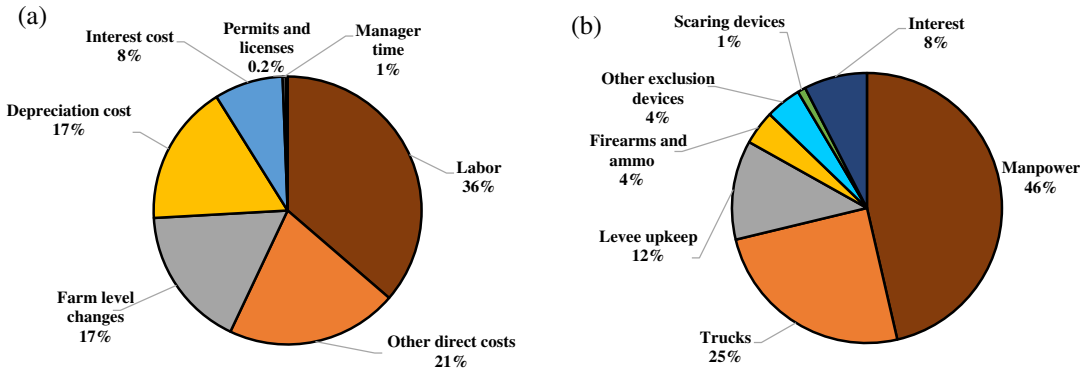

FIGURE 3 (a) Share of different types of costs in bird and other environmental regulations on catfish farms, 2019–2020. (b) Types of spending associated with bird management on catfish farms, 2019–2020.

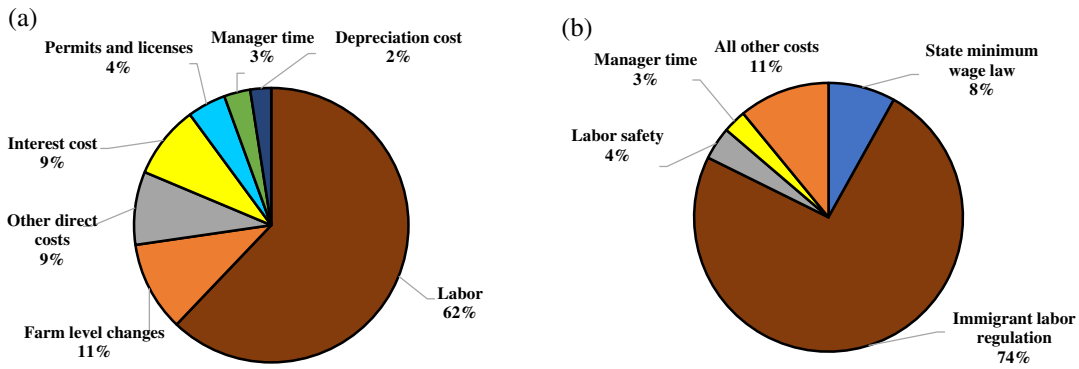

FIGURE 4 (a) Share of different cost types in labor regulations affecting catfish farms, 2019–2020. (b) Types of costs associated with labor regulations on catfish farms, 2019–2020.

($7.25/h). Other costs associated with H2A regulations include the provision of housing and utilities for foreign farm laborers. All other labor compliance costs amounted to 11% of the labor regulatory costs (mainly interest on operating expenses related to labor regulations). The next major cost under labor regulations came from compliance with state minimum wage laws (8%) that drove up labor costs on farms in certain states. For example, the state minimum wage mandated in Arkansas in 2019 was $9.25/h as opposed to the federal minimum wage requirement ($7.25/h) in Alabama and Mississippi. The cost of labor regulations also included additional costs from complying with labor-safety regulations (4%) stipulated by the Occupational Safety and Health Administration (OSHA), Department of Labor.

Mandated taxes and insurance contributed 15% of the total regulatory cost on catfish farms (Table 7). About 88% of these costs were direct costs associated with the actual payment of taxes and insurance required on farms. Specifically, this regulatory requirement amounted to 50% in insurance payments—mostly auto insurance and other liability insurance on farms and 39% in taxes (local land and property taxes).

All other regulations composed 11% of total regulatory costs, food safety 4%, interstate transport 3%, and fish health 0.2% (Table 7). The majority of the costs under all other regulations originated from third-party certification requirements, referred to as "voluntary regulations." Food safety regulations governing the

management of off-flavor restrict the permitted application of Diuron® to an annual maximum of nine treatments. This means that farms have to incur additional treatment costs on copper sulfate and hold fish longer in ponds to purge off-flavor, incurring additional treatment and holding costs. Fish health regulations include the cost of obtaining prescriptions for a VFD from veterinarians and the cost of procuring Investigative New Animal Drugs (INADs) in hatcheries.

Results of this study also showed comparisons of regulatory costs across different catfish-producing states. The costs associated with compliance with bird and other environmental regulations were the greatest regulatory costs in Alabama, Arkansas, and Mississippi (39%–55%) while being the second-largest cost in other catfish-producing states (23%). All other regulations were the highest regulatory category in other catfish-producing states. The cost associated with managing labor regulations was the second-largest regulatory cost in Alabama, Arkansas, and Mississippi (9%–36%), with the highest in Mississippi. Labor regulations were the third-largest cost in other catfish-producing states (12%). The contribution of taxes and insurance to total regulatory costs ranged between 10% and 18% among states. The share of interstate transport (7%) and food safety regulations (11%) were highest in Alabama, while that of fish health regulatory cost was highest (1%) in Arkansas (Table 7).

Table 8 presents mean and median state-level costs for each type of regulation at the farm level ($/farm). The regulatory cost per farm averaged $352,591/farm nationally. Average regulatory costs of almost all regulations were highest on Mississippi farms owing to their relatively larger sizes. Exceptions to this trend were the costs associated with fish health management and all other regulatory costs being higher on Arkansas farms and food safety regulations on Alabama farms. A noteworthy mention is the extent of regulatory cost on large farms, with some very large farms (>1600 ha) incurring regulatory costs greater than $6 million/year.

Regulatory costs were also expressed in terms of cost per unit area ($/ha) in Table 8. Among the regulatory cost categories, regulations protecting the migratory birds and other environmental regulations constituted $707/ha nationally, with the highest being in Arkansas ($1005/ha). Labor regulations constituted $481/ha nationally and the highest for farms in Mississippi ($676/ha). Food safety regulations were $78/ha nationally, with the highest on Alabama farms ($119/ha). Interstate transport regulations constituted $55/ha nationally and $74/ha in Alabama. Taxes and insurance constituted $276/ha nationally, with Mississippi farms having a per hectare cost of $331/ha. All other regulatory costs were $191/ha nationally, with other catfish-producing states incurring costs of $1495/ha on an average.

Regulatory costs expressed as $/kg of the catfish produced in catfish-producing states and the contribution of each regulatory category are provided in Table 9. Regulatory costs per kilogram of catfish produced were highest ($0.40/kg) in other catfish-producing states followed by Arkansas ($0.23/kg) and Mississippi farms ($0.21/kg). Nationally, regulatory costs averaged $0.21/kg of catfish produced.

3.7 | Cost of regulations by type of cost

Total regulatory costs were classified into key types of costs that included the cost of manpower, unexpected farm-level changes, permits and licenses, direct costs other than permits, the interest cost, and depreciation because of regulations. Manpower in the form of labor and management time (hired managers and owners) contributed over 38%, followed by other direct costs (25%), unexpected farm-level changes (18%), while interest and depreciation costs contributed 8% and 7%, respectively (Figure 5). Direct costs other than permits/licenses include the costs of testing, monitoring, record keeping, and reporting. Costs of the permits/licenses constituted only 2% of total regulatory costs.

Substantial variations in regulatory spending and the magnitude of various types of regulatory costs were observed within states, expressed as mean and median costs per farm, and cost per hectare (Table 10). The other

TABLE 8 Regulatory cost by category per farm ($/farm) and per hectare ($/ha) by state

Regulatory categories	Alabama	Arkansas	Mississippi	Other catfish-producing states	National
Bird depredation and other environmental regulations					
Mean ($/farm)	$111,974	$102,247	$214,453	$65,260	$146,531
Median ($/farm)	$18,932	$25,503	$8799	$9772	$9400
Mean ($/ha)	$615	$1005	$726	$649	$707
Labor					
Mean ($/farm)	$17,776	$57,458	$216,953	$64,442	$111,578
Median ($/farm)	$1890	$44,949	$866	$2549	$5371
Mean ($/ha)	$98	$565	$676	$351	$481
Food safety					
Mean ($/farm)	$21,587	$12,048	$18,333	$0	$16,017
Median ($/farm)	$15,366	$726	$6556	$0	$6556
Mean ($/ha)	$119	$118	$62	$35	$78
Fish health					
Mean ($/farm)	$195	$1744	$1414	$0	$908
Median ($/farm)	$14	$1838	$729	$0	$296
Mean ($/ha)	$1	$17	$5	$2	$4
Interstate transport					
Mean ($/farm)	$13,533	$5047	$15,013	$1892	$11,342
Median ($/farm)	$6683	$5173	$1100	$0	$2343
Mean ($/ha)	$74	$50	$51	$34	$55
Tax/insurance					
Mean ($/farm)	$29,223	$24,402	$97,872	$34,030	$57,261
Median ($/farm)	$4345	$7435	$7229	$1101	$5382
Mean ($/ha)	$160	$240	$331	$291	$276
All other regulations					
Mean ($/farm)	$10,883	$9830	$7850	$6802	$8954
Median ($/farm)	$6391	$8233	$779	$5060	$5413
Mean ($/ha)	$60	$97	$27	$1495	$191
Total regulatory costs					
Mean ($/farm)	$205,171	$212,776	$571,888	$172,425	$352,591
Median ($/farm)	$107,953	$175,900	$65,745	$98,991	$111,841
Mean ($/ha)	$1127	$2091	$1877	$2856	$1793

catfish-producing states incurred relatively higher costs per hectare on manpower, farm-level changes, all other direct costs, permits and licenses, and total cost per hectare. Smaller farming operations in these states have a lesser chance to spread such costs over greater volumes of production, and hence the costs per hectare were relatively higher. Except for depreciation costs being highest in Alabama, almost all the average costs were highest on farms in Mississippi owing to their relatively larger size. Interest cost was found to be highest in Arkansas. A huge difference between the mean ($352,591) and median ($111,841) regulatory costs at the national level is a testimony to the dissimilarities in regulatory costs across different states. These regional differences reflect variations in farm size and differences in regulatory spending.

TABLE 9 Regulatory cost per kilogram of fish produced by category of regulations and state ($/kg)

Regulatory categories	Alabama	Arkansas	Mississippi	Other catfish-producing states	National
Bird depredation and other environmental regulations	$0.07	$0.11	$0.08	$0.09	$0.08
Labor regulations	$0.01	$0.06	$0.08	$0.05	$0.06
Food safety regulations	$0.01	$0.01	$0.01	$0.00	$0.01
Fish health regulations	$0.00	$0.00	$0.00	$0.00	$0.00
Interstate transport regulations	$0.01	$0.01	$0.01	$0.00	$0.01
Taxes/insurance	$0.02	$0.03	$0.04	$0.04	$0.03
All other regulations	$0.01	$0.01	$0.00	$0.21	$0.02
Total regulatory costs	$0.13	$0.23	$0.21	$0.40	$0.21

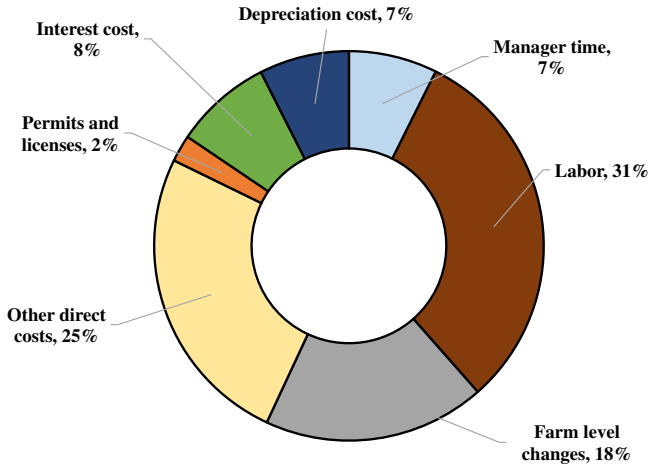

FIGURE 5 Share of various types of regulatory spending on catfish farms, 2019–2020

3.8 | Regulatory costs by farm size

Regulatory costs varied across small (<80 ha), medium (81–300 ha), and large (>301 ha) catfish farms (Table 11). Although the total regulatory costs per farm increased with farm size, the regulatory costs per kilogram decreased considerably with the size of the farm. The regulatory costs expressed as cost/kg on the smaller farms ($0.55/kg) were 2.6 times higher than the costs in the largest farm size category ($0.21/kg), depicting a greater regulatory cost burden on smaller farms and the existence of economies of scale. The percent that regulatory costs composed of total cost increased with the farm size. Although larger farms have to deal with a more diverse set of regulations, they have dedicated managers who invest a significant amount of time in regulatory affairs. This is not pragmatic on small family farms with a sole proprietorship business structure.

The study also separated the relative cost effects of various regulatory categories by farm size. On the smaller farms (<80 ha), bird and other environmental regulations had the largest share of regulatory cost followed by labor regulations, taxes/insurance. Several regulatory costs (bird and environmental regulations,

TABLE 10 Regulatory cost by type of cost per farm ($/farm) and per hectare ($/ha) by state

Type of cost	Alabama	Arkansas	Mississippi	Other catfish-producing states	National
Manpower					
Mean ($/farm)	$49,610	$77,098	$243,869	$68,851	$136,001
Median ($/farm)	$27,053	$58,222	$22,422	$11,898	$27,874
Mean ($/ha)	$272	$758	$773	$1278	$691
Farm-level changes					
Mean ($/farm)	$48,539	$39,932	$91,297	$30,146	$62,399
Median ($/farm)	$31,073	$31,763	$17,548	$2111	$28,016
Mean ($/ha)	$267	$392	$309	$567	$330
Other direct costs					
Mean ($/farm)	$50,162	$56,433	$145,410	$54,508	$90,760
Median ($/farm)	$19,993	$49,302	$17,753	$38,007	$26,779
Mean ($/ha)	$275	$555	$492	$635	$454
Permits and licenses					
Mean ($/farm)	$1177	$4331	$11,786	$4269	$6411
Median ($/farm)	$722	$1586	$785	$992	$830
Mean ($/ha)	$6	$43	$40	$129	$40
Interest costs					
Mean ($/farm)	$18,012	$18,883	$48,135	$11,595	$29,682
Median ($/farm)	$11,117	$18,458	$5087	$4536	$10,216
Mean ($/ha)	$99	$186	$158	$162	$144
Depreciation					
Mean ($/farm)	$37,671	$16,099	$31,391	$3057	$27,338
Median ($/farm)	$11,650	$14,036	$5890	$85	$10,200
Mean ($/ha)	$207	$158	$105	$85	$134
Total regulatory costs					
Mean ($/farm)	$205,171	$212,776	$571,888	$172,425	$352,591
Median ($/farm)	$107,953	$175,900	$65,745	$98,991	$111,841
Mean ($/ha)	$1127	$2091	$1877	$2856	$1793

food safety regulations, fish health regulations, and other regulations) on a per-hectare basis tended to decrease with an increase in farm size. In general, the cost per hectare of all regulations was higher on smaller farms relative to larger farms. The exception to this was in costs associated with labor regulations, which were highest on larger farms. Farms that tended to hire H2A foreign labor were mostly larger and or fingerling operations. This increase in costs of labor regulations on large farms (>301 ha) was primarily from the additional cost associated with the time spent and legal fees associated with hiring a greater number of H2A workers. The slightly higher cost associated with taxes/insurance and interstate transport regulations on larger farms relative to medium-sized farms (81–300 ha) was because of a greater number of farm vehicles on larger farms along with higher property taxes.

The increased regulatory costs per hectare on labor, taxes/insurance, and interstate regulations on larger farms were skewed mainly because of the presence of a few very large farms (>1600 ha), which may have certain

TABLE 11 Farm size effects on total regulatory costs ($/ha)

Regulatory categories and costs	Small (<80 ha)	Medium (80–300 ha)	Large (>300 ha)
Bird depredation and other environmental regulations	$1090	$625	$708
Labor regulations	$355	$390	$628
Food safety regulations	$145	$107	$59
Fish health regulations	$15	$5	$3
Interstate transport regulations	$70	$49	$56
Taxes/insurance	$308	$258	$285
All other regulations	$101	$56	$32
Total regulatory costs	$2083	$1490	$1772
Regulatory cost as a percentage of total costs	7.2%	7.4%	8.4%
Percent of fixed regulatory costs	44%	48%	36%
Percent of variable regulatory costs	56%	52%	64%
Regulatory costs per farm ($/farm)	$67,738	$234,858	$1,332,473
Regulatory costs per kilogram ($/kg)	$0.55	$0.29	$0.21

TABLE 12 Lost revenue from regulations

Regulations affecting farm revenue	Alabama	Arkansas	Mississippi	Other catfish-producing states	National
Lost production[a]					
Migratory Bird Treaty Act	$9,354,790	$2,594,598	$13,349,588	$2,117,478	$27,416,455
USDA FSIS inspection	$1,500,000	$0	$0	$0	$1,500,000
USDA FSA Wetland survey	$0	$45,360	$0	$0	$45,360
Value of lost markets[b]					
Lacey Act	$2,596,389	$602,535	$913,874	$198,831	$4,311,629
Value of lost opportunities[c]					
Restricted species permits	$0	$0	$0	$2,057,227	$2,057,227
Total lost revenue	$13,451,179	$3,242,493	$14,263,462	$4,373,536	$35,330,670
$/ha	$2002	$1885	$999	$1677	$1395
$/kg	$0.23	$0.20	$0.11	$0.23	$0.16

Note: All values were adjusted for coverage at the state and national levels.
Abbreviation: USDA FSIS, United States Department of Agriculture Food Safety Inspection Service.
[a]Lost production values are because of direct fish losses from predation by federally protected migratory birds; USDA FSIS inspection that led to false-positive results for malachite green causing marketing difficulties on farms leading to delays in the subsequent production cycle; USDA FSA loan required wetland surveys which were not conducted promptly causing loss of production on farms.
[b]Several catfish farmers lost markets for bighead carp as a result of Lacey Act prohibitions, which reduced farm revenue significantly.
[c]Local and state restrictions on species that can be cultured resulted in the loss of opportunities for culturing new species in several catfish-producing states.

diseconomies of scale owing to their geographically dispersed locations. An analysis excluding these few very large farms (>1600 ha) depicted lower regulatory costs per hectare on larger farms for all regulatory categories and economies of scale in regulatory costs on catfish farms up to a farm size of 1600 ha.

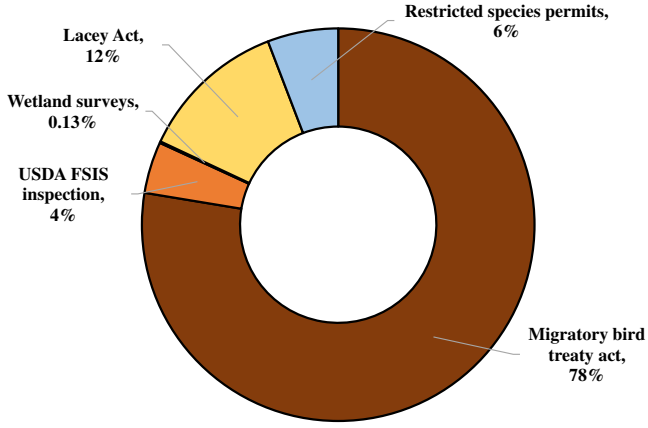

FIGURE 6 Regulations impacting catfish farm revenues, 2019–2020

3.9 | Lost revenue from regulations

Revenue lost from regulations (value of lost production, value of markets lost because of regulations, and value of lost business opportunities) was estimated at $35.3 million annually (Table 12). The revenue losses in Mississippi amounted to $14.3 million followed by $13.5 million in Alabama. Almost all revenue lost from lost opportunities was reported from other catfish-producing states.

Lost revenues on catfish farms demonstrated additional insights into how regulatory actions affect farm-level economics. About 78% of the total revenue effect was because of bird and other environmental regulations, occurring from fish lost to predation by federally protected birds (Figure 6). Another 12% of revenue losses occur because of interstate transport regulations surrounding the implementation of the Lacey Act that restricts the transport of Asian carp across state boundaries. Restriction of species being raised on farms contributed to 6% of the lost revenue, while the regulatory implementation of USDA-FSIS food safety regulations further contributed to 4% of revenue losses.

Lost opportunities because of regulations amounted to $2 million. This was because of the prohibition of the culture of certain species such as red drum, barramundi, largemouth bass, and hybrid striped bass in some states by state agencies. Such loss of opportunities on farms also implied that regulations hampered farms from taking advantage of economies of scope on catfish operations.

4 | DISCUSSION

Emerging studies quantifying the effect of regulations on US aquaculture suggest that aquaculture is over-regulated and has resulted in unintended negative consequences (Abate et al., 2016; Engle & Stone, 2013; Kite-Powell et al., 2013). Other studies have shown that regulations have significantly increased farm-level inefficiencies (Asche & Roll, 2013; van Senten, Dey, & Engle, 2018; van Senten, Engle, et al., 2018). This study investigated the regulatory costs on US catfish farms by specifically analyzing the types of regulations, their magnitude, and how farms internalize regulatory costs on farms to stay in business.

Findings from previous studies confirmed the dual economic effects of regulatory enforcement on aquaculture operations—increased cost of production and lost revenues (Engle et al., 2020; van Senten, Dey, & Engle, 2018; van Senten, Engle, et al., 2018; van Senten et al., 2020). While increased costs from regulatory compliance are incurred on farms, the regulatory effect on revenue arises from foregone revenues from lost sales opportunities, production, and expansion. Results found that the on-farm regulatory cost burden on US catfish farms exceeded $45 million and lost revenues $35 million. Regulatory costs averaged 8.4% nationally of the total costs on US catfish farms.

A major contributor to the regulatory burden on US catfish farms was environmental regulations, primarily for regulations surrounding the management of the MBTA. Catfish producers incur substantial costs in the form of manpower (personnel used to deter bird depredation, manager time), allotting trucks to scare birds, levee upkeep, and other farm-level changes associated with keeping federally protected birds off the farms. In addition to the cost of $18 million found in this study, catfish farms forego more than $27 million in lost production (not adjusted for the foregone growth) to federally protected birds, thus both increasing production costs and reducing revenue. Engle et al. (2020b) found that the total economic impact of bird predation from double-crested cormorants, *Phalacrocorax auritus*, alone in the catfish industry was $65 million ($18 million in bird scaring activities and $47 million in lost production). The Engle et al. (2020) study did account for the foregone growth and included an estimate of foregone market sales. Thus, the estimated $27 million lost revenue in this study likely underestimates the total losses from bird predation on farm-raised catfish. Moreover, cormorants are not the sole fish predators on catfish farms. An array of federally protected birds such as the Great Blue Heron, *Ardea herodias*, the American White Pelican (AWPE), *Pelecanus erythrorhynchos*, and the Great Egret, *Ardea alba*, are protected under federal laws, with very specific lethal control and take limits (Engle, 2003; Engle & Stone, 2013). These limits are minimal when compared with their growing population, especially of double-crested cormorants and the AWPE (Dorr et al., 2012a, 2012b; Dorr, Hatch, & Weseloh, 2014, Dorr, Hatch, Weseloh, & Poole, 2014), justifying greater bird management efforts (DOI, 2019). The prescriptive nature of lethal-take-limits in various regions where catfish farming is practiced is inadequate for effective control. The non-lethal activities used to scare birds from farms simply move birds within the farm or to a neighboring farm. Increased costs arising from federally protected birds is a reverse externality arising from previous public investments (Engle, Clements, et al., 2021) to clear wetland areas in the Mississippi River Delta (flood control levee systems; clearing for agricultural development, and urbanization). Although federal efforts to protect piscivorous migratory birds accomplished large-scale success, the significant negative economic aftermaths from rising numbers of piscivorous birds fall heavily on catfish farms. Yet catfish farms are not compensated under federal assistance programs for such losses, in stark contrast to relief provided to other livestock sectors. Further efforts to include catfish in such compensation programs are needed (Engle, Christie, et al., 2021; Engle, Clements, et al., 2021). More frequent federal roost dispersal activities are needed to reduce congregation of piscivorous birds from fish farms (Mott & Boyd, 1995).

Costs associated with labor regulations were the second most expensive regulation found on US catfish farms. Availability and quality of labor in rural regions where most catfish farms are located has been an on-going issue. Catfish farms, especially medium and large farms, have begun to rely on an immigrant workforce through compliance with H2A regulations. The annual paperwork (manager time/legal) required for these temporary hires (10 months/year) is tedious, redundant, time-consuming, and expensive. Moreover, the farms must pay workforce wages under the federally mandated prevailing wage rates that are 28%–50% above federal minimum wages ($7.25/h). Farms are further mandated to provide accommodation and transportation for this workforce. Enforcement of these wage limits means that catfish farms must pay domestic workers on their farms at the same rate as H2A workers, increasing the overall hourly wage rates. The result has been increased labor costs on farms that rely on immigrant labor. Catfish farms in a few states must also comply with the state minimum wage rates, which are often 23%–40% more than federal minimum rates, further increasing the cost of catfish production.

Taxes and insurance are considered favorable regulations needed for the functioning of free-market economies. The scale of the land-based catfish industry involves significant amounts of land and property taxes. Additionally, farms comply with mandatory insurance and registration requirements for farm vehicles. The taxes, insurance, and registration mandated by state/local laws contributed 15% to the total regulatory costs on catfish farms. The direct spending on taxes (property/vehicle) and insurance along with other proprietary income taxes in the catfish industry is a significant economic contributor to the economies of southern rural states of Alabama, Arkansas, and Mississippi, generating above $78 million annually in state, federal, and local taxes (Hegde et al., 2021). Such significant contributions to relatively poor economies should be valued while formulating new regulations or amendments to existing stringent regulations.

Catfish farms also comply with several third-party certification programs that mandate the farms to comply with numerous time-consuming record-keeping, training, and labor safety measures to meet annual certification requirements. A major portion of the manpower spent on regulatory affairs is associated with third-party certification needs and management of other regulations such as procuring and renewing permits and licenses, dealing with attorneys retained for regulatory affairs, and ensuring compliance with numerous county and state-level regulations. All other regulatory costs accounted for over $5 million (11%) of the total regulatory costs in the US catfish industry.

The United States has stringent food safety regulations that restrict the frequency of application of chemicals such as Diuron® on catfish farms, used to mitigate off-flavor issues surrounding freshwater finfish farming. To comply with EPA labeling laws, catfish farmers must use additional amounts of copper sulfate on farms and hold market-sized fish over a prolonged period (15–60 days; Tucker et al., 2020), incurring additional costs on chemicals and management. Several catfish farm respondents reported having to hold market-sized fish in ponds for more than 14 months because of false-positive test results on chemicals of food safety concerns. The farms were not allowed to sell their market-sized fish until the state chemical laboratory had corrected their testing procedure. This resulted in delays in subsequent stocking of the next crop. The farm bore the burden in the form of lost production valued at more than $1.5 million, nearly causing the farm to go out of business.

Interstate transport regulations, particularly the Lacey Act, prohibit the transport of species listed as injurious across state boundaries. Several catfish farms had sold bighead carp, *Hypophthalmichthys nobilis*, to ethnic Asian markets in the Northeast United States for years. The listing of black carp, *Mylopharyngodon piceus*, under the Lacey Act completely stopped the transport of all Asian carps across state boundaries, primarily from fear of the stiff penalties associated with any violation. Farms that historically sold bighead carp lost revenue and the associated ability to benefit from economies of scope through farm product diversification (Thomas & Hanson, 2007). Similarly, the injurious listing of black carp, used as a biological control agent of snails that are intermediate hosts of catfish trematodes, *Bolbophorus* sp., cost catfish farmers their best means of controlling this disease (Ledford & Kelly, 2006). Although enforcement of the Lacey Act for interstate transport of live animals has been suspended from a court ruling (USCA, 2017), fear of its reinstatement drove hatcheries that had produced carp fingerlings out of the business. Findings from this study may underestimate the effect of foregone revenues because many catfish farms that had raised these two carp species have gone out of business.

The catfish industry has been supported well by land-grant universities, especially with regard to disease management. Many of these state university laboratories have provided diagnostic and inspection services free of charge, mitigating costs associated with fish health regulations. Yet the Veterinary Client Patient Relationship (VCPR) mandate has posed a significant threat related to access to medicated diets on several catfish farms. Medicated diets that are the only approved treatment for important bacterial diseases (Enteric Septicemia of Catfish and Columnaris) are administered only through a VFD. Under FDA's VCPR regulation, veterinarians must establish and maintain annual visits to farms for making VFD prescriptions. Farms in very rural regions and isolated from veterinary services lost long-standing services because of this law. Without access to veterinary services, farms can only resort to less effective treatments, such as copper sulfate (Kumar & Gaunt, 2020).

Farm management (owners/managers) are spending greater amount of time coping with regulatory affairs, rather than being involved in activities that improve productivity on catfish farms. The cost of management time accounted for 7% of total regulatory spending. Managers/owners are compelled to maintain substantial volumes of records of daily activities associated with regulatory compliance, sacrificing attention to other production and marketing duties. The cost of labor spent on scaring birds and labor regulations accounted for another 31% of total regulatory costs. Such high use of manpower for compliance has been reported in previous regulatory cost studies in the baitfish/sportfish (van Senten & Engle, 2017), salmonid (Engle et al., 2019), and shellfish sectors (van Senten et al., 2020).

A sizable proportion of the regulatory cost incurred on catfish farms was found to be fixed cost, specifically 39%. The regulatory burden of a high proportion of the fixed cost is a relatively greater concern on small operations (Engle et al., 2019; Hurley & Noel, 2006; van Senten & Engle, 2017). About 75% of the catfish farms in the United States are either small or medium size in scale (USDA-NASS, 2018). Lower production volumes on such operations make it difficult to spread the increased fixed cost arising from regulatory actions. In this study, the regulatory

costs per kilogram ($/kg) on smaller catfish farms (<80 ha) were 2.6 times higher than those on larger farms (>301 ha). The presence of economies of scale is well identified in catfish farming (Engle, 2003, 2007; Engle et al., 2020; Kumar et al., 2020), with farms growing larger in size and scale of production. The higher proportion of small and medium catfish farms and the disproportionately higher regulatory costs ($/ha and $/kg) on such operations warrant greater attention to what proportion of increasing economies of scale is driven by regulatory costs.

Variations were observed in regulatory costs across various catfish-producing states. Regulatory costs associated with the management of birds and other environmental regulations were relatively higher in Alabama, Arkansas, and Mississippi as compared with other catfish-producing states. This reflects the high bird predation problems on catfish farms within the tristate region (Kumar et al., 2021) of Alabama, Arkansas, and Mississippi, which is the corridor of migration for many migratory birds including piscivorous birds. Catfish farms in Mississippi had the highest costs associated with labor regulations because of the increased hiring of an H2A workforce. The cost of labor regulations was also high in Arkansas, stemming from the higher minimum wage stipulations in the state. The minimum wage in Arkansas at the time of this study (2019) was $9.25, but increased to $11.00/h in 2021, likely increasing its negative effect even further over other states without minimum wage laws. The regulatory costs ($/ha) in Arkansas, Mississippi, and that of all other catfish-producing states were found to be higher than the national average. On the other hand, costs from all other regulations on a per-hectare ($/ha) and per-kilogram ($/kg) basis were higher in other catfish-producing states. This may be attributable to the differential implementation of federal and state laws in these regions and the relatively smaller-scale operations in these states. Osmundsen et al. (2017) detailed significant variations in the implementation of regulations in the context of EU nations, while Engle et al. (2019) noticed a similar differential implementation of laws in trout-producing states.

Regulatory costs increase the cost of production significantly. About 93% ($42 million) of the identified total regulatory costs were direct regulatory costs without considering manager time spent, equating to $0.18/kg or 8.4% of the total costs on catfish farms. Demand to catfish, similar to that of other seafood products, is price-elastic (more sensitive to changes in price), making it difficult to production cost increases from regulatory actions to final consumers (Engle, 2020; Kinnucan & Venkateswaran, 1991). Any streamlining of regulatory actions would abate costs and increase relative profits on catfish farms (Kumar et al., 2020).

Many of the regulations identified in this study that impact catfish farms date back to years before the catfish industry had become a commercially viable sector. Catfish farms face a multitude of dynamic production and marketing problems (Engle et al., 2020). Between 2003 and 2014, the industry contracted by 58% in the production area and 54% in production volume. This study provides, however, only a snapshot of regulatory costs on catfish farms in 2019–2020. There is no means of verifying whether regulations contributed to the large exodus of catfish farms during its period of contraction. Costs associated with the management of federally protected migratory birds, a previously negligible cost in farm budgets from 1970 to 2000 (Burtle et al., 1986; Crawford & McCoY, 1977; Keenum, 1989; Keenum & Waldrop, 1988) appear to have increased by several orders of magnitude to become the fifth-largest cost on catfish farms (Engle et al., 2020). Respondents in this survey identified several farms that have gone out of business because of heavy bird predation and spread of diseases linked directly to migratory birds (e.g., catfish trematode disease). The clustered exodus of such catfish farms has led to closures of allied businesses, especially in southern rural regions of the United States. Prior regulatory studies provided evidence for association of regulatory costs with farm exodus in baitfish/sportfish and salmonid industries (Engle et al., 2019; van Senten & Engle, 2017).

The complexity of the regulatory framework for aquaculture in the United States means that there likely is no one simple mechanism to streamline the regulatory framework and alleviate the growing regulatory cost burden on US aquaculture farms. Nevertheless, several studies point to opportunities with regard to specific types of potentially useful regulatory reforms. For example, van Senten, Engle, et al. (2018) and Engle, van Senten, et al. (2021) found that risk-based approaches to fish health testing required for interstate movement of live fish had potential for substantial reductions in on-farm compliance costs. Boldt et al. (2022) found that regulatory reforms that resulted in improved access to restricted drugs and chemicals for non-foodfish species and use of risk-based approaches to managing approvals of non-native species in aquaculture would reduce negative impacts to US aquaculture farms.

For catfish, the greatest negative economic effects were those related to losses to avian predators. A potential source of relief would be to include aquaculture in existing federal programs that compensate farmers either for the losses to avian predators or for the expenses incurred to scare birds from their farms (Engle et al., 2020). More generally, regulations that are less prescriptive, more flexible, and cost-efficient have been suggested as more appropriate for aquaculture, given the dynamic nature of the rapid evolution of new technologies in aquaculture (Osmundsen et al., 2017). Inclusion of sunset clauses and periodic re-evaluation would provide a mechanism for regulations to be revised to remain current with technology and to reward farms with track records of high degrees of conformity with required standards by reducing testing and monitoring frequency and the associated costs.

5 | CONCLUSIONS

Regulations meant for societal welfare should be pragmatic and implemented in a cost-efficient manner based on current science. A national survey identified and quantified the economic effects of the regulatory burden on US catfish farms. This study by no means suggests deregulation in aquaculture but rather validates the negative effects of regulations on catfish farms and the need for innovative ways to implement the necessary oversight more cost-effectively. Study results showed that the US regulatory system burdens catfish farms by increasing costs annually by an average of $352,591/farm, or $0.21/kg. The national annual regulatory costs on catfish farms were $45 million. Regulatory actions on US catfish farms further resulted in lost revenues of $35 million per year. The negative effects of regulatory costs were disproportionately greater on smaller farms.

Environmental regulations, primarily bird regulations, had the greatest effect followed by labor regulations. Most of the regulatory costs found on catfish farms were fixed costs. Many of the regulations identified in this study have been in existence for several years and increased the cost of production of catfish farming by $0.21/kg, a percentage increase of 8.4%. Implementation of regulations surrounding food safety and interstate transport has caused significant lost revenue on catfish farms. The ability to generate revenue from sales of additional catfish or species restricted by regulations reduces farm revenues and prevents farms from taking advantage of economies of scope.

With more US consumers demanding locally produced food, abatement of regulatory costs on the largest domestic aquaculture segment would increase overall benefits to the society. This study shows the overall economic effect of regulatory action on a well-established industry such as catfish and how certain regulations such as environmental and labor stifle the industry's ability to meet growing seafood demand from domestic production. The results of this study provide the economic effect and magnitude of regulations on catfish farms and would help policymakers to be more efficient in regulatory implementation.

ACKNOWLEDGMENTS

We thank all the catfish producers across the nation for providing their valuable inputs. We are thankful to Dr Luke Roy, Sunni Dahl, Larry Dorman, and Mark Peterman for helping us with the survey. The authors are grateful for the suggestions provided by Drs Suja Aarattuthodi, Jimmy Avery, and Jeff Johnson. We also thank the United States Department of Agriculture-National Institute of Food and Agriculture (USDA-NIFA Grant #2018-70007-28827, Accession #1017200) for funding this research along with support from the Mississippi Agriculture and Forestry Experiment Station Special Research Initiative (MAFES-SRI-Grant #MIS 371240), the U.S. Department of Agriculture National Institute of Food and Agriculture (USDA-NIFA Hatch Project Accession Number 1013160), and the Arkansas Catfish Promotion Board.

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How to cite this article: Hegde, S., Kumar, G., Engle, C., & van Senten, J. (2023). Cost of regulations on US catfish farms. *Journal of the World Aquaculture Society*, *54*(1), 32–53. https://doi.org/10.1111/jwas.12917