Received: 8 January 2019 | Revised: 2 February 2019 | Accepted: 14 February 2019

DOI: 10.1111/jwas.12604

WILEY Journal of the World Aquaculture Society

APPLIED STUDIES

Regulatory costs on U.S. salmonid farms

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Funding information
U.S. Trout Farmers Association; USDA-APHIS, Grant/Award Number: 422526; Western Regional Aquaculture Center, Grant/Award Number: 542209

The economic effects of the implementation of regulations on aquaculture farms in the United States, while of concern, are not well understood. A national survey was conducted of salmonid (trout and salmon) farms in 17 states of the United States to measure on-farm regulatory costs and to identify which regulations were the most costly to this industry segment. The response rate was 63%, with a coverage rate of 94.5% of the U.S. production of salmonids. The regulatory system resulted in increased national on-farm costs of $16.1 million/year, lost markets with a sales value of $7.1 million/year, lost production of $5.3 million/year, and thwarted expansion attempts estimated at $40.1 million/year. Mean farm regulatory costs were $150,506/farm annually, or $2.71/kg; lost markets with annual sales values of $66,274/farm; annual lost production of $49,064/farm; and an annual value of thwarted expansion attempts estimated at $375,459/farm. Smaller-scale farms were affected to a disproportionately greater negative extent than larger-scale farms. Per-farm regulatory costs were, on average, greater for foodfish producers than for producers selling to recreational markets, but per-kg regulatory costs were greater for those selling to recreational compared to foodfish markets. Regulatory costs constituted 12% of total production and marketing costs on U.S. salmonid farms. The greatest regulatory costs were found to be effluent discharge regulations. The majority of regulatory costs were fixed costs, but regulatory barriers to expansion precluded compensatory adjustments to the business in spite of growing demand for salmonid products. Results of this study show that the on-farm regulatory cost burden is substantial and has negatively affected the U.S. salmonid industry's ability to respond to strong demand for U.S. farm-raised salmonid products. Results also suggest that the regulatory system has contributed to the decline in the number of U.S. salmonid farms. While regulations will necessarily have some degree of cost to farms, the magnitude of the on-farm regulatory cost burden on U.S. salmonid farms calls for concerted efforts to identify and implement innovative

regulatory monitoring and compliance frameworks that reduce the on-farm regulatory cost burden.

KEYWORDS

aquaculture economics, aquaculture regulations, regulatory costs, salmon, trout

1 | INTRODUCTION

Laws and regulations are necessary to ensure environmental quality, minimize the transmission of diseases, and meet other goals of society. Monitoring and enforcement of regulatory compliance clearly entails some level of cost to regulatory agencies, to taxpayers, and to businesses. Many of the laws promulgated to meet various societal goals have resulted in well-documented benefits to society that take many different forms (Office of Management and Budget-Office of Information and Regulatory Affairs, 2017).

Questions have arisen in recent decades, however, related to whether businesses in developed nations such as the United States and the European Union (EU) are over-regulated and unduly burdened with redundant, duplicative, and overly costly compliance requirements. Other concerns have arisen related to unintended consequences, especially related to how various laws and regulations are implemented. If the regulatory system results in aquaculture production being moved from highly regulated environments in the United States and the EU to other world regions with less-developed enforcement systems, the net global environmental effect could be negative. The significant negative relationship between the stringency of environmental regulation and the growth rate of aquaculture identified by Abate, Nielsen, and Tveterås (2016), based on a regression analysis of data from 97 countries worldwide, supported earlier studies that discussed constraints to aquaculture growth in the United States (Engle, 2016; Engle & Stone, 2013; Kite-Powell, Rubino, & Morehead, 2013; Knapp & Rubino, 2016; Thunberg, Adams, & Cichra, 1994). Osmundsen, Almklov, and Tveterås (2017) examined why aquaculture fits the criteria of being a "wicked" problem in the sense that the often-prescriptive nature of regulatory implementation and the rigidity of the regulatory system do not provide for flexibility to adjust to the dynamic nature and rapid pace of technological advances of aquaculture. Abate, Nielsen, and Nielsen (2018) extended this work by developing a conceptual framework of the influence of rivalry among regulatory agencies and the effects of individual ideologies on development and enforcement of specific regulatory requirements.

Facility-level information on compliance costs of regulations are generally lacking but are especially important for industries that are heterogeneous in terms of size (National Center for Environmental Economics, 2014). To gain a better understanding of the on-farm economic effects of the implementation of regulations in the United States, van Senten and Engle (2017) found costs on baitfish/sportfish farms to be, on average, $148,554/farm, $7,383/ha, and to constitute 25% of total costs of production. Per-hectare costs were found to be substantially greater on smaller, when compared to larger, baitfish/sportfish farms and may have contributed to the exodus of small farms from the industry. A subsequent analysis showed that regulations decreased farm-level efficiency as owners and managers were required to spend greater amounts of time on record keeping and reporting and proportionately less time on farm-level innovation and market development (Kumar, 2018; van Senten, Dey, & Engle, 2018). Asche and Roll (2013) and Dresdner and Estay (2016) similarly found that regulatory requirements contributed to farm-level inefficiencies. The greatest regulatory costs in the U.S. baitfish/sportfish sector resulted from the fragmented state-level variation in fish health testing requirements (including differing sample sizes for testing) (van Senten, Engle, Hartman, Johnson, & Gustafson, 2019). The adoption of risk-based epidemiological approaches to fish health certification was

shown to have the potential to reduce total regulatory costs in the U.S. baitfish/sportfish sector by more than half (57%). Thus, there is some evidence, in at least one sector of aquaculture in the United States, that there may be opportunities to reduce the regulatory cost burden on aquaculture farms without compromising societal goals that led to the respective laws. The baitfish/sportfish regulatory cost studies further demonstrated a high degree of variation by state and by species raised (van Senten et al., 2018; van Senten & Engle, 2017). Thus, there is reason to believe that the magnitude and costs of regulations may differ for other species raised in other states.

According to the Census of Aquaculture, salmonids are raised in all 50 states in the United States (35 states for food-sized fish and an additional 15 states for conservation, stock enhancement, or restoration) (United States Department of Agriculture, 2014). The top five trout-producing states by volume in the United States are Idaho, Washington, North Carolina, Pennsylvania, and California. By number of farms, the top five trout-producing states are North Carolina, Pennsylvania, Wisconsin, Idaho, and Virginia. Trout production occurs mostly in mountainous areas with abundant cool water resources suitable for the species raised, while Atlantic salmon production occurs primarily in marine areas in northern latitudes, with some experimental indoor production.

Salmonids have been farmed in the United States for more than a century. The major salmonid species farmed in the United States is the rainbow trout (*Oncorhynchus mykiss*). Over time, several varieties of rainbow trout, including golden rainbow trout and albino rainbow trout, have been developed, propagated, and sold. Steelhead trout are anadromous rainbow trout. Other species of trout farmed in the United States include: brown trout (*Salmo trutta*); brook trout (*Salvelinus fontinalis*); cutthroat trout (*Oncorhynchus clarkii*); and several hybrids such as the tiger trout (♀ brown × ♂ brook), cutbow (♀ cutthroat × ♂ rainbow), and splake (♀ lake, *Salvelinus namaycush*, × ♂ brook). Other types of salmonid fishes raised in the United States include Arctic char (*Salvelinus alpinus*) and Atlantic salmon (*Salmo salar*). Of these, rainbow and steelhead trout and Atlantic salmon constitute the majority of sales of salmonid foodfish. Rainbow trout is the main species sold to recreational markets, but brown and brook trout are also important for recreational fishing sales. The various hybrids and varieties that have been developed are sold more as specialty fish to recreational angling markets.

The majority of salmonid production in the United States occurs in flow-through raceways—some earthen but mostly concrete in recent years. A few small-scale producers raise some trout in ponds and a few others in indoor systems, and Atlantic salmon production is mostly performed in net pens in marine waters, although there are attempts to raise Atlantic salmon commercially in indoor tanks.

Trout farms range in size from very small operations that produce and sell less than 9,070/kg a year to very large, sophisticated businesses that sell more than 226,757/kg a year. In addition to the number of different species and varieties of trout raised and sold on U.S. farms, trout farms sell to a variety of markets. Some farms sell primarily foodfish that are processed and sold through major food-marketing channels to restaurants and supermarkets. Other foodfish producers sell fish live to customers who purchase directly from farms. Still other producers sell live trout to recreational markets. Some sell various sizes to pond owners, catch-out ponds (also called paylakes or fish-and-pay lakes), fishing clubs, and others whose customers are anglers who enjoy trout fishing. Producers also sell various sizes and species to other farms for further grow out.

The salmonid industry in the United States provides an opportunity to study not only an industry in which interstate transport and fish health testing costs are important (to trout farmers who supply live fish to recreational markets or other farms) but also an industry with a substantial foodfish production sector. The U.S. trout industry primarily uses flow-through raceway production rather than the static ponds used in the U.S. baitfish/sportfish industry. Regulations differ substantially for flow-through as opposed to static water pond production systems. Thus, measuring farm-level costs of regulations on U.S. salmonid farms would contribute to the growing understanding of how regulatory compliance requirements affect the economics of aquaculture farms.

This article presents the initial results of a study of regulatory costs on U.S. salmonid farms. The goal of the study was to systematically collect data on the types and magnitude of costs faced by salmonid farmers as they seek to comply with the total set of regulations required for their businesses. The objectives of this article are to describe these costs on a national and state level, to compare the relative cost burden on different farm sizes and targeted

markets (recreational markets vs. foodfish markets), and to identify those regulations that are most costly to U.S. salmonid farms. While there are clear benefits from the set of existing laws and regulations, it is beyond the scope of this article to quantify those benefits. Subsequent studies will explore in detail those aspects of the regulatory burden that were found to be most costly and will seek to identify alternative models of implementation of regulations that would preserve benefits to farms and society by maintaining adequate oversight but reduce on-farm costs of monitoring and compliance.

2 | METHODS

2.1 | Survey methodology and questionnaire development

A national survey was conducted of the U.S. salmonid farming industry, with a focus on the 17 top-producing states (Colorado, California, Idaho, Maine, Michigan, Missouri, Nebraska, New York, North Carolina, Ohio, Oregon, Pennsylvania, Utah, Virginia, Washington, West Virginia, Wisconsin). Extensive efforts were made to obtain up-to-date and accurate listings of all salmonid producers in each of the 17 targeted states. These lists were compiled with assistance from extension aquaculture specialists in various states; lists of permits issued to producers; discussions with producers, particularly the board of the United States Trout Farmers Association; and internet searches.

The survey instrument included questions that focused on the overall salmonid operation, including species, numbers, and volumes of fish produced, as well as types of markets targeted. Questions that worked well in a previous survey with baitfish/sportfish producers were used to elicit information on the most important types of problems for the farm (i.e., labor, markets, diseases, etc.) and types of regulations that were the most problematic for producers. Respondents listed all local, state, federal, and international regulations; permits/licenses; and the various filings (engineering studies, consultant surveys, etc.) required. The survey instrument included detailed questions related to: (a) fish health testing required for import permits to sell live fish to various states and (b) permits related to the discharge of effluents. Respondents were asked to report on any changes in management and associated costs required to comply with each specific regulation. Manpower expended for various activities (such as collecting and transporting samples, monitoring, record keeping, reporting, attending meetings and hearings) was recorded for each employee who assisted with regulatory activities, as well as their salaries or wages. Additional questions focused on costs associated with all testing required, shipping samples to laboratories, and consultant and attorney fees, as well as the costs of the permits/licenses themselves. Questions were also asked about other effects of regulatory actions, such as: lost business opportunities, markets that were lost, production lost because of required reductions in production capacity, and expansion attempts that were thwarted because of regulatory barriers. Table 1 provides definitions of the terms used to categorize the various types of economic effects that resulted from regulatory actions. Effects were identified in terms of increased farm costs and reduced farm sales. Increased farm costs from regulations were referred to as "regulatory costs" and included direct costs of permitting, monitoring, testing, and reporting, as well as associated manpower costs. Farm sales effects were categorized as: (a) the value of lost markets, (b) the value of lost production, and (c) the value of thwarted expansion. The values of lost markets and lost production were based on farm records that documented annual average sales prior to regulatory action, whereas the annualized values of thwarted expansion were estimated based on permitting application requests by respondents that had not been approved at the time of the survey.[1] The final section of the questionnaire requested all farm production and marketing costs, as well as farm revenue.

Prior to initiating survey activities in each state, extension specialists were consulted to identify the most effective means to inform producers of the upcoming survey. In some states, project personnel were invited to announce the survey at meetings and explain the objectives and importance of high levels of participation. Articles were also provided to state and regional newsletters to inform producers and encourage participation. Shortly before launching the survey in each state, individuals identified as trusted sources by producers in that state were asked to actively

TABLE 1 Definitions of selected terms used in the analysis of regulatory costs and economic effects on U.S. salmonid farms

Term	Definition
Effects on farm costs	
Regulatory costs	Costs reported to acquire permits/licenses; testing and other direct costs; costs of equipment and supplies purchased as a result of regulatory actions; and the value of manpower used for monitoring, record keeping, reporting, and other compliance activities.
Effects on farm sales revenue	
Value of lost markets	Value of sales to specific markets that were subsequently lost because of regulatory action. Values based on farm records that documented those sales prior to regulatory action.
Value of lost production	Value of production lost because of a reduction in production capacity as a result of regulatory action, such as converting portions of raceways into quiescent zones that could not be stocked with fish. Values based on farm records that documented production prior to regulatory action.
Value of thwarted expansion	Value of sales not received because of regulatory barriers to expansion. Values based on respondent estimates rather than farm records.

contact other producers to encourage participation. Telephone and email contacts were made to ensure that those included on the contact lists were: (a) still in business and (b) actively feeding and raising fish (those who only bought or sold salmonids were removed from the lists). Of the initial list of 197 salmonid producers, 161 were determined to be in production at the time of the survey and were included in the list frame (Table 2). Twenty farms (10% of the initial list) were found to have gone out of business.

The interviews were conducted primarily as direct, in-person interviews. Project investigators traveled to each state and met individually with the majority of respondents, with a few interviews completed by telephone. Individual interviews lasted from 45 min to approximately 3 hr.

TABLE 2 List frame development

State	Initial list (no.)	Out of business	Not a trout producer (no.)	List frame (no.)
California	10	4	0	6
Colorado	12	1		11
Idaho	20	3	1[a]	16
Maine	1	0	0	1
Michigan	10	0	3	7
Missouri	5	0	0	5
Nebraska	7	1	0	6
New York	15	1	7[b]	7
North Carolina	21	0	2	19
Ohio	8	1	0	7
Oregon	10	1	0	9
Pennsylvania	21	3	2	16
Utah	8	0	1	7
Virginia	7	0	0	7
Washington	6	0	0	6
West Virginia	16	5	0	11
Wisconsin	20	0	0	20
Total	197	20	16	161

[a]Producer but in another state.
[b]Buys and resells or is a nonprofit.

2.2 | Data analysis and cost calculations

To calculate annual regulatory costs on trout farms, the following steps were taken: (a) total production costs were summarized for each observation; (b) total marketing costs were summarized for each observation; (c) costs related to regulations were separated from production and marketing costs and summed by observation; (d) regulatory costs for each observation were further sorted into cost categories (permits/licenses, direct costs other than permits, manpower, and costs of unexpected changes because of regulations); and (e) regulatory costs for each observation were sorted by regulatory category (fish health testing, effluent discharge, water rights, food safety/hazard analysis of critical control points (HACCP), and all other regulations). Once these tabulations were completed, the regulatory costs ($/farm and $/kg of production) for each cost category and for each regulatory category were summarized by state and across all states. Descriptive statistics reported included the mean and median of values nationally and by state, by farm, and by kg of production. States for which there were three or fewer observations were combined into the following categories to protect the confidentiality of individual farm data: "coastal states" (California, Maine, Oregon, Washington) and "Midwest states" (Missouri, Nebraska). The total responses nationally were then adjusted by the coverage rate (percentage of national industry represented in the data) to obtain a national estimate of the regulatory cost burden.

The concepts of fixed and variable costs have important economic implications for farm management. While variable costs per kg of fish produced remain the same as production volume increases (assuming no management changes), fixed costs per kg of fish produced decrease with greater volumes of production. An expense is categorized as a fixed cost if it does not change in direct proportion to increases or decreases in the quantity of fish produced. For example, the amount of feed fed in a given year would decrease if a farm lost fish because of a disease and would increase if water flows and temperatures were ideal for faster fish growth in that year; thus, feed is considered a variable cost. Property taxes and liability insurance, on the other hand, must be paid in full whether fish production that year was high or low; thus, property taxes and liability insurance are considered to be fixed costs. Regulatory costs for each farm observation were examined to determine whether they would constitute a fixed or a variable cost on salmonid farms.

2.3 | Regulatory costs by farm size

The dataset was sorted by farm size, based on total production, to determine if regulatory cost burden varied by farm size. The smallest farm size was selected as those farms that produced less than 9,070 kg a year because federal regulations generally exempt farms of this size from effluent discharge requirements.[2] Other size groupings were based on transition points identified by graphing the production scale of observations and included the following size categories with production volumes in the following ranges: 9,071–54,421 kg, 54,422–226,757 kg, and greater than 226,757 kg. For each of these four groups, the following metrics were calculated: (a) overall cost/kg within each size group, (b) mean and median $/farm and $/kg, and (c) percentage of regulatory costs and the various categories of lost sales composed of total farm costs.

2.4 | Regulatory costs by type of market outlet

Farms that sell fish to recreational markets tend to produce different species and sizes and manage their farms in ways that differ from farms that sell primarily to foodfish markets. Thus, production and marketing costs, and perhaps regulatory costs, would be expected to vary depending on the type of business model. To examine whether regulatory costs differed by type of principal market outlet, data were sorted by their principal type of market (i.e., recreational or foodfish market), and the resulting regulatory costs were calculated per kg, per farm, and as a percentage of total production and marketing costs.

2.5 | Coverage and response rates

The overall response rate of individual farms was 63% (Table 3). The response rate may be underestimated because some of the farms that did not respond may not have been in salmonid production any longer. Unless there was direct proof that the farm was no longer in business, it was maintained in the list frame. Completed responses

TABLE 3 Coverage and response rates

	List frame (no. trout farms)	Refusal/unable (no. farms)	No response (no. farms)	Completed	Response rate (%)
Colorado	11	0	5	6	55
Idaho	16	2	2	12	75
Michigan	7	0	1	6	86
New York	7	0	1	6	86
North Carolina	19	2	6	11	58
Ohio	7	2	1	4	57
Pennsylvania	16	0	2	14	87.5
Utah	7	0	1	6	86
Virginia	7	0	3	4	57
West Virginia	11	0	1	10	91
Wisconsin	20	1	9	10	50
Coastal states[a]	22	4	11	7	32
Midwest states[b]	11	1	5	5	45
Total	161	12	48	101	63%

Note. Coverage rates: by volume of production 92%; by sales 97%.
[a]California, Maine, Oregon, Washington.
[b]Missouri, Nebraska.

corresponded to coverage rates of 92% by volume of production and 97% by total farm sales; an average of 94.5% was used to adjust values to reflect national costs.

3 | RESULTS

3.1 | Top five problems on salmonid farms

When asked "what would you say were the top 5 biggest problems for your business," regulations were mentioned most frequently, followed by depredation by predators, fish health/diseases, labor, water rights/access, markets, and others (Figure 1). Of the respondents, 62% mentioned regulations as either the #1 or #2 greatest problem on the farm. Other types of problems rated #1 or #2 included depredation by predators (losses to birds such as herons and egrets (29%), fish health issues related mostly to testing to obtain fish health certificates (27%), labor problems (26%), water rights and access (14%), markets (10%), and other issues (10%). The "other" category included a wide variety of responses that are listed in Table A1.

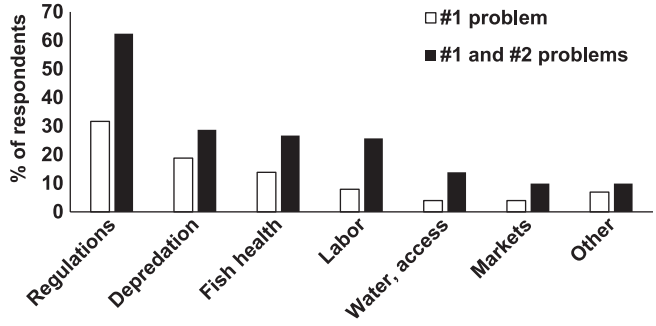

FIGURE 1 Producer responses to the following question: "We would like to put the importance of regulatory effects in the context of your overall business. What would you say are the top 5 biggest problems for your business? Please rank your top 5 problems with #1 being the biggest problem." (N = 101 respondents)

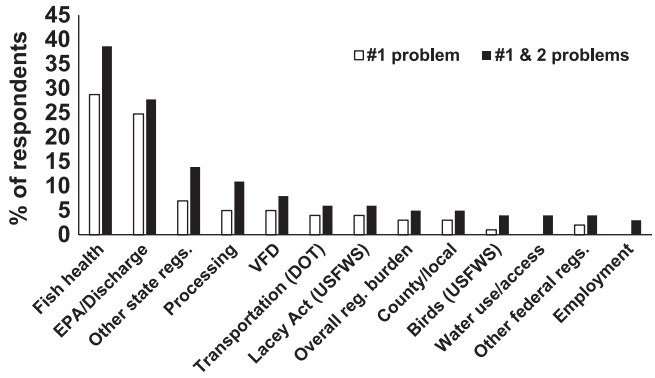

FIGURE 2 Producer responses to the following question: "Of all the regulations you deal with, which have created the greatest problems for your business, with #1 being the most problematic." (N = 101 respondents). EPA: Environmental Protection Agency; DOT: Department of Transportation; USFWS: US Fish and Wildlife Service; VFD: veterinary feed directive

3.2 | Most problematic regulatory problems

Respondents were asked to indicate which regulations were the most problematic for their business. Interstate shipping regulations related to fish health testing and certification requirements were mentioned as the most problematic (either #1 or #2) by 39% of respondents (Figure 2). The next most problematic regulations were environmental protection agency (EPA)-mandated discharge regulations (28% #1 or #2). These were followed in descending order by other state regulations, processing, the FDA veterinary feed directive (VFD), transportation regulations (Department of Transportation), the Lacey Act (U.S. Fish & Wildlife Service), the overall regulatory burden, county/local regulations, bird depredation permits (U.S. Fish & Wildlife Service), regulations related to water use and access, other federal regulations, and employment-related regulations.

3.3 | Notification of renewals and changes in regulations

Respondents were asked whether they received annual reminders of permit renewals; 60% said that they always received reminders for permit renewals, and 14% said that they never received reminders (Table 4). When asked if they received timely notifications from regulatory agencies of changes in compliance actions required to avoid penalties, however, only 28% responded that they did, and 39% indicated that they never did.

TABLE 4 Notification of annual renewals and changes in regulations (N = 101 respondents)

Rating (0 = never; 5 = always)	Do you receive annual reminders of permit renewals? (% of respondents)	Do you receive timely notifications from regulatory agencies of any changes to be in compliance and avoid penalties? (% of respondents)
0	14	39
1	1	2
2	3	1
3	3	7
4	10	8
5	60	28
No response	9	16

3.4 | Lost markets and opportunities

Respondents were asked if they knew of farms that had gone out of business because of regulations. Overall, 51% of respondents indicated that they did know of at least one farm that had reportedly gone out of business because of regulations and, in some cases, provided contact information (Table 5). Some respondents referred to the same farm mentioned by other respondents; thus, these responses indicate the percentage of farmers who have observed declines in the number of salmonid farms, not the percentage of farms that have gone out of business. Of respondents, 44% indicated that they had lost sales because of regulations; 41% had experienced unexpected changes because of regulations; and 32% stated that they had lost other opportunities because of regulations. The lost opportunities described included lost production from reduced production capacity that resulted from regulations (24%) and thwarted attempts to expand the business because of delays or denied permits (8%).

3.5 | Total numbers of permits and associated filings required

Respondents were asked to list all types of permits and regulatory filings[3] required for their salmonid farming businesses and to indicate whether these were local (county, township), state, federal, or international. The total number of unique permits required as reported across all respondents was 455 (data not shown in tables). Of these, 22% were federal (both direct and mandated for state enforcement), 49% were state, and 29% were local.

All permits and filings were categorized into one of six regulatory categories (aquaculture/propagator, interstate transport, environmental management, fish health, legal and labor standards, and food safety). Aquaculture/propagator permits were required by all states, although specific requirements varied by state. Interstate transport typically requires registration and various filings by the Department of Transportation that vary by the type of vehicle. Most environmental management permits were related to the discharge of effluents primarily by the EPA and the relevant state agency, but in some cases, involvement was also required of the U.S. Army Corps of Engineers, the U.S. Fish & Wildlife Service, and coastal regulatory authorities. Bird depredation permits were included in the environmental management category. Fish health permits/filings included certificates required by the producer's own state, as well as by destination market states, as a component of required state import permits and requirements related to the FDA VFD. Permits and filings related to legal and labor standards included local business licenses (distinct from fish farming or aquaculture permits and licenses), Occupational Safety and Health Administration requirements, and other employment-related requirements. Food safety permits/filings were mostly related to HACCP training requirements but also included myriad local health department and city ordinances related to processing, meat smoking, restaurant licenses, and selling fish in farmers' markets or food trucks, among others.

The number of unique permits does not adequately portray the effort required by survey respondents. An individual permit may require a series of substantive (and sometimes expensive) actions on the part of the farmer that must be filed with the agency as one step in the permit application process. These can include engineering studies, surveys of wetlands, or endangered species impact studies that must be filed sequentially. Respondents reported

TABLE 5 Farms that have gone out of business, lost markets, unexpected changes, lost production, and thwarted expansion attempts because of regulations (N = 101 respondents)

Survey question	Yes (%)
Do you know of farms that have either closed down or never started up due to regulations?	51
Are there states and/or countries/regions you used to sell trout to or would like to sell trout to, but do not due to the regulatory environment?	44
Have there been unexpected changes in the farm business as a result of having to comply with all regulations?	41
Are there any other opportunities that were lost due to regulations?	32
Lost production	24
Thwarted expansion due to delayed or denied permits	8

1,244 filings of this nature, with a mean of 12/farm (median = 6) that ranged from 1 to 135/farm (Table 6). Each of these filings required time and personnel in addition to other expenses, with each filing contributing to the total complexity of what individual salmonid farms must comply with.

Of total filings, 61% were state, 16% strictly federal, 9% federal filings that mandated enforcement by the state, 9% local, and 4% international (Table 7). Most of the local, federal, and international filings occurred in the coastal states. A third of the federally mandated state filings were in Idaho, while Utah joined Idaho with the greatest numbers of state filings. The environmental management and interstate transportation categories required more permits and filings than other categories and were primarily federal or federally mandated state filings (Table 8).

3.6 | Total regulatory costs

Table 9 presents the total regulatory costs by state, by farm, and by kg of production (weighted by production or averaged by farm). National total annual regulatory costs were $16.1 million. The values per state varied in large part because of the varying sizes of the industry in different states. For example, the top salmonid-producing states of Idaho, the coastal states, and North Carolina also exhibited the greatest total state-wide regulatory costs, as would be expected. The national mean regulatory cost per farm was $150,506 but varied from $3,026 per farm in West Virginia to $798,076 per farm in the coastal states.

Lost revenue resulted from markets and production lost because of regulatory action, as well as the estimated value of attempts to expand that had been thwarted by delay or denial of permits (Figure 3). The greatest percentage of total lost revenue was that reported from thwarted expansion attempts (57%), followed by the value of lost markets (25%) and then the value of lost production (18%). While some states reported no lost revenue, others—particularly the major salmonid-producing states (coastal states category, Idaho, and North Carolina)—had substantial

TABLE 6 Total number of regulatory filings[a] (includes all applications required)[b]

		Per farm		
State	Total number	Mean	Median	Range
Colorado	65	11	9	6–21
Idaho	194	16	7	2–84
Michigan	77	13	10	5–30
New York	24	4	4	2–7
North Carolina	51	5	4	1–12
Ohio	31	8	3	2–23
Pennsylvania	84	6	5	1–19
Utah	129	22	21	3–55
Virginia	65	16	18	4–26
West Virginia	55	6	5	1–15
Wisconsin	91	9	8	3–22
Coastal states[c]	287	41	15	4–135
Midwest states[d]	91	18	7	4–50
National	1,244	12	6	1–135

[a]A regulatory filing was defined as an activity required by regulatory agencies that required a substantive study, survey, or other submission by the farm to obtain specific certificates or other approvals required as part of a permit application process. Examples include engineering studies; wetland surveys conducted by hired consultants; and consultations required of tribal, coastal, or federal authorities. Routine submissions of water quality monitoring and testing, however, were not included as separate "filings."
[b]Respondents were provided with lists of permits and licenses by the agency and asked to check which ones they were required to have and to write in any that were missing.
[c]California, Maine, Oregon, Washington.
[d]Missouri, Nebraska.

TABLE 7 Total number of regulatory filings[a] (includes all applications required) by level of government agency[b]

	Local	State	Federally mandated state	Federal	International
Colorado	6	52	4	3	0
Idaho	11	112	38	31	2
Michigan	20	38	8	11	0
New York	0	22	0	2	0
North Carolina	0	24	16	11	0
Ohio	0	24	1	6	0
Pennsylvania	3	67	6	8	0
Utah	2	116	3	7	1
Virginia	0	58	5	2	0
West Virginia	7	39	2	7	0
Wisconsin	6	58	11	16	0
Coastal states[c]	50	77	17	92	51
Midwest states[d]	2	78	2	9	0
National	107	765	113	205	54
Percentage of total	9%	61%	9%	16%	4%

[a]A regulatory filing was defined as an activity required by regulatory agencies that required a substantive study, survey, or other submission by the farm to obtain specific certificates or other approvals required as part of a permit application process. Examples include engineering studies; wetland surveys conducted by hired consultants; and consultations required of tribal, coastal, or federal authorities. Routine submissions of water quality monitoring and testing, however, were not included as separate "filings."
[b]Respondents were provided with lists of permits and licenses by the agency and asked to check which ones they were required to have and to write in any that were missing. There were 14 "recommended studies" that were not formal requirements but without which permits were unlikely to be approved.
[c]California, Maine, Oregon, Washington.
[d]Missouri, Nebraska.

values of lost revenue, either as lost market sales, lost production, or thwarted expansion (Table 10). Other states, such as Utah, Michigan, and Colorado, that showed substantial lost revenue because of regulatory actions are also states with high percentages of decline in the number of salmonid farms (40, 63, and 62% decreases in the numbers of salmonid farms, respectively, from 1998 to 2014; United States Department of Agriculture, 2006, 2014). Salmonid farmers in several of these states have had prominent regulatory disputes and, in some cases, ongoing litigation. The lost revenue, combined with increasing fixed costs, was reported to have provided incentives for farms to exit the business. Respondents in six states reported that attempts to expand production had been thwarted in the permit review process, which further prevented those farms from operating at an efficient and optimal scale of production.

TABLE 8 Total number of permits/filings by six regulatory categories and level of government responsible[a]

		Government level						
	Total required	Local/state		Federally mandated			Federal	
	No.	%[b]	No.	%[c]	No.	%[c]	No.	%[b]
Aquaculture/propagator permit	170	14	170	100	0	0	0	0
Interstate transport	378	30	221	58	0	0	157	42
Environmental management	394	32	179	45	143	36	72	18
Fish health	111	9	107	96	0	0	4	4
Legal and labor standards	127	10	110	87	0	0	17	13
Food safety	64	5	24	38	30	47	10	16

[a]Reported by 101 responding farms in 17 states.
[b]Percent of column by regulatory category.
[c]Percent of row of each regulatory category promulgated by type of government level.

TABLE 9 Regulatory cost by state

State	$/state[a]	$/farm	$/kg averaged by total production[b]	$/kg averaged by farm[c]
Colorado	$331,202	$55,200	$2.98	$2.82
Idaho	$6,457,617	$538,135	$0.49	$0.46
Michigan	$546,565	$91,094	$2.09	$1.98
New York	$21,580	$3,597	$0.51	$3.75
North Carolina	$957,271	$87,025	$0.40	$1.06
Ohio	$73,952	$18,488	$0.82	$0.82
Pennsylvania	$168,186	$12,013	$0.24	$0.31
Utah	$291,967	$48,661	$2.16	$9.28
Virginia	$115,205	$28,801	$0.93	$0.73
West Virginia	$30,260	$3,026	$0.26	$0.84
Wisconsin	$381,185	$38,118	$1.74	$5.40
Coastal states[d]	$5,586,533	$798,076	$0.20	$10.12
Midwest states[e]	$239,581	$47,916	$0.37	$1.10
National	$15,201,104	$150,506	$0.33	$2.71
Coverage adjusted	$16,085,824	$150,506	$0.33	$2.71

[a]Calculated as sum of all regulatory costs across observations from that state.
[b]Calculated by dividing the $/state by the total weight of production reported for that state.
[c]Calculated by dividing the regulatory cost per kilogram of production on each farm in that state and then averaging the per-kg regulatory cost across all observations in that state.
[d]California, Maine, Oregon, Washington.
[e]Missouri, Nebraska.

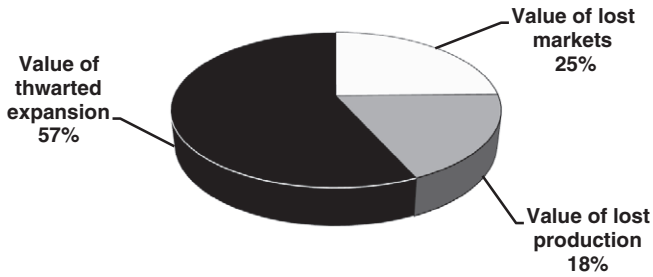

FIGURE 3 Types of lost sales (as a percent of total lost sales and thwarted expansion)

3.7 | Regulatory costs by type of cost category

Total regulatory costs were classified into key types of cost categories that included: permits and licenses, direct costs other than permits, manpower, and costs of unexpected changes because of regulations. Direct costs other than permits/licenses constituted 68%, manpower costs 23%, unexpected farm-level changes 7%, and the costs of the permits/licenses only 2% of the total regulatory cost (Figure 4). Direct costs other than permits/licenses include the costs of testing discharge water samples or fish health testing costs; delivery and shipping of samples to laboratories; the cost of fish sacrificed for fish health testing; and the manpower required for sampling, delivering samples, monitoring, record keeping, and reporting.

The magnitude of the various types of regulatory costs varied among states (Table 11). For example, permit/license costs were the lowest or next-to-lowest costs for 85% of the states, but in Utah and West Virginia, the permit/license costs were the greatest regulatory cost. Direct costs other than permit/license costs were either the greatest or second greatest cost for 77% of the states.

TABLE 10 Lost revenue from the value of lost market sales, lost production, and thwarted expansion

	Value of lost market sales revenue				Value of lost production				Value of thwarted expansion			
			Per-unit average ($/kg)				Per-unit average ($/kg)				Per-unit average ($/kg)	
State	State[a] ($ M)	Farm ($)	Farm[b]	Total kg[c]	State[a] ($ M)	Farm ($)	Farm[b]	Total kg[c]	State[a] ($ M)	Farm ($)	Farm[b]	Total kg[c]
Colorado	0.780	130,000	7.28	7.01	0.086	14,310	1.08	0.77	0	0	0	0
Idaho	1.194	99,458	2.15	0.09	0.515	42,946	0.45	0.04	0.087	7,250	0.24	0.01
Michigan	0.371	61,783	0.87	1.42	0.990	165,000	1.90	3.78	0	0	0	0
New York	0	0	0	0	0	0	0	0	0	0	0	0
North Carolina	0.100	9,091	0.09	0.04	0.738	67,076	1.38	0.31	22.550	2,050,000	1.34	9.41
Ohio	0	0		0	0	0	0	0	0	0	0	0
Pennsylvania	0.392	27,964	0.72	0.57	0.270	19,286	1.27	0.39	0.004	313	0.10	0.01
Utah	2.064	344,025	21.58	15.34	0.570	95,000	7.18	4.24	0.050	8,333	0.35	0.37
Virginia	0.017	4,250	0.10	0.13	0.035	8,750	0.20	0.28	0	0	0	0
West Virginia	0.022	2,200	0.22	0.19	0.058	5,783	0.45	0.49	0	0	0	0
Wisconsin	0.104	10,400	0.95	0.48	0.376	37,630	1.65	1.73	0.023	23,000	2.67	1.06
Coastal[d]	1.550	258,333	1.33	0.06	1.300	185,750	0.07	0.05	15.000	2,142,857	0.20	0.54
Midwest[e]	0.035	6,900	0.09	0.05	0.017	3,400	0.01	0.03	0	0	0	0
National	6.627	66,274	2.36	0.14	4.955	49,064	1.20	0.11	37.921	375,459	0.49	0.83
W/coverage	7.096	66,274	2.36	0.14	5.306	49,064	1.20	0.11	40.128	375,459	0.49	0.83

[a]Calculated as sum of all regulatory costs across observations from that state in million $ (U.S.).
[b]Calculated by dividing the regulatory cost per kilogram of production on each farm in that state and then averaging the per-kg regulatory cost across all observations in that state.
[c]Calculated by dividing the $/state by the total weight of production reported for that state.
[d]California, Maine, Oregon, Washington.
[e]Missouri, Nebraska.

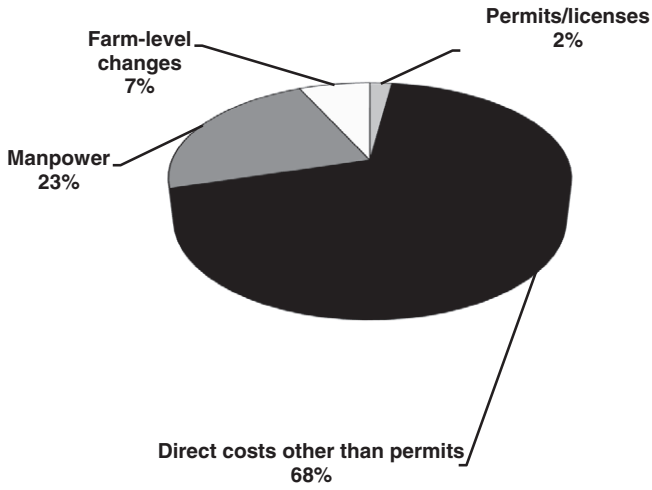

FIGURE 4 Regulatory costs by type of cost (% of total regulatory costs)

There was substantial variation within states as evidenced by differences between mean and median values per farm (Table 11). For example, in Idaho, the mean value of direct costs of regulations other than the permit/license cost was $444,035 per farm, while the median per-farm value was $6,114. In Michigan, the per-farm mean of regulatory manpower cost was $68,978, but the median was $14,775. In some states, mean and median values per farm were similar, such as the permit and license costs in North Carolina. These differences may reflect variations in farm size, regional differences, conditions specific to certain farms, and/or inconsistent regulatory actions required of different farms. This variability suggests the need for further analysis to explore in detail the causes of such variability.

TABLE 11 Means and medians of total regulatory costs (by type of cost) by farm and by state (Values in U.S. $/Farm)

	Permits & licenses		Direct costs other than permits		Manpower		Changes because of regulations	
State	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Colorado	1,340	1,385	39,147	13,050	8,652	6,701	6,062	3,312
Idaho	903	508	444,035	6,114	75,681	8,691	17,517	1,500
Michigan	921	646	10,539	3,363	68,978	14,775	10,656	4,805
New York	117	75	2,907	3,120	573	394	0	0
North Carolina	566	475	12,287	5,380	24,804	12,360	49,368	1,400
Ohio	1,006	900	4,183	2,275	11,366	9,305	1,993	—
Pennsylvania	1,454	343	5,010	1,951	5,371	441	179	—
Utah	17,729	952	10,896	9,455	11,173	7,030	8,863	7,500
Virginia	220	125	1,275	1,170	22,719	17,819	4,588	4,375
West Virginia	1,245	186	477	—	934	30	370	—
Wisconsin	1,455	670	7,577	3,906	22,984	14,850	6,102	1,817
Coastal states[a]	17,070	9,225	608,289	375,000	170,460	175,842	2,257	1,500
Midwest states[b]	1,131	725	16,586	9,540	25,164	23,800	5,035	0
National	3,120	495	102,554	3,480	34,525	3,180	10,307	—

[a]California, Maine, Oregon, Washington.
[b]Missouri, Nebraska.

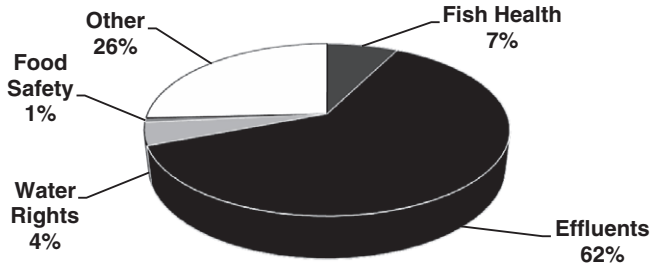

FIGURE 5 Regulatory cost by type of regulation (% of total regulatory costs)

3.8 | Regulatory costs by type of regulation

Regulatory costs were sorted by type of regulation, with primary categories of effluent discharge, fish health, water rights, food safety, and all other regulations (Figure 5). Of these, effluent discharge regulations comprised 62% of total regulatory costs and fish health 7% of total regulatory costs. All other types of regulations comprised 26% of total regulatory costs, water rights 4%, and food safety regulations 1%.

Table 12 presents state-level costs (mean $/farm) of each type of regulation. Costs associated with compliance with effluent discharges were the greatest regulatory costs in 46% of the states. Costs associated with fish health regulations, while considered to be the most difficult regulatory problem, were the greatest regulatory cost in only one state. While regulations related to water rights comprised only 5% of total annual national regulatory costs, water rights and access were the greatest regulatory cost in Colorado. The costs associated with water rights regulations were likely underestimated in this study. The survey did not capture those individuals or businesses that had gone out of business prior to the survey because of disallowed access to water suitable for trout production. The category of all other regulatory costs was the greatest cost in four states. All other regulatory costs included those specific to coastal and marine environments, as well as those promulgated on a local level. Per kg of production, all other

TABLE 12 Means and medians of regulatory costs by type of regulation, by farm, and by state (values in $/farm)

	Discharge		Fish health		Water rights		Food safety		All other regulations	
State	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Colorado	2,749	—	7,593	4,845	32,222	1,500	18	—	12,618	10,233
Idaho	455,957	19,826	3,973	38	32,470	0	5,250	—	40,487	1,758
Michigan	58,112	9,366	7,601	4,501	0	0	3,419	—	21,962	5,032
New York	0	0	3,407	3,325	0	0	0	0	190	83
North Carolina	73,466	9,399	1,163	—	4,273	0	262	—	7,861	1,143
Ohio	10,925	8,450	1,391	1,500	0	0	250	—	5,922	5,154
Pennsylvania	3,410	633	2,831	1,725	0	0	0	0	5,773	263
Utah	7,650	50	11,187	9,589	300	0	520	—	29,007	8,625
Virginia	18,000	18,286	519	511	0	0	0	0	10,282	5,291
West Virginia	1,478	—	142	—	0	0	0	0	1,406	198
Wisconsin	18,621	13,216	1,693	—	1,111	0	3,310	150	13,385	9,915
Coastal states[a]	320,926	158,008	113,266	275	143	0	429	—	363,313	113,740
Midwest states[b]	13,451	1,650	9,695	8,400	0	0	0	0	24,770	27,181
National	92,761	3,340	11,348	1,000	6,375	0	1,255	—	38,768	1,810

[a]California, Maine, Oregon, Washington.
[b]Missouri, Nebraska.

regulations imposed the greatest regulatory costs, followed by effluent discharge regulations and then fish health regulations (Table 13). Substantial within-state variations can be observed.

Lost revenue data demonstrate additional insights into how regulatory actions affect farm-level economics (Table 14). Discharge regulations did not result in lost markets but did cause lost production in 77% of the states and substantial estimated values from thwarted expansion attempts in three states. Fish health regulations, on the other hand, resulted in lost markets in 85% of the states, no lost production, and thwarted expansion attempts in three states. Water rights regulations affected only three states through lost production; food safety did not result in any reported lost revenue; and all other regulations resulted in lost markets in five states, lost production in two, and thwarted expansion attempts in one state. Per kg of production, lost revenues were the greatest for fish health regulations, followed by effluent discharge regulations, water rights, and then all other regulations (Table 15).

3.9 | Regulatory costs as a percentage of production, marketing, and total costs and of fixed and variable costs

As a percentage of total production and marketing costs, per-farm regulatory costs comprised 12%, and the value of lost revenue was 28% (Table 16). As a percent of production costs only, the mean national average regulatory cost was 15% (median = 8%), and the value of lost production was 13%. The cost of marketing-related regulatory costs on average was 4% of total marketing costs (median = 0.1%), and the value of lost revenue was 65% of total marketing costs.

The vast majority of regulatory costs on trout farms were fixed, not variable, costs. Permit/license costs that ensure rights to use water and food safety/HACCP training costs occur regardless of the volume of production. Fish health testing costs are based primarily on the frequency of testing, which depends on whether the farm sells to states that accept farm-level sampling or if lot-level testing is required. Farms that sell greater numbers of species and sizes of fish have greater testing costs, but such costs are not related to the volume of production. Farms that ship to states that require testing of each lot (shipment) have testing costs that are related to the number of shipments but not the volume of fish. Even small-scale farms may have many lots of fish, each of small quantities. At the

TABLE 13 Means and medians of regulatory costs per kilogram by type of regulation and state

	Fish health		Discharge		Water rights		Food safety		All other regulations	
State	Mean	Median[a]	Mean	Median[a]	Mean	Median[a]	Mean	Median[a]	Mean	Median
Colorado	0.584	0.276	0.154	—	1.345	0.141	0.001	—	0.743	0.630
Idaho	0.041	0.002	0.306	0.147	0.027	—	0	—	0.094	0.026
Michigan	0.699	0.183	0.842	0.701	0	—	0.046	—	0.385	0.165
New York	3.378	2.800	0	—	0	—	0	—	0.377	0.056
North Carolina	0.012	—	0.910	0.123	0.053	—	0.009	—	0.066	0.009
Ohio	0.099	0.106	0.441	0.282	0	—	0.018	—	0.258	0.194
Pennsylvania	0.055	0.022	0.146	0.024	0	—	0	—	0.115	0.0035
Utah	1.527	0.376	0.245	0.002	0.095	—	0.075	—	7.335	0.416
Virginia	0.015	0.018	0.503	0.600	0	—	0	—	0.212	0.126
West Virginia	0.018	—	0.326	—	0	—	0	—	0.484	0.038
Wisconsin	0.141	—	2.897	1.358	0.024	—	0.135	0.004	2.211	0.911
Coastal states[b]	1.354	0.066	6.269	0.221	0.002	—	0	—	2.487	0.282
Midwest states[c]	0.736	0.137	0.053	0.042	0	—	0	—	0.313	0.225
National	0.531	0.024	1.023	0.088	0.097	—	0.022	—	1.032	0.106

[a]Insufficient observations for some subcategories in some states prevented the calculation of median values.
[b]California, Maine, Oregon, Washington.
[c]Missouri, Nebraska.

TABLE 14 Lost revenue from the value of lost market sales, lost production, and thwarted expansion by type of regulation (Values reported are means of farms in $/farm)

	Discharge			Fish health			Water rights			Food safety			All other regulations		
State	Market	Prod.	Exp.	Market	Prod.	Exp.	Market	Prod.	Exp.	Market	Prod.	Exp.	Market	Prod.	Exp.
Colorado	0	14,310	0	129,583	0	0	0	0	0	0	0	0	417	0	0
Idaho	0	37,821	0	47,395	0	7,250	0	5,125	0	0	0	0	52,083	0	0
Michigan	0	165,000	0	45,117	0	0	0	0	0	0	0	0	16,667	0	0
New York	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
North Carolina	0	58,326	2.045M	9,091	0	0	0	8,750	0	0	0	0	0	0	4,545
Ohio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pennsylvania	0	19,286	0	27,964	0	313	0	0	0	0	0	0	0	0	0
Utah	0	11,667	0	344,025	0	8,333	0	83,333	0	0	0	0	0	0	0
Virginia	0	8,750	0	4,250	0	0	0	0	0	0	0	0	0	0	0
West Virginia	0	2,450	0	2,200	0	0	0	0	0	0	0	0	0	3,330	0
Wisconsin	0	37,630	23,000	4,700	0	0	0	0	0	0	0	0	5,700	0	0
Coastal[a]	0	0	2.143M	221,429	0	0	0	0	0	0	0	0	0	185,750	0
Midwest[b]	0	3,400	0	2,900	0	0	0	0	0	0	0	0	4,000	0	0
National	0	29,347	373,564	57,652	0	1,400	0	6,512	0	0	0	0	7,965	13,204	495

Note. Market: value of lost markets; Prod.: value of lost production; Exp.: value of thwarted expansion.
[a]California, Maine, Oregon, Washington.
[b]Missouri, Nebraska.

TABLE 15 Lost revenue from the value of lost market sales, lost production, and thwarted expansion by type of regulation. Values reported are per unit means in $/kg

	Discharge			Fish health			Water rights			Food safety			All other regulations		
State	Markets	Prod.	Exp.	Markets	Prod.	Exp.	Markets	Prod.	Exp.	Markets	Prod.	Exp.	Markets	Prod.	Exp.
Colorado	0	1.085	0	7.239	0	0	0	0	0	0	0	0	0.040	0	0
Idaho	0	0.375	0	1.707	0	0.238	0	0.071	0	0	0	0	0.441	0	0
Michigan	0	1.903	0	0.721	0	0	0	0	0	0	0	0	0.148	0	0
New York	0	0	0	0.000	0	0	0	0	0	0	0	0	0	0	0
North Carolina	0	1.374	1.289	0.092	0	0	0	0.006	0	0	0	0	0	0	0.051
Ohio	0	0	0	0.000	0	0	0	0	0	0	0	0	0	0	0
Pennsylvania	0	1.266	0	0.721	0	0.097	0	0	0	0	0	0	0	0	0
Utah	0	3.676	0	21.576	0	0.351	0	3.506	0	0	0	0	0	0	0
Virginia	0	0.198	0	0.097	0	0	0	0	0	0	0	0	0	0	0
West Virginia	0	0.101	0	0.225	0	0	0	0	0	0	0	0	0	0.342	0
Wisconsin	0	1.649	2.668	0.750	0	0	0	0	0	0	0	0	0.198	0	0
Coastal[a]	0	0.000	0.198	1.138	0	0	0	0	0	0	0	0	0	0.066	0
Midwest[b]	0	0.009	0	0.007	0	0	0	0	0	0	0	0	0.084	0	0
National	0	0.948	0.419	2.247	0	0.062	0	0.216	0	0	0	0	0.086	0.037	0.004

Note. Market: value of lost markets; Prod.: value of lost production; Exp.: value of thwarted expansion.
[a]California, Maine, Oregon, Washington.
[b]Missouri, Nebraska.

TABLE 16 Regulatory costs as percentage of production, marketing, and total costs

Cost categories/scenario	Mean (%)	Median (%)
Production-related regulatory costs		
Regulatory costs	15	8
Value of lost production	13	—
Marketing-related regulatory costs		
Regulatory costs	4	0.1
Value of lost revenue	65	—
Total costs		
Regulatory costs	12	7
Value of lost revenue[a]	28	1

[a]Includes values of lost markets, lost production, and thwarted expansion attempts.

farm level, fish health testing also occurs in advance of fish production and harvest, typically at the end of the calendar year, to meet deadlines for import permit applications by various states for the following year. Thus, fish health testing costs are often independent of the quantity of fish to be produced the following year and constitute fixed costs.

Similarly, effluent discharge water testing frequency and costs vary with farm location (farms located on waters with special protective designations are required to conduct more frequent testing) and the number of discharge outfalls. Both large and small farms can have greater numbers of outfalls. Required testing of water discharged as effluent must be conducted within time frames (i.e., weekly, monthly, quarterly) that are not related to the volume of fish grown. Thus, nearly all regulatory costs, with the exception of some transportation regulatory costs, were fixed costs.

3.10 | Effects of regulatory costs by farm size

While the total regulatory cost per farm increased with farm size, the regulatory cost per kilogram generally decreased with the size of farm[4] (Table 17). The cost/kg in the smallest farm size category ($7.30/kg) was 18 times greater than that in the largest size category ($0.41/kg). While the effects of the different types of lost revenue (i.e., lost production, lost markets, and thwarted expansion) varied, when combined into total lost revenue, the value of lost revenue increased with farm size, and the per-kg value decreased by farm size when weighted by total production within that farm size category. Smaller farms similarly had greater percentages of their total costs that comprised regulatory costs.

Table 18 includes relative cost effects of various types of regulations by farm size. For the smallest size category (less than 9,070 kg of production a year), the greatest proportion of regulatory costs was in the all other category, but effluent discharge regulatory costs comprised the greatest percentage of total regulatory costs for all farm sizes greater than 9,070 kg. In terms of lost revenue, effluent discharge regulatory costs were the greatest for the smallest farm sizes, as well as the two largest farm sizes. Fish health regulations, however, comprised the greatest percentage of total regulatory costs for the farm size category of 9,071–54,421 kg.

3.11 | Effects of regulatory costs by primary market type

Per farm, the mean regulatory cost on foodfish farms was 11 times greater than that on farms which produced primarily for the recreational market (Table 19). On a per-kg basis, however, regulatory costs were 30% greater for producers who primarily sold to the recreational, compared to foodfish, markets. Farms selling to recreational markets also had greater (4.4 times greater) costs per kg from the value of lost markets. Overall, the value of total lost revenue because of regulatory action averaged 30 and 27% of total costs, respectively, for foodfish and recreational-based farms.

TABLE 17 Farm size effects of regulatory costs

	<9,070 kg	9,071–54,421 kg	54,422–226,757 kg	>226,757 kg
Regulatory costs				
$/farm	15,362	23,393	126,846	964,772
$/kg				
Averaged by farm[a]	7.301	0.970	1.636	0.408
Production weighted by farm size category[b]	4.653	0.933	1.248	0.269
Value of lost production				
$/farm	7,650	35,170	80,618	146,646
$/kg				
Averaged by farm	1.453	1.528	0.743	0.095
Production weighted by farm size category	2.317	1.402	0.792	0.042
Value of lost markets, sales revenue				
$/farm	1,630	83,630	67,971	138,708
$/kg				
Averaged by farm	0.518	4.551	0.849	0.207
Production weighted by farm size category	0.494	3.334	0.668	0.040
Value of thwarted expansion				
$/farm	8,681	3,044	2,941	3,125,000
$/kg				
Averaged by farm	1.039	0.110	0.033	1.297
Production weighted by farm size category	2.628	0.121	0.029	0.873
Value of total lost revenue				
$/farm	17,960	121,844	151,529	3,413,354
$/kg				
Averaged by farm	3.010	6.189	1.605	1.599
Production weighted by farm size category	5.440	4.858	1.491	0.955

[a]Calculated based on the $/kg of each farm respondent, not weighted for production.
[b]Calculated by summing total regulatory costs within each farm size group and dividing by total production summed across all farms in each farm size group.

Effluent discharge regulatory actions constituted high percentages of the regulatory costs (67%) and lost revenues (91%) for foodfish producers (Table 20). For recreational salmonid farms, fish health costs were proportionately greater (31% of regulatory costs and 71% of lost revenue) than on foodfish farms. Thus, fish health-related regulatory actions constitute the greatest impediment to industry growth for trout farms selling to recreational markets, whereas effluent regulations pose the greater impediment to the growth of trout foodfish markets.

4 | DISCUSSION

While laws and regulations result in clear benefits to society, questions have been raised as to whether aquaculture businesses have been over-regulated, causing unintended negative consequences in developed countries such as the United States. This study took a step toward addressing this question by systematically collecting and analyzing national data on the types and magnitude of costs faced by U.S. salmonid farmers as they seek to comply with the total set of regulations required for their businesses.

Findings from this study demonstrated two major types of economic effects of regulatory implementation: (a) increased on-farm costs because of regulations and (b) lost farm revenue (from lost markets, reduced production

TABLE 18 Farm size effects of regulatory costs by regulatory cost category (values in % of total regulatory cost)

	<9,070 kg (%)	9,071–54,421 kg (%)	54,422–226,757 kg (%)	>226,757 kg (%)
Regulatory costs[a]				
Fish health	18.0	15.9	21.9	3.7
Effluents	28.0	31.3	59.0	66.1
Water rights	0.4	20.0	2.0	3.4
Food safety/HACCP	0.8	3.5	1.0	0.6
All other	52.8	29.3	16.2	26.2
Lost revenue[b]				
Fish health	9.6	67.4	41.0	2.8
Effluents	90.0	19.1	50.8	92.5
Water rights	0.0	9.1	2.4	0.2
Food safety/HACCP	0.0	0.0	0.0	0.0
All other	0.5	4.3	5.8	4.4

Note. HACCP: Hazard Analysis of Critical Control Points.
[a]Percent of total regulatory costs.
[b]Percent of total lost revenue.

TABLE 19 Effects of primary markets on regulatory costs (values are means, averaged by farm)

Category	Foodfish	Recreational/other farms
Regulatory costs		
$/farm[a]	$381,419	$33,326
$/kg, averaged by farm[b]	$2.25	$2.93
% of total costs	13%	11%
Value of lost production		
$/farm	$104,262	$21,053
$/kg, averaged by farm	$1.06	$1.28
% of total costs	10%	8%
Value of lost markets, sales revenue		
$/farm	$72,515	$63,058
$/kg, averaged by farm	$0.71	$3.15
% of total costs	10%	18%
Value of thwarted expansion		
$/farm	$1,112,265	$1,558
$/kg, averaged by farm	$1.32	$0.07
% of total costs	10%	1%
Value of total lost revenue		
$/farm	$1,289,041	$84,728
$/kg, averaged by farm	$3.09	$4.50
% of total costs	30%	27%

[a]Calculated by summing total regulatory costs within each farm size group and dividing by total production summed across all farms in each farm size group.
[b]Calculated based on the $/kg of each farm respondent, not weighted for production.

capacity because of regulatory actions, and foregone sales from regulatory barriers that prevented business expansion). Nationally, on-farm regulatory costs were found to be $16.1 million annually, while sales from markets lost because of regulatory actions were $7.1 million/year, an additional $5.3 million/year from lost production, and an

TABLE 20 Effects of primary markets on relative percentage contribution of each regulatory category

	Foodfish (%)	Recreational/other farms (%)
Regulatory costs[a]		
Fish health	3.5	30.8
Effluents	67.2	29.2
Water rights	4.7	1.5
Food safety/HACCP	0.7	1.6
All other	23.8	36.9
Lost revenue[b]		
Fish health	4.4	70.7
Effluents	90.8	15.4
Water rights	0.4	8.8
Food safety/HACCP	0.0	0.0
All other	4.3	5.0

Note. HACCP: Hazard Analysis of Critical Control Points.
[a]Percent of total regulatory costs.
[b]Percent of total lost revenue.

additional $40.1 million/year in estimated foregone sales revenue from thwarted expansion attempts. These findings show that the on-farm economic effects of the regulatory framework are large and substantial, with regulatory costs (averaged across all farms) comprising 12% of total production and marketing costs and lost revenue 28% of total production and marketing costs.

In addition to their magnitude, regulatory costs were found to largely function as fixed costs on U.S. salmonid farms. Hurley and Noel (2006), on agricultural farms in California, and van Senten and Engle (2017), for U.S. baitfish/sportfish farms, found that smaller farms experienced disproportionately greater negative effects of the increased fixed costs from regulatory actions. Smaller farms have lower production volumes across which to spread increased fixed costs, and in this study, smaller U.S. salmonid farms were found to have regulatory costs per kg that were more than 18 times greater than those on larger salmonid farms.

The increased fixed costs from regulations are also important because the principal economic strategy to manage increasing fixed costs is to increase the scale of production. Yet study results found that U.S. salmonid farms were forced to reduce the scale of production because of regulatory actions that forced them out of markets and also required farms to reduce production capacity. Several respondents reported that their attempts to expand production to achieve an optimal scale had been thwarted by regulatory barriers in the permitting process. Such reductions in the scale of a farming business with high annual fixed costs have further been shown to reduce the likelihood of adoption of new, more efficient farming technologies (Kumar, Engle, & Tucker, 2018). These combined results suggest that many U.S. salmonid farms may be operating at suboptimal levels because of the regulatory monitoring and reporting paradigms. Other, more formal studies of production efficiencies on aquaculture farms have shown that regulatory actions can have significant effects in terms of increasing farm-level inefficiencies (Asche & Roll, 2013; van Senten et al., 2018).

Farm-level inefficiencies can also arise if owners and managers must spend increasing amounts of time on regulatory requirements instead of farm innovations and market development. Manpower regulatory costs on salmonid farms were 23% of regulatory costs, greater than the 11% reported for baitfish/sportfish farms (van Senten & Engle, 2017). Some farms reported hiring additional employees to focus on regulatory record keeping and reporting, but on other farms, these tasks were performed by owners, managers, and other employees who had specific production and/or marketing responsibilities. Manpower was required for record keeping, report preparation and filing, attending meetings, preparing for fish health testing, collecting and delivering water samples to laboratories (time spent delivering water samples varied from 5 min to 3 hr each way), and other activities.

These study results are important to U.S. aquaculture and to those who design regulatory implementation programs because they suggest that the overall set of regulatory requirements may have had the unintended result of forcing U.S. salmonid farms out of business in spite of the strong domestic demand reported by many respondents (including many small-scale producers). The Census of Aquaculture (United States Department of Agriculture, 2006, 2014) data show a 5% decrease in the volume of food-sized trout produced, a 41% decrease in the volume of stocker trout produced, and a 13% decrease in the number of salmonid farms from 2005 to 2014. Increased regulatory costs on farms and operating at reduced production levels further would be expected to reduce the competitiveness of U.S. salmonid products compared to imported products. Fornshell (2018) reported that national import data show that the average volume of trout imports has more than doubled from 2012 to 2016 (the years for which the most recent import data are available) in spite of increasing evidence that U.S. consumer preferences are trending toward more locally produced food (Chen, Haws, Fong, & Leung, 2017; Darby, Batte, Ernst, & Roe, 2008). Thus, it appears that the negative economic effects of the regulatory monitoring and compliance system are contributing to the decline in the numbers of U.S. salmonid farms, supporting similar findings by van Senten and Engle (2017) for the U.S. baitfish/sportfish sector. This is a concern in several states given the importance of aquaculture industries to local rural economies (Kaliba, Engle, Pomerleau, Hinshaw, & Sloan, 2004; Slater, 2017).

The greatest percentage of the regulatory cost burden on U.S. salmonid farms was for environmental regulations, primarily for effluent discharge permitting and monitoring. Direct costs from environmental management regulations included costs of testing discharge water samples; delivery of samples to laboratories; and the services of engineers, environmental consultants, and attorneys. Environmental regulations have tended to be implemented as command-and-control types of regulations that prescribe specific practices with little flexibility to adjust to local conditions (Engle & Stone, 2013; Engle & Wossink, 2008). In contrast, animal disease regulatory approaches have begun to move to a more risk-based surveillance type of approach (Häsler, Howe, & Stärk, 2011; Oidtmann, Thrush, Denham, & Peeler, 2011) that may have the potential to reduce on-farm costs (van Senten et al., 2019). Additional, detailed analysis is needed to search for ways to eliminate unnecessary costs related to environmental management regulatory costs on U.S. salmonid farms.

Regulatory costs varied by the type of market outlet, with regulatory costs/kg of salmonids greater on farms that sold to recreational markets than those that sold to foodfish markets. Farms that target recreational markets typically sell live fish to a number of other states, for which import permits require fish health testing to issue health certificates in addition to the costs associated with effluent discharge regulations required on nearly all salmonid farms.

Results showed substantial variation among states, as well as within states, beyond that explained by farm size and type of target market. Variation among states was particularly evident with regard to revenue lost from lost markets and lost production. The variation in regulatory costs per farm and per kg of production suggests inconsistencies among states that may reflect differing perceptions of risk (either related to effluent discharge or to aquatic animal health) in some states that lead to overly burdensome regulatory actions than in other states that may be underregulated. With federally mandated regulatory programs, states have the right to enact more stringent enforcement conditions than those specified federally and can enact state-specific laws. A confounding factor is that some of the losses reported were quite specific to individual farms. Some of the variations may be because of differing and inconsistent enforcement by inspectors as mentioned by respondents and discussed by Osmundsen et al. (2017) in the context of the EU. In this study, respondents reported inconsistencies among instructions from the various actors in the regulatory system, which include managers in a central or district office, permit writers, and inspectors, each of whom may have somewhat differing views and perspectives on the most appropriate guidance or action for a specific farm. Respondents expressed frustration over actions that were not warranted by state and local laws and a sense that various agencies wanted to put them out of business. Other respondents expressed concern over the lack of a clear appeal process, particularly with regard to environmental management regulations.

This study measured the economic effects of the regulatory framework at a single point in time, but the effects of regulatory actions occur over a period of many years. Thus, this study provides a snapshot of effects at the time of the survey but does not consider the cumulative effects of the increased number of regulations and requirements

over time. As a result, it is likely that these costs have been underestimated in spite of the substantial magnitude measured. The costs presented were those obtained from farm financial records of producers who were in business at the time the survey was conducted. More than half of the respondents knew of other farms that had gone out of business because of regulatory actions, but those individuals were not interviewed, and their costs were not included in this study. It is possible that the regulatory costs of the farms that have exited the salmonid industry because of regulations were even higher than those reported by survey respondents, whether because of a lack of access to water, excessive costs of water and fish health testing, lost markets, attorney and consultant fees, or some other reason. Comments were made by several respondents that their state had implemented a series of onerous regulations several decades ago that resulted in the exodus of a number of farms. For example, one state that had been the second-largest trout-producing state in the United States four decades ago had fallen to ninth place, with more than 25 farms exiting the industry in that one state. Loss of a critical mass of farms in what had been a geographic cluster may result in the loss of the benefits from such agglomerations, which have been shown to increase access to specialized inputs and increased adoption of innovative technologies in aquaculture (Guttormsen, 2002; Tveterås, 2002; Tveterås & Heshmati, 2002). Other comments from respondents pointed to competition between state agencies that raise and stock fish and private producers who also sell for stocking. Examples were provided of regulatory actions in several states by agencies that had a perceived conflict of interest in terms of fish stockings that, according to respondents, led to negative outcomes for private farms.

Of particular concern is that the major salmonid-producing state in the United States, Idaho, was found in this study to have the third largest statewide value of lost market sales and also experienced a 27% reduction in the number of farms from 1998 to 2013. States such as the coastal states, North Carolina, and Idaho (some of the leading salmonid-producing states) that show high per-farm estimated values of thwarted expansion attempts are of concern for the future. If the capital being expended on lawsuits or investment in aquaculture can earn more in another activity, these businesses may also give up and move out of aquaculture in spite of the potential profits and strong market demand. Similar concerns related to reductions in output as an indirect consequence of regulations have been expressed in reference to other sectors of the U.S. economy (Crain & Crain, 2014). The U.S. General Accounting Office (1978), in discussing the indirect consequences of the proliferation of regulatory actions in the 1970s, stated that "society pays a price in terms of lost opportunities."

Agriculture, generally, has exhibited a trend toward a smaller number of larger farms. This trend has commonly been attributed to increasing economies of scale in agriculture. While increasing consolidation in U.S. food markets may contribute to such farm-level economies of scale in agriculture, there has not been a substantive attempt to measure what portion of increasing economies of scale in agriculture may be because of an increasingly onerous regulatory implementation system. The present study suggests that efforts to better understand the economic effects of the implementation of the overall regulatory framework on U.S. agriculture would be useful in determining if the decline is due strictly to market consolidation effects on economies of scale or if regulatory or other effects have also contributed to the decline in the numbers of farms.

5 | CONCLUSIONS

Laws and regulatory enforcement in developed countries have led to improved environmental quality, reduced the spread of aquatic animal pathogens, and had other societal enhancements. Increasing numbers of questions have arisen, however, in terms of whether there are more cost-effective and less burdensome ways to achieve the same societal goals. This study implemented a national survey of U.S. salmonid farms to take the first step toward addressing this question for U.S. salmonid farms. This article reports the initial project results of the magnitude of the economic effects of the total regulatory burden on U.S. salmonid farms. Subsequent analyses are needed to examine alternative regulatory implementation models with the potential to reduce the farm-level burden.

Study results showed that the regulatory system in the United States increased on-farm costs annually by an average of $150,506, or $2.71/kg, for a national regulatory cost of $16.1 million/year. In addition, regulatory actions on U.S. salmonid farms resulted in lost markets with an annual value of $66,274/farm, lost production of $49,064/farm, and an estimated value of thwarted expansion attempts of $375,459/farm. Nationally, the value of markets lost because of regulatory actions was $7.1 million/year, $5.3 million/year of lost production, and $40.1 million/year in thwarted expansion attempts. Smaller-scale farms were affected to a disproportionately greater negative extent than larger-scale farms.

Environmental management regulations comprised the greatest proportion of total regulatory costs and were followed by those associated with fish health testing for the interstate shipping of live fish. The majority of regulatory costs were fixed costs. Thus, strategies to adapt to greater fixed costs would require expanding the scale of operation to spread the greater fixed costs across greater production levels. Study findings, however, show that the regulatory system also forced farms to reduce their scale of production and prevented them from selling to existing markets. The combination of lost production and lost sales further decreased the overall scale of the operation. Thus, the regulatory system has forced farms to reduce their production scale and hindered them from taking the steps that would be required to adjust effectively to increased regulatory fixed costs.

Respondents reported generally good demand for trout as interest in locally raised food has increased. Yet more than half of respondents knew of farms that had been driven out of business by the regulatory framework, and volumes of imported salmonids have increased rapidly in recent years. U.S. consumers are demanding more locally grown foods; yet the on-farm burden and reporting complexities in the regulatory system appear to be contributing to a decline in domestic production of salmonid products that are desired by U.S. consumers.

Study results clearly show a strong need for greater attention to be paid to reducing those portions of farm-level regulatory costs that are duplicative and redundant. For U.S. salmonid producers, additional analyses are needed to seek alternative models of monitoring and surveillance that are more cost-effective than current implementation methods, especially of environmental management and aquatic animal health regulations.

ACKNOWLEDGMENTS

We thank all the individuals who contributed to the planning, implementation, and completion of this study, particularly our project collaborators Fred Conte, Gunnar Knapp, and William Hanshumaker, as well as subject matter experts from USDA Veterinary Services: Kathleen Hartman, Kami Johnson, Lori Gustafson, and Lynn Creekmore. In addition, Debra Sloan, Jeff Hinshaw, Chris Weeks, and Matthew Smith were very helpful. We especially thank all the producers who took the time to participate and contribute data for this study. This study was funded by the Western Regional Aquaculture Center Agreement Award no. 542209, the United States Trout Farmers Association, and USDA-APHIS Cooperative Agreement Award no. 422526. The findings and conclusions in this publication have not been formally disseminated by the U.S. Department of Agriculture and should not be construed to represent any agency determination or policy.

ENDNOTES

[1]In some cases, permit applications had been denied; in other cases, applications were still pending, and some had been pending for a number of years.

[2]It should be noted that the exemption for farms that produce less than 9,070 kg a year and use less than 2,268 kg of feed in any one calendar month, while true for most situations, is not universally so. For example, in a state such as Idaho with facilities regulated under a TMDL, there is no exemption for small farms. In addition, the EPA always has the discretion to designate a small facility a major source of pollution.

[3]A regulatory filing was defined as an activity required by regulatory agencies that required a substantive study, survey, or other submission by the farm to obtain specific certificates or other approvals required as part of a permit application process. Examples include engineering studies; wetland surveys conducted by hired consultants; and

consultations required of tribal, coastal, or federal authorities. Routine submissions of water quality monitoring and testing, however, were not included as separate "filings."

[4]The exception was the increased regulatory cost per kg as farm size increased from the third- to the second-largest farm size.

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How to cite this article: Engle CR, van Senten J, Fornshell G. Regulatory costs on U.S. salmonid farms. *J World Aquacult Soc*. 2019;1–28. https://doi.org/10.1111/jwas.12604

APPENDIX

TABLE A1 "Other" top problems faced by trout farmers

Regulatory
All the different agencies tagged with inspection, especially HACCP paperwork
Zoning
Have a person in plant for regulatory compliance
Discharge, cost of discharge ($3,000/month on recirculating tanks)
Sanitary district
Water rights/access/availability
Water issue/drought
Well water
Cannot get water rights; no regulatory process to acquire water rights
Markets/marketing
People familiar with product
Public perceptions: Assumptions about fish farming. Fish feeds and GMOs; educate customers
Processing
Processing is Achille's heel
For the processing plant, #1 problem is the supply of fish
Inputs and costs
Feed. Quality feed at a good price; 3–4 years of consolidation
Feed used to be $12/bag; now $26/bag
Electric costs

TABLE A1 (Continued)

Vehicle registration fees
Insurance
Prices
Prices, farm-gate price and input prices, feed, and DO; 7- or 8- year contract, kept bumping price up; for years, fish prices did not go up; $1.92/lb last 2–3 weeks. Has gone up 2–3 times in last several weeks
Risks
Power outages and bad dials
Profitability
Profitability/competition/ much of the industry is willing to operate at unacceptable profit margins
Capital
Capital for building/rebuilding facilities; related to profits; how much capital improvement can we invest each year
Impossible to find capital
Other
Certification scheduling demands
Pollution from dairy farms; filed 2 lawsuits on this due to major fish kills