An Approach to Determining Economic Impacts of U.S. Aquaculture

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U.S. Department of Commerce
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ABSTRACT

Fisheries Economics of the United States is produced annually by the National Marine Fisheries Service and provides national and state level estimates of the total economic impacts of U.S. seafood landings and imported seafood on the U.S. economy. However, it does not contain an estimate of the impact of U.S. aquaculturally produced seafood. As a demonstration of the potential for incorporating this information into *Fisheries Economics of the United States*, we took estimates of production and value for four aquaculture species: crawfish, salmon, oysters and clams. Using published production cost data and the same input/output model used for *Fisheries Economics of the United States*, we produced estimates of economic impacts. We make recommendations for improving the annual production and value estimates that are used for the input/output model, and for developing standardized industry surveys on production costs so that reliable impact estimates can be developed on an annual basis and included as part of *Fisheries Economics of the United States*.

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Executive Summary

This report describes initial efforts to develop an estimate of the economic impacts of all U.S. aquaculture (marine and freshwater) that could be integrated into *Fisheries Economics of the United States*, an annual report published by the National Marine Fisheries Service. Our approach was to gather production budgets for several aquaculture species from published reports along with the annual production and value estimates obtained on an annual basis through various sources, and using these numbers, calculate the direct, indirect, and induced economic impacts using an input-output model of the U.S. seafood economy.

The U.S. fishing and seafood industries are important components of the U.S. economy. According to *Fisheries Economics of the U.S. 2015*, the seafood industry supported 1.2 million full-and part-time jobs and generated $144.2 billion in sales, $39.7 billion in income, and $60.6 billion in value-added impacts nationwide. These estimates include the impacts from domestic wild harvest products and imports of wild-harvested and foreign aquaculture products, but not the impacts of domestic aquaculture. The omission of domestic aquaculture production from the estimates will become more problematic as domestic aquaculture expands and becomes a greater share of the U.S. seafood market. Domestic aquaculture already represents one fifth of U.S. seafood production by value.

Due to a lack of current, sufficiently detailed and standardized production budgets for major aquaculture species, it is not currently possible to produce a comprehensive estimate of the national economic impact from aquaculture production for all major species. NOAA and USDA in partnership with industry associations and university researchers could work with aquaculture companies to develop representative and updated aquaculture production budgets to be used in the development of annual estimates of aquaculture impacts.

To explore how this could be accomplished, we developed estimates of the economic impacts of four major species: crawfish, salmon, clams and oysters. Crawfish are a freshwater species and have the most reliable production and cost estimates compared to the other three marine species. Oysters, clams and salmon represented 95% of the first sale value of marine aquaculture production in 2015. From *Fisheries of the U.S. 2016*, marine aquaculture production in 2015 had total first sales (farm gate) of about $394 million. By assuming that the 5% of production we have not calculated impacts for create impacts in the same proportion as those we have calculated, then the total impact for marine aquaculture production on the U.S. economy is estimated to be about $5.1 billion, and results in over 53,000 jobs.

We envision what the economic impact would be if a goal of increasing U.S. aquaculture production to 2.5 times its current level in ten years is met. Depending on assumptions about the species composition of the increase, we estimate the total economic impact would range from $10.7 - $12.8 billion and the number of jobs from 109,500 - 133,400.

The above estimates should be used cautiously given the lack of reliability in the statistics about the current level of aquaculture production, and the production budgets on which the estimates are based. We make several findings and recommendations as to actions needed to produce reliable annual economic impact estimates that are summarized here:

1) *Fisheries Economics of the United States* currently provides useful information to stakeholders and the general public about the economic impact of the fishing and seafood industries, and

should include domestic aquaculture impact estimates, particularly as domestic aquaculture increases in importance as a component of U.S. seafood supply.

2) There is insufficient extant cost information and only greatly outdated information on production costs for several major species to develop a reasonable national estimate of economic impacts.

3) A systematic way of collecting annual aquaculture production data from states, industry associations, or directly from producers is essential to ensuring the quality of the estimates that rely on these numbers.

    a. A clear definition of what constitutes aquaculture production, particularly for shellfish, is necessary and will help avoid some double counting in commercial landings that occurs now.
    b. Since there is interest in reporting on marine versus freshwater aquaculture production, classification of what constitutes each will have to be agreed upon.
    c. Protecting confidentiality of firm level data will be an issue when there are a small number of firms constituting the production for a particular species.

4) Systematic collection of production costs via standardized industry surveys will provide the most reliable information for economic impact analysis. The relevant Federal agencies (i.e., USDA and NOAA), in conjunction with state agencies and aquaculture industry organizations, should come together and plan a survey methodology and a way to administer maintain and update it on a regular basis.

    a. Updating industry cost data every five years would allow National Income and Product Accounts data to be updated at the same frequency.
    b. Short of a census, any type of survey sample would have to be designed to capture the heterogeneity of the industry, even for production of the same species.

5) A comprehensive study on the seafood market chain would allow us to more accurately model product flows and increase reliability of the impact analysis.
    a. Interstate product flows need to be quantified
    b. Upstream (i.e., hatchery and nursery) production costs need to be better quantified, particularly for emerging industries.

6) Aquaculture production for other than just seafood markets (e.g., bait fish, pond stocking, etc.) will require additional analysis.

1. Introduction

Estimating the economic impact contributed by the aquaculture sector is essential information used to inform Federal, state and local policies. An economic impact analysis denotes the relative importance of the sector to the overall economy as well as quantifies the dependencies among different economic sectors on a regional and national level. Each year, the National Marine Fisheries Service (NMFS) publishes *Fisheries Economics of the United States (FEUS)*[1], providing national and state-by-state economic impact estimates. These estimates include commercial fisheries landings impacts on a state-by-state level, as well as state-level and national impacts from imported seafood as it moves through the value chain to the final consumer. NMFS also has developed regional economic impact models which aid in determining impacts for fisheries management regulations on a more detailed level than the national model. NMFS's analysis to date has not included domestic or imported aquaculture products, except some domestic product that may be included in domestic wild catch[2].

It is estimated that as much as 90% by value of U.S. seafood consumed by Americans is imported, with about 50% of that produced via aquaculture[3]. Because *FEUS* includes imports, the contribution of imported aquaculture products to the U.S. economy is accounted for in the *FEUS* analysis. Missing from these reports, however, are the economic impacts of domestic aquaculture production. While still a small percentage of domestic fisheries production in pounds (6.5%), U.S. aquaculture production in 2015 was 21% of the first sale value (*Fisheries of the U.S. 2016*). As domestic aquaculture grows in importance, ignoring its role in economic impact estimates will become more problematic in terms of correctly quantifying the impact of fish and seafood production on the U.S. economy. Additionally, a greater understanding of the economic linkages of domestic aquaculture production in the economy will help in predicting and planning for the potential future contribution of aquaculture as it expands to play an even more significant role in the seafood economy.

Without an annual national survey for all aquaculture, NMFS relies on a variety of sources to estimate U.S. aquaculture production and value on an annual basis, and publishes this with an additional year lag in *Fisheries of the United States* (Table 1)[4]. Sources include the USDA Census of Agriculture and the periodic Census of Aquaculture[5] along with state and industry association supplied data. As in wild harvest production, an accurate estimate of annual production and value is essential to producing meaningful economic impact estimates because these numbers form the basis of all subsequent calculations of impacts, as will be discussed below.

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[1] National Marine Fisheries Service (2017a) Available at: http://www.st.nmfs.noaa.gov/economics/publications/feus/fisheries_economics_2015/index
[2] Some aquaculture production statistics, particularly those for shellfish, may be mixed in with commercial landings data at the individual state level. For example, oyster aquaculture on public bottom may be counted as part of wild harvest landings.
[3] https://www.fisheries.noaa.gov/national/aquaculture/us-aquaculture
[4] Fisheries of the United States, 2016 (National Marine Fisheries Service, 2017b) is released in 2017, but the aquaculture production estimates that are included are from 2015.
[5] https://www.agcensus.usda.gov/Publications/Census_of_Aquaculture/

1.1 Purpose and Organization of the Study

The original purpose of this study was to demonstrate that we could produce aquaculture economic impact estimates for most species from existing data that could be incorporated on a regular basis into *Fisheries Economics of the U.S.* By attempting to calculate the economic impact of four aquaculture species with currently available cost data and production estimates, we uncover what changes and additional research are necessary to produce future estimates that are equivalent in rigor to those currently published in *Fisheries Economics of the U.S.* for domestic wild caught fish production.

The work was conducted by a team of University of Maryland and NMFS staff. The research team received design guidance from an Advisory Committee of university and private sector economists along with staff at the U.S. Department of Agriculture (USDA). Difficulties gathering reliable production data for several species and advice from our Advisory Committee led us to narrow the study from all U.S. aquaculture to one focused on four species and one that would provide guidance in terms of data collection and analysis for developing future estimates of the economic impact of all of U.S. domestic aquaculture production. The four species are oysters, clams, salmon, and crawfish.

The paper is organized as follows. First we provide a description of the *FEUS* calculation framework and then demonstrate how domestic aquaculture production can enter into the framework. Case studies for several species, where current data was of acceptable quality, are developed to demonstrate the approach. We discuss shortcomings of the existing data for the case study species, and the necessary steps to include all the major aquaculture species in the analysis. We conclude with recommendations for steps necessary to achieve the goal of producing an annual estimate of the economic impact of U.S. aquaculture production.

Table 1. Estimate of 2015 U.S. aquaculture production and value.

	Thousand Pounds	Metric Tons	Thousand Dollars
Freshwater			
Catfish	317,445	143,992	347,021
Striped bass	8,111	3,679	30,831
Tilapia	18,999	8,618	42,745
Trout	45,854	20,799	76,748
Crawfish	140,411	63,690	199,350
Total Freshwater	**530,820**	**240,778**	**696,695**
Marine			
Salmon	47,528	21,559	87,743
Clams	9,086	4,121	112,139
Mussels	717	325	10,201
Oysters	35,229	15,980	172,778
Shrimp	3,979	1,805	11,137
Total Marine	**96,539**	**43,790**	**393,998**
Miscellaneous	-	-	302,774
Totals	**627,359**	**284,568**	**1,393,468**

Source: *Fisheries of the United States, 2016*.

2.0 Integrating Domestic Aquaculture Production Impacts into *Fisheries Economics of the U.S.*

Since our goal is to develop a method to integrate domestic aquaculture production into the calculations made for *FEUS*, we briefly describe the current methodology for the calculations for wild harvest and imports. Fish harvesting and seafood production is a major industry and data collected by the Economic Census, Bureau of Labor Statistics, and other sources are used by the Bureau of Economic Analysis as part of the development of national income accounts used to calculate the gross domestic product of the United States. The North American Industry Classification System (NAICS) describes industry code 114111 Finfish Fishing as:

"This U.S. industry comprises establishments primarily engaged in the commercial catching or taking of finfish (e.g., bluefish, salmon, trout, tuna) from their natural habitat."

Code 114112 is Shellfish Fishing. With only one code for finfish harvesting and one for shellfish, this is a highly aggregated accounting of a diverse industry that is of limited use for decision-making impacting a particular species or region.[6] Additionally, the underlying source of data used by BEA[7] does not capture

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[6] There is some greater species specificity in the underlying data that helps to generate the input-output tables in the national accounts. The categories are: Alaska pollock, tuna, salmon, sardines, ground fish (cod, cusk, haddock, hake, Atlantic ocean perch, Atlantic pollock and whiting), flounder, other finfish, shrimp, crabs, oysters, clams, other shellfish, surimi and frozen fish blocks.

[7] See NIPA Handbook: Concepts and Methods of the U.S. National Income and Product Accounts, https://www.bea.gov/methodologies/index.htm.

the great variability of scale and input use in commercial fisheries harvest in the United States. For these reasons, NMFS had developed its own national economic impact model and also has developed regional models with even greater specificity to support the economic analyses required by law for fisheries management plans.

2.1 Wild Domestic Harvest in *Fisheries Economics of the U.S.*

Kirkley (2009) describes the process used by the National Marine Fisheries Service for developing economic impact estimates for the domestic fishing and seafood industry. The approach is a modification and customization of a basic input/output model of the U.S. economy using IMPLAN[8] software and data. The model is designed to provide a national estimate of impacts and state level estimates for 23 coastal states. Figure 1 demonstrates the linkages. Starting with domestic landings, to develop estimates of the upstream impacts, it is necessary to determine fishing production costs by category. The downstream impacts require knowledge of the percentage of product that flows to each of the downstream sectors, and then the value added by expenditure category by each of those downstream sectors.

Table 2 shows the typical expenditure categories for which data is obtained for domestic fish landings. One decision made early on in developing the process was that it would not be feasible to develop separate expenditure estimates for every species in the landings database. Landings were aggregated into 16 major groupings as shown in Table 3. This aggregation ameliorates the complication that many fisheries are mixed, in that they catch multiple species on the same trip, and it would be difficult to allocate both trip and durable expenditures by category to individual species. Cost data corresponding to the categories shown in Table 2 were obtained from a variety of existing surveys and publications and assigned to each of the harvest groupings. Cost data is periodically updated when new studies and surveys become available. Adjustments are also made on an annual basis for price changes for some volatile sectors such as energy. As can be seen in Table 4, downstream product flows are even more highly aggregated than fish harvesting with only seven harvester categories, three processors and two wholesale/distributor categories. These percentages are updated periodically as new data becomes available.

Once the product flows and expenditures are estimated for the 16 categories of seafood, these are then mapped into North American Industrial Classification System (NAICS) codes, and the direct, indirect and induced impacts can be calculated using an input-output model such as IMPLAN.

[8] IMPLAN is a commercial software product commonly used for the calculation of economic impacts of industry sectors, nationally and regionally (www.implan.com).

Figure 1. Schematic of the seafood market underlying calculations of economic impacts for Fisheries Economics of the U.S.

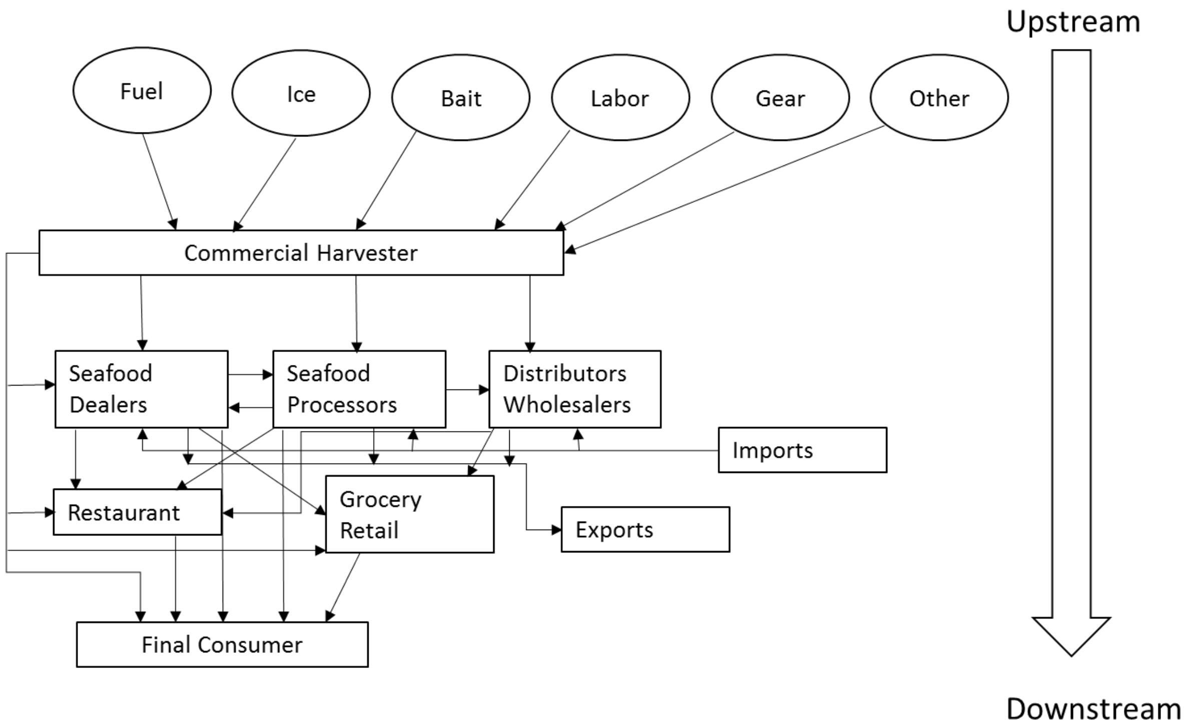


Table 2. Typical fishing expenditure categories for inclusion in Fisheries Economics of the U.S. *calculations (from Kirkley, 2009).*

Purchases of goods	**Fixed and general expenses**
• Fishing gear	• Moorage
• Miscellaneous hardware & supplies	• Dues, fees
• Electronics	• Licenses, permits
Repair & maintenance	• Accounting
• Fishing gear, nets	• Insurance
• Vessel & engine	• Bank fees and services
• Electronics	• Vehicle costs
Trip expenses	• Capital costs, boats
• Groceries, food, & supplies	• Other expenses
• Fuel & lubricants	**Taxes**
• Ice	**Income and profit**
• Bait	• Crew & captain shares, other income
	• Profit

Table 3. Species groupings used for impact analysis for Fisheries Economics of the U.S. *(from Kirkley, 2009).*

Species group	**Major species in group**
Shrimp	All Shrimp
Crab	All Crab except Blue Crab
Lobster	American Lobster
East Coast Groundfish	Cod, Flounder, Goosefish, Haddock, Hake, Plaice, Pollock, Shark (Dogfish)
Highly Migratory Species	Shark (other than Dogfish), Swordfish, Tuna
Reef Fish	Gag, Grouper, Mackerel (King & Spanish), Snapper, Tilefish
West Coast Groundfish	Cod, Hake, Pollock, Rockfish, Sablefish, Sole, Whiting Halibut All Halibut
Menhaden/Industrial	Alewife, Ladyfish, Menhaden
Salmon	All Salmon
Sea Scallop	All Scallop
Surf Clam/Ocean Quahog	Surf Clam, Ocean Quahog, Quahog
Other Trawl	Anchovies, Croaker, Herring, Mackerel (other than King & Spanish), Mullet, Sardine, Shad, Squid
All Other Finfish	Amberjack, Drum, Hind, Pompano, Porgy, Scad, Sea Bass, Tautog
All Other Shellfish	Clam, Spiny Lobster, Mussel, Oyster, Sea Urchin, Snail (Conch)
Freshwater	Catfish, Crayfish, Perch, Tilapia, Trout
Inshore & Miscellaneous	Bass, Blue Crab, Seaweed, Sponge Bait Worms, Bait fish

Table 4. Downstream Product Flow for Fishing & Seafood Industries Related to Domestic Harvest (from Kirkley, 2009).

Source of fish, seafood products	Processors	Wholesalers/ Distributors	Restaurants/ Food Service	Groceries/ Retail Markets	Exports	Final Consumer
Harvesters: non-shrimp, non-bait	40.0%	45.0%	2.5%	7.0%	0.0%	5.5%
Harvesters: shrimp, except as noted	87.5%	12.5%	0.0%	0.0%	0.0%	0.0%
Harvesters: non- bait species in AL, MS	90.0%	5.0%	2.5%	2.5%	0.0%	0.0%
Harvesters: non- bait species in AK	90.0%	5.0%	1.0%	1.0%	0.0%	3.0%
Harvesters: non- bait species in CT, FL, HI, ME, NJ, NY, RI, SC	20.0%	25.0%	5.1%	6.2%	35.0%	8.7%
Harvesters: non- bait species in US	60.7%	27.8%	2.5%	4.0%	5.0%	0.0%
Harvesters: bait	0.0%	100.0%	0.0%	0.0%	0.0%	0.0%
Processors: non-shrimp, non-bait except AK	0.0%	51.7%	17.7%	23.0%	0.0%	7.6%
Processors: shrimp: except AK	0.0%	10.0%	72.0%	17.8%	0.3%	0.0%
Processors: AK	0.0%	5.0%	1.0%	1.0%	93.0%	0.0%
Wholesalers/ distributors: except	0.0%	0.0%	60.0%	30.0%	8.0%	2.0%
Wholesalers/ distributors: AK	0.0%	0.0%	6.0%	3.0%	91.0%	0.0%

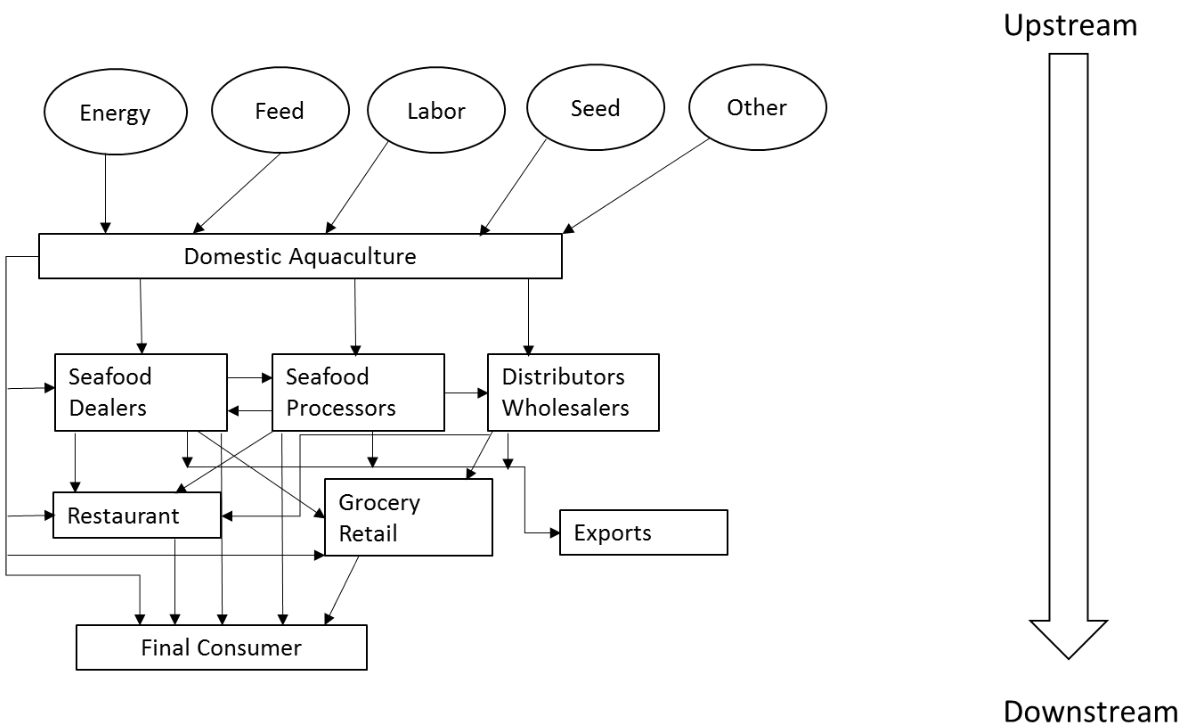
2.2 Aquaculture Integration

Similar to wild caught fisheries, the National Accounts include highly aggregated NAICS codes for finfish (112511), shellfish (112512) and other (112519) aquaculture production and hatcheries. The definitions from the 2017 NAICS publication[9] demonstrate the lack of specificity for these industries. For finfish farming and fish hatcheries, the description is *"This U.S. industry comprises establishments primarily engaged in (1) farm raising finfish (e.g., catfish, trout, goldfish, tropical fish, minnows) and/or (2) hatching fish of any kind."* For shellfish farming and hatcheries, the description is, *"This U.S. industry comprises establishments primarily engaged in farm raising shellfish (e.g., crayfish, shrimp, oysters, clams, mollusks)."* Finally, for other, the description is, *"This U.S. industry comprises establishments primarily engaged in (1) farm raising of aquatic animals (except finfish and shellfish) and/or (2) farm raising of aquatic plants. Alligator, algae, frog, seaweed, or turtle production is included in this industry."*

Figure 2 depicts, in general, how a more detailed economic impact analysis can be conducted for domestic aquaculture production. As shown, domestic aquaculture production is assumed to enter the market in a parallel manner to wild caught seafood, and thus can be handled exactly the same for estimating downstream impacts. In the analysis that follows, the aquaculture product is matched with the species groupings in Table 3 and then enters the marketing channels as shown in Table 4. In contrast, for upstream impacts – the upper ovals in Figure 2 – the economics of the production of aquacultured species is treated as fundamentally different from wild-caught fish production. For wild caught fish, all production costs are only associated with harvest. For aquaculture, most of the costs incurred are prior to harvest, with harvesting cost playing a lesser role in the overall cost of production depending on the species and grow-out method. As a result, even if the farm-gate price for an aquacultured species is the same as or similar to the ex-vessel price for a wild caught species, the upstream impacts by expenditure category may be quite different; although the aggregate effect on the economy may be similar. Therefore, it is necessary to develop production expenditure estimates by species and production method for aquaculture production in a manner similar to what was done for wild caught species. A comprehensive literature review revealed a number of studies of aquaculture budgets for different species and production methods that form the basis of the analysis in the ensuing "Case Studies" section of this report.

[9] https://www.census.gov/eos/www/naics/2017NAICS/2017_NAICS_Manual.pdf (pp. 95-96)

Figure 2. Schematic of the domestic aquaculture seafood market for estimating economic impacts.



3.0 Case Studies

In this section, we develop case study production budgets for four aquaculture species: crawfish, salmon, clams, and oysters. Although crawfish is not a marine species, we include it here because it has the most complete data. A brief discussion of the data used for each species and its potential shortcomings are discussed, and then we present a table of the calculated economic impact estimates using the NMFS national economic impact model.

3.1 Crawfish Aquaculture

3.1.1 Crawfish Production Data

Production cost and returns data on crawfish was derived from Boucher and Gillespie (2014) which provides estimates for three types of crawfish operations: a single crop crawfish operation and two types of rice-crawfish double crop operations. The report provides significant detail on costs and the volume of production, but we had to reach out to the authors for explanation of some of the costs to properly classify them for the IMPLAN modeling. For example, a significant portion of costs were attributed in the text to “irrig single” and “pond&eq single”. These costs were later determined to be associated with the cost of running the pond pump to irrigate in single crop crawfish operations, and the pond and equipment costs, respectively. Another challenge was how to convert detailed data on labor hours required to produce crawfish to a jobs impact in IMPLAN, due to the likelihood of part-time or seasonal employment in crawfish production. For our purposes we assumed that on average, a job in crawfish production is equivalent to 1,200 labor hours per year. Another uncertainty was determining how much of the three different production operations for which costs were obtained contributed to aggregate production. In the absence of additional information, we assumed that the models each represented one-third of aggregate production, and thus were assigned equal weights.

3.1.2 Crawfish Economic Impacts

Given the above qualifications, the estimated national impacts of aquaculture crawfish are presented in Table 5. Estimates of employment impacts (a mix of full-time and part-time jobs), income (both employee compensation and proprietor income), and output are provided for the aquaculture operations (i.e., harvesters) and the other segments in the value-added chain as well as a summary for all industry segments. Estimates include direct effects (the segment itself), indirect effects (those associated with the segment’s supply chain), and induced effects (those created by the consumer spending of the directly and indirectly affected workers).

Reading horizontally across Table 5, one can see the impact on the national economy in terms of output, income, and jobs of just the farm level sales. Growers sell $199 million worth of crawfish which leads to a total economic impact of $590 million, due to the indirect and induced effects. Looking at the table vertically at the direct impacts, the farm level sales of $199 million lead to sales to final consumers (grocery and restaurant sales) of $877 million, which is the sum of farm level sales and the value-added for each of the downstream market sectors (i.e., processors, wholesalers, grocers, and restaurants) of $678 million. Finally, the total economic impact of crawfish aquaculture in 2015 was over $2.6 billion, the summing up of direct, indirect, and induced effects from all segments of the market. Note that the largest contributor to the impact are induced impacts related to restaurant sales ($528 million). We want to emphasize the large contribution that the restaurant final demand sector makes, accounting for 46% of the output impacts and 55% of the jobs.

Table 5. Summary of All Impacts for Aquaculture: Crawfish

Industry Sector	Direct	Indirect	Induced	Total
Growers				
Employment impacts (jobs)	1,316	979	895	3,190
Income Impacts (000 of dollars)	45,464	58,111	45,141	148,716
Output Impacts (000 of dollars)	199,350	245,922	144,880	590,151
Primary dealers/processors				
Employment impacts (jobs)	862	639	940	2,441
Income Impacts (000 of dollars)	43,275	36,042	47,455	126,772
Output Impacts (000 of dollars)	127,420	107,490	152,033	386,943
Secondary wholesalers/distributors				
Employment impacts (jobs)	1,105	636	702	2,443
Income Impacts (000 of dollars)	78,481	37,691	35,405	151,577
Output Impacts (000 of dollars)	104,921	109,805	113,562	328,289
Grocers				
Employment impacts (jobs)	1,536	163	338	2,037
Income Impacts (000 of dollars)	39,575	10,660	17,074	67,310
Output Impacts (000 of dollars)	45,092	28,817	54,673	128,581
Restaurants				
Employment impacts (jobs)	10,677	1,499	3,265	15,440
Income Impacts (000 of dollars)	224,059	91,118	164,844	480,021
Output Impacts (000 of dollars)	400,106	269,703	527,716	1,197,524
Harvesters and seafood industry				
Employment impacts (jobs)	15,496	3,916	6,140	25,552
Income Impacts (000 of dollars)	430,855	233,623	309,919	974,396
Output Impacts (000 of dollars)	876,888	761,736	992,864	2,631,488

3.2 Oyster Aquaculture

3.2.1 Oyster Production Data

Unlike crawfish aquaculture production, which is concentrated in Louisiana, significant aquaculture production of oysters occurs in many coastal states, including Massachusetts, Maryland, Virginia, North Carolina, Washington, Oregon, and California. The state of Washington, however, dominates production, accounting for nearly half of the total value of production. Production cost data were available for each of these states and were weighted by value of production per state to determine a "national" production cost for aquaculture oyster production.[10]

Among the significant uncertainties associated with these production costs are the facts that oyster production is often mingled with other shellfish and the wide variation in size of shellfish operations. Reports on production costs in Massachusetts (Augusto and Homes, 2013) and the West Coast states (Northern Economics, 2013) have detailed data on costs, but the data typically address operations that produce two or more shellfish species. Because of this mixing of data on species, it was necessary to dig deeper into the data in order to use it for a national estimate of oyster production costs. For the estimates below, survey data from Washington and California were reviewed, and only those operations that exclusively produced oysters were used to estimate production costs. These "oyster-only" producers were a minority of all operations, accounting for a small fraction of production value, therefore production costs from the West Coast states may be lower in reality than those included in this study since the dominant and potentially lower cost producers grow multiple species of shellfish. Alternatively, a report on Massachusetts shellfish production determined that oyster production accounted for roughly 90 percent of total shellfish production value.

The wide variation in size of operation is also likely to affect estimates of unit costs of production. For example, West Coast production is dominated by two large shellfish companies, which raise multiple species. On the East Coast, where there are about 1,000 shellfish aquaculture companies, three companies in Virginia represent a large share of the production.

As with crawfish, estimating job impacts involved assumptions that introduce uncertainty into the overall estimates. For Maryland, Virginia, and North Carolina, detailed information on either labor hours or labor costs was available. These data made clear that employment involves a mix of full-time and part-time or seasonal work. Accordingly, an average of 1,200 hours per job was assumed in generating an estimate of the number of jobs associated with these operations. Data on employment in Massachusetts, Washington, and California were defined in terms of employees (i.e. jobs) and could be used with less uncertainty to estimate the relationship between value of production and employment.

Other uncertainties include unspecified costs, which made up a significant share of the production data for West Coast states. Guidance from the lead author of that report (Northern Economics, 2013) was used to allocate the unspecified costs to memberships, travel, and marketing. As with other production operations, it was not always clear how costs (e.g., capital or oyster seed/spat) should be modeled. For

[10] Data on production costs in Maryland, Virginia, and North Carolina were collected by the authors in consultation with industry experts. Data on Massachusetts were taken from "Massachusetts Shellfish Aquaculture Economic Impact Study", Winter 2015, a report from the University of Massachusetts, Dartmouth. Data for West Coast states was derived from surveys conducted for "The Economic Impact of Shellfish Aquaculture in Washington, Oregon and California" prepared for the Pacific Shellfish Institute by Northern Economics, April 2013.

capital, it was general assumed that trucks or boats were the primary capital cost for small and mid-sized oyster-only operations. Large scale operations also have high capital costs associated with their own hatchery and nursery operations. Seed or spat costs were allocated to an IMPLAN sector that includes fish hatcheries, but may not accurately reflect the economic characteristics of oyster seed production operations.

3.2.2 Oyster Economic Impacts

The preliminary estimates of impacts of aquaculture oysters are presented in Table 6. The 2015 first sale oyster production value was estimated to be $173 million, $26 million less (13%) than crawfish value. Interestingly, the indirect effect of this oyster production was significantly less (60%) than the impact from crawfish, while the induced effect is higher by 23% for oysters. This is due to the fact that labor costs make up a much higher percentage of oyster production compared to crawfish production. The greater labor reliance in oyster production can be seen in the direct employment estimates which equate to 23 jobs per $1 million of production compared to less than 7 jobs per $1 million for crawfish.

Table 6. Summary of All Impacts for Aquaculture: Oysters

Industry Sector	Direct	Indirect	Induced	Total
Growers				
Employment impacts (jobs)	3,936	553	1,103	5,593
Income Impacts (000 of dollars)	99,748	33,823	55,704	189,274
Output Impacts (000 of dollars)	172,778	98,400	178,358	449,536
Primary dealers/processors				
Employment impacts (jobs)	748	553	815	2,116
Income Impacts (000 of dollars)	37,507	31,238	41,129	109,874
Output Impacts (000 of dollars)	110,435	93,162	131,768	335,366
Secondary wholesalers/distributors				
Employment impacts (jobs)	958	551	608	2,117
Income Impacts (000 of dollars)	68,020	32,667	30,686	131,373
Output Impacts (000 of dollars)	90,936	95,169	98,425	284,530
Grocers				
Employment impacts (jobs)	1,331	142	293	1,766
Income Impacts (000 of dollars)	34,300	9,239	14,798	58,338
Output Impacts (000 of dollars)	39,081	24,976	47,385	111,442
Restaurants				
Employment impacts (jobs)	9,253	1,299	2,830	13,382
Income Impacts (000 of dollars)	194,194	78,972	142,871	416,037
Output Impacts (000 of dollars)	346,775	233,753	457,375	1,037,902
Harvesters and seafood industry				
Employment impacts (jobs)	16,269	3,104	5,661	25,033
Income Impacts (000 of dollars)	433,768	185,940	285,189	904,896
Output Impacts (000 of dollars)	760,005	545,460	913,311	2,218,777

3.3 Clam Aquaculture

3.3.1 Clam Production Data

Washington State is the largest producer of aquaculture clams with 45% of U.S. value. While there are good data on shellfish aquaculture operations in Washington State, most operations produce more than one type of shellfish. Consequently, extracting data on individual species was not practical for this effort.

Data for costs of production and income are from operations in Florida and Virginia as reported by the University of Florida Institute of Food and Agricultural Sciences Shellfish Aquaculture Extension Program and the Virginia Institute of Marine Science, Virginia Sea Grant Extension Program. Data represent statewide conditions and are assumed to be reasonable reflections of the average aquaculture operation in each state. Florida and Virginia are major sources of hard clams, representing 15% and 17% of 2014 value of production, respectively. Connecticut is another significant producer of hard clams with 15% of U.S. production value, but no cost data from Connecticut were available for this analysis.

3.3.2 Clam Economic Impacts

Table 7 provides the summary economic impacts for clam aquaculture. One thing that stands out immediately is that as currently practiced, clam aquaculture is nowhere near as labor intensive as oyster aquaculture; it is more similar in labor utilization to crawfish production. As a result, the induced impacts at the first sale level are more in line with crawfish production.

Table 7. Summary of All Impacts for Aquaculture: Clams

Industry Sector	Direct	Indirect	Induced	Total
Growers				
Employment impacts (jobs)	1,025	461	565	2,052
Income Impacts (000 of dollars)	44,501	25,948	28,528	98,977
Output Impacts (000 of dollars)	112,139	79,894	91,419	283,452
Primary dealers/processors				
Employment impacts (jobs)	485	359	529	1,373
Income Impacts (000 of dollars)	24,343	20,275	26,694	71,312
Output Impacts (000 of dollars)	71,677	60,465	85,522	217,664
Secondary wholesalers/distributors				
Employment impacts (jobs)	622	358	395	1,374
Income Impacts (000 of dollars)	44,147	21,202	19,916	85,266
Output Impacts (000 of dollars)	59,020	61,768	63,882	184,670
Grocers				
Employment impacts (jobs)	864	92	190	1,146
Income Impacts (000 of dollars)	22,262	5,996	9,605	37,863
Output Impacts (000 of dollars)	25,365	16,210	30,755	72,330
Restaurants				
Employment impacts (jobs)	6,006	843	1,836	8,685
Income Impacts (000 of dollars)	126,039	51,256	92,728	270,023
Output Impacts (000 of dollars)	225,069	151,714	296,852	673,635
Harvesters and seafood industry				
Employment impacts (jobs)	9,013	2,118	3,522	14,653
Income Impacts (000 of dollars)	261,292	124,677	177,472	563,441
Output Impacts (000 of dollars)	493,270	370,052	568,429	1,431,751

3.4 Salmon Aquaculture

3.4.1 Salmon Production Data

Obtaining detailed farm production budgets for salmon aquaculture in the U.S. is difficult because of the limited number of operations. Even when data is available, protecting confidentiality to prevent disclosure of sensitive company financial data is an issue. Atlantic salmon farming in net pens in Maine and Washington State is now almost all owned by one company, Cooke Aquaculture. Pacific Aquaculture has several steelhead net pen farms on the Columbia River with operational features and costs similar to Atlantic salmon. Several small operations growing Atlantic salmon are using land-based recirculating aquaculture facilities and at least four larger land-based Atlantic salmon facilities are in construction or design phases in the U.S. Given these limitations, we examined more readily available production cost data from Canada and Norway to provide cost estimates for this study.

Through discussion with industry experts, we estimate that currently, nearly 100% of U.S. aquaculture salmon production is from open water net pens. We developed an enterprise budget based on Boulet et al. (2010) to determine the percentage cost of production for each input. Due to the geographic proximity and the fact that there is a significant percentage of U.S. net pen salmon operation with Canadian ownership, we determined that these British Columbia-based net pen production estimates were better estimates of U.S. production cost and returns than a set of Norwegian production estimates available in Liu et al. (2016). Cost data in Boulet et al. (2010) was inflated from 2010 U.S. dollars to 2015 U.S. dollars based on the producer price index from the Bureau of Labor Statistics[11].

Once the direct impacts of aquaculture salmon were calculated, the output from growers was treated as the equivalent of commercially harvested wild salmon in the downstream sectors. That is, it was distributed among processors, wholesalers, and retailers as if it were commercially harvested salmon, as calculated in Table 4. However, it is clear from Boulet et al. (2010) that the enterprise budgets represented operations that produced head-on, gutted salmon as the initial product entering the marketing chain. This level of vertical integration is different from the product of commercial fishing and undermines the assumption about how farmed salmon moves through the value-added chain. Compared to commercially harvested salmon, it would seem reasonable to assume large producers process their own product and that a smaller share of aquaculture salmon flows to secondary processors and a larger share to other value-added segments.

3.4.2 Salmon Economic Impacts

Table 8 provides estimates of the 2015 production by U.S. salmon aquaculture operations. Basic input is the *Fisheries of the United States* estimate of the value of this production in 2015:$87.7 million. The direct impacts of salmon aquaculture are based on revenue and expense data for net-pen operations from a feasibility study of British Columbia closed containment aquaculture (Boulet et al. 2010).

[11] https://www.bls.gov/ppi/

Table 8. Summary of All impacts for Aquaculture: Salmon

Industry Sector	Direct	Indirect	Induced	Total
Growers				
Employment impacts (jobs)	87	422	476	985
Income Impacts (000 of dollars)	5,630	26,723	24,019	56,372
Output Impacts (000 of dollars)	87,743	121,743	77,042	286,527
Primary dealers/processors				
Employment impacts (jobs)	388	199	437	1,024
Income Impacts (000 of dollars)	22,930	12,276	22,077	57,283
Output Impacts (000 of dollars)	57,360	38,485	70,679	166,523
Secondary wholesalers/distributors				
Employment impacts (jobs)	486	280	309	1,075
Income Impacts (000 of dollars)	34,543	16,590	15,583	66,716
Output Impacts (000 of dollars)	46,180	48,330	49,984	144,495
Grocers				
Employment impacts (jobs)	676	72	149	897
Income Impacts (000 of dollars)	17,419	4,692	7,515	29,626
Output Impacts (000 of dollars)	19,847	12,684	24,064	56,595
Restaurants				
Employment impacts (jobs)	4,699	660	1,437	6,796
Income Impacts (000 of dollars)	98,619	40,105	72,555	211,279
Output Impacts (000 of dollars)	176,105	118,708	232,272	527,085
Harvesters and seafood industry				
Employment impacts (jobs)	6,337	1,633	2,808	10,777
Income Impacts (000 of dollars)	179,140	100,386	141,750	421,276
Output Impacts (000 of dollars)	387,235	339,950	454,040	1,181,225

4.0 Aggregate Summary and Analysis

4.1 Overview

The four species for which we provide impact estimates only comprise 41% of the total first sales value of U.S. aquaculture production. Catfish, which we did not include due to a lack of readily available recent cost and returns data, comprises 25% of the total value of production. However, from the marine production perspective, the three marine species analyzed, oysters, clams, and salmon, represent 95% of the first sale value of marine aquaculture production in 2015. Total aquaculture first sale value was $1.3 billion in 2014 and $1.4 billion in 2015. For aquaculture production as a whole, it would be misleading to extrapolate from our measured values in this study to the full impact of U.S. aquaculture, but for marine aquaculture production it is reasonable to extrapolate our estimates from the 95% of production value included in the analysis to an estimate of the full impacts of marine aquaculture production.

From *Fisheries of the U.S. 2016*, marine aquaculture production in 2015 had total first sales of about $394 million. By assuming that the 5% of production we have not calculated impacts for creates impacts in the same proportion as those we have calculated, then the total impacts for marine aquaculture production are estimated in Table 9.

Table 9. Summary of All Impacts for Aquaculture: All Marine

Industry Sector	Direct	Indirect	Induced	Total
Growers				
Employment impacts (jobs)	5,337	1,518	2,267	**9,122**
Income Impacts (000 of dollars)	158,461	91,447	114,449	**364,357**
Output Impacts (000 of dollars)	393,998	317,217	366,678	**1,077,893**
Primary dealers/processors				
Employment impacts (jobs)	1,714	1,175	1,883	**4,771**
Income Impacts (000 of dollars)	89,634	67,441	95,048	**252,124**
Output Impacts (000 of dollars)	253,184	203,112	304,458	**760,754**
Secondary wholesalers/distributors				
Employment impacts (jobs)	2,184	1,257	1,387	**4,829**
Income Impacts (000 of dollars)	155,110	74,493	69,975	**299,579**
Output Impacts (000 of dollars)	207,367	217,020	224,447	**648,834**
Grocers				
Employment impacts (jobs)	3,035	324	668	**4,027**
Income Impacts (000 of dollars)	78,217	21,068	33,746	**133,031**
Output Impacts (000 of dollars)	89,120	56,955	108,056	**254,130**
Restaurants				
Employment impacts (jobs)	21,101	2,962	6,452	**30,516**
Income Impacts (000 of dollars)	442,835	180,086	325,799	**948,720**
Output Impacts (000 of dollars)	790,776	533,044	1,042,985	**2,366,804**
Harvesters and seafood industry				
Employment impacts (jobs)	**33,429**	**7,248**	**12,678**	**53,355**
Income Impacts (000 of dollars)	**924,256**	**434,537**	**639,019**	**1,997,811**
Output Impacts (000 of dollars)	**1,734,444**	**1,327,349**	**2,046,621**	**5,108,413**

The $394 million in first sales of U.S. marine aquaculture production, through processing and distribution, ended up with final sales to consumers of over $1.7 billion. The indirect and induced effects added $1.3 billion and $2.0 billion, respectively, for a total impact on the U.S. economy of $5.1 billion. There were 33,429 jobs directly related to the production, processing, distribution, and final sales of marine aquaculture products. The indirect and induced effects added an additional 19,926 jobs for a total impact of 53,355 jobs.

4.2 Demonstration - Using Analysis For Future Impacts

The NMFS Office of Aquaculture, in consultation with industry leaders, suggests a reasonable target is for there to be a 2.5 times increase in U.S. marine aquaculture production in the next ten years. We adopt that target to demonstrate how the preceding analysis can be used to provide an estimate of the economic impacts from achieving that goal. Even though a 2.5 times increase in marine aquaculture is larger than the recent growth as indicated in *Fisheries of the U.S.*, an even larger expansion is possible. This will depend on changes in U.S. policy (e.g., opening up federal waters to aquaculture), providing access to sites in state waters by overcoming reluctance of coastal landowners to support aquaculture in some states, and via a reduction in production costs in recirculating aquaculture systems (see Knapp and Rubino, 2016).

4.2.1 Estimating Increase in First Sales Value

To estimate the economic impact of an increase in U.S. marine aquaculture production, it is necessary to project what the composition of the increased production will be. Scenario 1 uses a simple and perhaps naïve assumption that production will maintain its current composition of species, prices will not change, and thus result in a simple 2.5 times increase in first sale value to $985 million. It is rather straightforward, then, to estimate the increase in impacts, since the underlying impact model structure is linear, and all the values increase by the same 2.5 times.

Alternatively, for Scenario 2, the Office of Aquaculture, based on interviews with market experts, estimates that a larger percentage, say 75%, of the production volume increase will result from an expansion in finfish production, and this will require a different weighting. We will use salmon value and production costs for this weighting, but it is believed that other species for which we do not yet have reliable production budgets or price projections such as red drum, striped bass, yellowtail, sablefish, and cobia are likely to contribute to this increase. For the assumption of a greater increase in finfish production, we take the same absolute increase in sales volume, but assign 75% of the volume to a price associated with finfish (i.e., salmon) production. This yields a projected first sale value for marine finfish of $288 million, compared with Scenario 1 finfish value of $219 million. The remaining 25% of the increase in volume is split between oysters and clams in proportion to their 2015 production volume. The total first sale value produced in Scenario 2 is $821 million. The weighting towards more finfish lowers the overall first sales value because current production is more heavily weighted towards high unit value oysters and clams.

4.2.2 Estimating Total Impact and Jobs of First Sales Value

The process of estimating total economic impacts, once the first sale production number is set, proceeds as in the previous examples. Impact estimates are provided in Tables 10 and 11 for Scenarios 1 and 2, respectively. At the producer/grower level, total impacts are $2.7 billion (Scenario 1) or $2.3 billion (Scenario 2). Direct employment associated with production is 13,343 jobs (Scenario 1) or 9,503 jobs (Scenario 2). The difference in scenarios is driven by the fact that the budget we used for salmon production is much less labor intensive than for either shellfish species. Total employment associated with production is estimated at 22,805 jobs (Scenario 1) or 17,468 jobs (Scenario 2). That represents an increase in employment of 13,683 jobs (Scenario 1) or 8,346 jobs (Scenario 2). The increase in jobs associated with production are of particular note, because they potentially represent the difference between producing the increased seafood in the U.S. and importing product produced in overseas aquaculture. The downstream impacts discussed in the next section are generated regardless of where the seafood product is initially grown.

4.2.3 Including Downstream Impacts

The downstream impacts calculated in Tables 10 and 11 are based not only on the assumption that aquaculture products will follow the same distribution and consumption patterns of wild caught domestic products, but also that this pattern will continue into the future. If those assumptions hold, then 2.5 times growth will result in 133,386 jobs (Scenario 1) or 109,515 jobs (Scenario 2) associated with production and final sale of U.S. aquaculture products. This is an increase over the year 2015 associated jobs of 80,031 (Scenario 1) or 56,160 (Scenario 2). The total impact on the U.S. economy will be $12.8 billion (Scenario 1) or $10.7 billion (Scenario 2).

Table 10. Scenario 1 of Projected Impacts for Aquaculture at 2.5 Times Current: All Marine Fixed Composition

Industry Sector	Direct	Indirect	Induced	Total
Growers				
Employment impacts (jobs)	13,343	3,796	5,667	**22,805**
Income Impacts (000 of dollars)	396,152	228,616	286,123	**910,892**
Output Impacts (000 of dollars)	984,995	793,042	916,694	**2,694,731**
Primary dealers/processors				
Employment impacts (jobs)	4,285	2,937	4,707	**11,929**
Income Impacts (000 of dollars)	224,086	168,604	237,619	**630,309**
Output Impacts (000 of dollars)	632,960	507,780	761,145	**1,901,885**
Secondary wholesalers/distributors				
Employment impacts (jobs)	5,461	3,143	3,468	**12,071**
Income Impacts (000 of dollars)	387,776	186,234	174,937	**748,946**
Output Impacts (000 of dollars)	518,416	542,551	561,116	**1,622,084**
Grocers				
Employment impacts (jobs)	7,588	809	1,670	**10,068**
Income Impacts (000 of dollars)	195,543	52,670	84,364	**332,577**
Output Impacts (000 of dollars)	222,799	142,386	270,140	**635,325**
Restaurants				
Employment impacts (jobs)	52,752	7,406	16,131	**76,289**
Income Impacts (000 of dollars)	1,107,088	450,215	814,497	**2,371,799**
Output Impacts (000 of dollars)	1,976,940	1,332,609	2,607,462	**5,917,011**
Harvesters and seafood industry				
Employment impacts (jobs)	**83,574**	**18,119**	**31,694**	**133,386**
Income Impacts (000 of dollars)	**2,310,640**	**1,086,342**	**1,597,547**	**4,994,529**
Output Impacts (000 of dollars)	**4,336,110**	**3,318,371**	**5,116,552**	**12,771,034**

Table 11. Scenario 2 of Projected Impacts for Aquaculture at 2.5 Times Current: All Marine 75% Growth in Finfish

Industry Sector	Direct	Indirect	Induced	Total
Growers				
Employment impacts (jobs)	9,503	3,285	4,676	**17,468**
Income Impacts (000 of dollars)	287,364	199,632	236,055	**723,050**
Output Impacts (000 of dollars)	820,716	733,710	756,411	**2,310,833**
Primary dealers/processors				
Employment impacts (jobs)	3,579	2,358	3,947	**9,884**
Income Impacts (000 of dollars)	190,917	136,599	199,277	**526,793**
Output Impacts (000 of dollars)	528,776	413,535	638,273	**1,580,583**
Secondary wholesalers/distributors				
Employment impacts (jobs)	4,549	2,619	2,890	**10,056**
Income Impacts (000 of dollars)	323,102	155,174	145,760	**624,038**
Output Impacts (000 of dollars)	431,953	452,063	467,532	**1,351,552**
Grocers				
Employment impacts (jobs)	6,323	674	1,392	**8,389**
Income Impacts (000 of dollars)	162,930	43,886	70,293	**277,111**
Output Impacts (000 of dollars)	185,640	118,639	225,086	**529,365**
Restaurants				
Employment impacts (jobs)	43,954	6,171	13,441	**63,566**
Income Impacts (000 of dollars)	922,446	375,128	678,653	**1,976,226**
Output Impacts (000 of dollars)	1,647,222	1,110,354	2,172,585	**4,930,159**
Harvesters and seafood industry				
Employment impacts (jobs)	**68,012**	**15,127**	**26,381**	**109,515**
Income Impacts (000 of dollars)	**1,886,754**	**910,420**	**1,330,045**	**4,127,217**
Output Impacts (000 of dollars)	**3,614,308**	**2,828,303**	**4,259,882**	**10,702,494**

5.0 Conclusion and Recommendations

Fisheries Economics of the United States currently provides useful information to stakeholders and the general public about the importance of the fishing and seafood industries, and demonstrates year over year changes and trends in economic impacts. Adding domestic aquaculture production estimates will increase the utility of this information and provide a greater understanding of the entire seafood industry, particularly as domestic aquaculture increases in importance as a component of U.S. supply.

When we started on this study, the original intent was to develop an estimate of the total economic impact from U.S. aquaculture production for most major species as a demonstration of how this could be incorporated into *FEUS*. We discovered that there is insufficient extant cost information and only greatly outdated information on production for several major species to develop a reasonable national estimate of economic impacts. Many of the published budgets were out of date, missing key pieces of information, did not include newer production methods, or were only relevant to a single production method in a specific geographic area so that it might not be representative of the industry as a whole. As a result, the project morphed into a data and methodological gap analysis focused on four species as an initial trial analysis of economic impact.

We began the impact analysis with an estimate of annual aquaculture production value by major species as published in *Fisheries of the U.S.* These figures are based on a combination of state reports, industry reports and estimates, USDA's Census of Agriculture and Census of Aquaculture (a survey done once every five years), USDA's regular collection of catfish and trout production data, information from selected companies, and NMFS and USDA staff estimates based on professional knowledge about the industry. Production numbers from some states are not available on an annual basis. Some states gather production data as part of lease or permit requirements but are unwilling to make the data available to a federal agency. A systematic way of collecting this data from states, industry associations or directly from producers is essential to ensuring the quality of the estimates that rely on these numbers.

There are other issues that arise when developing annual aquaculture production estimates. A clear definition of what constitutes aquaculture production, particularly for shellfish[12], is necessary and will help avoid some double counting in commercial landings that occurs now. Close coordination with reporting states is essential for determining this data. Responsibility for aquaculture production figures may be housed in different state agencies or different parts of the same agency than that with which NMFS typically coordinates in reporting fish landings. Since there is interest in reporting on marine versus freshwater aquaculture production, classification of what constitutes each will have to be agreed upon. For example, land-based recirculating aquaculture systems produce both freshwater and marine species. Is a marine species grown in a land-based system considered marine aquaculture production? The annual industry survey-based report produced by the Virginia Sea Grant Marine Extension Program (Hudson, 2018) is an excellent example of the type and quality of production data needed for all aquaculture species. Another challenge in reporting production by species will be the requirement of protecting confidentiality of firm level data, which may be raised as an issue when there are a small number of firms constituting the production for a particular species. Atlantic salmon farming in net pens in Maine and Washington State is currently all owned by one company and shellfish farming is dominated by two companies on the West Coast and three in Virginia.

Once we determined production levels and farm gate values, our next step was to allocate production value to different cost categories. Even when there were recent comprehensive studies of aquaculture production costs for a species, it was sometimes difficult to place costs in an appropriate category. Multiple studies may classify costs differently. As a result, relying on one-off production cost studies that appear in the literature from time to time is an unreliable way of developing representative industry budgets. Systematic collection of production costs via standardized industry surveys will provide the most reliable information. The relevant Federal agencies (i.e., USDA and NOAA), in conjunction with state agencies and aquaculture industry organizations, should come together and plan a survey methodology and a way to administer, maintain, and update it on a regular basis.

[12] There is a long history of state-supported preparation of shellfish bottom, planting shell and placing wild or hatchery produced seed oysters subsequently harvested by a limited access fishery and reported as part of total fish landings. Essentially, the same production methods are used in privately held leased bottom, which may be reported separately.

Two of the major items to be determined in planning an aquaculture industry production cost survey are the survey frequency and the target sample size. The Bureau of Economic Analysis, in producing National Income Accounts, opens up their underlying model to major revisions every five years, so it would make sense for the same level of updating for an aquaculture survey. The need for a particular industry sample size will depend on the ultimate use of the survey data and will be higher when there is a need for stratification when the industry is diverse in its production technologies. As mentioned above, some of the published cost data from specialized surveys were not representative of the industry. An industry census would ameliorate the concern about representativeness, but short of a census, any type of survey sample would have to be designed with this concern in mind. The aggregate species groupings for commercial landings (Table 3) demonstrates the tradeoffs necessary in developing representative cost estimates.

Our analysis used a very simple assumption about downstream impacts of aquaculture fish. We used the same product flows as shown in Table 4. We are aware that even for currently produced aquaculture species like Atlantic salmon, these product flows may be inaccurate. Emerging aquaculture production may also follow very different routes through the marketing chain. A comprehensive study on the seafood market chain would allow us to relax this assumption and provide insight on how inaccurate or not the impact estimates are as a result. Some publicly available data (e.g., What We Eat in America[13]) and private industry data should be researched to get a better understanding of the geographic distribution of final purchase of seafood. This will be particularly important to eventually produce state level economic impact estimates.

We also need to be concerned about measuring upstream impacts from aquaculture production. Budgets should be developed for finfish and shellfish hatcheries and nurseries for the key aquaculture species as an improvement over the current NAICS data.

Not all aquaculture production is for seafood. Some freshwater aquaculture is for pond stocking for recreational fishing, and there is a substantial market for aquacultured baitfish (Senten and Engle, 2017). Marine algae production will likely be used for both direct consumption and as additives to foods and other products. These other markets will have to be examined and quantified as they develop.

[13] https://data.nal.usda.gov/dataset/what-we-eat-america-wweia-database

6.0 Literature Cited

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