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U.S. Offshore Aquaculture Regulation and Development

Harold F. Upton
Analyst in Natural Resources Policy

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SUMMARY

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Regulatory uncertainty has been identified as one of the main barriers to offshore aquaculture development in the United States. Many industry observers have emphasized that congressional action may be necessary to provide statutory authority to develop aquaculture in offshore areas. Offshore aquaculture is generally defined as the rearing of marine organisms in ocean waters beyond significant coastal influence, primarily in the federal waters of the exclusive economic zone (EEZ). Establishing an offshore aquaculture operation is contingent on obtaining several federal permits and fulfilling a number of additional consultation and review requirements from different federal agencies responsible for various general authorities that apply to aquaculture. However, there is no explicit statutory authority for permitting and developing aquaculture in federal waters. The aquaculture permit and consultation process in federal waters has been described as complex, time consuming, and difficult to navigate.

Supporters of aquaculture have asserted that development of the industry, especially in offshore areas, has significant potential to increase U.S. seafood production and provide economic opportunities for coastal communities. Currently, marine aquaculture facilities are located in nearshore state waters. Although there are some research-focused and proposed commercial offshore facilities, no commercial facilities are currently operating in U.S. federal waters. Aquaculture supporters note that the extensive U.S. coastline and adjacent U.S. ocean waters provide potential sites for offshore aquaculture development. They reason that by moving offshore, aquaculturalists can avoid many user conflicts they have encountered in inshore areas. Offshore areas also are considered to be less prone to pollution and fish diseases.

Environmental organizations and fishermen generally have opposed development of offshore aquaculture. They assert that poorly regulated aquaculture development in inshore areas has degraded the environment and harmed wild fish populations and ecosystems. Those who oppose aquaculture development generally advocate for new authorities to regulate offshore aquaculture and to safeguard the environment and other uses of offshore waters. Some segments of the commercial fishing industry also have expressed concerns with potential development of aquaculture on fishing grounds and competition between cultured and wild products in domestic markets.

Proponents of aquaculture counter that in many parts of the world a combination of farming experiences, technological advances, proper siting, and industry regulation has decreased environmental impacts and improved efficiency of marine aquaculture. They argue that many who oppose marine aquaculture lack an understanding of the benefits and risks of aquaculture and that opposition persists despite research that contradicts the extent or existence of these risks.

Generally, the outcomes associated with aquaculture development depend on a variety of factors, such as the characteristics of aquaculture sites, species, technology, and facility management. Regardless of potential environmental harm, it remains to be seen whether moving to offshore areas would be profitable and if offshore aquaculture could compete with inshore aquaculture development and lower costs in other countries.

Comprehensive offshore aquaculture bills were introduced in the 109th, 110th, 111th, 112th, and 115th Congresses, but none were enacted. In the 115th Congress, the Advancing the Quality and Understanding of American Aquaculture Act (AQUAA; S. 3138 and H.R. 6966) was introduced; AQUAA would have established a regulatory framework for aquaculture development in federal waters. It also would have provided National Oceanic and Atmospheric Administration (NOAA) Fisheries with the authority to issue aquaculture permits and coordinate with other federal agencies that have permitting and consultative responsibilities. Conversely, since the 109th Congress, bills have been introduced that would constrain or prohibit the permitting of aquaculture in the EEZ. The Keep Finfish Free Act of 2019 (H.R. 2467), introduced in the 116th Congress, would prohibit the issuance of permits to conduct finfish aquaculture in the EEZ until a law is enacted that allows such action. It remains an open question whether legislation could be crafted that would provide the regulatory framework desired by potential commercial developers of offshore aquaculture and avoid or minimize risks of environmental harm to the satisfaction of those currently opposed to offshore aquaculture development.

Contents

Figures

Tables

Contacts

Introduction

Offshore aquaculture is generally defined as the rearing of marine organisms in ocean waters beyond significant coastal influence, primarily in the federal waters of the exclusive economic zone (EEZ).[1] Currently, marine aquaculture facilities are located in nearshore state waters, but no commercial facilities operate in U.S. federal waters. Some aquaculture advocates contend that developing such offshore aquaculture facilities could increase U.S. seafood production and provide economic opportunities for coastal communities; opponents counter that doing so could harm the environment and have negative impacts on other coastal activities, such as fishing.

Offshore aquaculture development will likely depend on several interrelated legal and institutional requisites, such as establishing a regulatory framework, minimizing environmental harm, and developing the capacity to manage and support the industry. Regulatory uncertainty has been identified as one of the main barriers to developing offshore aquaculture in federal waters of the United States.[2] According to the U.S. Commission on Ocean Policy, "aquaculture operations in offshore waters lack a clear regulatory regime, and questions about exclusive access have created an environment of uncertainty that is detrimental to investment in the industry."[3] Some observers have concluded that "offshore aquaculture will not fully develop unless governments create a supportive political climate and resulting regulatory conditions."[4] A framework also may be needed to assure environmentalists, fishermen, and other stakeholders that coastal and fisheries managers would have the authority to address potential threats to the environment and other impacts.

According to most observers, congressional action may be necessary to develop a comprehensive regulatory framework for offshore aquaculture. Comprehensive legislation has been introduced a number of times since the 109th Congress, but none of the bills have been enacted. Controversy has stemmed from different perspectives of aquaculturalists, environmentalists, fishermen, and others. Some environmental organizations and fishermen have asserted that poorly regulated aquaculture development has degraded the environment and harmed wild fish populations and ecosystems.[5] Some segments of the commercial fishing industry are opposed to marine aquaculture because of potential development on fishing grounds, environmental effects on fish populations, and competition of cultured products with wild products in domestic markets. Offshore aquaculture advocates counter that a combination of farming experiences, technological advances, proper siting, and industry regulation has decreased environmental impacts and improved the efficiency of marine aquaculture. It appears that renewed efforts have emerged in

[1] Proclamation 5030, "Exclusive Economic Zone of the United States of America," March 10, 1983.

[2] U.S. Congress, Senate Committee on Commerce, Science, and Transportation, Ocean Policy Study, *Statement of William T. Hogarth, Assistance Administrator, National Marine Fisheries Service*, Hearing on Offshore Aquaculture, 109th Cong., 2nd sess., April 6, 2006.

[3] U.S. Commission on Ocean Policy, *An Ocean Blueprint for the 21st Century*: *Final Report. P. 330*. Hereinafter cited as Oceans Commission, *Ocean Blueprint*.

[4] John S. Corbin, John Holmyard, and Scott Lindell, "Aquaculture Perspectives of Multi-use Sites in the Open Ocean," in *Regulation and Permitting of Standalone and Co-located Open Ocean Aquaculture Facilities* (Springer, 2017), pp. 187-229.

[5] Center for Food Safety, Fishing and Public Interest Groups File Challenge to Fed's Unprecedented Decision to Establish Aquaculture in Offshore U.S. Waters, February 16, 2016, at https://www.centerforfoodsafety.org/press-releases/4229/fishing-and-public-interest-groups-file-challenge-to-feds-unprecedented-decision-to-establish-aquaculture-in-offshore-us-waters.

the 116th Congress to meet current challenges by attempting to improve regulatory efficiency, minimize environmental degradation, and avoid impacts on existing ocean uses.

Additional related factors, such as technical advances, economic feasibility, and the level of government support, also are likely to affect future growth of the U.S. aquaculture industry. Although a regulatory framework appears to be necessary for establishing offshore aquaculture in federal waters, it may not be sufficient for significant development of the industry. Sometimes overlooked are the services that may be needed to establish a new industry, such as program administration, research, and other services (e.g., disaster assistance, insurance). Technical uncertainties related to harsher offshore environmental conditions and higher costs of operating farther from shore may slow extensive offshore development, especially in the immediate future.

This report examines issues and challenges related to the development of offshore aquaculture in federal waters.[6] It introduces the topic with background information that covers aquaculture production and methods, federal agencies involved in aquaculture, and potential congressional interest in the topic. It then focuses on three of the main challenges faced by the industry, including the current regulatory framework, environmental concerns, and economic viability. The report concludes with issues related to regulatory and institutional development that have been identified by researchers and stakeholders, potential issues for Congress, and a summary of legislation that has been introduced in recent Congresses.

Background

Seafood Production

Global aquaculture production is nearly equal to the volume of seafood produced for human consumption by wild fisheries.[7] From 1997 to 2016, world seafood production from wild sources (capture fisheries) leveled off at a range of 89 million metric tons (mmt) to 96 mmt.[8] According to the United Nations Food and Agriculture Organization, further growth of global wild fisheries production is unlikely, because approximately 93% of marine stocks are now either fished unsustainably or fished at maximum sustainable levels.[9] During the same period, world aquaculture production increased from 28.3 mmt to 80.0 mmt; it now makes up 47% of global fish production.[10] It is likely that aquaculture production will continue to expand with advances in aquaculture technologies and the need to satisfy the demand of the world's growing population.[11] **Figure 1** illustrates the growth in global aquaculture production and relatively constant wild fisheries production. Nearly all of global marine aquaculture production is from inshore areas, such as estuaries and coastal areas, not from offshore areas.

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[6] Comparisons and references are made to inshore and land-based aquaculture, but the focus of this report is offshore aquaculture.

[7] Global aquaculture totals include both freshwater and marine aquaculture.

[8] Food and Agriculture Organization (FAO), *The State of World Fisheries and Aquaculture 2018*: *Meeting the Sustainable Development Goals*, 2018. Hereinafter cited as FAO, *State of World Fisheries*. The total includes all fresh and marine landings, which was 90.9 mmt in 2016.

[9] FAO, *State of World Fisheries*, p. 40.

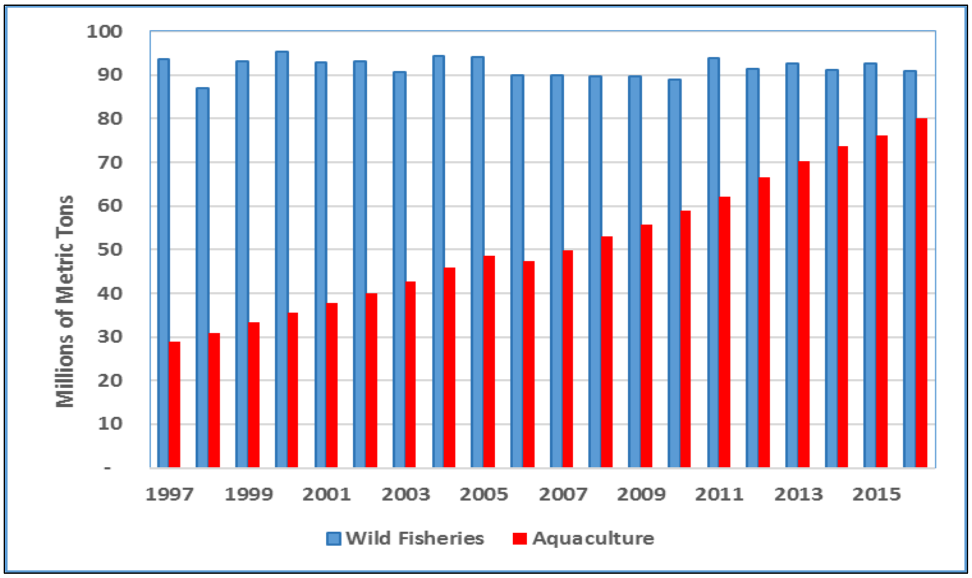
[10] Aquaculture represents 47% of all fish landings, including fish used for purposes other than direct human consumption such as fish meal and fish oil for animal feeds, and 53% of fish landed for direct human consumption. The term *fish* includes harvest of invertebrates such as crustaceans, mollusks, and echinoderms.

[11] FAO, *State of World Fisheries*, p. 182.

Wild fisheries in the United States are limited by the productive capacity of U.S. waters. Most U.S. stocks are now fished at their maximum sustainable levels. However, unlike worldwide trends, U.S. aquaculture production has generally stagnated and makes up a relatively small portion of total U.S. seafood production. In 2016, the United States ranked fifth in global seafood production at 5.36 mmt; 0.44 mmt (8.2%) of this total was produced by aquaculture.[12] **Figure 2** illustrates the relatively constant domestic production of aquaculture and wild fisheries. Most U.S. aquaculture production consists of freshwater species, such as catfish, trout, and crawfish. Growth in U.S. seafood consumption has depended on imports, which provide approximately 80% to 90% of the seafood consumed in the United States.[13] Approximately 50% of seafood imports, such as shrimp from Southeast Asia and salmon from Norway or Chile, are produced by aquaculture in ponds and nearshore areas. According to some observers, U.S. reliance on seafood imports will continue to increase without changes to current policies and regulatory obstacles that currently impede expansion of aquaculture.[14]

Figure 1. Global Wild Fisheries and Aquaculture Production

(1997-2016)



Source: National Marine Fisheries Service, *Fisheries of the United States* reports, 1999-2017.

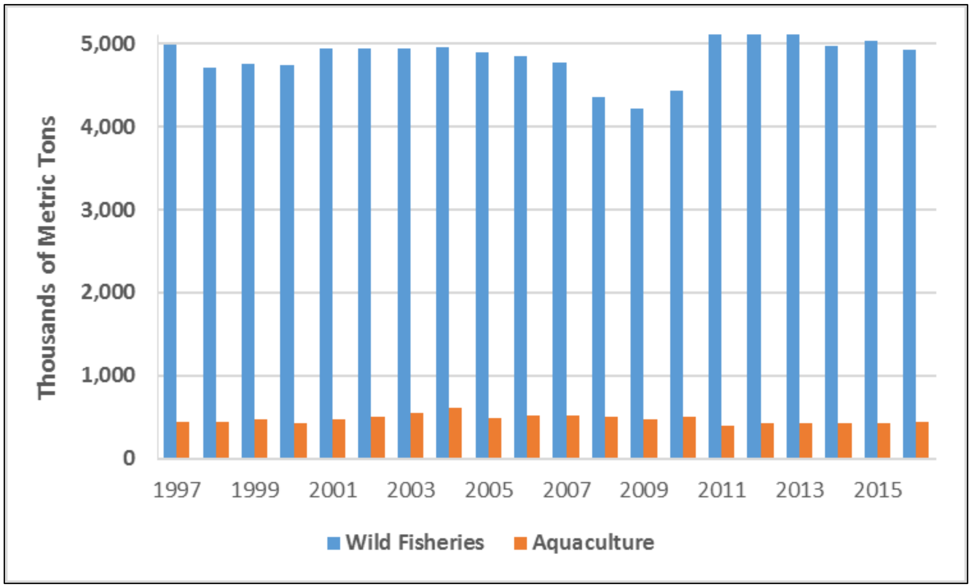
Notes: Fisheries and aquaculture totals include marine and freshwater sources.

[12] U.S. total and aquaculture production reported to FAO includes shell weight of oysters and clams. The National Marine Fisheries Service (NMFS) reported U.S. aquaculture production in meat weight without shells. Thus, the NMFS reported figure was 0.29 million metric tons (mmt).

[13] NMFS, Office of Science and Technology, *Fisheries of the United States, 2017 Report*, Current Fishery Statistics No. 2017, September 2018, p. 114. Hereinafter cited as NMFS, *Fisheries of the United States*. A portion of imports include domestic catch that was exported for further processing and returned to the United States as an import in processed form.

[14] Hauke L. Kite-Powell, Michael C. Rubino, and Bruce Morehead, "The Future of U.S. Seafood Supply," *Aquaculture Economics & Management*, vol. 17, no. 3 (August 2013), p. 229.

Figure 2. U.S. Wild Fisheries and Aquaculture Production
(1997-2016)



Source: National Marine Fisheries Service, *Fisheries of the United States* reports, 1999-2017.

Notes: Aquaculture totals include marine and freshwater production.

Aquaculture Overview

Aquaculture is broadly defined as the propagation and rearing of aquatic species in controlled or selected environments.[15] Aquaculture is difficult to characterize because of the diverse nature of facilities, methods, technologies, and species that are cultured. Organisms are cultured in freshwater environments, land-based closed systems, coastal and estuarine areas, and offshore areas.[16] Often, hatcheries are used to spawn fish and shellfish to produce eggs that are hatched and grown to specific stages; these organisms are then transferred to facilities where they are grown to marketable size.

Aquaculture operations range from systems where there is only minimal control over the organism's environment to intensive operations where there is complete control at each stage of the organism's life history. For example, an intensive system would include freshwater species such as catfish that are often raised in shallow earthen ponds; production relies on control of inputs. Water, feed, and disease treatment are controlled to maximize growth while minimizing costs. Farming of finfish, such as salmon, also requires stocking at high densities and relies on extensive feeding. Commercial salmon aquaculture facilities often employ net pens (**Figure 3**), which are moored to the bottom and located in protected inshore marine areas, such as bays and fjords.[17]

[15] This definition of aquaculture is from the Aquaculture Act of 1980 (16 U.S.C. §1802(1)).

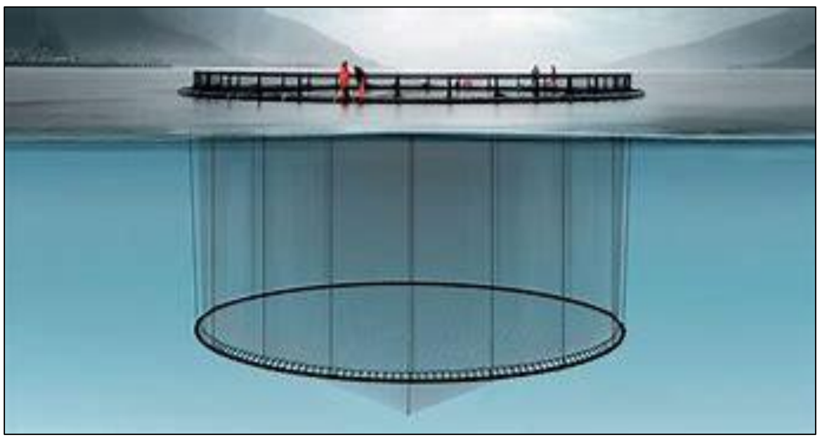
[16] Most production is from freshwater and coastal areas, whereas offshore and closed systems account for only a small portion of global and domestic production.

[17] Most commercial salmon aquaculture facilities use net pens, floating enclosures that are anchored to the ocean bottom. The enclosures are separated from the environment by netting which allows for the free exchange of water and fish wastes between the enclosure and the environment. Salmon aquaculture also can be conducted in land-based tanks

Bivalves such as oysters and clams are grown in estuaries and inshore areas, feeding on a diet of plankton and detritus that they filter from seawater. Bivalve aquaculture may employ varying degrees of control. In some cases, they are suspended on lines, in wire cages, and on rafts. Oyster larvae are grown in hatcheries and transferred to these structures as oyster spat or seed and grown to market size. Some oyster production is less intensive and depends on enhancement of the benthic (ocean bottom) environment by placing oyster shells on the bottom to facilitate attachment of wild oyster larvae.[18]

In Alaska, hatcheries are used to enhance the production of salmon fry, which are released to the wild to feed and grow until they are caught by fishermen as adults. These programs are run as nonprofit cooperatives overseen by Alaska fishermen.[19] Most states and the U.S. Fish and Wildlife Service run public stocking programs, which often address a variety of objectives such as enhancing recreational fisheries and restoring depleted populations. Each strategy requires different inputs and interacts with the environment to differing degrees. Nevertheless, a common factor is to control some aspect(s) of the organism's life to enhance survival and growth.

Figure 3. Example of a Salmon Net Pen



Source: AKVA Group, https://www.akvagroup.com/news/image-gallery.

Over the last decade, catfish aquaculture has accounted for most food fish production by volume and revenue in the United States (**Table 1**). However, catfish production has declined by nearly 44% over this period due to a variety of factors, including competition from Asian imports. For freshwater species, only crawfish production (78.0%) and revenue (66.2%) increased significantly. During the same period, production of salmon and oysters increased in both volume and revenue. Cultured oysters exhibited the largest increases in production (66.0%) and revenue (86.5%), which is likely related to greater demand for high quality raw oysters.[20] However, except for cultured oysters, production of most domestic marine seafood products is from wild marine fisheries.[21]

and raceways.

[18] In other cases, small oysters (spat) may already be attached to the shell when it is placed on the bottom of the estuary.

[19] Alaska Department of Fish and Game, Hatcheries at https://www.adfg.alaska.gov/index.cfm?adfg=fishingHatcheries.main.

[20] Cultured oysters provide a consistent and aesthetically pleasing product for the raw oyster market.

[21] NMFS, *Fisheries of the United States*.

Table 1. U.S. Aquaculture Production and Revenue

(2006 and 2016)

Species	Production (thousands of pounds)		Production (metric tons)		Revenue ($ in thousands)	
	2006[a]	2016	2006	2016	2006[b]	2016
Freshwater						
Catfish	568,900	320,174	258,049	145,230	$519,015	$363,075
Crawfish	83,714	149,015	37,972	67,593	118,356	196,695
Trout	49,659	48,451	22,525	21,977	67,824	79,558
Tilapia	20,000	18,999	9,072	8,618	40,441	42,745
Striped Bass	11,925	10,322	5,409	4,682	35,360	37,737
Total Freshwater	***734,198***	***546,961***	***333,027***	***248,100***	***$780,996***	***$719,810***
Marine						
Salmon	23,115	35,682	10,485	16,185	$50,070	$67,654
Oysters	22,046	36,601	10,000	16,602	103,103	192,328
Clams	11,307	9.722	5,129	4,410	88,635	137,793
Shrimp	7.800	3,600	3,538	1,633	19,226	10,075
Mussels	1,008	859	457	325	8,382	10,201
Total Marine	***65,276***	***86,499***	***29,609***	***43,790***	***$269,416***	***$393,998***
Miscellaneous/ Other[c]	—	—	—	—	404,265	315,944
Totals	***799,474***	***633,460***	***362,636***	***287,336***	***$1,454,677***	***$1,454,080***

Sources: NMFS, Office of Science and Technology, *Fisheries of the United States, 2017*, Current Fishery Statistics No. 2017, September 2018, and NMFS, Office of Science and Technology, *Fisheries of the United States, 2012*, Current Fishery Statistics No. 2012, September 2013.

a. Clams, oysters, and mussels are reported as meat weight, whereas all other species are reported as whole live weight.

b. Aquaculture revenue in 2006 is provided in real 2016 dollars as calculated using U.S. Bureau of Economic Analysis, Interactive Data Application, Table 1.1.9 Implicit Price Deflators for GDP, at https://www.bea.gov/itable/.

c. The miscellaneous category was only reported by value and includes baitfish, ornamental/tropical fish, alligators, algae, aquatic plants, and others.

Offshore Aquaculture

As stated above, offshore aquaculture is the rearing of marine organisms in ocean waters beyond significant coastal influence, primarily in the federal waters of the EEZ. Aquaculturalists, the Department of Commerce, several task force and commission reports, and some academics have identified offshore aquaculture as a potential alternative to some land-based and nearshore aquaculture. Supporters of aquaculture have asserted that development of the industry, especially in offshore areas, has significant potential to increase U.S. seafood production and provide economic opportunities for coastal communities. The potential of offshore aquaculture in the United States is likely to differ by species, region, and technology.[22]

Despite plans for several offshore operations, no commercial offshore aquaculture facilities are currently operating in the U.S. EEZ. Some marine aquaculture facilities are located in nearshore state waters, however. In the future, inshore marine production is likely to be constrained by the availability of suitable sites, poor water quality, high coastal land values, and competition with other ocean uses.[23] Potential aquaculture development in offshore areas has received increasing attention because of these limitations.

The cost of working offshore may be greater than the costs of working in inshore and land-based areas, in part because offshore aquaculture in the EEZ would be subject to relatively high-energy offshore environments caused by high and variable winds and storms.[24] However, research and technical advances have demonstrated that operating in these environments is feasible. Expansion of offshore aquaculture into clean, well-flushed waters appears to have nearly unlimited potential, although major technological and operational challenges remain.[25] For example, further development will require structures and materials that will contain stocks under harsh oceanic conditions and keep costs low enough to remain profitable.[26]

It is likely that offshore aquaculture, at least initially, would employ species with established markets and production systems that are similar to those used in inshore areas.[27] Examples of marine species that are candidates for offshore areas may include Atlantic salmon (*Salmo salar*), white sea bass (*Atractoscion nobilis*), cobia (*Rachycentron canadum*), and blue mussel (*Mytilus edulis*).[28] Currently, salmon net pen facilities operate in protected inshore waters of Maine and Washington. Several other net pen aquaculture facilities have operated in exposed state waters of Hawaii and Puerto Rico that have characteristics similar to those of offshore areas.[29] Over the last two decades, permits have been issued to conduct research and limited commercial aquaculture in the EEZ.[30] Recently, three mussel farms received permits from the U.S. Army Corps of Engineers

[22] Gunnar Knapp, "Economic Potential for U.S. Offshore Aquaculture: An Analytical Approach," in *Offshore Aquaculture in the United States: Economic Considerations, Implications, and Opportunities,* NOAA, NOAA Technical Memorandum NMFS F/SPO-103, July 2008, pp. 15-50. Hereinafter cited as Knapp, "Economic Potential."

[23] B. Cicin-Sain et al., *An Operational Framework for Offshore Marine Aquaculture in Federal Waters,* Center for Marine Policy, University of Delaware, 2005.

[24] This report uses the terms *open ocean* and *offshore* interchangeably to refer to aquaculture in federal waters in the exclusive economic zone (EEZ). *Federal waters* and *EEZ* are also used interchangeably to refer to water ranging from 3 nautical miles (nm) to 200 nm from shore.

[25] Peter Edwards, "Aquaculture Environment Interactions: Past, Present and Likely Future Trends," *Aquaculture,* vol. 447 (2015), pp. 2-14. Hereinafter cited as Edwards, "Aquaculture Environment Interactions."

[26] John Forster, *Emerging Technologies in Marine Aquaculture,* ed. NOAA Aquaculture Program (Silver Spring, MD: National Marine Fisheries Service, 2008), pp. 51-71. Hereinafter cited as Forster, *Emerging Technologies*.

[27] James McDaid Kapetsky, Jose Aguilar-Manjarrez, and Jeff Jenness, *A Global Assessment of Offshore Mariculture Potential from a Spatial Perspective,* FAO, FAO Fisheries and Aquaculture Technical Paper 549, 2013.

[28] There are many potential candidates, and this list includes only selected species commonly considered in the press or aquaculture trade literature.

[29] It appears that only one of these facilities is currently operating in the United States. See State of Hawaii, Animal Industry Division, "Open Ocean Fish Farming," at http://hdoa.hawaii.gov/ai/aquaculture-and-livestock-support-services-branch/open-ocean-fish-farming/.

[30] No commercial production statistics are available for these cases, and production has not been significant. Examples include blue mussel and scallop culture off New England. In the Southeast, permits have been issued for live rock aquaculture that provides material for use in aquaria.

(USACE) to operate in offshore waters. Several other ventures have been proposed;[31] including proposals to operate commercial facilities in several regions.

Researchers are developing systems to adapt facilities used in inshore areas to the unique needs of offshore aquaculture. Offshore systems (e.g., submersible cages, net pens, longline arrays) may be free-floating, secured to a structure, moored to the ocean bottom, or towed by a vessel. Systems have been developed to overcome problems associated with harsh open ocean conditions, including submersible cage designs that do not deform under strong currents and waves, and single-point moorings. Cage-mounted autonomous feeding systems have been developed that can operate both at the surface and submerged. Other components under development include mechanized and remote systems that can be controlled from land-based facilities; for example, universities and private-sector research interests are developing automated buoys that can monitor the condition of stock and feed fish on a regular basis for weeks at a time.[32]

Federal Government Involvement in Aquaculture

Federal aquaculture, regulation, research, and support are conducted by a number of federal agencies. Their roles vary widely depending on the agency's statutory responsibilities, which may be related directly or indirectly to aquaculture. Congress enacted the National Aquaculture Act of 1980 to encourage development of the aquaculture industry and coordinate federal activities.[33] The act established the Subcommittee on Aquaculture (SCA) to provide opportunities to exchange information and enhance cooperation among federal agencies.[34] SCA's main functions include the following:

- reviewing national needs for aquaculture research, technology transfer, and technology assistance programs;
- supporting coordination and communication among federal agencies engaged in the science, engineering, and technology of aquaculture;
- collecting and disseminating information on aquaculture;
- encouraging joint programs among federal agencies in areas of mutual interest relating to aquaculture; and
- recommending specific actions on issues, problems, plans, and programs in aquaculture.[35]

SCA operates under the Committee on Environment of the National Science and Technology Council in the Executive Office of the President. SCA is chaired by the Secretary of Agriculture, in consultation with the Secretaries of Commerce and the Interior. In addition to the three main

[31] NMFS, "NOAA Expands Opportunities for U.S. Aquaculture," press release, January 11, 2016, https://www.fisheries.noaa.gov/media-release/noaa-expands-opportunities-us-aquaculture. Proposals have included mussel and seaweed aquaculture off California and striped bass net pen culture off Long Island, NY. According to the National Oceanic and Atmospheric Administration's (NOAA's) aquaculture website, as of January 2016 there were no commercial aquaculture facilities operating in the EEZ.

[32] Forster, *Emerging Technologies*.

[33] 16 U.S.C. §§2801 et seq.

[34] The Subcommittee on Aquaculture was known previously as the Interagency Working Group on Aquaculture and initially as the Joint Subcommittee on Aquaculture.

[35] National Institute of Food and Agriculture, USDA, "Notice of Public Meeting for the IWGA of the Committee on Science of the National Science and Technology Council," 82 *Federal Register* 4026-4027, January 29, 2018.

departments, SCA includes nine additional departments and agencies with an interest in aquaculture.[36] SCA meets quarterly and has provided information on topics such as fish disease, aquaculture regulation, and other areas of interest.

Most federal aquaculture activities and programs that are specific to aquaculture are carried out by the Department of the Interior (DOI), Department of Commerce (DOC), and the Department of Agriculture (USDA). Other federal agencies have roles that are indirectly related to aquaculture, such as regulatory programs that apply to a variety of aquatic or marine activities, including aquaculture. Examples include USACE for activities in navigable waters, the Environmental Protection Agency (EPA) for protection of environmental quality, and the Food and Drug Administration for regulation of drugs used to treat fish diseases.

U.S. Department of Agriculture

USDA plays a lead role in support of freshwater aquaculture for species such as catfish that are raised on private property in fishponds. USDA is authorized to conduct cooperative research and extension: it funds five aquaculture regional research centers. Work at aquaculture centers complements other USDA research and education programs undertaken at state land-grant universities. The USDA National Agricultural Statistics Service periodically conducts the national aquaculture census and collects and publishes other related statistical information. The Animal and Plant Inspection Service provides animal health certifications for exports of live species and products; assistance for producers experiencing losses from predators; and veterinary biologics for preventing and treating animal diseases, including those affecting aquatic species. The Farm Service Agency administers farm lending programs, including ownership, operating, and emergency disaster loans. Under certain circumstances, aquaculture operations may be eligible for disaster assistance under the Noninsured Crop Disaster Assistance Program and the Emergency Assistance for Livestock, Honeybees, and Farm-Raised Fish Program.[37] It appears that some of USDA's programs and experiences that focus on land-based agriculture, such as finance, research, disaster assistance, marketing, and extension, may be adapted and applied to marine aquaculture development.

Department of the Interior

DOI's U.S. Fish and Wildlife Service (FWS) focuses on support of public efforts, such as stocking programs, that benefit recreational fishing of freshwater and anadromous species. FWS operates the National Fish Hatchery System, which consists of more than 60 facilities used to enhance fish stocks, restore fish populations, and mitigate fish losses. The system includes fish production and distribution facilities, fish health centers, fish passage facilities, and technology centers. FWS research programs indirectly benefit the private sector through research and applications that control fish disease and regulation of potentially invasive species. FWS and NMFS are responsible for regulating potential interactions between aquaculture activities and endangered species and marine mammals under the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA).[38]

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[36] Department of Energy, Department of Health and Human Services, Environmental Protection Agency, Agency for International Development, Small Business Administration, National Science Foundation, Farm Credit Administration, Tennessee Valley Authority, and U.S. Army Corps of Engineers.

[37] For further discussion, see CRS Report RS21212, *Agricultural Disaster Assistance*, by Megan Stubbs.

[38] 16 U.S.C. §§1531 et seq. (ESA) and 16 U.S.C. §§1361 et seq. (MMPA).

Department of Commerce

The NMFS Office of Aquaculture in DOC focuses on regulatory, technical, and scientific services related to marine aquaculture. NOAA headquarters provides general direction for the program and coordinates with other NOAA offices, federal agencies, and the general public. The program includes five regional aquaculture coordinators, who coordinate regulatory and permitting activities, serve as liaisons with the state and local government and stockholders, and assist with grant management. Aquaculture in federal waters is regulated as a regional fishery under the Magnuson Stevens Fishery Conservation and Management Act (MSA).[39] NOAA's efforts to regulate offshore aquaculture are discussed in the following section concerning federal agency regulatory responsibilities (see Current Regulatory Framework).

In October 2015, NOAA released its five-year strategic plan (2016-2020) for marine aquaculture.[40] NOAA's vision is a "robust U.S. marine aquaculture sector that creates jobs, provides sustainable seafood, and supports a healthy ocean." The plan provides a blueprint of NOAA's involvement in marine aquaculture, including program impact, goals and strategies, deliverables, and crosscutting strategies. To increase aquaculture production, the program's four main goals are to

- develop coordinated, consistent, and efficient regulatory processes for the marine aquaculture sector;
- encourage environmentally responsible marine aquaculture using the best available science;
- develop technologies and provide extension services for the aquaculture sector; and
- improve public understanding of marine aquaculture.

The plan also includes four crosscutting strategies to achieve these goals and objectives:

- strengthen government, academic, industry, and other partnerships;
- improve communications within NOAA;
- build agency infrastructure within NOAA; and
- develop sound and consistent management within NOAA.

Various NOAA programs may support aquaculture both directly and indirectly. The National Sea Grant Marine Aquaculture Grant Program is the only U.S. government grant program that funds marine aquaculture exclusively.[41] These grants focus on industry challenges, such as improving aquaculture feeds, enhancing seafood safety and quality, refining culture methods, and diversifying aquaculture species.[42] Other NOAA offices or programs that may contribute to or become involved in aquaculture development include inspections provided by the NOAA

[39] 16 U.S.C. §§1801 et seq.

[40] Office of Aquaculture, *Marine Aquaculture Strategic Plan FY2016-2020*, NMFS, February 2015, https://www.fisheries.noaa.gov/aquaculture-library.

[41] The general mission of the Sea Grant College Program is to enhance the practical use and conservation of coastal, marine, and Great Lakes resources to provide for a sustainable economy and environment.

[42] NOAA Sea Grant, "Sea Grant in Aquaculture," at https://seagrant.noaa.gov/Our-Work/Aquaculture.

Seafood Inspection Program, research conducted at NOAA regional fisheries science centers, and awards funded by the Saltonstall-Kennedy Grant Program.[43]

Offshore Aquaculture Challenges

A broad array of challenges is associated with offshore aquaculture development and expansion. These challenges pertain to evolving production technology, uncertain economic costs and benefits, and potential environmental and social impacts. Generalizations about how to address these challenges are difficult to make because of the variety of candidate species, different technologies, and potential scales of operation.

Major categories of concerns related to offshore aquaculture development include (1) the legal and regulatory environment; (2) potential environmental harm; (3) economic, trade, and stakeholder concerns related to development of a new industry; and (4) business and institutional support.[44]

Current Regulatory Framework[45]

One of the main issues associated with marine offshore aquaculture is the concept of ownership and individuals' rights to use the marine environment for economic gain (in contrast to, for example, the catfish industry, where fishponds are constructed and operated on private land). Some envision development and management as a partnership, where the government's role is one of both enabler and steward.[46] This partnership could provide for property rights and regulatory clarity, certainty, and stability. For example, the government already provides specific rights to businesses that extract or use resources of the continental shelf, such as oil and gas and wind energy development.

Aquaculture regulation depends primarily on the geographic location and characteristics of aquaculture facilities. In state waters, in accordance with the federal Submerged Lands Act of 1953, coastal states exercise jurisdiction over an area extending 3 nautical miles (nm) from their officially recognized coast (or *baseline*).[47] States also have jurisdiction over internal waters, areas inside the baseline in bays and estuaries, such as the Chesapeake Bay or Puget Sound. States may impose restrictions or requirements as they see fit, subject to any applicable federal laws. If located in federal waters, in waters from 3 nm to 200 nm from the baseline, aquaculture facilities are regulated primarily by federal agencies under a number of federal statutes and regulatory requirements (**Figure 4**). Some federal laws apply to marine aquaculture and waters of the United States generally and include facilities located in both state and federal marine waters.

[43] NMFS, "Saltonstall-Kennedy Grant Program," at https://www.fisheries.noaa.gov/grant/saltonstall-kennedy-grant-program.

[44] Detailed discussions of many of the issues discussed in this section are available in *Development of a Policy Framework for Offshore Marine Aquaculture in the 3-200 Mile U.S. Ocean Zone* (2001) by the University of Delaware's Center for the Study of Marine Policy, at http://darc.cms.udel.edu/sgeez/sgeez1final.pdf; and *Recommendations for an Operational Framework for Offshore Aquaculture in U.S. Federal Waters* (October 2005) by the University of Delaware's Gerard J. Mangone Center for Marine Policy, at http://darc.cms.udel.edu/sgeez/sgeez2final.pdf.

[45] Adam Vann of the CRS American Law Division contributed to this section.

[46] John Forster, "Broader Issues in the Offshore Fish Farming Debate," in *Offshore Aquaculture in the United States: Economic Considerations, Implications, and Opportunities*, NOAA, NOAA Technical Memorandum NMFS F/SPO-103, July 2008, pp. 245-263. Hereinafter cited as Forster, "Broader Issues."

[47] 43 U.S.C. §1301(b).

Marine Jurisdictional Zones

Federal management of marine fisheries generally extends from 3 nautical miles (nm) to 200 nm from shore (*baseline*). State waters are measured from the baseline to 3 nm offshore. Exceptions include the west coast of Florida, Texas, and the Commonwealth of Puerto Rico, where state and commonwealth waters extend out to 9 nm. Under international law, internal waters include those areas landward of the baseline, territorial waters include those waters from 0 nm to 12 nm seaward of the baseline, and the exclusive economic zone (EEZ) includes waters from 12 nm to 200 nm from the baseline. In the United States, fisheries in the territorial sea beyond state waters and in the EEZ are managed by the federal government under the MSA.

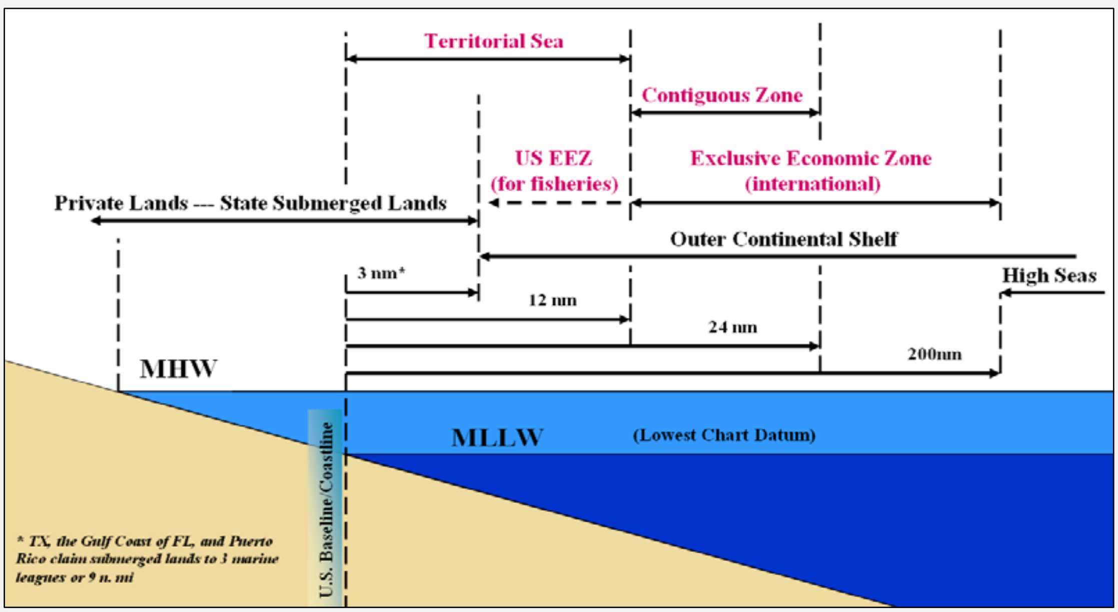
Internal Waters – waters landward of the baseline from which the territorial sea is measured. States manage internal waters.

Baseline – generally measured as the low-water line along the coast; also accounts for features such as bays, river mouths, and fringing reefs.

Territorial Sea – the coastal state (nation) may claim sovereignty over the territorial sea, the airspace above it, and the seabed and subsoil below it from 0 nm to 12 nm seaward of the baseline. In 1988, the United States claimed a territorial sea (Presidential Proclamation 5928), which includes both state waters (generally 0 nm to 3 nm and federal waters (generally from 3 nm to 12 nm).

Exclusive Economic Zone – the coastal state (nation) may claim sovereign rights for the purpose of exploring, exploiting, conserving, and managing natural resources, either living or nonliving, in the EEZ.

Figure 4. U.S. Maritime Zones



Source: Meredith A. Westington and Matthew J. Slagel, *U.S. Maritime Zones and the Determination of the National Baseline*, NOAA, Office of the Coastal Survey, at http://ushydro.thsoa.org/hy07/11_01.pdf.

Notes: EEZ = exclusive economic zone; MHW = mean high water; MLLW = mean lower low water. The tidal datum is a standard elevation defined by a certain phase of the tide.

Currently, no single federal agency is authorized to approve or permit offshore aquaculture facilities in federal waters, generally the EEZ. USACE, NMFS (NOAA Fisheries), and EPA are separately authorized to regulate certain activities that are required to establish and operate aquaculture facilities.[48] Federal agencies that issue permits are required to consult with other regulatory agencies concerning the potential effects of each application. The permitting process

[48] Stephanie S. Otts and Terra Bowling, *Offshore Mussel Culture Operations: Current Legal Framework and Regulatory Authority*, National Sea Grant Law Center, April 2012.

also involves consultation and other requirements that are incorporated into the review of these applications. The following sections summarize the required federal permits, consultation, and review requirements.

Federal Permits to Conduct Aquaculture in the Federal Waters

Section 10 Permits

Section 10 of the Rivers and Harbors Act of 1899 (hereinafter referred to as Section 10) prohibits the unauthorized obstruction or alteration of any navigable water of the United States.[49] Authorization by the Secretary of the Army, through USACE, must be provided before construction is initiated. Construction may include any structure or work in or affecting the course, condition, or capacity of navigable waters, excavation or fill, including aquaculture facilities, in or over any navigable waters of the United States within 3 nm from shore. Because aquaculture facilities may be located in and may affect navigable waters, the developer of the facility may be required to obtain authorization from USACE under Section 10. USACE's role is to regulate the use of the navigable water (not to regulate aquaculture per se).

The Outer Continental Shelf Lands Act extends USACE authority over all artificial islands and all installations and other devices permanently or temporarily attached to the seabed, which may be erected for the purpose of exploring for, developing, or producing resources.[50] Therefore, a Section 10 permit is also required prior to construction or placement of installations—such as aquaculture facilities—in federal waters from the seaward limit of state waters to the seaward limit of the outer continental shelf.[51] The decision to issue a permit is based on the effects on navigation and the proposed activity's probable impacts on the public interest. The public interest is assessed by comparing the benefits that may be expected to accrue from the proposed activity and the reasonably foreseeable harm that reflects the national concern for the protection and use of important resources.[52] Offshore aquaculture permits would be required for structures such as cages, net pens, or lines that are anchored or attached to the sea floor.

Section 10 permit requirements for aquaculture development beyond 3 nm may differ from those within 3 nm, because installations or other devices that are not temporarily or permanently attached to the seabed do not appear to be included. Examples of facilities beyond 3 nm that may not require Section 10 permits include bottom shellfish culture or unmoored floating aquaculture facilities if they do not impede navigation.

National Pollutant Discharge Elimination System Permit

EPA protects water quality by regulating the discharges of pollutants into U.S. waters under the Clean Water Act (CWA).[53] Under the CWA, a National Pollutant Discharge Elimination System (NPDES) permit is required to discharge pollutants from point sources into federal ocean waters.[54] A *point source* is defined as "any discernable, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure,

[49] 33 U.S.C. §403.

[50] 43 U.S.C. §1333(a)(1).

[51] 33 C.F.R. §320.2(b).

[52] 33 C.F.R. §320.4(a)(1). The processing of the permits is addressed in 33 C.F.R. §325.

[53] 33 U.S.C. §§1251 et seq.

[54] 33 U.S.C. §1342.

container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged."[55]

Aquaculture facilities may discharge materials such as fecal matter; excess feed; antifoulants; and therapeutic agents, such as antibiotics. EPA currently regulates aquaculture facilities as a point source if the activity qualifies as a Concentrated Aquatic Animal Production (CAAP) facility;[56] CAAPs are defined according to discharge frequency and production level or as designated by EPA on a case-by-case basis if they are significant contributors of pollution.[57] Commercial scale aquaculture operations in federal waters would be likely to trigger the CAAPs threshold and require a NPDES permit.[58]

Fishing (Aquaculture) Permit

NMFS is the only federal agency that claims explicit management authority over offshore aquaculture. Currently, NMFS manages federal fisheries under authority of the MSA. The MSA regulates fishing in the EEZ through development and implementation of federal fishery management plans (FMPs). The MSA "does not expressly address whether aquaculture falls within the purview of the act."[59] The MSA defines a *fishery* as "one or more stocks of fish ... and any fishing for such stocks" and *fishing* as the "catching, taking, or harvesting of fish."[60]

> The Magnuson-Stevens Act does not expressly address whether aquaculture falls within the purview of the Act. However, the Magnuson-Stevens Act's assertion of exclusive fishery management authority over all fish within the EEZ, its direction to fishery management councils to prepare fishery management plans for any "fishery" needing conservation and management, together with the statutory definitions of "fishery" and "fishing," provide a sound basis for interpreting the Act as providing authority to regulate aquaculture in the EEZ. [61]

Under the MSA's authority, several regional fishery management councils and NMFS have exercised regulatory oversight over offshore aquaculture.[62] In some cases, NMFS authorized offshore aquaculture in federal waters for research and experimental purposes under an exempted fishing permit.[63] These permits are of limited duration and not intended to apply to development of permanent commercial operations.

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[55] 33 U.S.C. §1362(14).

[56] 40 C.F.R. §122.24(a).

[57] 40 C.F.R. §122.24(a), 40 C.F.R. 122 Appendix C. Concentrated Aquatic Animal Production facilities include cold-water facilities that discharge at least 30 days per year, produce more than 20,000 pounds of fish per year, and use 5,000 pounds or more of feed per month and warm-water facilities that discharge at least 30 days per year and produce at least 100,000 pounds of fish per year.

[58] Section 404 of the Clean Water Act regulates discharges of dredged or fill material into the waters of the United States, which does not include federal waters beyond 3 nm. This permit is often required for shellfish aquaculture in state waters.

[59] Memorandum from Constance Sathre, Office of the General Counsel, to Lois Schiffer, NOAA General Counsel, June 9, 2011. Hereinafter cited as Sathre, 2011.

[60] Sathre, 2011.

[61] Sathre, 2011.

[62] Regional fishery management councils were established by Congress under the Fishery Conservation and Management Act (P.L. 94-265).

[63] 50 C.F.R. §600.745(b).

The Gulf of Mexico Fishery Management Council (GMFMC) has been particularly active on aquaculture issues.[64] In 2009, an aquaculture FMP was approved by the GMFMC; NMFS issued its final rule to implement that FMP in 2016.[65] The aquaculture plan establishes a regional permitting process for regulating aquaculture in the Gulf of Mexico EEZ. The regulations authorize permits for up to 20 facilities that are limited to combined total production of 64 million pounds annually of species that are native to the Gulf of Mexico. Applicants are required to acquire other federal permits before NMFS can issue a Gulf aquaculture permit. NMFS also has developed a memorandum of understanding to coordinate federal agency actions and outline the permitting responsibilities of each agency in the Gulf.[66]

However, a recent legal decision has cast doubt on NMFS's authority to regulate aquaculture under the MSA. In *Gulf Fisherman's Association v. National Marine Fisheries Service*,[67] the U.S. District Court for the Eastern District of Louisiana held that NMFS exceeded its authority under the MSA when it adopted a regulatory scheme for aquaculture operations in the Gulf of Mexico. The court found that the MSA's grant of authority to regulate "fishing" and "harvesting" did not include aquaculture, noting that "[h]ad Congress intended to give [NMFS] the authority to create an entirely new regulatory permitting scheme for aquaculture operations, it would have said more than 'harvesting.' The MSA is a conservation statute, aimed at the conservation and management of natural resources. Fish farmed in aquaculture are neither 'found' off the coasts of the United States nor are they 'natural resources.'"[68]

Some are concerned that regional management of offshore aquaculture under the MSA may add another additional administrative requirements, especially if several regional fishery management councils develop their own, possibly contradictory, open ocean aquaculture management policies.[69] Currently, commercial aquaculture is less likely to occur in federal waters under the jurisdiction of other regional fishery management councils because they have not prepared aquaculture FMPs or generic aquaculture amendments to the appropriate FMPs for species that could be cultured. In addition, it is unclear what regulatory authority NMFS and the regional councils might have over species, such as mussels, that are not managed under a federal FMP.

Federal Consultation and Review Requirements

Consultation and review requirements are often triggered by federal permitting programs. Some crosscutting environmental requirements are entirely procedural, because they require that the federal agency implement certain procedures to ensure the agency identifies and analyzes potential impacts the proposal would have on certain resources before deciding whether to issue

[64] Eight Regional Fishery Management Councils were established under the Magnuson Stevens Fishery Conservation and Management Act (16 U.S.C. §§1801 et seq.) to develop fishery management plans for fisheries in each of the eight regions.

[65] NMFS, "Fisheries of the Caribbean, Gulf, and South Atlantic; Aquaculture," 81 *Federal Register* 1762-1800, January 13, 2016.

[66] NOAA, *Memorandum of Understanding for Permitting Offshore Aquaculture Activities in Federal Waters of the Gulf of Mexico*, 2016, at http://sero.nmfs.noaa.gov/sustainable_fisheries/gulf_fisheries/aquaculture/documents/pdfs/final_offshore_aquaculture_mou_020617.pdf.

[67] No. 16-1271, 2018 U.S. Dist. LEXIS 163685 (E.D. La. Sept. 25, 2018).

[68] No. 16-1271, 2018 U.S. Dist. LEXIS 163685 (E.D. La. Sept. 25, 2018).

[69] Gulf of Mexico Fishery Management Council, *Fishery Management Plan for Regulating Aquaculture in the Gulf of Mexico* (Tampa, FL: January 2009).

the permit. Other environmental requirements may prohibit the agency from permitting the action, as proposed, unless the level of adverse impacts can be minimized or mitigated.

Coastal Zone Management Act

Under Section 306 of the Coastal Zone Management Act (CZMA),[70] states may develop and implement a coastal management program (CMP) pursuant to federal guidance. State CMPs "describe the uses subject to the management program, the authorities and enforceable policies of the management program, the boundaries of the state's coastal zone, the organization of the management program, and related state coastal management concerns."[71]

Arguably the main feature of the CZMA is federal consistency.[72] Federal agency activities that have reasonably foreseeable effects on a state's coastal zone resources and uses should be consistent with the enforceable policies of the state's coastal management plan.[73] Section 307 of the CZMA requires

> any applicant for a required Federal license or permit to conduct an activity, in or outside of the coastal zone, affecting any land or water use or natural resource of the coastal zone of that state" to "provide in the application to the licensing or permitting agency a certification that the proposed activity complies with the enforceable policies of the state's approved program and that such activity will be conducted in a manner consistent with the program.[74]

Enforceable policies are legally binding state policies, such as constitutional provisions, laws, regulations, land use plans, or judicial or administrative decisions.[75]

Federal licensing and permitting (such as aquaculture permit requirements) is one of four general categories of federal activities that may be reviewed for consistency.[76] The state lists federal licenses and permits that affect coastal uses and resources in its federally approved CMP. For listed activities, the applicant submits related data and information and a consistency certification that the proposed activity will be conducted in a manner consistent with the state's approved management program.[77] For a listed activity outside the coastal zone (such as in federal waters), the state also must describe the geographic location or area in its CMP.[78]

If a license, permit, or geographic location in federal waters is not listed in the state's CMP, the activity is treated as unlisted. To review an unlisted activity, the state notifies the applicant, federal agency, and NOAA Office of Coastal Management (OCM) that it intends to review the activity. OCM decides whether to approve the request, generally based on whether the activity will have reasonably foreseeable effects on the state's coastal zone. If approved, the consistency review proceeds as in the case of a listed activity.

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[70] 16 U.S.C. §1455.

[71] NOAA, *CZMA Federal Consistency Overview*, February 20, 2009 (revised January 4, 2016), p. 3.

[72] 16 U.S.C. §§1451 et seq.

[73] NOAA, *CZMA Federal Consistency Overview*, February 20, 2009 (revised January 4, 2016).

[74] 16 U.S.C. §1456(c)(3)(A).

[75] NOAA, *CZMA Federal Consistency Overview*, February 20, 2009 (revised January 4, 2016).

[76] Other activities that may be subject to review include direct federal agency activities; outer continental shelf exploration, development, and production plans; and federal assistance to state and local governments.

[77] 30 C.F.R. §930.50.

[78] For example, the state may identify the area from the seaward boundary of state waters to 20 miles beyond state waters.

The state may object to the applicant's consistency certification and stop the federal agency from authorizing the activity or issue a conditional concurrence to the applicant. The permit is issued for the activity if (1) the state concurs with the consistency determination; (2) the state fails to act, resulting in a presumption of consistency; or (3) the Secretary of Commerce overrules the state on appeal and concludes that the activity is consistent with CZMA objectives or is otherwise necessary for national security.[79] In the vast majority of federal actions, states concur with the applicant's self-certification, often resolving any disputes collaboratively.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) requires federal agencies to consider the potential environmental consequences of proposed federal actions but does not compel agencies to choose a particular course of action.[80] If an agency anticipates that an action would significantly affect the quality of the human environment, the agency must document its consideration of those impacts in an environmental impact statement (EIS).[81] If the impacts are uncertain, an agency may prepare an environmental assessment (EA) to determine whether a finding of no significant impact could be made or whether an EIS is necessary.[82] NEPA creates procedural requirements but does not mandate specific outcomes.[83]

Endangered Species Act and Marine Mammal Protection Act

NMFS and FWS have responsibilities under the ESA and the MMPA to review project proposals that may affect marine mammals or threatened and endangered species.[84] If issuance of a federal permit may adversely affect a species listed under the ESA, consultation may be required under Section 7 of the ESA.[85] Through consultation with either FWS or NMFS, federal agencies must ensure that their actions are not likely to jeopardize the continued existence of any endangered or threatened species or adversely modify critical habitat. If the appropriate Secretary judges that the proposed activity jeopardizes the listed species or adversely modifies critical habitat, then the Secretary must suggest reasonable and prudent alternatives that would avoid harm to the species.[86] If reasonable and prudent measures are adopted, the federal action is allowed to go forward.

The MMPA prohibits the harassment, hunting, capturing, killing (or *taking*) of marine mammals without a permit from the Secretary of the Interior or the Secretary of Commerce.[87] If marine

[79] 16 U.S.C. §1456 (c)(3)(B).

[80] See 42 U.S.C. §4332.

[81] 40 C.F.R. §1502.

[82] 40 C.F.R. §1508.9.

[83] CRS Report RL33152, *The National Environmental Policy Act (NEPA): Background and Implementation*, by Linda Luther.

[84] Endangered Species Act (ESA; 16 U.S.C. §§1531 et seq.) and Marine Mammal Protection Act (MMPA; 16 U.S.C. §§1361 et seq.).

[85] For further information on the ESA, see CRS Report RL31654, *The Endangered Species Act: A Primer*, by Pervaze A. Sheikh.

[86] The Secretary of Commerce is generally responsible for listing and ESA-related activities for marine species, and the Secretary of the Interior is responsible for all other species.

[87] Under the MMPA, the Secretary of Commerce, acting through NMFS is responsible for the conservation and management of whales, dolphins, and porpoises (cetaceans), as well as seals and sea lions (pinnipeds). The Secretary of the Interior, acting through the Fish and Wildlife Service, is responsible for walruses, sea and marine otters, polar bears, manatees, and dugongs. This division of authority derives from agency responsibilities as they existed when the

mammals are likely to interact with aquaculture facilities and this interaction is likely to result in the taking of marine mammals, a marine mammal exemption would be required.[88] To be eligible for an exemption, the aquaculture facility would need to obtain a Marine Mammal Authorization Program certificate from NMFS.[89]

MSA Essential Fish Habitat

The MSA also requires the federal permitting agency (e.g., USACE) for any aquaculture facility to consult with NMFS if the activity has the potential to harm essential fish habitat (EFH). EFH is designated for all marine species for which there is an FMP and may include habitat in both state and federal waters.[90]

National Marine Sanctuary Act

NOAA manages national marine sanctuaries established under the National Marine Sanctuary Act (NMSA).[91] Federal agencies are required to consult with the Secretary of Commerce when federal actions within or outside a national marine sanctuary, including activities that are authorized by licenses, leases, and permits, are likely to harm sanctuary resources.[92] If the Secretary finds that the activity is likely to injure a sanctuary resource, the Secretary recommends reasonable and prudent measures that the federal agency can take to avoid harm to the sanctuary resource. If the measures are not followed and sanctuary resources are destroyed or injured, the NMSA requires the federal agency that issued the permit to restore or replace the damaged resources.

National Historic Preservation Act

The National Historic Preservation Act (NHPA) is another procedural statute.[93] Under Section 106 of NHPA,[94] federal agencies must determine whether actions they may permit or license will have adverse effects on properties listed or eligible for listing in the National Register of Historic Places. Such sites could include shipwrecks, prehistoric sites, or other cultural resources. Federal agencies must determine whether such resources may be affected in consultation with state and/or tribal historic preservation officers.[95].

MMPA was enacted.

[88] A Marine Mammal Authorization Program certificate is issued when marine mammals may be taken incidentally in marine fisheries. If aquaculture is not defined as fishing, an incidental take authorization may be required, as in the case of non-fishing activities that take marine mammals such as construction projects and oil and gas development. See NMFS, "Incidental Take Authorizations Under the Marine Mammal Protection Act," at https://www.fisheries.noaa.gov/node/23111.

[89] NMFS, *A Guide to the Application Process for Offshore Aquaculture in U.S. Federal Waters of the Gulf of Mexico*, Southeast Regional Office, August 2017, at http://sero.nmfs.noaa.gov/sustainable_fisheries/gulf_fisheries/aquaculture/documents/pdfs/permit_applicant_guide_updated_aug2017.pdf.

[90] 16 U.S.C. §1855(b).

[91] 16 U.S.C. §§1431 et seq.

[92] 16 U.S.C. §1434(d).

[93] 16 U.S.C. 470 et seq.

[94] 54 U.S.C. §306108.

[95] CRS Report R45800, *The Federal Role in Historic Preservation: An Overview*, by Mark K. DeSantis.

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act requires federal agencies to consult with FWS, NMFS, and state wildlife agencies when activities that are authorized, permitted, or funded by the federal government affect, control, or modify waters of any stream or bodies of water.[96] Consultation generally is incorporated into the process of complying with other federal permit requirements, such as the NEPA and CWA.

Other Authorizations and Approvals

The Coast Guard has authority to control private aids to navigation in U.S. waters.[97] Regulations require structures such as aquaculture facilities be marked with lights and signals for protection of maritime navigation.[98] To establish a private aid to navigation, the applicant would need formal authorization from the appropriate U.S. Coast Guard district.

The Bureau of Safety and Environmental Enforcement (BSEE) has regulatory responsibility for the offshore energy industry on the outer continental shelf.[99] BSEE would review aquaculture applications and provide comments regarding potential conflicts, interactions, or effects on mineral exploration, development, and production operations. The Bureau of Ocean Energy Management (BOEM) manages development of the outer continental shelf energy and mineral resources. BOEM would require a right-of-use easement for any offshore aquaculture operations that uses or tethers to an existing oil and gas facility.[100]

Environmental Concerns

One of the main features of many previous aquaculture bills has been consideration of environmental protection and monitoring of offshore aquaculture facilities. Critics of offshore aquaculture have expressed concern with potential environmental degradation and conflicts with existing uses of marine areas. They cite historic problems in inshore areas—such as escapes of cultured organisms, the introduction of disease and invasive species, pollution in areas adjacent to net pens, and habitat loss—which have created a negative perception of aquaculture.[101]

Aquaculture supporters assert that those who oppose marine aquaculture lack an understanding of aquaculture's benefits and risks and that "these perceptions persist despite significant scientific literature that contradicts the extent or existence of risk to the values that these groups want to protect."[102] Supporters contend that, in many parts of the world, a combination of farming experiences, technological advances, proper siting, and industry regulation has decreased environmental impacts and improved efficiency of marine aquaculture. Some researchers suggest that by moving operations offshore and selecting appropriate sites, the remaining impacts can be

[96] 16 U.S.C. §661.

[97] 14 U.S.C. §83.

[98] 33 C.F.R. §§66.01 and 64.21.

[99] 43 U.S.C. §§1331 et seq.

[100] 30 C.F.R. §585.

[101] Carol S. Price and Jessica Beck-Stimpert, *Best Management Practices for Marine Cage Culture Operations in the U.S. Caribbean*, NOAA, GCFI Special Publication Series Number 4, 2014.

[102] Gunnar Knapp and Michael C. Rubino, "The Political Economics of Marine Aquaculture in the United States," *Reviews in Fisheries Science & Aquaculture*, vol. 24, no. 3 (2016), pp. 213-229. Hereinafter cited as Knapp and Rubino, "Political Economics of Marine Aquaculture."

further reduced.[103] Others add that offshore waters would be less prone to environmental impacts than inshore waters because fish wastes and other pollutants would dissipate more rapidly in the deeper and better-flushed offshore areas.

A present lack of knowledge—owing to limited experience and few studies focusing specifically on offshore aquaculture—limits understanding of potential harm to the environment from offshore aquaculture. Most information has been collected from inshore areas, where salmon net pens and other types of aquaculture farms have been established. Some characteristics of inshore operations are similar to those that would be established offshore (e.g., both are open to the surrounding environment); however, other characteristics of offshore operations, such as offshore currents, wind and waves, water quality, and depth, are likely to differ from inshore areas. Generally, the outcomes associated with offshore aquaculture development depend on characteristics of aquaculture sites and how technology is employed and managed.

Over the years, researchers have identified several issues related to marine aquaculture and the use of net pens in inshore areas. These issues include water pollution from uneaten feed and waste products (including drugs, chemicals, and other inputs); habitat degradation, such as alteration of benthic habitat from settling wastes; sustainability of fish used in aquaculture feeds; use of antibiotics and other animal drugs; introduction of invasive species; escape of cultured organisms; and the spread of waterborne disease from cultured to wild fish. During the last two decades, technical advances and farming practices have reduced these impacts in nearshore areas.[104] Existing laws and regulations also have established performance standards and addressed many of the potential adverse environmental effects of net pen aquaculture.[105]

Fish Waste

Fish feed is the main source of waste from aquaculture and contributes to most environmental impacts associated with aquaculture.[106] The discharge of wastes, such as unused feed, and metabolic fish wastes, such as nitrogen (ammonia and urea), has been an ongoing concern because of potential effects on water quality and degradation of the seafloor environment under net pens. Treatment of effluent is not feasible because wastes are discharged directly into the ocean through net enclosures. Impacts on the environment depend on a variety of factors, such as feed quality, digestion and metabolism, feeding rate, biomass of fish, and species. Site characteristics such as cage design, depth, currents, existing water quality or nutrient levels, and benthic features also influence nutrient dispersion and impacts.

Impacts on water quality in the water column adjacent to net pens are often related to a combination of increases in nitrogen, phosphorus, lipids, and turbidity and depletion of oxygen.[107] Eutrophication may occur when net pens are placed at high densities and flushing of semi-

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[103] Rebecca R. Gentry et al., "Mapping the Global Potential for Marine Aquaculture," *Nature Ecology & Evolution,* vol. 1 (September 2017), pp. 1317-1324.

[104] Michael B. Rust et al., "Environmental Performance of Marine Net-Pen Aquaculture in the United States," *Fisheries,* vol. 39, no. 11 (November 2014), pp. 508-524. Hereinafter cited as Rust et al., "Environmental Performance."

[105] Rust et al., "Environmental Performance," p. 519.

[106] Stefanie M. Hixson, "Fish Nutrition and Current Issues in Aquaculture: The Balance in Providing Safe and Nutritious Seafood in an Environmentally Sustainable Manner," *Journal of Aquaculture Research and Development,* 2014, pp. 1-10. Hereinafter cited as Hixson, "Fish Nutrition."

[107] Lipids are a large group of organic compounds composed of fats and fatty compounds that are insoluble in water. They are a source of stored energy and a component of cell membranes.

enclosed water bodies is poor.[108] According to studies, aquaculture's contribution to nitrogen in areas adjacent to net pens ranged broadly from none to significant levels depending on a variety of factors, including environmental characteristics and species.[109] In some cases, it appears that nutrients are flushed away from the immediate cage area to the surrounding water body. Management practices such as choosing sites with adequate current and depth are likely to improve circulation and dissipation of waste products.[110]

Solid feed and fish waste descend through the water column and may accumulate on the bottom below and around aquaculture facilities. In some cases, wastes accumulate at rates greater than the assimilative capacity of the environment, and the increase of respiration from microbial decomposition decreases oxygen levels (hypoxia) and changes sediment chemistry. This may cause hypoxia in sediments and the water overlying the bottom, which may in turn affect the abundance and diversity of marine organisms in the area. Reviews have identified changes to sediment chemistry as one of the primary impacts of marine aquaculture in the United States.[111]

Over the last several decades, harmful environmental impacts have been reduced because of advances in technology, improved facility siting, better feed management, and stricter regulatory requirements.[112] Feed formulations have been modified to improve digestibility without losses in growth. When feed is more fully digested, the amount of waste (nutrient) outputs per unit of fish produced is reduced and fewer solid wastes and nutrients are released to the environment. Modifying feeding practices also has reduced the loss of uneaten food.[113] Some facilities now use underwater devices to monitor feeding to avoid overfeeding and waste. Environmental monitoring also informs farmers and regulators of the need to leave a site fallow or to adjust feeding.

Some researchers and aquaculturalists have proposed the use of multi-tropic aquaculture by adding other organisms such as invertebrates and seaweeds to the aquaculture system. The system would mimic natural tropic relationships, where wastes from cultured organisms are food for other organisms, such as shellfish, and supply nutrients for seaweed.[114] These additions could lessen environmental impacts from nutrients and increase the efficiency of feed utilization.[115]

Proponents suggest that offshore aquaculture may produce fewer and less severe environmental impacts than those caused in nearshore areas. They hold that open ocean waters are normally nutrient deficient, and nutrients released from offshore aquaculture operations would likely dissipate. Critics question whether experiences with experimental facilities are relevant to future commercial operations, which may need to operate at larger scales to be profitable. Generally,

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108 Eutrophication is the process by which a water body or coastal area is overly enriched with nutrients that stimulate excessive growth of algae. When algae die, they are decomposed by bacteria that use and deplete oxygen.

109 Carol Seals Price and James A. Morris, Jr., *Marine Cage Culture and the Environment*, NOAA, NOAA Technical Memorandum NOS NCCOS 164, December 2013. Hereinafter cited as Price and Morris, *Marine Cage Culture*.

110 Rust et al., "Environmental Performance," p. 513.

111 Price and Morris, *Marine Cage Culture*, p. 22.

112 Rust et al., "Environmental Performance," p. 519.

113 Rust et al., "Environmental Performance," p. 512.

114 B. H. Buck et al., "Offshore and Multi-Use Aquaculture with Extractive Species: Seaweeds and Bivalves," in *Aquaculture Perspective of Multi-Use Sites in the Open Ocean,* ed. B. H. Buck and R. Langan (Cham, Switzerland: Springer International, 2017), pp. 23-70.

115 In nature, different tropic levels generally refer to plants (algae and seaweed), herbivores (organisms that graze on plants), and carnivores (predators of herbivores).

environmental impacts are likely to vary depending on management and culture techniques, location, size and scale, and species.

Fish Diseases

Fish diseases are caused by bacteria, viruses, and parasites that commonly occur in wild populations. Aquaculture production is vulnerable to mortality associated with fish diseases, and serious losses have occurred.[116] Disease outbreaks cost the global aquaculture industry an estimated $6 billion per year.[117] Starting in 2007, the Chilean aquaculture industry suffered the worst disease outbreak ever observed in salmon aquaculture.[118] The outbreak of infectious salmon anemia virus cost the industry 350,000-400,000 mt of production and $2 billion.[119]

Net pens are open to the marine environment, so pathogens may pass freely as water moves through net pen enclosures. Cultured organisms are often more susceptible to diseases because fish are kept at higher densities, which increases the rate of contact among fish and may induce stress. Research suggests that fish pathogens may be transferred from farmed to wild fish and that non-native pathogens may be introduced when fish are moved from different areas.[120] Some fish farmers counter that more disease problems originate in wild populations, where reservoirs of disease naturally exist and are subsequently transferred to cultured organisms.

For example, some researchers have identified sea lice as a serious problem for Atlantic salmon farming because of lost production and the costs of disease management.[121] Studies demonstrate that high host densities in net pens promote transmission and growth of the parasite.[122] It has been hypothesized that sea lice may be spread from salmon in net pens to wild counterparts that are passing in adjacent waters. Some assert that sea lice have harmed wild salmon populations migrating near infested salmon farms. Studies have shown that transmission is initiated from wild to cultured fish, and then the lice are transmitted back to wild salmon hosts.[123] The extent of the impact on wild salmon is a matter of debate, because many different factors affect salmon population abundance. However, a recent study concluded that "Atlantic salmon populations are already under pressure from reductions in marine survival and the addition of significant lice-related mortality during the coastal stage of smolt out-migration could be critical."[124] Sea lice control and prevention strategies have included the use of approved therapeutants (aquaculture drugs) and fallowing of sites between production cycles.

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[116] Frank Asche et al., "The Salmon Disease Crisis in Chile," *Marine Resource Economics*, vol. 24, no. 4 (2009), pp. 405-411. Hereinafter cited as Asche et al., "Salmon Disease Crisis."

[117] World Bank, *Reducing Disease Risk in Aquaculture*, Agriculture and Environmental Services Discussion Paper 09, June 2014.

[118] Asche et al., "Salmon Disease Crisis," p. 405.

[119] Asche et al., "Salmon Disease Crisis," p. 408.

[120] Rust et al., "Environmental Performance," p. 514

[121] O. Torrissen, "Salmon Lice—Impact on Wild Salmonids and Salmon Aquaculture," *Journal of Fish Diseases*, vol. 36, no. 3 (January 2013), pp. 171-194.

[122] Sea lice is a parasite that lives in the water column as planktonic larvae. It attaches to fish and feeds on the host's mucus, skin, and blood.

[123] Rust et al., "Environmental Performance."

[124] Samuel Shepard and Patrick Gargan, "Quantifying the Contribution of Sea Lice from Aquaculture to Declining Annual Returns of a Wild Atlantic Salmon Population," *Aquaculture Environmental Interactions*, vol. 9 (May 5, 2017), pp. 181-192.

Drugs and Other Chemicals

Various drugs have been used to treat and prevent the occurrence of disease, including disinfectants, such as hydrogen peroxide and malachite green; antibiotics, such as sulfonamides and tetracyclines; and anthelmintic agents, such as pyrethroid insecticides and avermectins.[125] Antibiotics are used to control bacterial diseases and are sometimes introduced to cultured fish in their feed. Drugs also are used to aid in spawning, to treat infections, to remove parasites, and to sedate fish for transport or handling. Viral diseases are managed by monitoring and focusing on management practices, such as lowering stress, selecting organisms with greater resistance, and providing feed with proper nutrients. However, in some cases it is necessary to depopulate farms to stop the spread of the disease.

The Food and Drug Administration (FDA) is responsible for approving drugs used in aquaculture. The drug must be shown to be safe and effective for a specific use in a specific species.[126] Only drugs approved by the FDA Center for Veterinary Medicine may be administered to aquatic animals. Drug withdrawal periods and testing are required to prevent the sale of fish that contain drug residues. The USDA Animal and Plant Health Inspection Service is responsible for controlling the spread of infectious diseases and requires an import permit and health certificate for certain fish species.[127] Many states also have animal health regulations to prevent disease introductions and manage disease outbreaks.

Aquaculture drugs such as antibiotics that are used to treat marine finfish may be transferred to open water environments when unconsumed feed or fish wastes pass through net pen enclosures. Extensive use of these agents may result in the development and spread of bacteria that are resistant to antibiotics.[128] The use of many of these drugs reportedly is declining, as vaccines eliminate the need to treat bacterial diseases with antibiotics and other drugs.[129] Examples include salmon farming in Norway, where antibiotic use has decreased by 95%, and in Maine, where antibiotics are now rarely used.[130] Proponents of offshore aquaculture suggest that, because of the more pristine and better oxygenated water conditions offshore as compared to many inshore areas, the occurrence of fish diseases could be lower for offshore aquaculture.

Escapes, Genetic Concerns, and Invasive Species

The escape of organisms from aquaculture facilities, especially non-native species, is another environmental concern related to aquaculture. This issue might arise if genetically selected or non-native fish escape and persist in the wild. Historically, non-native species have been used in aquaculture, sometimes resulting in long-term environmental harm. For example, Asian carp such

[125] Priyadarshini Pandiyan et al., "Probiotics in Aquaculture," *Drug Prevention Today*, 2013, pp. 55-59. Anthelmintics are a type of medicine that kills helminths, worm-like parasites such as flukes, roundworms, and tapeworms. The medicine is selectively toxic to the parasite and not the host, in this case salmon.

[126] Letter from FDA, Center for Veterinary Medicine to Aquaculture Professionals, October 2015, at https://www.fda.gov/animal-veterinary/product-safety-information/letter-aquaculture-professionals.

[127] Animal Health Inspection Service, *Import Live Fish*, U.S. Department of Agriculture, February 15, 2017, at https://www.aphis.usda.gov/aphis/ourfocus/animalhealth/animal-and-animal-product-import-information/import-live-animals/sa_marine_life/ct_marine_import_fish.

[128] Jaime Romero, Carmen Gloria Feijoo, and Paola Navarrete, "Health and Environment in Aquaculture," in *Antibiotics in Aquaculture -Use, Abuse and Alternatives*, ed. Edmir Carvalho (Rijeka, Croatia: In InTech Europe, 2012), pp. 159-198.

[129] Carol Seals Price et al., *Protected Species and Marine Aquaculture Interactions*, NOAA, NOAA Technical Memorandum, January 2017. Hereinafter cited as Price et al., *Protected Species*.

[130] Rust et al., "Environmental Performance," p. 515.

as silver, bighead, and grass carp were introduced to the United States from Asia to improve water quality of freshwater aquaculture ponds and waste treatment ponds. These species are now found in most of the Mississippi drainage area, and they have affected the basin's aquatic ecology and harmed species such as freshwater mussels and native fish.[131]

Genetic diversity could be affected if hatchery-raised fish spawn with wild conspecifics (wild fish of the same species). Interbreeding could result in the loss of fitness in the population due in part to the loss of genetic diversity. Genetic risks would depend on the number of escapes relative to the number of wild fish, the genetic differences between wild and escaped fish, and the ability of escaped fish to successfully spawn in the wild.[132] There are also concerns that non-native fish could become established in the wild and compete with wild fish for food, habitat, mates, and other resources.

Experiences with farmed Atlantic salmon may provide some insight regarding escape of farmed fish both within and outside their native ranges.[133] Atlantic salmon have escaped from farms in the Pacific Northwest (outside their native range) and have been recaptured in Alaskan commercial fisheries. In 2017, over 100,000 Atlantic salmon escaped from facilities owned by Cook Aquaculture off Cypress Island, WA.[134] Many of the escaped fish were recovered, and fishery managers assumed the remaining fish were unable to make the transition to a natural diet. In British Columbia, escaped Atlantic salmon have spawned and produced wild-spawned juvenile Atlantic salmon, but it is uncertain whether they have established self-reproducing breeding populations.[135]

Within the range of Atlantic salmon, farmed salmon have been found on spawning grounds during the period when wild Atlantic salmon spawning occurs. Domestication of farmed salmon has changed their genetic composition and reduced genetic variation. These changes have occurred because limited numbers of brood fish are used for spawning farmed fish and farmers select for specific traits.[136] Much present-day farm production of Atlantic salmon is based on five Norwegian strains. Farmed and wild hybrids and backcrossing of hybrids in subsequent generations may change genetic variability and the frequency and type of alleles present in wild populations.[137] The extent and nature of these changes to genetic variability may affect survival (fitness) of these populations.[138] Changes in the genetic profiles of wild populations have been found in several rivers in Norway and Ireland, where interbreeding of wild and farmed fish is common.[139] Large-scale experiments in Norway and Ireland show highly reduced survival and

[131] U.S. Geological Survey, *Nonindigenous Aquatic Species*, Data Queries and Species Lists, at https://nas.er.usgs.gov/taxgroup/fish/default.aspx.

[132] Price et al., *Protected Species*.

[133] Eva B. Thorstad, Ian A. Fleming, and Philip McGinnity, *Incidence and Impacts of Escaped Farmed Atlantic Salmon Salmo Salar in Nature*, Norwegian Institute for Nature Research, 2008. Hereinafter cited as Thorstad et al., *Incidence and Impacts*.

[134] Lynda V. Mapes, "Escaped Atlantic salmon have disappeared from Puget Sound but legal fight begins," *Seattle Times*, November 14, 2017.

[135] Thorstad et al., *Incidence and Impacts*, p. 67.

[136] Oystein Skaala, Vidar Wennevik, and Kevin A. Glover, "Evidence of temporal genetic change in wild Atlantic salmon, *Salmo salar*, populations affected by farm escapees," *ICES Journal of Marine Science*, vol. 63 (2006), pp. 1224-1233.

[137] An allele is one of two or more versions of a gene occupying a specific spot on a chromosome that controls a specific trait.

[138] Fitness can be generally described as the ability to survive and reproduce.

[139] Thorstad et al., *Incidence and Impacts*, p. 60.

lifetime success rates of farmed and hybrid salmon compared to wild salmon.[140] Some researchers have concluded that further measures are needed to reduce the escape of salmon from aquaculture farms and their spawning with wild populations.[141]

Researchers and managers have made several recommendations to decrease the risk of invasive species introductions and the loss of genetic diversity. There appears to be common agreement, as in the case of the Gulf of Mexico FMP, that only native species should be farmed. To decrease genetic risks associated with escapes, farmers might be required to use wild broodstock with a genetic makeup that is similar to local wild populations. However, by using this approach, farmers may forgo benefits of selective breeding. Another approach might involve the use of sterile fish created through techniques such as hybridization, chemical sterilization, polyploidy, and others.[142] However, these methods are not always 100% effective and the approach may increase costs of production.[143]

Interactions with Other Species

Interactions between aquaculture operations and marine wildlife may occur when predators in search of food are attracted to aquaculture facilities or if aquaculture sites overlap with the ranges or migration of marine species. These interactions are common in Chile, British Columbia, and Norway, where marine mammals and birds often are attracted to salmon farms.[144] Most interactions are seasonal and involve sea lions, seals, and otters, as well as seabirds such as sea gulls and cormorants. Predation can result in loss of fish, damage to equipment, and stress to fish. Deterrence measures seek to address these concerns; for example, predator nets may be placed outside the main net to stop marine mammals directly accessing the net pen. Some farms also install bird nets over net pens to protect fish from bird predation. When nonlethal measures fail, sea mammals are sometime culled.

Offshore facilities could affect some endangered species as they migrate or alter essential habitat for feeding, breeding, and nursing. Information on incidental entanglement and mortality is limited, because of the small number of facilities working in offshore areas. NOAA recently investigated longline aquaculture gear that might be used for mussel culture and found that interactions are rare.[145] However, researchers questioned whether the small number of interactions indicates that this type of aquaculture is benign or is due to the failure to detect and report interactions. Minimizing impacts on protected species may require monitoring and research into natural interactions between predators and prey. Management strategies might involve preventive measures, such as spatial planning and aquaculture gear modifications.

Wild fish also are sometimes attracted to net pens to consume feed that has fallen through net pen enclosures.[146] The attraction of wild fish may provide a benefit, because their consumption of feed may lessen environmental impacts such as the release of nutrients or deposits of feed near net pens. At the same time, it could have negative impacts, such as the transfer of diseases from

[140] Thorstad et al., *Incidence and Impacts,* p. 60.

[141] Kjetil Hindar et al., "Genetic and Ecological Effects of Salmon Farming on Wild Salmon: Modeling from Experimental Results," *ICES Journal of Marine Science*, vol. 63, no. 7 (January 2006), pp. 1234-1247.

[142] Polypliody occurs in organisms with cells containing more than two paired sets of chromosomes.

[143] Price et al., *Protected Species*, p. 12.

[144] Cermaq, *Marine Mammals and Birds,* Fact Sheet, October 18, 2012.

[145] Price et al., *Protected Species,* p. 8.

[146] Ingebrigt Uglem, "Impacts of wild fishes attracted to open-cage salmonid farms in Norway," *Aquaculture Environment Interactions,* vol. 6 (2014), pp. 91-103.

farmed to wild fish or from wild to farmed fish. Impacts related to changes in wild fish physiology from the ingestion of feed and changes in the distribution of wild fish are unknown.

Aquaculture Feeds and Related Issues

Fish feed is a critical input, because it must provide all of the essential nutrients and energy needed to meet the cultured organism's physiological requirements. The supply and use of aquaculture feed are directly related to the economic viability of aquaculture operations, fish growth and health, environmental quality, ecological concerns, and human nutritional benefits from aquaculture products.[147] Fish meal and oil are used to produce feed for carnivorous species such as salmon, because these ingredients provide nutritional requirements that are similar to those found in the wild. Aquaculture feeds must have a composition that maintains growth and fish health while balancing the costs of feed components against the value of outputs associated with fish growth. Researchers note that future aquaculture production is likely to be constrained if feeds are limited to sources of fish meal and oil, which require wild fish production and fish processing wastes. Research efforts have focused on the use of fish meal and oil substitutes that are derived from terrestrial plants.[148] Plant meal and oils now supply the bulk of feed ingredients, but they are not a perfect substitute and, in many cases, fish meal and oil are still an important component of most fish feeds.

Feed Production and Use

Nutritional requirements and feed composition vary according to species, the life stage of the organism (e.g., larvae, fry, fingerlings, adults), and management objectives.[149] Fish feeds are formulated to provide a mixture of ingredients, such as proteins, lipids, carbohydrates, vitamins, and minerals, which provide the greatest growth at the lowest cost. Historically, fish meal and oil have been principal ingredients of many aquaculture feeds, because these ingredients have been a cost-effective means of providing the nutritional requirements of many cultured species. Fish meal and oil are obtained from reduction fisheries that target small pelagic species such as anchovies, capelin, herring, and menhaden and from fish processing wastes of wild and aquaculture products.[150] Reduction fisheries target species that are generally less valuable than those used for human consumption.[151] The fish are heated and pressed to obtain fish oil and milled and dried to produce fish meal. Since 2006, the annual world supply of fish meal has ranged from 4.49 mmt to 5.86 mmt and the supply of fish oil has ranged from 0.86 mmt to 1.08 mmt.[152] In 2016, the United States produced 253,600 metric tons (mt) of fish meal and 80,500 mt of fish oil, approximately 5% and 8% of global production, respectively.[153]

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[147] Hixson, "Fish Nutrition," p. 1.

[148] Michael B. Rust, *The Future of Aquafeeds*, NOAA and USDA, December 2011.

[149] Production of food fish is one of many potential objectives of aquaculture. Other examples of aquaculture objectives may involve enhancement of recreational fishing or restoration of aquatic populations.

[150] A reduction fishery uses fish to produce fish oil and fish meal for animal feeds, including those used for aquaculture.

[151] Many oppose the use of these species for animal feeds, because they assert that the protein should be available for direct human consumption. In many cases, such as U.S. menhaden fisheries, fish are not marketed as food items because of the taste and texture of their flesh. However, in some parts of the world, direct human consumption of other forage fisrubionh (often small pelagic species) is increasing.

[152] Seafish, *Fishmeal and Fish Oil Facts and Figures*, December 2016. Hereinafter cited as Seafish, *Fishmeal and Fish Oil*.

[153] NMFS, *Fisheries of the United States, 2016*, NOAA Current Fishery Statistics No. 2016, Silver Spring, MD, 2017, at https://www.fisheries.noaa.gov/feature-story/fisheries-united-states-2016.

Reduction fisheries supply approximately 70% of fish meal and fish oil, with the remainder obtained from fish processing wastes.[154] In the last 20 years, global production of fish meal and oil has declined in part because of increasing use of fish from reduction fisheries for direct human consumption and tighter quotas and controls on unregulated fishing.[155] The global decrease in total fish meal production has occurred despite increasing production of meal and oil from fish processing wastes.

Conversion of Aquaculture Feed to Fish Flesh

Researchers have found that fish meal (protein) and fish oil (lipids) are important ingredients for fish growth.[156] Most feeds are formulated to increase efficiency by using high-energy lipid to allow for greater conversion of dietary protein into fish muscle. In addition to fish protein and oil, fish feeds may include plant proteins, terrestrial animal protein, carbohydrates, moisture, ash, vitamins, and minerals. In comparison to other animals, fish are relatively efficient in converting fish feed to flesh.[157] For example, feed conversion ratios for Atlantic salmon are approximately 1.15 (approximately 1.15 kilograms [kg] of dry feed are used to produce 1.0 kg of salmon flesh [wet]).[158] In 2013, salmon fish feed used on Norwegian farms consisted of approximately 18% fish meal and 11% fish oil.

The amount of marine fish protein and oil needed to produce a unit measure of seafood such as salmon has been decreasing with the use of plant-based substitutes. The "fish in fish out" ratio is the amount of wild fish needed to produce the fish meal and fish oil required to produce one kilogram of farmed fish. The ratio of "fish in to fish out" varies according to the nutritional requirements of different species, with higher ratios for carnivorous fish such as eels (1.75) that are fed higher fish protein and fish oil diets and lower ratios for omnivorous fish such as tilapia (0.18).[159] When aggregated across species, worldwide aquaculture is a net producer of fish protein, with estimates ranging from 0.22 kg to 0.5 kg of wild marine fish used to produce a kilogram of farmed seafood.[160]

Substitutes for Fish Meal and Oil

Over the last two decades, research on fish dietary requirements has contributed to progress in developing substitutes for fish meal and oil from terrestrial plant ingredients and other potential sources, such as marine algae.[161] This has led to reductions in the use of fish meal and oil as ingredients in fish food. Terrestrial plant meal and oils now supply the bulk of feed ingredients for

[154] Rust et al., "Environmental Performance," p. 511.

[155] Seafish, *Fishmeal and Fish Oil*.

[156] Hixson, "Fish Nutrition," p. 1.

[157] Knapp and Rubino, "Political Economics of Marine Aquaculture."

[158] Trine Ytrestoyl, Turid Synnove Aas, and Torbjorn Asgard, "Utilization of Feed Resources in Production of Atlantic Salmon," *Aquaculture*, vol. 448 (2015), pp. 365-374.

[159] Marine Ingredients Organization (IFFO), "Fish In: Fish Out (FIFO) Ratios for the Conversion of Wild Feed to Farmed Fish Including Salmon," at http://www.iffo.net/fish-fish-out-fifo-ratios-conversion-wild-feed (hereinafter IFFO, "Fish In: Fish Out"). These estimates attempt to provide a ratio that includes fish meal and fish oil.

[160] NOAA Fisheries, Office of Aquaculture, *Feeds for Aquaculture*, at http://www.nmfs.noaa.gov/aquaculture/faqs/faq_feeds.html. (hereinafter cited as NOAA, *Feeds for Aquaculture*) and IFFO, "Fish In: Fish Out."

[161] Fish oils are produced by marine algae, and in nature algae are consumed by fish that feed at relatively low tropic levels.

most fish species.[162] The focus of research has been on plant protein and oil sources such as soy, canola, sunflower, cottonseed, and others. For example, the Norwegian salmon industry has reduced the content of fish meal and oil in fish feed from over 60% to less than 25% by using plant proteins and oils.[163]

In spite of decreasing global production of fish oil and meal, use of plant-based substitutes has allowed production of feeds for all aquaculture to expand at 6% to 8% per year.[164] Increasing demand and a limited supply of fish meal and oil have caused prices to triple for these ingredients in recent years.[165] These price increases are likely to continue, because production is generally limited to supplies from wild sources.[166] The cost of aquaculture feeds accounts for approximately 50% of net pen aquaculture operating costs. Limited wild supplies and rising feed costs have encouraged researchers and aquaculturalists to improve feeding techniques to reduce waste, modify feed formulations, use alternatives such as waste from fish-processing plants, and investigate new sources. Substitution has become more attractive, as the prices of fish meal and oil have risen faster than the prices of plant proteins and oils. Fish can be cultured with substitutes for fish meal and oil, but the commercial use of substitutes depend on whether the lower costs of the substitute can offset losses associated with lower growth rates, less disease resistance, and inferior nutritional value of aquaculture products.[167]

Although significant progress has been made in using plant protein and oil substitutes for fish feeds, there are still limitations to their use. In the near future, some fish meal and oil will still be needed in feed formulations. Plant meals are deficient in certain essential amino acids and contain fiber, carbohydrates, and certain antinutritional factors, which can adversely affect absorption, digestion, and growth.[168] Nutritional quality of plant proteins can be improved through chemical and mechanical processing, which can reduce certain antinutrients and concentrate protein. Plant oils are an excellent source of energy, but they do not contain omega-3 fatty acids (eicosapentaenoic acid [EPA] and docosahexaenoic acid [DHA]). These fish oils have been found to improve immune responses and fish health generally.[169] Fish species have differing tolerances to diets without certain fatty acids, which appear to be related to their natural diet. The use and substitution of plant protein and oils is likely to increase with further research into alternatives and as prices of fish meal and oil increase.

Fish Health

Proper feed formulations also are essential to promote fish health and prevent disease outbreaks. When fish are farmed at high densities, good nutrition tends to reduce stress, decrease the incidence of disease, and boost immune systems. A deficiency in any required nutrient may impair health by affecting the organism's metabolism and increasing susceptibility to disease. Research has shown that the use of plant oils and the ratio of different fatty acids can affect the immune response in fish. Dietary additives of immunostimulants, probiotics, and prebiotics have been found to increase immunity, feed efficiency, and growth.[170] An ongoing challenge is to

[162] Michael B. Rust, *The Future of Aquafeeds*, NOAA and USDA, December 2011.

[163] Rust et al., "Environmental Performance," p. 512.

[164] NOAA, *Feeds for Aquaculture*.

[165] Knapp and Rubino, "Political Economics of Marine Aquaculture," p.220.

[166] Wild sources include both forage species and wastes from processing wild and farmed fish.

[167] Nutritional value to consumers (humans) of fish.

[168] Hixson, "Fish Nutrition," p. 3.

[169] Hixson, "Fish Nutrition," p. 5.

[170] Hixson, "Fish Nutrition," p. 5.

improve knowledge and commercial application of feed formulations, especially for nutrimental requirements of newly domesticated species.

Human Health and Preferences

The human health benefits of seafood are widely recognized because fish species contain high-quality protein, oils, minerals, and vitamins. Some research has found that diets that include omega-3 fatty acids enhance early brain and eye development and reduce heart disease and cognitive decline later in life. Feeds with plant-based substitutes can affect the quality of seafood products because these alternatives lack the fatty acids that are beneficial to human health. Farmed fish products that have been fed plant substitutes for fish oil may have lower concentrations of beneficial fish oils in their flesh. Two potential ways to reduce the use of fish oils in feed while maintaining high levels of omega-3 fatty acids in fish are (1) to develop genetically modified plants, fungi, or microbes to produce DHA and EPA for use in fish feeds or (2) to grow fish on low fish oil diets in the beginning of the production cycle and boost the omega-3 fatty acids in fish diets to raise their levels at the end of the production cycle.

There also are growing public health concerns about persistent organic pollutants, such as polychlorinated biphenyls (PCBs), and inorganic contaminants, such as heavy metals, in farmed fish. The accumulation of contaminants varies by location and associated sources of pollutants. It can occur in both wild and farmed fish.[171] Fish fed with fish meal and oils may accumulate contaminants from marine sources. Several studies have reported elevated levels of contaminants in feeds and farmed Atlantic salmon flesh. An advantage of using plant protein and oil is the potentially lower contaminant levels than those found in some wild seafood products. Several studies have found that replacing fish protein and oil with plant-derived material lowered the level of contaminants significantly.[172]

Consumer perceptions of changes in the quality of fish raised with substitute feeds also may affect acceptance of aquaculture products. There are widely held beliefs regarding the composition and health benefits of farmed and wild fish. Studies have shown that there are differences in taste and texture of fish farmed with alternative proteins and oils, but consumer preference studies have yielded mixed results.[173] Public perceptions of aquaculture products also include concerns with the use of therapeutants such as antibiotics and the crowding and industrial nature of fish farming.

Sustainability Concerns

Some stakeholders have described the use of fish meal and oils for aquaculture feeds as an issue related to the sustainability of forage species and marine ecosystems. More than 30% of global fish production and a large portion of fish meal and oil used for aquaculture feeds (75%) is derived from the harvest of forage species, such as herring, anchovies, capelin, and menhaden. Fatty acids are produced by marine algae (phytoplankton), consumed and concentrated in fish that consume algae, and transferred to organisms higher in the food chain that consume forage species. As stated earlier, forage species have a relatively low economic value, and most are not marketed for direct human consumption. However, their biomass is relatively large because they feed at somewhat low tropic levels, and they can be caught fairly easily in large volumes because

[171] Hixson, "Fish Nutrition," p. 7.

[172] Hixson, "Fish Nutrition," p. 8.

[173] Hixson, "Fish Nutrition," p. 7.

they are schooling species.[174] Forage species serve as prey for higher tropic level fish species such as tuna, cod, and striped bass, marine mammals, and marine birds. [175]

Aquatic ecologists question whether aquaculture demand and increasing prices may encourage higher levels of fishing pressure and cause or continue overfishing of forage fish populations. Management of wild fish stocks is improving in many parts of the world, and many stocks are now considered to be well managed. However, some researchers have concluded that fishing for forage species should be limited to relatively low levels, because forage species are needed to support production of other marine species.[176] Research using ecosystem models suggests that forage fish should be fished at lower rates to benefit the ecosystem rather than at rates that would provide long-term maximum yield.[177] One report recommended that catch rates should be reduced by half and biomass of forage fish should be doubled.[178] However, other researchers have questioned whether there is a strong connection between forage fish abundance and the abundance of their predators;[179] they conclude that harvest policies for forage species need to be guided by a variety of factors that recognize the complexities of fisheries and ecosystems.

Economics, International Conditions, and Stakeholder Concerns

Increasing demand for seafood, advances in aquaculture methods, and increases in global aquaculture production have led many observers to take an optimistic view of potential offshore aquaculture development in the United States. Nevertheless, the future of offshore development is uncertain because of the paucity of experiences in establishing and managing U.S. offshore aquaculture facilities. Greater regulatory certainty may encourage U.S. offshore development, but economic viability will determine whether the industry expands and produces significant quantities of seafood.

The viability of offshore aquaculture in the United States is likely to depend on future developments, such as further technical advances, economic conditions, and social and political acceptance. Another economic consideration for policymakers is how to integrate policies that recognize the potential costs (externalities) of environmental harm that may be caused by offshore aquaculture and are not captured by markets.[180] In addition to economics, user conflicts and related political factors are likely to play a role in the potential development of an offshore industry.

[174] *Tropic levels* generally refer to organisms in an ecosystem that occupy a similar level in the food chain. Prey items, such as sardines, occupy a lower tropic level with relatively higher levels of biomass than predators at higher tropic levels and lower biomass, such as tuna.

[175] Timothy E. Essington and Stephen B. Munch, "Trade-Offs Between Supportive and Provisioning Ecosystem Services of Forage Species in Marine Food Webs," *Ecological Applications*, vol. 24, no. 6 (September 2014).

[176] E. Pikitch et al., *Little Fish, Big Impact: Managing a Crucial Link in Ocean Food Webs*, Lenfest Ocean Program, 2012. Hereinafter cited as Pikitch et al., *Little Fish, Big Impact*.

[177] Anthony D. M. Smith et al., "Impacts of Fishing Low Trophic Level Species on Marine Ecosystems," *Science*, vol. 333 (August 2011), pp. 1147-1150.

[178] Pikitch et al., *Little Fish, Big Impact*.

[179] Ray Hilborn et al., "When Does Fishing Forage Species Affect Their Predators?" *Fisheries Research*, vol. 191 (2017), pp. 211-221.

[180] Externalities are defined as spillover costs or benefits, which are unintended consequences or side effects associated with an economic activity.

Factors Related to the Economic Viability of Offshore Aquaculture

The economic potential of offshore aquaculture will depend on the prices of seafood products and the cost to produce them. The following discussion identifies some of the factors that will determine whether offshore aquaculture may be profitable.

Demand

The quantity demanded for an aquaculture product is a function of price—each point along the demand curve is the quantity that consumers are willing to buy at a specific price. Consumers are generally willing to buy less product at higher prices and more product for lower prices. A change in demand, a shift of the demand curve, depends on a variety of factors, such as changes in income, prices of substitutes (domestic wild fish) and complements, and consumer tastes and preferences.[181]

Offshore aquaculture production will compete with a variety of other protein products, such as imported seafood; domestically produced wild fish; and agriculture sources such as chicken, pork, and beef. Generally, demand for seafood products is rising both globally and domestically because of increasing population levels and incomes. The health benefits of seafood are also influencing changes in consumer preferences, with general movement away from traditional protein sources such as beef. Other types of domestic marine aquaculture production, such as land-based and inshore aquaculture, may compete with offshore aquaculture, but currently these activities provide a relatively small portion of the seafood consumed in the United States.[182] Domestic sources of seafood may increase marginally as some overfished stocks recover, but most domestic fisheries are already at or near their natural limits.

Some have reported that offshore aquaculture could produce a higher-quality product because of the constant flow of clean water through net pens. If it can be shown that offshore products contain fewer toxin residues or if offshore products can be raised without aquaculture drugs, these products may become more attractive to health-conscious consumers. The FDA Seafood Safety Program and the NOAA Seafood Inspection Program also may reassure U.S. consumers of the safety and quality of domestic seafood, including seafood produced by offshore aquaculture.[183] These factors may allow offshore producers to differentiate their products and receive higher prices relative to imports or other domestic seafood, especially in niche markets.

Supply

The amount of seafood that aquaculturalists will be willing to produce at a given price depends on production costs. Economic conditions determine the costs of labor, hatchery supplies for stocking, feed, maintenance, and other inputs. For most aquaculture operations, the bulk of costs are for feed and stocking of early life stages, such as finfish fingerlings or oyster seed.[184] Fixed

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[181] A change in demand results in a shift of the demand curve rather than a change in quantity demanded, movement along the demand curve.

[182] Advances in more intensive land-based culture techniques, such as recirculating systems, are another means to increase production with minimal environmental impacts, but the viability of these operations is still uncertain.

[183] The FDA program also inspects imports and may be found at https://www.fda.gov/food/resources-you-food/seafood. The Department of Commerce program can be found at https://www.fisheries.noaa.gov/insight/noaas-seafood-inspection-program.

[184] Early stages of marine organisms are often raised in hatcheries and subsequently transferred to larger enclosures to be grown to adult size.

costs include equipment depreciation, insurance, taxes, and lease payments. Shifts in supply result from changes in input prices, which also may be affected by technology, weather conditions, and other influences. At the level of individual farms or facilities, most costs are not set and often depend on short-run and long-run choices of the aquaculturalist. For example, in the short run, the producer may change feed quality and quantity, harvest intervals, or stocking rates, while in the longer term she may change species, location, technology, and scale.[185]

Costs to produce seafood in offshore aquaculture facilities are likely to be higher than costs in inshore areas, because of the need for more resilient cage materials and construction, shore-side infrastructure, specialized vessels, and automation of facility systems. The location of offshore aquaculture facilities also is likely to increase costs for fuel, monitoring, harvest, and security.[186] According to the Food and Agriculture Organization, offshore facilities operating at distances of greater than 25 nm from shore are unlikely to be profitable, because costs increase with distance from shore.[187]

Some have speculated that offshore facilities will need to take advantage of economies of scale because of the relatively high costs of transporting materials between inshore and offshore facilities. Operating large-scale operations will require new coastal facilities and networks to supply and transport feed, construction materials, fingerlings, and harvested fish. Logistics networks to supply these inputs would need to be developed in coastal areas, where "working waterfronts" are already threatened due to competing uses and the relatively high cost of coastal real estate. These startup costs may exclude smaller producers who may not have access to the capital and resources needed to establish large-scale operations.

Financial risk, generally the probability of losing money, is another factor that is related to potential viability of offshore aquaculture and may affect the availability of capital and insurance. *Risk* is defined as uncertain consequences, usually unfavorable outcomes, due to imperfect knowledge.[188] Assessing risk for offshore aquaculture is complicated by different species, technologies, site characteristics, and the lack of experience working in offshore areas. Risks may be greater in offshore than inshore areas because of the threat of severe weather conditions and exposed offshore environments. Attracting investment may be difficult because offshore aquaculture is a new industry with limited experiences for investors to evaluate. As risk and uncertainty increase, generally, a greater revenue stream is required to justify the same level of investment.[189] Known risks can be reduced by decreasing the probability of adverse outcomes, such as by using stronger materials to build more resilient structures. The cost of reducing risks must be weighed against the probability and magnitude of potential losses.

Another approach to reducing risk is through insurance. Insurance transfers risk from the producer to the insurance underwriter through payments of insurance premiums. The cost of

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[185] Knapp, "Economic Potential."

[186] California Environmental Associates (CEA), *Offshore Finfish Aquaculture Global Review and U.S. Prospects*, The David and Lucile Packard Foundation, 2018. Hereinafter cited as CEA, *Offshore Finfish Aquaculture*.

[187] FAO, *A Global Assessment of Offshore Mariculture Potential from a Spatial Perspective,* Technical Paper 549 2013.

[188] Lotus E. Kam and Pingsum Leung, "Financial Risk Analysis in Aquaculture" in *Understanding and Applying Risk Analysis in Aquaculture*, FAO, 2008.

[189] Di Jin, "Economic Models of Potential U.S. Offshore Aquaculture Operations," in *Offshore Aquaculture in the United States: Economic Considerations, Implications, and Opportunities,* NOAA, NOAA Technical Memorandum NMFS F/SPO-103, July 2008, pp. 117-140.

insurance premiums may be higher for offshore than inshore areas because of greater uncertainty and potentially higher risks of losses for offshore facilities.

Private Benefits and Externalities

The previous discussion of supply and demand considers private costs of production that are borne by the producer. Policymakers are concerned with a broader definition of costs that may affect individuals who are not involved in the aquaculture business—often referred to as *externalities*. Externalities are defined as spillover costs or benefits, which are unintended consequences or side effects associated with an economic activity.[190] For example, commercial fishermen may be harmed by habitat degradation caused by pollution from aquaculture because of associated declines of wild populations. When externalities are not considered, markets become inefficient because more of a good or service is produced than when the externality is fully considered.

The recognition of externalities is another way in which policymakers can examine the tradeoffs related to the private benefits from aquaculture production and the environmental harm caused by the activity. In the case of offshore aquaculture, external costs may be associated with environmental harm from pollution, escaped organisms, disease transmission, and other effects. The existence of externalities means that policymakers may need to consider whether and to what degree the government should intervene to account for these costs. Intervention may involve regulatory measures that minimize externalities while maximizing benefits associated with the industry (e.g., fish production). Decisions related to site selection, technology, and facility operations are likely to be some of the main factors that determine the level of offshore aquaculture externalities.

International Factors and Domestic Experiences

Trade

DOC has expressed concern with increasing U.S. imports of seafood products. According to NMFS, 80%-90% of the seafood consumed in the United States is imported.[191] International trade in seafood has grown over the last several decades. The value of seafood trade is now more than twice the trade of meat and poultry combined.[192] Relatively high-value seafood from wild fisheries and aquaculture dominates imports. In 2017, the United States imported approximately 2.7 mmt of edible seafood valued at $21.5 billion.[193] After accounting for exports valued at $5.7 billion, the value of imports was $15.8 billion greater than exports of edible seafood products. Approximately half of seafood imports are cultured. The two main imported products are farmed

[190] Externalities may be related to costs or harm related to pollution or benefits, such as the utility gained from observing flowers planted in roadside areas.

[191] NMFS, 2018. A portion of imports include domestic catch that was exported for further processing and returned to the United States as an import in processed form.

[192] James L. Anderson and Gina Shamshak, "Future Markets for Aquaculture Products," in *Offshore Aquaculture in the United States: Economic Considerations, Implications, and Opportunities,* NOAA, NOAA Technical Memorandum NMFS F/SPO-103, July 2008, pp. 231-244.

[193] NMFS, *Imports and Exports of Fishery Products Annual Summary, 2016*, Current Fishery Statistics No. 2016-2, Silver Spring, MD , July 19, 2017, at https://www.st.nmfs.noaa.gov/Assets/commercial/trade/Trade2016.pdf.

shrimp and salmon. In 2017, shrimp accounted for $6.5 billion and salmon accounted for $3.5 billion of U.S. seafood imports.[194]

Supporters of offshore aquaculture assert that development of offshore areas and associated increases in seafood production could reduce the U.S. deficit in seafood trade. The Department of Commerce Strategic Plan states that, "a strong U.S. marine aquaculture industry will serve a key role in U.S. food security and improve our trade balance with other nations."[195]

Some may counter that the seafood trade deficit is not a good reason to support development of the aquaculture industry. Cultured salmon and shrimp imports have lowered prices and, therefore, the profits of domestic wild fisheries and aquaculture producers, but U.S. consumers have benefited from lower salmon and shrimp prices. According to economic theory, countries gain from trade when they specialize in products that they are best at producing. If other countries have an absolute or comparative advantage in aquaculture, the United States would likely benefit from supporting other industries.[196] Advocates of aquaculture note that the United States has advantages compared to other countries because of its extensive coastline and EEZ, skilled labor, technology, domestic feed production, stable government and economy, and large seafood market.[197] Others counter that U.S. federal waters are exposed to high winds and wave action for large parts of the year, whereas other parts of the world have readily available inshore areas and calmer offshore waters that could be developed, as well as lower labor costs.[198]

Overall operating costs and environmental standards for aquaculture in other countries are often lower than in the United States. Some have speculated that costs of inputs such as labor and less strict regulations provide producers outside the United States with an insurmountable competitive advantage. Other observers stress that costs may be lower in other countries, but if prices are high enough, U.S. producers may still be able to operate profitably.[199] Domestic producers also have some advantages, such as a large and relatively wealthy market and lower shipping costs than those for imports.

The government sometimes provides government-sponsored trade protections such as tariffs or import quotas to new industries. Protection may be rationalized by an infant industry that claims it requires time to overcome short-term cost disadvantages.[200] Cost disadvantages may be related to the need to become more efficient by constructing new facilities, training workers, and installing new equipment. In these cases, tariffs would act as a subsidy that increases the domestic price of the good. When the industry becomes more efficient, the tariff would expire. However, as

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[194] An unknown portion of seafood imports, including salmon, was harvested in U.S. wild fisheries and exported to other countries for processing. Some of these products are then exported back into the United States.

[195] U.S. Department of Commerce, *U.S. Department of Commerce Strategic Plan 2018-2022*: *Helping the American Economy Grow*, 2018, p. 9, at https://www.commerce.gov/about/strategic-plan.

[196] A country has an absolute advantage if its production costs for a good are lower than those of other countries at prevailing prices and exchange rates. According to the concept of comparative advantage, a country should import goods when the international price is less than the domestic opportunity cost (the potential benefit foregone) of producing an additional unit domestically. The opportunity cost is the cost of producing additional units of the product in terms of the reduction in the output of another product.

[197] Knapp and Rubino, "Political Economics of Marine Aquaculture," p. 213.

[198] CEA, *Offshore Finfish Aquaculture*, p. 4.

[199] Knapp, "Economic Potential."

[200] James P. Houck, *Elements of Agricultural Trade Policies* (University of Minnesota: Waveland Press Inc., 1992), p. p. 21. Hereinafter cited as Houck, *Elements of Agricultural Trade*.

the industry becomes larger and more politically powerful, it may become difficult to remove the tariff.[201]

U.S. Experiences

U.S. aquaculture production from inshore marine areas and freshwater ponds and raceways is small relative to global production levels. The bulk of U.S. aquaculture production is from freshwater catfish, crayfish, and trout. Catfish production increased from 62,256 mt in 1983 to its peak of 300,056 mt in 2003. Factors that have supported the industry's development include research and development, marketing efforts, industry leadership, and vertical integration.[202] However, production decreased from 215,888 mt in 2009 to 145,230 mt in 2016. An increase of pangasius (an Asian catfish) and tilapia imports has contributed to lower prices, which have contributed to decisions by less profitable catfish farms to take acreage out of production.[203]

Salmon is the only marine finfish with significant U.S. marine aquaculture production, but it has struggled to compete with relatively inexpensive imports from Norway, Chile, and Canada.[204] These countries are endowed with protected coastal areas such as fjords or bays where net pens may be deployed. Although environmental regulations and limitations on inshore leases may have affected U.S. salmon aquaculture production, stagnant prices and competitive imports also appear to have played a role. There is room for expansion of inshore net pen salmon aquaculture in areas of Maine, Washington, and Alaska.[205] However, many residents in these areas do not support establishing or expanding net pen aquaculture because of environmental concerns and potential impacts on existing fishing industries. The ban on finfish aquaculture in Alaska and regulatory constraints in other states reflect these concerns.[206]

Offshore Development in Other Countries

Currently, nearly all worldwide marine aquaculture production is from relatively well-protected inshore waters. Countries in the forefront of efforts to move offshore have experience with inshore aquaculture and with aquaculture industries that are characterized by relatively large investments in vertically integrated firms.[207] Norway and China are the two largest investors in offshore aquaculture development, but neither country has facilities that are operating commercially. Their efforts have focused on developing structures that can withstand harsh offshore conditions and operate at scales that may offset the higher costs of offshore areas as compared to inshore areas.[208]

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[201] Houck, *Elements of Agricultural Trade,* p. 21.

[202] James L. Anderson and Gina Shamshak, "Lessons from the Development of the U.S. Broiler and Catfish Industries: Implications for Offshore Aquaculture in the United States," in *Offshore Aquaculture in the United States: Economic Considerations, Implications, and Opportunities,* NOAA, NOAA Technical Memorandum NMFS F/SPO-103, July 2008, pp. 97-116. Hereinafter cited as Anderson and Shamshak, "Lessons."

[203] The increase in fish feed prices is another factor that has affected U.S. catfish businesses.

[204] Shrimp are the largest seafood import by value and volume, but shrimp are not considered to be a viable candidate for offshore aquaculture because they are raised in topical coastal ponds and do not appear to be suited for offshore aquaculture.

[205] Atlantic salmon net pen aquaculture is not currently allowed in Alaska. Washington and Maine allow net pen salmon aquaculture but have limited its expansion because of environmental concerns.

[206] Knapp, "Economic Potential," p. 183.

[207] CEA, *Offshore Finfish Aquaculture*, p. 5.

[208] CEA, *Offshore Finfish Aquaculture*, p.4.

Norway's industry already has extensive experience with inshore salmon aquaculture industry and is a leader in developing technology needed to move farther offshore.[209] Norway has granted development licenses in offshore waters, and Norwegian companies are experimenting with different offshore concepts. Although there has been significant investment in offshore aquaculture in Norway, it is unclear whether these concepts will be profitable. It appears that long-term business strategies are still focused on inshore waters.[210] Offshore aquaculture facilities are also under development in other countries, including Mexico, Panama, and Turkey.[211]

The characteristics of specific regions also may offer advantages, as some believe future development will occur in the calm water tropical belt between 10°N and 10°S.[212] One former offshore aquaculture farmer believes future investment will focus on new species in tropical and subtropical regions.[213] It appears that growth of marine aquaculture may take different approaches in different parts of the world, with further increases in production from proven nearshore areas and research and development of potential land-based and offshore areas. Generally, movement offshore is likely to occur if seafood demand continues to increase and suitable nearshore areas are occupied or constrained by other factors.[214]

Stakeholder Concerns and Aquaculture Development

Some stakeholders have expressed concerns about offshore aquaculture that include environmental degradation, competition for ocean space, and market interactions between wild fishery and aquaculture products. Historically, user conflicts associated with aquaculture have occurred in inshore areas where oceans activity and use are more intensive. For example, some fishermen oppose aquaculture and perceive it as competition that lowers prices and fishing revenues. Most interactions are characterized as conflicts, but in some cases synergistic relationships may emerge.[215]

Environmental concerns have been among the most controversial elements of the aquaculture debate, including expansion of aquaculture into offshore waters. Generally, environmental and commercial fishing interests have been opposed to plans for offshore aquaculture development because of potential harm to marine resources. They have asserted that poorly regulated inshore aquaculture development has degraded the environment and harmed wild fish populations and ecosystems.[216] Concerns identified by these stakeholders include pollution, the use of wild

[209] The Alaska shoreline may include suitable areas for salmon net pens, but the state does not allow net pen aquaculture and many salmon fishermen believe this activity is not compatible with wild salmon fisheries.

[210] CEA, *Offshore Finfish Aquaculture*, p. 21.

[211] The definition of offshore aquaculture varies across countries. For example, offshore aquaculture facilities in Turkey are reported have characteristics that more closely resemble inshore aquaculture. CEA, *Offshore Finfish Aquaculture*.

[212] Edwards, "Aquaculture Environment Interactions," p. 11.

[213] U.S. Congress, Senate Committee on Commerce, Science, and Transportation, Ocean Policy Study, *Written Statement by John R. Cates*, Hearing on Offshore Aquaculture, 109th Cong., 2nd sess., April 6, 2006.

[214] CEA, *Offshore Finfish Aquaculture*, p. 4.

[215] Diego Valderrama and James Anderson, "Interactions Between Capture Fisheries and Aquaculture," in *Offshore Aquaculture in the United States: Economic Considerations, Implications, and Opportunities,* NOAA, NOAA Technical Memorandum NMFS F/SPO-103, July 2008, pp. 189-206.

[216] Center for Food Safety, "Fishing and Public Interest Groups File Challenge to Fed's Unprecedented Decision to Establish Aquaculture in Offshore U.S. Waters," press release, February 16, 2016, at https://www.centerforfoodsafety.org/press-releases/4229/fishing-and-public-interest-groups-file-challenge-to-feds-unprecedented-decision-to-establish-aquaculture-in-offshore-us-waters. Hereinafter cited as Center for Food Safety, "Fishing and Public Interest Groups."

species for fishmeal, fish escapement, threat of disease and parasites, harm to marine wildlife, and general impacts on marine ecosystems.[217] Most commercial fishing and environmental interests advocate a precautionary approach.

Industry supporters and aquaculturalists respond that research, innovation, and management practices have reduced or eliminated environmental risks.[218] Generally, aquaculturalists assert that many previous environmental concerns have been addressed and that long-term aquaculture production relies on maintaining a clean and productive environment, an objective that environmental and fishing industry advocates also hold. Some also view offshore aquaculture as an additional means to support the domestic seafood industry, which has decreasing levels of employment in many regions. Some have noted that synergistic effects might support infrastructure and services such as docks, cold storage, and processing facilities that benefit both wild fishing and aquaculture.

Seafood imports from aquaculture production have affected seafood markets and coastal communities, such as salmon fishermen in Alaska and shrimp fishermen in the Gulf of Mexico.[219] Prices fell during the 1990s, as global salmon and shrimp aquaculture production and associated imports increased. This shift caused significant economic difficulties for Alaska salmon fishermen, processors, and communities.[220] Wild salmon prices have recovered to some extent, likely due to growing consumer differentiation between wild and cultured products. Some have responded that competition will occur with or without domestic growth in aquaculture because imports of farmed products are likely to continue and grow.[221] Other changes that have been attributed to aquaculture include accelerated globalization of the seafood industry, increased industry concentration and vertical integration, and introduction of new product forms.[222]

Marine aquaculture, especially the offshore aquaculture industry, is a small and new industry with few committed supporters and relatively little money and political influence.[223] One observer noted that, "marine aquaculture will become politically stronger as it grows—but it is difficult to grow without becoming politically stronger."[224] The industry also faces opposition from environmental and commercial fishing interests. Several developments will need to take place if offshore aquaculture can be expected to become established and grow into a viable commercial industry; these developments are discussed in the next section.

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[217] Center for Food Safety, "Fishing and Public Interest Groups."

[218] Knapp and Rubino, "Political Economics of Marine Aquaculture," p. 219.

[219] Written statement of Mark Vinsel, *Hearing on Offshore Aquaculture*, before the U.S. Senate, Committee on Commerce, Science, and Transportation, National Ocean Policy Study (April 6, 2006).

[220] Knapp, "Economic Potential," p. 175.

[221] Knapp, "Economic Potential," p. 175.

[222] Diego Valderrama and James Anderson, "Interactions Between Capture Fisheries and Aquaculture," in *Offshore Aquaculture in the United States: Economic Considerations, Implications, and Opportunities,* NOAA, NOAA Technical Memorandum NMFS F/SPO-103, July 2008, pp. 189-206.

[223] Knapp and Rubino, "Political Economics of Marine Aquaculture," p. 215.

[224] Knapp and Rubino, "Political Economics of Marine Aquaculture," p. 216.

Institutional Needs and Industry Support

Regulatory Framework for Offshore Aquaculture

Most stakeholders agree that a regulatory framework likely needs to be developed before establishing offshore aquaculture in U.S. federal waters. A potential framework would need to fulfill the government's public trust responsibilities while remaining flexible enough to take advantage of evolving technology and markets.[225] Many of the basic elements of the framework would depend on legislation providing statutory authority and requirements for leasing offshore areas, agency leadership and interagency coordination, and environmental protection. A regulatory framework could provide the industry with clear and understandable requirements for aquaculture facilities while minimizing potential environmental harm. Supporters of offshore aquaculture have advocated for a permitting and consultation process that is more timely, efficient, and orderly than the existing process. Most also agree that the regulatory process should be transparent and support public involvement.

Lead Agency

NMFS has been the lead federal agency for marine aquaculture in inshore areas and for the potential development of offshore aquaculture.[226] According to a 2008 U.S. Government Accountability Office (GAO) study, "there is no lead federal agency for regulating offshore aquaculture, and no comprehensive law that directly addresses how it should be administered, regulated, and monitored."[227] Stakeholders also have supported NOAA's role in managing federal aquaculture research, including research and development of offshore aquaculture technologies.[228]

Since publication of the GAO report, NMFS has attempted to regulate offshore aquaculture under the MSA. A recent court decision, however, cast doubt on whether NOAA has the authority under MSA to regulate offshore aquaculture. Several studies have recommended that NOAA should be granted clear authority to regulate offshore aquaculture.[229] They point out that NOAA already has authority to evaluate proposed marine activities and projects to ensure the protection of marine mammals, endangered species, and marine sanctuaries. Furthermore, NOAA is responsible for federal management of marine fisheries and essential fish habitat.

Permits and Leases

One of the needs for offshore aquaculture development is permitting or leasing of discrete ocean areas.[230] Within the EEZ, the United States has sovereign rights for the purpose of exploring,

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[225] Oceans Commission, *Ocean Blueprint, p. 332.*

[226] NOAA has played a supportive role in state waters but does not have jurisdiction to lease or regulate aquaculture in state waters.

[227] U.S. Government Accountability Office (GAO), *Offshore Marine Aquaculture*, GAO—08-594, May 2008. p. 2. Hereinafter cited as GAO, *Offshore Marine Aquaculture*.

[228] GAO, *Offshore Marine Aquaculture*.

[229] B. Cicin-Sain et al., *An Operational Framework for Offshore Marine Aquaculture in Federal Waters*, Center for Marnie Policy, University of Delaware, 2005; Oceans Commission, *Ocean Blueprint*.

[230] The terms *permits* and *leases* are used interchangeably in this report. The rights to discrete areas associated with permits or leases define their general meaning. Whether considered a lease or permit, the most important concerns are related to the rights and responsibilities granted to the offshore aquaculture developer.

exploiting, conserving, and managing natural resources, whether living and nonliving, of the seabed and subsoil and superjacent waters. The federal government grants rights to develop specific areas for specific activities in the EEZ are granted. Currently, no permitting or leasing program is specific to offshore aquaculture and leases depend on permits and consultation requirements under different laws and agencies that apply to marine activities generally.

Observers generally agree that aquaculture developers will need assurances that they will have exclusive rights via leases or permits to use specific ocean areas for agreed-upon periods.[231] A leasing system could provide aquaculturalists with clearly defined rights to ocean space including the water surface, water column, and ocean bottom. Other characteristics of a leasing system might include transferability of the lease or permit, which would allow the aquaculturalist to transfer the permit or lease and benefit from its sale or use. Stakeholders told GAO that clear rights to use specific ocean areas would be needed to obtain loans.[232] Proponents of offshore aquaculture development stress that, without some form of long-term (at least 25 years) permitting or leasing, offshore aquaculture will have problems securing capital from traditional funding sources and obtaining suitable insurance on the capital investment and stock.[233]

The Gulf of Mexico Aquaculture Fishery Management Plan (Gulf FMP) provides a 10-year site permit and 5-year permit renewals.[234] Aquaculture industry representatives have expressed concern that these intervals are too short because of the time it will take their businesses to become profitable. Environmentalists would prefer "shorter timeframes to ensure more frequent reviews and closer scrutiny of environmental impacts during the lease or permit renewal process."[235] In state waters, Maine grants 10-year leases for salmon net pen aquaculture. Hawaii grants 20-year leases for permits in its waters.

The public's primary concerns are likely to include minimizing harmful effects on environmental quality and conflicts among ocean uses. Most recognize that a leasing framework will require review of potential environmental impacts of offshore aquaculture. This review likely would require the preparation of a programmatic environmental impact statement (PEIS) with a follow-up site-specific environmental review before a facility might be established.[236] A PEIS could review potential environmental impacts of offshore aquaculture over broad areas of the ocean. Aquaculturalists generally agree that this approach would be useful if it reduced the need for facility-specific reviews.[237]

Some have suggested that permits should be issued on a case-by-case basis by determining whether a specific site is appropriate for the proposed aquaculture facility. Others oppose this approach, because it could lead to an approval process that is less consistent and it could make it more difficult for regulators to assess cumulative impacts of different facilities within a region.

231 Anderson and Shamshak, "Lessons."

232 GAO, *Offshore Marine Aquaculture*, p. 5.

233 Some nations (e.g., Canada) lease nearshore areas with implied automatic renewal of tenure as long as the lessee meets current licensing requirements.

234 NMFS, "Fisheries of the Caribbean, Gulf, and South Atlantic; Aquaculture," 81 *Federal Register* 1762-1800, January 13, 2016.

235 GAO, *Offshore Marine Aquaculture*, p. 5.

236 Bureau of Reclamation, *What is the Difference Between a Programmatic and a Project-Level Environmental Impact Statement?*, Yakima River Basin Integrated Water Resource Management Plan, November 2013,at https://www.usbr.gov/pn/programs/eis/kkc/scoping/progsite.pdf. A programmatic environmental impact statement evaluates the effects of broad proposals for planning-level decisions that may include a wide variety of individual projects.

237 GAO, *Offshore Marine Aquaculture*.

Still others have suggested that ocean planning should identify both appropriate and prohibited areas for aquaculture. Regulators could assess potential sites for permitting aquaculture before and independently of individual permit applications. Some believe that this would make permitting more predictable and consistent. For example, the likelihood of harm to marine mammals might be decreased by limiting permits for aquaculture facilities to areas with a low risk of interactions.[238] However, some aquaculturalists question whether regulators will choose the most viable sites for aquaculture.

Conditions of Use

A regulatory framework is likely to require specific conditions on the use of a site. These requirements likely will vary depending on the species and technology employed. Nevertheless, some basic requirements related to environmental quality, inspections, and other public concerns are likely to be common to many offshore aquaculture operations. The Gulf FMP includes specific requirements that could be applicable to managing offshore aquaculture in other regions. A partial list of operational requirements under the Gulf FMP includes the following:

- placing at least 25% of the facility in the water at the site within two years of issuance of the permit;
- marking each system placed in the water with an electronic locating device;
- obtaining juveniles for stocking from certified hatcheries within the United States;
- providing a health certificate prior to stocking fish at the aquaculture facility;
- complying with all FDA requirements when using drugs or other chemicals;
- monitoring and reporting environmental survey parameters consistent with NMFS guidelines,
- inspecting for interactions or entanglements of protected species; and
- allowing access to facilities to conduct inspections.

Some have recommended requirements for aquaculture facility plans to address potential contingencies, such as fish escapes from aquaculture facilities. Some representatives of fishery management councils supported marking or tagging hatchery fish as a potential means of tracking escaped organisms. However, some have questioned whether the added costs of marking fish are warranted and contend that tagging requirements should depend on the level of associated risk to natural resources.

Monitoring could also be required to track interactions with marine life and other changes to the environment. State regulators in Maine and Washington have developed monitoring requirements for net pen salmon aquaculture, such as monitoring the benthic community under net pens. Both states also require notification of disease outbreaks and can require specific mitigation measures depending on the severity of the outbreak. Federal monitoring requirements could be informed by state experiences and modified as better information becomes available. The Gulf FMP includes reporting requirements for stocking, major escapement, pathogen episodes (disease), harvest, change of hatchery, marine mammal and sea bird entanglement, and other activities or events.

Aquaculture facilities in offshore areas would occupy areas that may be used for other ocean uses, such as oil and gas development, wind and tidal energy, maritime transportation, and commercial and recreational fisheries. Some have recommended that "development of a national aquaculture

[238] GAO, *Offshore Marine Aquaculture*, p. 24.

management framework must be considered within the context of overall ocean policy development, taking into account other traditional, existing, and proposed uses of the nation's ocean resources."[239] If conflicts develop over access to particular areas, a process would need to be developed to identify suitable areas in federal waters for aquaculture development and/or to mediate disputes. For example, commercial and recreational fishermen may have concerns regarding access to areas they have fished historically and potential interactions of cultured and wild fish. Some ocean managers have suggested that overlaying maps of different jurisdictions, ocean uses, and conditions favorable to aquaculture would be useful in avoiding user conflicts.[240]

Other Management Entities

As a regulatory framework for offshore aquaculture is developed, it could be enhanced by improving coordination and cooperation among federal, state, territorial, and tribal entities. Existing groups, such as the Subcommittee on Aquaculture, have provided a means for communication among federal agencies that might be used to enhance federal coordination of offshore aquaculture development and management.

The fishery management councils established under the MSA likely would have a role in offshore aquaculture development. Each of the eight regional councils develops FMPs for wild marine fisheries within its particular region. These plans are then sent to NMFS for approval and implementation. Historically, fishery management councils have had a role in considering whether to support offshore aquaculture in federal waters. In addition to the Gulf of Mexico FMP for aquaculture, several exempted fishing permits were issued for limited periods to investigate potential aquaculture development in federal waters off New England. Potential interactions with wild fisheries and harm to essential fish habitat and wild fish populations are likely to be fishery management councils' main concerns.

In addition to consultation requirements under the Coastal Zone Management Act, the state role in developing a regulatory framework for offshore aquaculture may deserve additional consideration. Some stakeholders support an opt-out provision allowing states to refuse development in federal waters adjacent to state waters. Others suggest that the opt-out provision should apply only within a certain distance of shore (such as 12 nm).[241] In response to earlier proposed legislation, NOAA supported a 12 nm distance to provide states with a buffer zone and simplify the difficulties of projecting state boundaries out to 200 nm.[242] Harmonizing aquaculture regulations with adjacent states could provide an advantage to future development, because states would be in a position to limit or promote offshore aquaculture development.

Federal Support for Offshore Aquaculture

Some assert that federal government assistance would be needed to promote the initial development of a U.S. offshore aquaculture industry. Assistance could range from general support of research to direct support of industry needs, such as finance. One argument in support of government assistance is that, in comparison to relatively well-known agriculture sectors such as

[239] Oceans Commission, *Ocean Blueprint*, p.333

[240] Carol S. Price and Jessica Beck-Stimpert, *Best Management Practices for Marine Cage Culture Operations in the U.S. Caribbean*, NOAA, GCFI Special Publication Series Number 4, 2014.

[241] GAO, *Offshore Marine Aquaculture*.

[242] Projecting state zones in the northeastern United States could be problematic because of the number and geography of coastal states in the region.

animal husbandry, there are more uncertainties associated with offshore aquaculture.[243] With the exception of Atlantic salmon, culture of most marine finfish is still at a relatively early stage of development. Development of offshore aquaculture is likely to require new culture techniques for rearing species not presently cultured. For this reason, the U.S. Oceans Commission recommended more assistance for aquaculture generally and an active government role to foster industry development.

Stakeholders identified federal research needs in four areas:[244]

- developing fish feeds that do not rely on harvesting wild fish;
- developing best management practices;
- exploring how escaped offshore aquaculture-raised fish might impact wild fish populations; and
- developing strategies to breed and raise fish while effectively managing disease.

In addition to improving culture techniques, further research of interactions between aquaculture and the environment and potential harm to specific species and ecosystems could inform decisions related to site selection and monitoring needs.

A remaining question is which agency or agencies will provide the support needed for offshore aquaculture development. Some may question whether NOAA has adequate institutional experience with aquaculture or whether additional resources are needed to provide adequate program management and services. Some NOAA programs support the fishing industry, but none focus specifically on offshore aquaculture. Similarly, USDA administers a number of programs that support agriculture in areas such as finance, research, extension, market development, and disaster assistance, but none are specifically focused on offshore aquaculture. Legislation in the 116th Congress to support offshore aquaculture may address whether and how NOAA and/or USDA programs could be adapted to the needs of offshore aquaculture, which is the appropriate agency to manage specific programs, and what level of federal support is appropriate.

Potential Issues for Congress

Currently, development of offshore aquaculture appears unlikely because of regulatory, technical, and economic uncertainties. One of the main issues for Congress is whether legislation can be developed that could provide the industry with greater regulatory certainty while assuring other stakeholders that environmental quality can be maintained and other potential conflicts minimized. Research and development of inshore facilities have shown that offshore aquaculture is technically feasible but have not shown whether moving facilities to offshore areas would be profitable. It is likely that the investment required for commercial development of offshore aquaculture facilities will depend to some degree on greater regulatory certainty. For example, one business that was developing offshore aquaculture in Puerto Rico has moved its operations to Panama; according to the owner, U.S. regulations made expansion impossible.[245]

Aquaculturalists and investors are likely to require secure property or leasing rights and clear regulatory requirements before investing in large-scale operations. Stakeholders with concerns

[243] Some would argue that this is also true for most inshore and freshwater species. Only freshwater finfish, such as catfish, salmon, and trout, and oysters in estuarine waters have been cultured extensively in the United States.

[244] GAO, *Offshore Marine Aquaculture*.

[245] Eva Tallaksen, "Deep-Sea Cobia Producer Gears up for Full-Scale Launch," *Under Current News*, March 22, 2013, at https://www.undercurrentnews.com/2013/03/22/deep-sea-cobia-producer-gears-up-for-full-scale-launch/.

that aquaculture will degrade the environment also may need assurances that adequate regulation, inspections, and enforcement will be required features of a regulatory program. These concerns have been reflected in several aquaculture bills that would prohibit offshore development until comprehensive legislation is enacted.

Previous congressional actions, such as hearings and bills, have concentrated on several areas, which include

- providing institutional support for aquaculture, such as planning, research, and technology transfer;
- identifying a lead agency to administer and coordinate aquaculture development and regulation;
- establishing and streamlining permit and consultation requirements to improve the efficiency of the permitting process;
- developing processes to consult and communicate with other stakeholders to reduce user conflicts; and
- minimizing environmental harm and addressing environmental concerns through planning and monitoring.

If aquaculture is developed in the EEZ, most stakeholders likely would agree that there is a need for better coordination, clear regulation, and focused agency leadership. Some assert that congressional action will be necessary to support both commercial development and environmental protection.

Congressional Actions

Congress has made several attempts to pass offshore aquaculture legislation, including bills in the 109th, 110th, 111th, 112th, and 115th Congresses, but none of these bills were enacted. Bills also were introduced that would have prevented aquaculture development in federal waters until statutory authority for offshore aquaculture development is enacted. While many stakeholders continue to call for federal legislation, it has been difficult to find a common vision among them for future development of an offshore aquaculture industry.

116th Congress

In the 116th Congress, no comprehensive offshore aquaculture legislation has been introduced, but several bills have been introduced that are related to offshore aquaculture and aquaculture generally. The Keep Finfish Free Act of 2019 (H.R. 2467) would prohibit the issuance of permits to conduct finfish aquaculture in the EEZ until a law is enacted that allows such action. The Commercial Fishing and Aquaculture Protection Act of 2019 (S. 2209) would amend the MSA to provide assistance to eligible commercial fishermen and aquaculture producers.[246] Assistance could be provided when an eligible loss occurs due to an algal bloom, freshwater intrusion, adverse weather, bird depredation, disease, or another condition determined by the Secretary of Commerce. Other bills include the Prevention of Escapement of Genetically Altered Salmon to

[246] An eligible commercial fisherman and farm-raised fish producer generally are described as an individual or entity that assumes production and market risks associated with harvesting fish (fisherman) or production of fish in a controlled environment (farm-raised fish producer) for commerce. The term *fish* would include shellfish, finfish, and other aquatic organisms harvested with the intent of entering commerce.

the United States Act (H.R. 1105) and the Shellfish Aquaculture Improvement Act of 2019 (H.R. 2425).

115th Congress

In the 115th Congress, the Advancing the Quality and Understanding of American Aquaculture Act (AQUAA Act; S. 3138 and H.R. 6966) would have established a regulatory framework for aquaculture development in federal waters.[247] The bills would have provided NMFS with the authority to issue aquaculture permits and to coordinate with other federal agencies that have permitting and consultative responsibilities. They also would have identified NOAA as the lead federal agency for providing information on federal permitting requirements in federal waters.

S. 3138 and H.R. 6966 would have required the Secretary of Commerce to develop programmatic environmental impact statements for areas determined to be favorable for marine aquaculture and compatible with other ocean uses. Section 9 of the bills stated that it would not supersede the requirements of the National Environmental Policy Act of 1969 (NEPA) and that individual projects may require additional review pursuant to NEPA.[248] The bills would have required the Secretary of Commerce to consult with other federal agencies, coastal states, and fishery management councils to identify the environmental and management requirements and standards that apply to offshore aquaculture under existing federal and state laws. The bills also identified 10 standards that should be considered for offshore aquaculture and applied when issuing permits conducting programmatic environmental impact statements. These standards included other ocean uses, conservation and management of fisheries under the MSA, and minimizing adverse impacts on the marine environment, among others.

S. 3138 and H.R. 6966 would have provided institutional support of offshore aquaculture by establishing the Office of Marine Aquaculture within NOAA. The Office of Marine Aquaculture would have been responsible for coordinating NOAA activities related to regulation, scientific research, outreach, and international issues. The Office of Marine Aquaculture would have replaced the current Office of Aquaculture, which conducts activities that are similar to those proposed by the bills.[249] The bills also would have made NOAA the lead agency for establishing and coordinating a research and development aquaculture grant program

A bill was also introduced (H.R. 223) that would have prohibited the issuance of permits to conduct finfish aquaculture in the EEZ except in accordance with a law authorizing such action. Similar bills also were introduced in earlier Congresses to stop offshore aquaculture development in the EEZ.

Congressional Actions Prior to the 115th Congress

Offshore aquaculture bills also were introduced in the 109th, 110th, 111th, and 112th Congresses.[250] Generally, these bills focused on establishing a regulatory framework to develop offshore aquaculture in federal waters of the EEZ. The bills varied to some degree on the balance between the potential rights and responsibilities of aquaculturalists, especially between aquaculture development and environmental protection. For example, S. 1195 (109th Congress), and H.R. 2010 and S. 1609 (110th Congress) would have supported production of food, encouraged

[247] H.R. 6966 is nearly identical to S. 3138 and was introduced in the House near the end of the 115th Congress.

[248] 42 U.S.C. §§4321 et seq.

[249] NMFS, NOAA Office of Aquaculture, at https://www.fisheries.noaa.gov/about/office-aquaculture.

[250] Bills included S. 1195 (109th Congress), S. 1609 and H.R. 2010 (110th Congress), H.R. 4363 (111th Congress), and H.R. 2373 (112th Congress).

development, established a permitting process, and promoted research and development of offshore aquaculture. In contrast, H.R. 4363 (111th Congress) and H.R. 2373 (112th Congress) would have focused to a greater degree on potential impacts of offshore aquaculture. These bills stressed elements such as determining appropriate locations, issuing regulations to prevent impacts on marine ecosystems and fisheries, and supporting research to guide precautionary development of offshore aquaculture.

Other bills that would have constrained offshore aquaculture development were introduced in the 108th, 109th, 110th, 112th, 113th, and 114th Congresses. Most of these bills would have prohibited the issuance of permits for marine aquaculture facilities in the EEZ until requirements for issuing aquaculture permits are enacted into law.[251]

Conclusion

The United States is the largest importer of seafood products in the world, and nearly half of domestic seafood imports are produced by aquaculture. Aquaculture development and production in the United States have lagged behind other countries due to a variety of factors, such as relatively inexpensive imports, regulatory policies, user conflicts, and higher costs of production. Some have speculated that marine aquaculture facilities could be developed farther offshore in federal waters, where they would be subject to fewer user conflicts and have space to operate in relatively clean ocean waters. However, movement to offshore areas also would involve several significant challenges, such as establishing a regulatory framework, developing new technologies, and competing with other existing sources of seafood.

According to many stakeholders and researchers, the lack of a governance system for regulating offshore aquaculture hinders the industry's development in the United States. Development of marine offshore aquaculture would likely require a new regulatory framework for establishing offshore aquaculture in federal waters.[252] A regulatory framework potentially could provide the industry with clear requirements for its development while minimizing potential environmental harm. It remains an open question whether legislation could be crafted to achieve a balance between providing the certainty sought by potential commercial developers of aquaculture and satisfying environmental and other concerns of stakeholders such as environmentalists and fishermen.

While a new regulatory framework potentially could provide greater certainty to offshore aquaculture developers, other challenges would remain. For example, offshore aquaculture may involve higher costs and greater risk of losses associated as compared to inshore operations. Lack of experience operating in offshore areas and limited knowledge of culture techniques for many candidate marine species contribute to the financial risk of offshore aquaculture. Some observers expect that offshore aquaculture may occur incrementally as inshore areas are developed and culture techniques are refined. Federal support may be needed for finance, research, extension, market development, and disaster assistance, similar to USDA support of agriculture.

[251] Examples include S. 2859 (108th Congress), S. 796 (109th Congress), S. 533 and H.R. 7109 (110th Congress), H.R. 574 (112th Congress), H.R. 753 (113th Congress), and H.R. 331 (114th Congress).

[252] B. Cicin-Sain et al., *An Operational Framework for Offshore Marine Aquaculture in Federal Waters,* Center for Marine Policy, University of Delaware, 2005.

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