Social Constraints and Solutions for the Development of the Nation's Offshore Aquaculture Industry

Final Technical Report: Short version

Background: It is widely recognized that levels of production in the world's capture fisheries are not likely to increase substantially in the years to come, and that marine aquaculture has the potential to provide a reliable source of seafood. Currently, aquaculture comprises over 40% of seafood production worldwide; 30% of aquaculture is composed of mariculture[1] (Food and Agriculture Organization of the United Nations 2012).

There are many economic, social and ecological benefits associated with developing the nation's marine aquaculture industry. Marine aquaculture can reduce dependence on imports, increase national seafood self-sufficiency, supplement the economies of commercial fishermen, reinvigorate working waterfronts, support seafood producing and distributing infrastructure, and create new jobs. The development of the industry would increase the supply and year around availability of a healthy food choice. Marine aquaculture can reduce fishing pressure on wild fish populations and reduce the demand on land and fresh water resources. Recent scientific findings indicate that the feed conversion ratios (the ratio of pounds of food fed to the animal to the number of pounds of animal harvested) of fish are generally much lower those of chicken, pork, and beef suggesting that aquaculture is an efficient form of protein production (cf. Hall et al. 2011). The consumption of locally produced seafood would also replace the need to transport seafood caught or farmed abroad and thus has the potential to reduce carbon footprint of our seafood.

Federal agencies, universities, and entrepreneurs have actively promoted the development of marine aquaculture in offshore[2] environment as a way to reduce many of the challenges that have been associated with marine aquaculture in coastal waters. These challenges include: space use conflicts; aesthetic concerns expressed by contiguous landowners and residents; and environmental problems associated with human land activities. Offshore waters also hold promise for increased fish growth and improved health while being more suitable for ocean species that also offer higher market values. Additionally, according to a recent global assessment of offshore aquaculture potential, the Unites States ranks high. The United State's Exclusive Economic Zone (EEZ), over which the nation has exclusive rights of resource extraction, is the second most expansive in the world. The US EEZ ranks 1st, 3rd, and 4th in size in terms of the important siting criteria of cost effectiveness, current speed, and depth (Kapetsky

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[1] Mariculture refers to the breeding, raising, and harvesting of marine species in onshore facilities or in the ocean.

[2] The terms offshore and open ocean aquaculture are frequently use interchangeably to refer to aquaculture that is conducted in waters that are unsheltered by land and exposed to high energy wind and wave environment. For the purpose of our report, we use the term offshore to refer to the area beyond coastal jurisdictions but within a nation's Exclusive Economic Zone, and as such, is regulated primarily by federal agencies. The offshore designation encompasses areas from three miles to 200 miles from the shore, with the exception of Florida and Texas where state rights extend to nine miles offshore.

et al. 2013). Additionally, the US EEZ contains a wide range of ocean ecosystems, including high Arctic, subarctic, temperate, subtropical, and tropical.

The benefits and liabilities of offshore aquaculture as a way to contribute to the United States' seafood demand have, however, been a subject of intense public debate and political contestation. To date, concerns regarding the industry's potential impacts to marine ecosystems, capture fisheries, and other ocean users have limited the development of aquaculture in state waters and stalled the implementation of regulations for the conduct of aquaculture activities within federal waters. The topical focus of this research is based on the recognition that an in-depth social science research effort could improve the understanding of:
(1) the issues around which public debate are focused;
(2) the policies and practices of those agencies that have regulatory authority over offshore aquaculture; and
(3) socioeconomic factors influencing the development of an offshore industry.

Project Goal: The research has been designed to analyze social factors that are constraining the development of an offshore aquaculture industry and to identify strategies that could mitigate such constraints. The study is being conducted to provide the National Oceanic and Atmospheric Administration (NOAA), Sea Grant, other public sector agencies, and non-governmental organizations with important descriptive information and analysis of expert perspectives. It is hoped that findings will assist formal policy deliberations on the future of the offshore aquaculture industry.

Study Objectives: The primary study objectives are:
(1) to determine the current status of federal and state regulatory policies regarding offshore aquaculture and identify state and federal resource management agency information needs in order to develop a legal and effective regulatory structure;
(2) to identify the primary social constraints on the progressive development of the industry– as envisioned or experienced by key industry representatives, involved public officials, and other concerned persons and groups. These constraints include matters of policy; economic challenges or impacts; technical problems; opposing cultural perspectives; competition for ocean space; and manageable ecological impacts; and
(3) to ascertain how principal social constraints identified in (2) above might be obviated to enable development of the offshore industry.

Research Methods: This research uses a case study approach focusing on three areas/regions of Hawaii, Southern California and Gulf of Maine. A multi-regional focus was chosen to facilitate understanding of geographic variability and overarching social context, as well as inform industry participants about approaches used in areas other than those with which they are most familiar. The regions were chosen due to their varying degrees of involvement in marine aquaculture research and commercial production and the reported potential for offshore aquaculture development.

Findings contained in this final technical report are based on data gathered through:

(1) ethnographic field visits to California, Hawaii, and the Gulf of Maine region;

(2) ongoing research interaction with over 100 key respondents within the field of aquaculture research, the aquaculture industry, and regulatory agencies involved in permitting and/or promoting aquaculture in state and federal waters;
(3) literature review of technical reports, legislative hearings, and aquaculture workshop proceedings, scientific journal articles on environmental impacts and best management practices, amongst others.

Study Results: This report covers the following topics: current regional and local management approaches for offshore aquaculture; characterization of each case study area for the development of offshore aquaculture; the involvement of non-governmental organizations (NGO) in the development of marine aquaculture in United States; siting criteria for offshore aquaculture operations and status of coastal marine spatial planning; and overview of challenges and solutions for the development of offshore aquaculture. Readers are encouraged to refer a long version of this report for more detailed information.

Legislative and Regulatory Trends: Multiple laws extend federal authority to regulate offshore aquaculture across multiple agencies, including the National Marine Fisheries Service, United States Army Corps of Engineers, United States Coast Guard, Environmental Protection Agency, Bureau of Ocean Energy Management, Fish and Wildlife Services, Food and Drug Administration, and Department of Agriculture. These agencies have different primary functions of regulating, monitoring, researching, and assisting the industry and have different interests in offshore aquaculture regarding: siting and permitting of projects, issuing offshore leases, mitigating environmental impacts and user conflicts, and ensuring food safety. The National Marine Fisheries Services, within NOAA, has an extensive role, interest, and expertise in commercial and recreational use of the ocean and conservation and protection of marine resources. As such it has been identified in major reviews of US ocean policy as the most suitable federal agency to create and oversee a public permitting process.

Regional regulatory agencies—such as the regional fishery management councils[3]—and state agencies also have an interest in regulating and managing the developing offshore aquaculture industry. The Coastal Zone Management Act confers to states the authority to undertake a federal consistency review for operations sited in federal waters that may potentially impact state waters and/or adjacent coastal lands.[4]

During the past decade, there have been various unsuccessful attempts at the legislative level to clarify a national regulatory framework. Legislation failed to pass because of a lack of agreement regarding: the potential benefits and impacts of marine aquaculture; best ways to ensure the mitigation of environmental problems and negative socioeconomic impacts; and necessary conditions to ensure commercial feasibility. With no overarching legislative framework for guidance, federal and state entities have approached the regulation of the developing industry in a number of ways.

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[3] Fishery management councils are quasi-regulatory bodies that develop fishery management and conservation measures for the EEZ. These measures are then implemented by NOAA's National Marine Fisheries Service. There are eight regional fishery management councils.

[4] Final decisions regarding a state's rights of review remain in the hands of the Secretary of Commerce who can override a state's objections if a project is deemed consistent with objectives of the Federal Coastal Management Act, or is in the interest of national security.

Gulf of Mexico Fishery Management Council Plan for Offshore Aquaculture. Beginning in 2004, the Gulf of Mexico Fishery Management Council began developing guidelines whereby aquaculture could be permitted at a commercial scale in the federal waters of Gulf of Mexico. Currently the draft rules are being reviewed by the public and by various federal agencies that have regulatory authority over aquaculture. NOAA foresees initiation of the permit application process in 2016, at the earliest. The legality and workability of the provisions will become more apparent as aquaculture companies submit applications and the Plan is subsequently contested by conservation organizations.

Of note, the Plan does not obviate the necessity for applicants to meet requirements for other permits from, for example, the Army Corps of Engineers and the Environmental Protection Agency, and to abide by the regulations and/or reporting requirements of other agencies. The Plan, if enacted, represents a necessary step toward permitting offshore aquaculture of federally managed species but does not create a streamlined one-stop permitting process. The Plan provides one model through which other regional management councils may pursue permitting and regulating offshore aquaculture.

The proposed rules pertain to federally managed species native to the Gulf —not including corals, shrimps, or any endangered or threatened species —and to operations sited in federal waters. The rules would permit an individual operator to harvest up to 12.8 million pounds (approximately 5.8 metric tons) annually and a total annual harvest for the Gulf of Mexico of 64 million pounds (approximately 29,000 metric tons). Initial permits are valid for 10 years and renewals are for five years.[5]

Respondents in the industry and research sector, regulatory agencies, and NGOs within our case study regions have expressed differing concerns regarding the Gulf of Mexico Fishery Management Plan for Regulating Offshore Marine Aquaculture and the possible ramifications for the development of aquaculture in other regions. For example, the NGO Environmental Law Institute has recommended the following modifications be made to the Gulf Plan (cf. Emmett Environmental Law and Policy Clinic et al. 2014):

- requirement that all stock juveniles are first generation of brood stock that are collected for each "spawning event";

[5] Various alternatives were considered in regards to: permissible species and types of aquaculture systems; permit duration; siting and zoning restrictions; recordkeeping and reporting requirements; and maximum total industry and individual production capacity. The proposed permit length was established at 10 year with a five year renewal versus various alternatives in order to: encourage industry development and sustainability; preclude the long-term exclusion of others from the permit area; and establish periodic permit review. The particular species proposed for permitting were decided on the basis of biological suitability for offshore aquaculture and the need to maximize the economic benefit of offshore aquaculture to the industry and nation while also minimizing any detrimental economic impacts to fishermen that could potentially result from overt competition in the marketplace. The limit of 12.8 million pounds was decided on in recognition of: the need for individual operators to achieve an appropriate economy of scale and the benefit of encouraging market competition within the offshore industry. Rules regarding aquaculture systems were based on the recognition of: the rapid rate of technological innovation in cage systems; permit holders' need to use the most economically beneficial and suitable systems; and the importance of reducing detrimental environmental impacts. Siting criteria were established in recognition of: industry needs for flexibility in determining economically feasible locations; potential impacts to other marine users, specifically commercial and for-hire fishing businesses; and conservation priorities.

- establishment of numerical guidelines for optimal yields and allowable "catch" limits that are scientifically based in reference to biological and ecological factors;
- expansion of the range of environmental impacts under permit review to include: the impact of operational design and location on the environment and on all organisms and habitats – not just those that are endangered, protected, or essential;
- increase environmental protection from that of "likely significant risk" to a standard of lower probability
- increase in the scope and specificity of monitoring and reporting requirements and remedial actions available to the NMFS regional administrator;
- establishment of shorter term permit length for novel technologies;
- increase financial guarantees to cover natural resource damages; among others;
- expansion of permissible farm species to include shellfish currently managed at the state level

On the industry side, the primary concerns relate to: permit duration; individual and total harvest limits; the establishment of restricted zones around aquaculture operations; prohibition against siting in marine protected areas; limitations on the use of stock that have been selectively breed; and prohibitions against all genetic modifications (cf. CUSP 2014; Ocean Stewards Institute 2014). Additionally, there have been calls for clarification of the Council's intent to utilize wild stock thresholds to determine the impact of offshore aquaculture and on criteria for permit renewal.

Industry respondents in Hawaii and California reported that current permit durations are too short and harvest limits are too low to attract investment interest and support the capitalization needs of an operation in federal waters. The ten year permit length coupled with a lack of clear criteria for renewal reportedly may lead companies to overcapitalize to maximize profit in the short term rather than be motivated by long term environmental and economic sustainability. The Coalition of U.S. Seafood Production (CUSP), an organization of aquaculture industry stakeholders, has recommended: initial permit duration of ten years be abolished or be extended to twenty years; renewal permit duration be extended from five to ten years; and current individual harvest limits be abolished. The Ocean Stewards Institute, a trade organization for the open ocean aquaculture industry, has similarly recommended removing individual harvest limits or expanding them to a minimum of 20 million pounds, and extending and/or and removing limits on the duration of renewed permits. Additionally, the Institute has expressed concerns that the establishment of restriction zones around aquaculture facilities may increase opposition from fishermen. The Institute recommends that access to permit area should be decided on a case-by-case basis, in consultation with the fishing sector, and taking into consideration the operational configuration of the farm and production constraints. The Institute also objects to the Plan's prohibition of siting aquaculture operations in all marine protected areas noting that aquaculture operations may result in ecosystem benefits congruent with the goals of marine protected areas.

Respondents in aquaculture research, the industry, and staff in aquaculture development programs have expressed concerns about the Plan's brood stock requirements. Selective breeding is essential to improving growth efficiency, feed conversion rates, stock health, and stock suitability for farm conditions.

Fishery Management Plans in other regions. New England and Western Pacific Fishery Management Councils have also developed management approaches to offshore aquaculture. Currently the New England Fishery Management Council has an "abbreviated framework adjustment process" whereby aquaculture of species currently under management can be permitted through an amended fishery management plan. The Western Pacific Fishery Management Council has amended their fishery management plans to enable the permitting of aquaculture cages and other infrastructure as a gear type. To date, no commercial projects have been proposed in either region that would require a federal permit and as such the processes have not yet been tested.

The advancement of offshore shellfish aquaculture in federal waters off California and Massachusetts. In 2014, three shellfish farms sited in federal waters off California and two off the coast of Massachusetts; one in Nantucket Sound and one off of Rockport were permitted. The process by which and requirements associated with the offshore shellfish farms in California and Massachusetts differ. The California project underwent a federal consistency review by the California Coastal Commission in addition to the review process conducted by the Army Corps of Engineers. Neither projects sited in federal waters of Massachusetts were required to undergo a federal consistency review, although the state did request the conduct of a review.

In California, a proposed project for the cultivation of Mediterranean mussels *(Mytilus galloprovincialia)* and Pacific oysters *(Crassostrea gigas)*, non-native but commonly cultivated and well-established species in the region, by moored long-line technology was approved by the Army Corps of Engineers and California Coastal Commission in January 2014. The requirements, established by California Coastal Commission, for the former farm include: Monitoring Program; Wildlife Entanglement Minimization Plan; Gear Compensation Program; Letter of Credit (for $100,000 to ensure removal of any farm structures); Marine Debris Management Plan; and a Spill Prevention and Response Plan prior to the commencement of construction. The Monitoring Program assesses potential changes in the benthos and water column and includes consideration of biotic, infaunal, epifaunal, marine animal, and human communities in the project area.

The two aquaculture operations proposed for federal waters offshore of Massachusetts are for the long-line cultivation of blue mussels (*Mytilus edulis)*, a native shellfish species. The operations sited for Nantucket Sound was approved in August 2014; an operation sited offshore of Cape Anne in early 2015. Requirements for the longline mussel operation sited for federal jurisdiction waters off Massachusetts are fewer and reportedly less onerous and focus primarily on strategies to mitigate the potential entanglement of marine mammals.

Respondents expressed various concerns regarding the permitting and monitoring requirements established by the California Coastal Commission. Of particular note, researchers with expertise in shellfish aquaculture in California and New England assert that the monitoring requirements and requirements for handling marine debris (fouling organism and other biological material) have arisen from invalid concerns and will impose inappropriate if not impossible conditions for the operator. Respondents also report that video and in-water (SCUBA) monitoring required as part of the Commission's Wildlife Entanglement Minimization Plan is costly and unnecessary and have recommended instead the use of sonar equipment, standard equipment in commercial fishing vessels. Industry respondents in California have expressed concerns that the

Commission's permitting and monitoring requirements shall establish a precedent for future projects proposed for federal jurisdiction waters off California and/or be retroactively applied to the existing open ocean farm in state waters. Staff within state agencies and NOAA's Office of Aquaculture noted that permit and monitoring requirements will result in considerable amount of data that staff within the requesting will agency (the California Coastal Commission) will be required to manage.

The advancement of finfish aquaculture in federal waters off Hawaii and California. In Hawaii, two offshore research and development operations have been permitted by the National Marine Fisheries Service through a one year Special Coral Reef Ecosystem Fishing Permit (SCREP). The Velella Beta project initiated in 2011 tested cage operations and grow out results for an untethered aquapod. The Velella Gamma project initiated in 2013 tested the use of a single moored pen. At the time of this writing, the firm is applying for a third one year SCREP permit. In addition, they are planning to apply for a commercial permit to farm mahi-mahi. Reportedly, the species will not require a permit from the National Marine Fisheries Service.

In October 2014, Hubbs-Sea World Research Institute in partnership with US based aquaculture investment firm Cuna del Mar submitted a permit request to the Army Corps of Engineers, the Environmental Protection Agency, the California Coastal Commission, and NOAA for a commercial scale project in federal waters off Mission Bay, San Diego. The Rose Canyon Fisheries Sustainable Aquaculture Project proposes to farm white seabass (*Atractoscion nobilis*), striped bass (*Morone saxatilis*), and/or California yellowtail (*Seriola lalandi*). The project has been designed to examine the environmental and economic sustainability of finfish open ocean aquaculture in the region and will assist government agencies, key decision makers, scientists, and the public to develop national guidelines for offshore aquaculture. The NEPA review required of the project will also provide a record of the permitting process that may serve as a template for future applicants elsewhere in federal jurisdiction waters.

The development of the Gulf of Mexico Fishery Management Plan for Offshore Aquaculture, recent permitting of two offshore shellfish farms, and the recent submission of two applications for offshore finfish aquaculture operations suggests that federal policy guidance is being clarified and implemented to achieve the development of some forms of offshore aquaculture.

Of note, the advancement of the offshore industry is occurring through different regulatory approaches. The creation of a FMP in the Gulf of Mexico "frontloads" the informational effort required to regulate and permit offshore aquaculture by considering general impacts, weighing regulatory alternatives, and establishing general mitigation measures. The creation of the FMP did not necessitate the existence of a particular proposed operation but required considerable commitment of staff time and labor on the part of the agencies. The resulting plan will serve as an education document for regulatory agencies, and will lessen the burden on the individual project applicant to provide information. (The conduct of programmatic environmental impact reports or studies (PEIR/S) can serve a similar function).

In contrast to the establishment of FMPs, the promotion of demonstration or commercial projects, as in the case of the shellfish farms sited for federal jurisdiction waters of California and Massachusetts, creates an ad hoc agency response. The initial applicant has the burden of negotiating the regulatory process. The successfully permitting of an aquaculture operation can,

however, provide a template and timeline for future applicants and may set a precedent for future (similar) operations.

Characterization of Case Study Areas for the Development of Offshore Aquaculture:

California. Key respondents noted the suitability of the Southern California Bight for offshore aquaculture in terms of oceanic conditions, regional expertise in finfish and shellfish aquaculture, and availability of coastal support infrastructure. To date, applicants who have proposed projects within federal waters have noted the following challenges: the costs to fulfill permitting requirements; overlapping regulatory jurisdictions with redundant review processes; limited experience by agency staff permitting operations; lack of agreement on a set of environmental factors that must be required for baseline studies and monitoring; and lack of a lease structure for federal waters.

Hawaii. Key respondents noted the suitability of Hawaii for aquaculture development in federal jurisdiction waters in terms of the presence of: regional expertise in open ocean aquaculture; public and private hatcheries; research in and development of advanced cage technology; state economic incentives; and market conditions. Respondents in the aquaculture industry report the following challenges for the development of open ocean aquaculture in both state and federal jurisdiction waters: oceanographic conditions; limited availability of coastal support infrastructure; and "unrealistic" environmental monitoring requirements required for deepwater projects.

Gulf of Maine. Key respondents noted the suitability of Gulf of Maine for offshore aquaculture in terms of: presence of aquaculture research programs; existing well-developed coastal aquaculture industry; expertise in permitting and management of aquaculture operations in state waters; aquaculture training programs for the commercial fishing industry; and high market demand for fresh seafood. The primary constraints for the development of offshore aquaculture in the Gulf of Maine reportedly arise from challenging ocean and weather conditions and attending scale requirements and financial demands, particularly for finfish aquaculture. In addition, respondents report challenges related to siting projects to avoid other user conflicts, including marine mammals, and increasing competition for access to limited waterfront facilities.

Our research reveals not only that the potential for development of offshore aquaculture differs by region but that the drive to develop offshore aquaculture is originating from different kinds of parties. In the Gulf of Maine, the advancement of offshore aquaculture is currently being driven by aquaculture researchers associated with local universities and colleges who are working with commercial fishermen. The species, technologies, and (small) scale of operations that are the focus of attention are seen as compatible with the equipment, skill sets, and lifestyles of commercial fishermen. In Southern California, proposals for offshore aquaculture operations have been submitted by a private entrepreneur and a non-profit research institute working in partnership with an aquaculture investment firm. Proposals are for the eventual establishment of large scale operations. In Hawaii, interest in the expansion of commercial scale aquaculture operations in federal waters is from member of aquaculture industry with extensive experience in hatchery technology and finfish net-pen aquaculture. Operations sited for federal waters utilize advanced submersible cage and single mooring technology. Table One at the end of this

document provides a comparative assessment of the three case study areas for the potential near term development of offshore aquaculture.

Of note, aquaculture firms in our study regions are currently focusing on species that do not require a federal permit through the council process from NMFS. These species include: white seabass, California yellowtail, blue mussels, Olympia oysters, Pacific oysters, Mediterranean mussels, and mahi-mahi.[6]

Non-government Organizations and the Development of Marine Aquaculture:
Environmental concerns expressed/reported by NGOs regarding marine aquaculture generally have centered on impacts to: (1) water quality and benthic communities due nutrient pollution and chemical use; (2) wild fish stock due to disease transmission from farmed stock, competition from escapes, use of wild forage species in aquaculture feed; and use of broodstock; and (3) marine mammals due to entanglement or siting of operations in important feeding or breeding areas.

NGOs have utilized a number of different strategies to seek redress for environmental problems associated with marine aquaculture and influence the development of the industry within the United States. These strategies include: litigation directed at regulatory agencies or individual companies; lobbying for or against legislation; grass root activism directed at proposed aquaculture operations; and a market-based approach.

Of the twenty organizations considered as part of this study, eight showed a distinct preference for self-contained (land-based) re-circulating aquaculture system (RAS) technology that treat and/or re-use waste. Ten organizations acknowledged the need for and acceptability of some form of open ocean aquaculture. Nine of these organizations showed preferences for integrated multi-trophic aquaculture (IMTA) or polyculture systems. Seven organizations expressed preferences for shellfish and/or kelp. Shellfish and kelp extract nutrients from the environment and do not require the addition of feed and thus are perceived as having a lower environmental impact. Four organizations promote traditional land based aquaponic and coastal fish ponds as the future of aquaculture. Six organizations reported preferences for the farming of herbivore or omnivore species to reduced reliance and impact on wild fish food sources. One organization favors the use of only sustainably grown plant based food sources or use of trimmings from seafood processing. One organization opposes the use of any soy based feeds, due to concerns with potential food safety issues related to GMO soy.

Technological and management improvements developed by the industry and researchers combined with changing understandings of: seafood supply and demand; energy requirements of various food production systems; food security issues related to climate change and increasing water shortage; and national health crisis are encouraging some NGOs to re-consider previous positions on marine aquaculture (cf. Hall et al. 2011; Monterey Bay Aquarium 2011). In the context of growing concerns about illegal fishing, aquaculture is also being considered as a possible method of preventing seafood fraud. Additionally, NGOs are considering the potential

[6] Although mahi-mahi is a federally managed species, harvesting does not reportedly require a permit.

positive eco-system impact of aquaculture for creating habitat in open ocean environments and improving water quality in coastal waters. United States is being recognized for its stringent safety regulations and a place to provide an exemplar of environmentally sustainable aquaculture.

Two conservations organizations are focusing particularly on offshore aquaculture. The Nature Conservancy is currently seeking funding to develop an offshore aquaculture initiative that will include United States and other countries and focus on the potential of offshore aquaculture to address food security issues. The Environmental Law Institute is reviewing how current laws can be refined to ensure that the environment is protected should offshore aquaculture continue to develop. To date, the Institute has reviewed Magnuson-Stevens Fishery Conservation and Management Act and the Clean Water Act and provided a White paper of regulatory recommendations (cf Emmett Environmental Law and Policy Clinic et al. 2012, 2103). The Institute is currently reviewing Army Corp of Engineer regulations and reportedly is considering extending their review efforts to improve the Marine Mammal Protection, Endangered Species, National Environmental Protection, and Coastal Zone Management Acts.

Other NGOs that are working toward the advancement of sustainable marine aquaculture include: the World Wildlife Federation, Sea Web, New England Aquarium, and Aquarium of the Pacific. The World Wildlife Fund has brought together aquaculture researchers, government representatives, members from the seafood production and distribution sector, staff from NGOs to create aquaculture standards for the five marine species groups: salmon, shrimp, abalone, bivalves and seriola/cobia.[7] Industry respondents noted the Federation's early recognition of marine aquaculture "as the only means to keep pace with aquatic food production" and emphasis on resolving problems and conflicts. Sea Web established the SeaStead webinar series to provide a venue for scientists, the industry, agency staff and NGOs to discuss the role of the evolving industry in meeting global seafood demands and the role of NGOs and governments in regulating best management practices. In California, the Aquarium of the Pacific has created workshops on the development of offshore finfish aquaculture in the region and accurate aquaculture messaging (Aquarium of the Pacific 2013). To reach out to the public, the Aquarium of the Pacific has also created a visually compelling and easily understandable video outlining the need to and potential benefits of advancing marine aquaculture in United States (Aquarium of the Pacific 2014). In the Gulf of Maine region, the New England Aquarium has taken the lead in creating a multi-stakeholder workshop to discuss the environmental impacts of aquaculture, managing scientific uncertainty, and mechanisms for creating stakeholder consensus.[8]

The Siting of Aquaculture Operations and Marine Spatial Planning: Appropriate siting of aquaculture operations is well recognized as an important mitigation strategy for addressing potential environmental impacts as well as social conflicts. Recognition of the importance of siting has led to increasing emphasis being placed, by industry and regulators, on the collection of marine spatial data; development of geographic information system (GIS); creation of

[7] Seriola/cobia has been identified by industry respondents as particularly suitable species for offshore aquaculture in California, Hawaii, and Gulf of Mexico.

[8] To our knowledge, no research has been conducted on the number of persons reached by or the impact of these various educational efforts.

software models to assess cost and benefit analysis of criterion; and establishment of marine spatial planning policies and programs.

Siting Criteria: Criteria important to the siting of aquaculture operations can be divided into a number of different rubrics: physical-oceanographic factors, marine and coastal infrastructure, human use patterns, and protected habitats and species. The table below includes criteria important to the siting of offshore aquaculture operations.

Select Siting Criteria

Physical Oceanographic Criteria	
Wave Height	Storm tracks
Wind Speed	Ocean Depth
Current Speed	Seafloor Substrate
Temperature (minimum, maximum)	Dissolved Oxygen Concentration
Turbidity	Nutrient Levels/Red Tide and Hypoxic areas
Salinity	Pollution (bacterial)/PSP closures
Clorophyll A Concentration	Pollution (chemical)
Marine and Coastal Criteria	
Offshore energy installations	Shoreline access/launch sites
Offshore communication cables	Land-based Industrial Zoning
Dumping and Mining Areas	Hatcheries
Human Use	
Military use zones	Commercial fishing areas
Marine transport routes/lanes	Recreational fishing areas
Protected Habitats and Species	
Sanctuaries and Marine reserves/protected areas	Fishery management areas/closures
Areas associated with protected or threatened species	Essential fish habitat

The activities that represent absolute spatial conflicts vary regionally and by aquaculture system and the constraints vary by species and aquaculture system. Aquaculture technology advances, such as singly moored or un-tethered submersed cages, will undoubtedly change the importance of certain criteria. The necessity of excluding aquaculture from marine protected areas, and/or sanctuaries varies by region and remains a topic of debate.

Although the importance of various criteria for siting aquaculture operations is well understood, the necessary information is not always available. Proxies are frequently utilized, for example, essential fish habitat can be used as a proxy for wild populations and marina density may be used for recreational fishing intensity. Data regarding oceanographic conditions is often extrapolated from limited number of sampling stations and thus may not be accurate. In all our case study regions, respondents reported that current availability of data regarding commercial and recreational fishing effort is neither complete nor in appropriately fine scale. Additionally, there is no universal approach for weighing siting factors. And finally, industry respondents report that the small amount of space needed for aquaculture facilities is not adequately understood by the public; tools to help the public understand the (small) scale of sites and visual impact of facilities are needed.

Coastal and Marine Spatial Planning (CMSP). Intensifying human use of ocean space, increasing variety of marine based industries, growing interest in ocean conservation, and greater understanding of marine ecosystems have led to the recognition of the need for marine spatial

planning. The goal of CMSP is to minimize user conflicts; reduce political and social opposition to new ocean uses; ensure ecosystem health; increase predictability and access of industries to marine resources; maximize efficient resource use; and improve regulatory efficiency. Additionally, marine spatial planning can consider and address economic constraints and technical limitations of aquaculture operations. Marine spatial planning efforts currently vary by region and state in terms of: extent of regional collaboration; pre-existing agency and stakeholder data collection efforts; purpose of data collection and kinds of data collected; and public availability of data and ease of use, amongst others.

The CMSP planning process can result in a range of management outcomes from the establishment of useful and voluntary guidelines for siting to statutorily authorized rules regarding (exclusionary) use, for example, military exclusion zones, shipping lanes, or conservation areas. In regards to aquaculture, various possible outcomes have been linked to or recommended in relation to CMSP efforts such as, per-permitted areas; marine aquaculture parks; designated sites for pilot projects; and state or federal water sector zoning.

Although, CMSP has received attention from regional planners and NGOs for its potential benefits, members of the aquaculture industry and research, contacted as part of our study, have been less sanguine. Members of the open ocean aquaculture industry in California and Maine who have had experience with regional mapping efforts report that the industry cannot successfully represent itself. Because aquaculture technology is evolving, the needs, likely locations, and potential conflicts are not easily knowable. Key industry experts in Maine and Hawaii expressed the fear that aquaculture would be "left with the leftovers" as the ocean areas would be delegated to other uses. The aquaculture industry would then "locked into unsuitable areas" that would be technically less feasible, economically more costly, and environmentally more impactful. A challenge facing CMSP lies in ensuring planning efforts provide some certainty regarding management decisions while also enabling long term flexibility especially as technological advancements and research findings create opportunities for the co-siting of activities.

Of note, the Gulf of Mexico Fishery Management Plan for Offshore Aquaculture opted for case-by-case site selection over marine zoning. The Fishery management Council considered the establishment of 13 aquaculture zones within the Gulf. Marine zoning was rejected for both economic and environmental reasons: zoning could "require the use of inferior sites with higher start-up and operational costs" and "result in density problems" (Gulf of Mexico Fishery Management Council and NOAA 2009: 405).

Staff at regulatory agencies and participants in the aquaculture industry in Hawaii and Gulf of Maine also reported concerns regarding the appropriate scale; kinds; and accuracy of data used for CMSP. Additionally, industry respondents and staff at regulatory agencies report that the site requirements for species and technologies differ such that regional efforts at mapping and/or zoning are not likely to serve the informational needs of the industry. Participants expressed concerns about the limited resources available to keep maps updated and the possibility that data could become outdated and yet still be used inform permitting and leasing decisions. Participants discussed the need for data to be credible and updated regularly.

In Hawaii and California, staff within NOAA report that maps and site selection models should be viewed as "tools for communication purposes" and "a mechanism to bring stakeholders together to discuss possibilities of co-siting activities" not the end result. Additionally, staff in Hawaii reported that modeling for siting criteria must be transparent to ensure stakeholder buy in.

At best, respondents suggest that mapping of the distribution and abundance of species, benthic types and human uses may provide some information on areas where there are certain to be conflicts. In particular, industry respondents reported a need for oceanographic data and fishing effort at a finer scale for siting individual operations. In regards to offshore aquaculture in particular, participants in the Northeast Regional Ocean Council marine mapping workshops reported a need for a regional protocol for tracking red tide and water quality to ensure food/safety standards are met.[9] Additionally, industry respondents expressed interest in GIS information that would evaluate the potential of co-locating aquaculture operations on offshore energy installations. Staff in NOAA's protected resources reported the need for more information on marine mammal presence.

Challenges and Solutions for the Development of Offshore Aquaculture: A wide range of human factors and processes have thus far acted to constrain development of the offshore aquaculture industry, including: (1) policy limitations or lack of a sufficient policy framework for enabling and guiding an offshore industry; (2) economic and technical challenges inherent in developing such an industry and effectively marketing its products; (3) differing cultural perspectives on offshore aquaculture among persons in public trust governance positions, non-governmental organizations (NGOs), capture fisheries, and the general public; and (4) competition for, or conflicts regarding, use of finite ocean space.

Analysis of interview data and literature suggest that there are considerable similarities in understanding of the primary constraints and challenges to the development of offshore aquaculture across all categories of respondents and in all three regions of study. Those constraints include: unclear or cumbersome permitting policies; lack of adequate financing for research and business start-up; and negative public perceptions of marine aquaculture generally. The perceived need or desirability to expand into federal waters, however, differs by region and relates in part to regulatory hurdles associated with the establishment of operations in state waters.

Policy and regulatory challenges and solutions. As aquaculture firms in our study regions apply to carry out commercial operations in federal waters, operators report facing: uncertainty regarding permit requirements and permit lengths; difficulty negotiating the permit process; unreasonable or potentially contradictory conditions established by agencies; and/or unclear timeline for permitting.

NOAA's Office of Aquaculture. Staff are working to overcome regulatory challenges by: facilitating intra-and interagency consultation processes for permit applicants; coordinating interagency working groups to address permit and monitoring requirements for operations sited in open ocean environments; and providing information about marine aquaculture systems and impacts to agency staff and key decision makers.

[9] Various research efforts are underway to model and monitor harmful algal blooms in the Gulf of Maine.

Regional Aquaculture Coordinators assist applicants navigating permitting process by providing information on permits requirements and facilitating meetings and coordination between different agencies. Regional aquaculture coordinators note that concurrent interagency reviews can allow for better sharing of expert knowledge between agencies and better communication between agencies regarding project concerns and possible mitigation strategies. Concurrent reviews can shorten the duration of the review process; decrease the number of informational requests; address contradictory conditions established by different agencies, and result in the establishment of "workable" permit conditions. The degree to which regional coordinators and entrepreneurs have worked closely together to navigate the permitting process has reportedly varied.

Regional coordinators have also been pivotal in identifying research and informational needs of the industry by requesting legal clarifications and identifying white paper needs. Under requests by NOAA staff, the National Sea Grant Law Center, has provided legal reviews of permit requirements for shellfish and finfish aquaculture in offshore waters.[10] White papers on development of alternative feeds and their potential implications for the environment and human health and on the environmental impacts of marine cage aquaculture were completed in 2011 and 2013, respectively (cf. Rust et al. 2011; Price and Morris 2013). The latter has been especially welcomed by the industry. A similar effort has recently commenced regarding potential impacts of long line aquaculture operations on marine mammals. Additionally, staff member report that modeling tools are currently being developed to assess: water column and benthic impacts of farms; genetic risks associated with escaped fish; and risk of disease transmission to wild fish.[11,12] These tools will assist in the siting of operations and in meeting scientific needs of regulators. Additionally, NOAA Office of Aquaculture staff note they are working to procure more funding from within NOAA to support industry and agency research needs. The Office reportedly has focused to a lesser degree on changing public perceptions of marine aquaculture.

Industry consultants report the need for a concerted and ongoing effort to identify agency staff and key decision makers that can benefit from white papers and new analytic tools, especially in light of high staff turn-over rates and changes in political appointees. NOAA staff also report the need for greater coordination between staff within the Division of Protected Resources, which is housed in National Marine Fisheries Service, and between staff within the Sanctuary program, which is housed within the National Ocean Services.

State level experience and efforts: Although a regulatory framework for development of aquaculture in federal waters is being worked out separate from that in the state waters, the knowledge of state agency staff; the status of interagency relationships; and existence of cooperative processes, or lack thereof, has the potential to influence the development of regulatory framework for federal water operations. California, Hawaii, and Maine stand at

[10] Papers can be accessed at: http://nsglc.olemiss.edu/Advisory/#aquaculture

[11] The AquaModel models environmental impacts, through oceanographic and operational parameters such as currents, depth, fish species, farm capacity, and feed. The OMEGA (Offshore Mariculture Escapes Genetics/Ecological Assessment) model assesses impacts on wild species in terms fitness and abundance and includes parameters on broodstock source, cultured fish size and growth, and escape magnitude and frequency.

[12] The USDA's Animal and Plant Health Inspection Services (APHIS) leads the collaborative efforts on the lattermost research.

different points in a continuum regarding experience permitting and regulating open ocean aquaculture in state jurisdiction waters. Currently, agencies are gaining experience and developing procedural solutions as they review permit applications for federal waters.

As a consequence of reviewing an application for an offshore shellfish farm in 2013, agency respondents in California report a better understanding of the missions of other regulatory agencies and the establishment of important personal connections with staff at other federal and state agencies. Respondents report that the next step is to arrive at a "collective bottom line" regarding permitting requirements and establish one application form that fills the informational needs of all agencies. To achieve these ends, agency staff within NOAA's Office of Aquaculture, the California Department of Fish and Wildlife (CDFW) report the establishment of offshore aquaculture working group that includes the various federal and state agencies and regional entities that have regulatory authority over aquaculture. In addition, respondents within the industry, research, and regulatory sectors have suggested the importance of demonstration projects through which to create a shared vision of permitting and monitoring requirements for federal waters. The recent filing of a permit application by Hubbs SeaWorld Research Institute and Cuna del Mar, the Rose Canyon Fisheries Sustainable Aquaculture Project, reportedly represents just such an opportunity.

In Hawaii, an interagency Offshore Aquaculture Monitoring Working Group was established to create a set of water quality and benthic monitoring requirements suited for Hawaii's deepwater and strong current ocean environment. The group includes staff from the Army Corps of Engineers, EPA, NOAA's Essential Fish Habitat Division, and state agencies. The objective is created a standardized monitoring protocol that can efficiently measure pollution impact and operational compliance and ensure mitigation efforts effectively reduce pollutants. In the course of our research, working group effort has reportedly been transferred from the region to the federal level. Agency staff also noted the goal of creating a programmatic environmental impact statement for offshore aquaculture that would clarify permitting requirements and streamline the review process and thereby reduce the time and costs of preparing an application and undertaking proposal review. Included in this effort would be programmatic agreements with other relevant federal agencies such as the Environmental Protection Agency and Army Corps of Engineers. A programmatic environmental impact study would preclude the necessity of an extensive NEPA review for each project. The streamlined review process would require that applicants prepare an environmental assessment and NEPA review would be conducted in regards to site specific concerns related to for example, impacts to protected resources and/or essential fish habitats.

In Massachusetts, agencies have experience permitting long line mussels farms in state and federal jurisdiction waters. The potential for marine mammal entanglements are of particular concern for longline mussel farms. Staff at the Office of Aquaculture within the Greater Atlantic Regional Office of NOAA are currently conducting interagency workshops regarding the issues associated with mooring technology and marine mammal protection. Staff within NOAA's Office of Protected Resources are currently creating internal guidelines for assessing the potential risk of aquaculture gear to protected marine mammals, and to provide technical assistance to applicants regarding suitable site locations and gear configurations to mitigate the potential of entanglement. A white paper regarding the potential of and mitigation strategies for

marine mammal entanglement and aquaculture operations is forthcoming. Information gained from this regional effort may assist other regions in assessing the risks of marine mammal entanglement and formulating appropriate mitigation strategies. There are no proposed projects for federal jurisdiction waters of New Hampshire and Maine and thus no regulatory challenges or progress specific to federal waters was reported by respondents.

Political challenges and industry efforts. Currently industry respondents in all the case study regions note the noted a lack of political allies with the necessary clout to influence state or national policies and politics in favor of marine aquaculture development. The new and poorly funded industry has found it difficult to counter the longstanding negative views of aquaculture presented by well funded and powerful conservation organizations. Industry respondents recognize that the industry itself must be more active in lobbying and engaging in public relations regarding offshore aquaculture. The Coalition for U.S. Seafood Production (CUSP) was formed in early 2014 to represent the aquaculture industry in discussions with agencies and legislators at the federal level and to the public. The coalition includes members from the feed industry, aquaculture system makers, seafood processors and distributors, aquaculture research, and aquaculture associations. The trade organization Ocean Stewards Institute, established in 2008, is also an active voice and advocate for the nascent open ocean aquaculture industry.

Economic constraints and recommendations: Respondents at state and federal agencies, from the industry, and within the research sector all report economic challenges associated with the development of the marine aquaculture industry generally. Aquaculture programs that have supported the development of open ocean aquaculture in state waters have experienced defunding and restructuring in Hawaii and Maine. Staff at state agencies report lack of staff to conduct permit processes in a timely manner and engage in aquaculture development activities. Staff at federal agencies report the lack of funding to conduct the research necessary to develop the industry in federal jurisdiction waters. In Hawaii, NOAA staff noted inadequate funding for the development of GIS and utilization of impact modeling software. Tools such as these could fulfill scientific needs of regulators and communication needs of stakeholders. In addition, staff note the lack of funding and human resources needed to conduct interagency workshops to create new or streamline regulatory processes. Industry representatives report high costs for preparing the information necessary for permitting. Additionally, they report difficulty accessing investment capital due to lack of clear regulatory framework and successful domestic examples of the offshore industry.

Although the need for extensive funding support is a common theme expressed by respondents and reported in the literature, there are divergent perspectives on the roles of the private sector and government in providing funds for research and development. The recently established aquaculture group, Coalition of US Seafood Production (CUSP), has recommended that commercial scale demonstration operations be funded by private-sector investors but supported by the efforts of federally funded investigators researching technological engineering, business planning, and management approaches. Regional demonstration projects could produce benchmark studies to attract investors, assess ecological impacts, and provide the public with evidence that "farms are not the end of the world." Additionally, the successful permitting of a project in the federal waters could provide a template for the process. Additionally a public-private venture could ensure that those making the regulations would be better apprised of the costs of those regulations and promote the creation of permitting (and monitoring) requirements

that are economically workable for the applicant and manageable for agency staff. To provide adequate evidence regarding commercial viability and ecological sustainability of farming, respondents note that demonstration farms need to operate 10-20 years.

Additionally, regional and state efforts to conduct programmatic reviews, such as the Gulf of Mexico fishery management plans will reduce the burden on applicants to provide scientific information and create a more efficient and focused environmental review process thus saving applicants time and costs to undergo permit review.

Socio-cultural perspectives. The industry has faced challenges related to public perceptions of marine aquaculture generally and opposition from fishing community more specifically. Respondents within the industry and conducting aquaculture research argue social opposition to marine aquaculture generally reflects a lack of understanding on the part of the general public and decision-makers regarding: the potential severity of future seafood shortages; advancements within the aquaculture industry; the state of scientific knowledge regarding aquaculture impacts; and regulatory and monitoring requirements placed on existing farms. Additionally, respondents express concerns that the overriding negative view presented of aquaculture by conservation organizations over the past two decades has led to a great deal of skepticism regarding the current body of knowledge.

Industry respondents reported a need for NOAA to take a stronger role in countering misinformation by providing official statements regarding the science of what is known regarding aquaculture impacts and benefits. Respondents in educationally orientated NGOs reported the need for, and challenges of translating complicated scientific and technical information of an evolving industry to the general public, especially in light of a history of polemic messaging. According to NOAA agency staff what is needed is more effort to translate scientists' focus on "being methodical, meticulous, and documenting their evidence" to the public's preference for information to be conveyed in short time spans and in compelling visual representations.

Industry respondents report undertaking their own outreach and educational response; utilizing social media to inform public of advancements in their practices and the industry as a whole; and collaborating with renowned chefs, to act as ambassadors for farmed seafood. Industry respondents also reported potential opportunities for conducting public education and ecotourism at hatcheries and farms and outreach to journalists to tell their stories. Aquariums also play an important role in educating the public in our study regions.

Opposition from the commercial and recreational fishing sectors has centered on space conflicts; the potential impact of marine aquaculture to essential fish habitat; and the impact of ranching of tuna species on stock abundance. Additionally, the commercial fishing sector has expressed concerns regarding the impact on the pricing of wild caught seafood.

Siting to avoid major fishing grounds and spacing and/or submerging of farm structures to enable the continuation of fishing activities have been the primary strategies used to mitigate space-use conflicts. Respondents within the industry sector and aquaculture research reported efforts to mitigate market impact by choosing farm species that are undesirable targets as wild species for sales and consumption (Almaco jack/*kahala* in Hawaii or mussels in New England) or can

replace an imported product substitute for an imported product (California yellowtail in California). Other candidate species in our study regions - Atlantic cod, Atlantic halibut, and white bass are a commercially important species. Proponents of aquaculture have suggested that market conflict can be addressed through product differentiation and market segmentation, much as has happened in the case of salmon.

In the Gulf of Maine, aquaculture training programs have been established that target commercial fishermen. Candidate farms species are chosen that are operationally and seasonally compatible with current commercial fishing operations (seaweed in Maine and mussels in New England). In California and Hawaii, open ocean aquaculture companies have instituted programs in stock enhancement that have been received favorably by recreational fishermen.

In Hawaii, opposition to operations sited in state jurisdiction waters has been expressed from parts of the native Hawaiian community. Concerns have focused on how aquaculture operations may impact traditional fishing ground (*ko'a*) and culturally valued shark species. Some members of the native Hawaiian community also have long standing grievances regarding the state and federal government making decision about what they perceive as native Hawaiian's resources. A respondent in the native Hawaiian community reported the importance of honoring native Hawaiian cultural traditions of sharing resources and "giving back to nature" and suggested offering farmed product the local community at discount rates or giving seafood to school cafeterias. To date operations sited in open ocean environments of state waters have attempted to address these concerns by: proper siting of operations to avoid traditional harvest areas and cultural resources; establishment of predator management practices; provisioning local stores with farmed seafood; and supporting stock replenishment efforts.

Recreational and commercial fishermen in Hawaii have reported the affect aquaculture operations have on attracting fish. The community response to the FAD (fish aggregating device) effect of the offshore operation has generally been favorable due do a recent dearth in state funded FADs. To maximize the benefit of the FAD effect, fishing community respondents report the need for "clear cut guidelines for operating around structures" and diagram of operation configurations for avoiding entanglement. Respondents have, however, also noted concerns about the FAD effect of farms drawing fish away from traditional grounds and/or increase predation by sharks of target wild catch species. Respondents involved in tourism reported the potential attractiveness of farms for (consumptive and non-consumptive) diving and eco-tourism.

It should be noted that the aquaculture industry is currently being asked to address potentially contradictory concerns, for example, community desires to increase the supply of affordable seafood versus commercial fishermen's desire to protect the market prices of locally caught seafood. The industry and regulators are also being asked to weigh trade-offs of mitigation strategies. For example, although submersible structures can increase transit accessibility for marine users, offer greater security of stock, and address aesthetic concerns, submersible structures have some disadvantages vis-à-vis conventional surface net pens. The cost of operating and maintaining submersible cages is generally higher than that of surface net pens. Surface cages do not require that workers have specialized diving skills and thus allow for the more ready transition of skills for fishermen displaced from wild catch fisheries.

Environmental concerns, technological solutions, and management measures. Social opposition and regulatory and policy impasses are in part due to concerns about environmental impacts. Advances in technologies and best management practices are providing the means to resolve many environmental concerns. Additionally, conservation NGOs have created various, and in some instances competing, standards and certification programs to address public concerns regarding the food safety, environmental sustainability and social ethics of aquaculture practices. The USDA is also creating an organic standard for aquaculture (based on such criteria as: use of chemical therapeutants, stocking density, fish meal use etc) that may also serve to assuage public concerns regarding the safety of farmed seafood.

Impacts to water quality, benthos, and micro and macro fauna communities can be mitigated through proper site selection for current flow and water depth; use of improved feed formulations; and best management practices for feeding, stocking density, net cleaning, and fallowing (cf. Corbin 2010, Price and Morris 2013). Research conducted on marine cage aquaculture operations sited in open ocean environments reveals negligible impact. Additionally, integrated multitrophic aquaculture (IMTA) is being promoted as a mitigation strategy for nutrient impacts.

Common disease management practices include use of brood stock that have been raised in land-based sites and have undergone quarantine procedures. In addition, aquaculture operators commonly mitigate the potential of disease transmission from wild to culture species by maintaining low stocking densities and separation zones between sites (cf. Bridger 2004). Concerns regarding potential impact of farm escapees on the genetic make-up of wild fish populations have arisen in relation to salmon species and relate to the distinct genetic make-up of salmon populations located in river systems. These concerns are commonly addressed by prohibiting the use of non-indigenous and GMO species; choosing regional species that are considered one genetic stock; and stocking only reproductively sterile species. Significant declines in the number of escapements have also been realized by advancement in cage materials to withstand extreme weather and improvement in cage technology to deter predators (cf. Corbin 2010).

Concerns regarding increased demand for wild stock sources to be used for feeding farmed species are being mitigated by advances in food formulation, and in particular, the inclusion of soy as a protein source for carnivorous fish. Trimming from seafood processing are also being used in fish meal (cf. Stickney and McVey 2002). Additionally, automated feeding system that incorporate monitoring capabilities have been developed (cf. Price and Morris 2013).

Practices to mitigate the potential for marine mammal entanglement include: (1) siting to avoid emplacement of aquaculture operations in areas of high marine mammal presence including important movement/migration routes; ensuring mooring lines are taut; and utilizing rigid netting (cf. Price and Morris 2013). Inspection of mooring lines is routinely required and conducted as part of industry management practices. Additional mitigation strategies were incorporated into a recently approved longline shell fish farm sited in federal waters of Nantucket Sound; they include: limiting the number of vertical lines; minimizing diagonal mooring configurations; and utilizing high visibility materials and break away linkages.

In Hawaii, concerns have been expressed regarding how aquaculture operations may attract sharks and result in increased predation of dolphins and monk seals. The primary mitigation strategies utilized for decreasing the attractiveness of aquaculture operations to sharks and other species center on feeding practices – the use of fish feed pellets rather than fresh fish and the monitoring of feed to avoid excess feed waste – and the routine removal of dead fish. Shark resistant netting, double netting, and shark avoidance colors are also commonly utilized (cf. Price and Morris 2013).

The development of vaccination protocols in conjunction with establishment of best management practices for stocking density reduce stress and have resulted in declines in use of antibiotics and other chemical therapeutants. In addition, screening for chemical residues is widely accepted as an industry practice (cf. Stickney and McVey 2002).

Of note, the economic feasibility and practical trade-offs of various mitigation strategies (will) vary by location and operational configuration. For example, although weak break away linkages are currently being considered as an appropriate mitigation strategy for whale entanglement, their use must be considered in regards to equally pressing environmental and economic ramifications of losing pens, cages, or lines. Additionally, although the Gulf of Mexico Fishery Management Plan for Offshore Aquaculture, current aquaculture operations in Hawaii, and a proposed aquaculture operation in California, limit the stocking of fish to second generation, ostensibly to mitigate potential impacts to wild fisheries from escapes, there is no clear consensus that this practice is best for the environment, companies, or the nation's seafood supply. Respondents within the industry and aquaculture research assert that selective breeding is essential to improving growth efficiencies, feed conversation rates, and disease resistance and thus can lead to a decrease in environmental pollution and an increase commercial viability of operations and product affordability.

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Table One: Identification of Select Factors Important to the Development of Offshore Aquaculture

Factor	California	Hawaii	Gulf of Maine
Offshore Environmental Conditions	(+) suitable bathymetric conditions for current conventional open ocean cage technology (+) warm water temperatures conducive to high growth rate (+) mild weather conditions.	(+) warm water temperatures conducive to high growth rate (+) mild weather conditions (-) steep bathymetry in offshore waters necessitate advanced cage technology	(-) strong and complex wind and current patterns (-) icy winter conditions
Market Demand	(+) proximate to urban population (+) availability of transport infrastructure	**(+)** high tourist demand (+) high per capita seafood consumption (+) proximate to Asian markets (-) distant from US mainland markets	(+) proximate to urban population (+) availability of transport infrastructure (+) strong local food movement
Coastal Support Infrastructure (see Interim Report for detailed infrastructure assessments by harbor and fishing community)	(+) availability of commercial fishing and seafood processing infrastructure (-)competition for harbor space and limited facilities in some ports	(-) lack of suitably zoned land (Oahu) (-) limited port facilities (all other islands)	(+) extensive throughout region (+) availability of commercial fishing and seafood processing (-) increasing competition for access to waterfront facilities
State Financial Support/Investment Incentives	-	+	+ (Maine)
Research Support	private	private and public	private and public
Existing State Regulatory Framework for Open Ocean	established for shellfish	good regulatory structure for finfish	good regulatory structure for finfish, shellfish and seaweed
Number of open ocean sites, proposed, reviewed, permitted and currently active (state/federal waters)*	● one operation permitted and active (shellfish – state waters) ● one operation permitted (shellfish – federal waters) ● two operation proposed (finfish – federal waters) ● one operation under review (finfish – federal waters)	● eight projects proposed (finfish – state waters) ● three projects permitted (finfish – state waters) ● one project currently active (finfish –state waters) ● one project under review (finfish – state waters) ● two projects permitted for one year (finfish – federal waters) ● one project under review (finfish – federal waters)	● three permitted projects (shellfish – state waters) ● one permitted and active project (shellfish – state waters) ● one project pending approval (shellfish – federal waters)

History of Community Acceptance	Shellfish	Finfish	Finfish and Shellfish
Candidate Species	• Mediterranean mussel *(Mytilus galloprovincialia)* • Pacific oyster *(Crassostrea gigas)* • White seabass (*Atractoscion nobilis)* • California yellowtail (*Seriola lalandi)* • Striped bass (*Morone saxatilis*) • California halibut (*Paralichthys californicus*)	• Pacific Threadfin (*Polydactylus sexfilis)* • Almaco jack (*Seriola rivoliana)* • Yellowfin tuna (*Thunnus albacares)* • Bigeye ahi tuna *(Thunnus obesus*) • Mahimahi (*Coryphaena hippurus*)	• Atlantic salmon (*Salmo salar*) • Atlantic Cod (*gadus morhua*) • Atlantic Halibut (*Hippoglossus hippoglossus)* • Steelhead Trout (*Oncorhynchus mykiss)* • Blue mussels (*Mytilus edulis)* • Seaweed –various species
Other	(+) Offshore oil platforms for possible co-siting with aquaculture operations (-) marine mammal presence	(-) marine mammal presence	(+) presence of fishing cooperatives for technology transfer and cooperative management of farms (-) marine mammal presence

* Projects/operations in Massachusetts south of the Gulf of Maine are not included.