Aquaculture in the Mid-Atlantic Region

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Contents

Document scope

This document is intended to provide an overview of aquaculture activities in the Mid-Atlantic region and information related to their potential effects on Mid Atlantic Fishery Management Council (MAFMC) managed species and habitats. The document also provides an overview of the current aquaculture permitting and authorization process in the region and the review process in place designed to consider and avoid or minimize potential negative effects to MAFMC managed species and habitats. This document briefly summarizes how aquaculture operations may interact with other human activities, including fishing, but does not directly address protected species considerations associated with aquaculture activities. The discussion does not attempt to assess the full benefits and costs of aquaculture against alternate uses.

Activity overview

What is aquaculture?

Aquaculture is defined as the controlled cultivation and harvest of aquatic organisms, including finfish, shellfish, and plants (Goldburg et al. 2001). Another definition is the organized rearing, feeding, propagation, or protection of aquatic resources for commercial, recreational, or public purpose (FAO 2018), with mariculture occurring in nearshore and marine environments. NOAA considers aquaculture to be "the breeding, rearing, and harvesting of fish, shellfish, algae, and other organisms in all types of water environments" (NOAA 2019). Operations of interest to the Council from the perspective of habitat, fish, and fisheries effects would be considered mariculture, but for simplicity the term aquaculture is used throughout. Enhancement of wild stocks is a close cousin to aquaculture but is outside the scope of this document. To the extent that enhancement requires aquaculture activities to occur, such issues would be covered by the permitting requirements described below.

Species cultured

Currently cultivated species in the Mid-Atlantic include the Eastern oyster, quahog or hard clam, bay scallop, striped bass, hybrid striped bass, Russian sturgeon, mussels, soft shell clams, and sugar kelp (**Table 1**). Other species of interest for potential future culture include black sea bass (*Centropristis striata*), surfclam (*Spisula solidissima*), blue crab (*Callinectes sapidus*), tautog (*Tautoga onitis*), steelhead trout (*Oncorhynchus mykiss*), yellowfin tuna, bluefin tuna, seaweeds, urchins, and others.

Areas where aquaculture occurs

Aquaculture activities in Mid-Atlantic can occur onshore, and in nearshore and offshore waters. For the purposes of this document, we only discuss onshore aquaculture activities that utilize systems with discharge into coastal or marine waters. We refer to nearshore marine aquaculture activities as those that occur in rivers, sounds, estuaries, and other protected or semi-protected

nearshore areas within the coastal zone. We refer to offshore aquaculture activities as those that occur in exposed open ocean environments in both the coastal zone[1] and Exclusive Economic Zone (EEZ[2]).

Onshore Aquaculture Activities in the Mid-Atlantic primarily consist of hatchery facilities that produce seed and juvenile molluscan shellfish, and to a lesser extent juvenile finfish, for planting on nearshore aquaculture operations for further grow out and harvest. Interest in the use of onshore aquaculture systems for all stages of marine fish culture is growing in the region.

Nearshore Aquaculture Activities in the Mid-Atlantic primarily consist of molluscan shellfish aquaculture sites utilizing bottom planting, off-bottom, and suspended and floating culture methods. Nearshore molluscan shellfish aquaculture is expected to continue to increase in the region. There are also multiple pilot scale projects focused on macroalgae cultivation using suspended methods in nearshore waters. The potential for significant increases in nearshore commercial scale fish aquaculture production in the region are uncertain. This is primarily due to high summer water temperatures in nearshore waters that can exceed the tolerance for many cultured fish species.

Offshore Aquaculture Activities There are currently no offshore aquaculture activities occurring in Federal waters off the Mid-Atlantic coast. Interest in offshore aquaculture activities in both the coastal zone and EEZ has grown in recent years, with interest primarily focused on fish, shellfish (e.g., bay and sea scallops), and seaweeds.

[1] The coastal zone are the waters that extend seaward to the outer limit of State title and ownership under the Submerged Lands Act (43 U.S.C. 1301 et seq.).

[2] The Exclusive Economic Zone are the waters under federal jurisdiction, which typically extend from 3-200 nautical miles from the shoreline.

Table 1. Summary of cultured species, locations, and gear types in the Mid-Atlantic.

Species	Mid-Atlantic states where cultured	Typical culture methods	Relative economic importance
Eastern Oyster *Crassostrea virginica*	NY, NJ, DE, MD VA, NC	Traditional bottom planting, also floating and off-bottom gear (e.g., cages, racks, bags for nursery, intermediate grow out, and grow out; nearshore intertidal and subtidal. Nursery rearing in upwellers, downwellers, and tanks	Major species in most Mid-Atlantic states. Shellfish aquaculture in the Inland Bays in DE is new
Hard clam *Mercenaria*	NY, NJ, DE, MD, VA, NC	On-bottom (broadcast-planted directly onto the bay bottom; no containment); under nets or in mesh bags; nursery rearing	High in NY, NJ, and VA. Secondary species in NC. Low in MD. Shellfish aquaculture in the Inland Bays in DE is new
Bay Scallop *Argopecten irradians*	NY, MD,VA, NC	Off-bottom (e.g., cages, racks, bags) that may be resting on the bottom or suspended in the water column. Lantern nets or surface floats estuarine, intertidal, and subtidal	Limited number of growers in NY and MD. Lesser species in NY and NC. Pilot scale in VA
Striped Bass *Morone saxatilis*	NY, NC	Hatchery, land-based tanks (onshore)	Low. Sporadic production
Hybrid Striped Bass *Morone saxatilis/M. chrysops*	NC	Hatchery, land-based tanks (onshore)	Low but there has been recent growth in number of growers.
Russian Sturgeon *Acipenser gueldenstaedtii*	NC	Hatchery, land-based tanks (onshore)	Only one facility.
Mussel *Lampsilis spp.*	NC	Bottom planting; Nursery rearing in upwellers, downwellers, and tanks; estuarine subtidal	Lesser species
Blue Mussels *Mytilus edulis*	MD	On-bottom. Off-bottom suspended lines	No culture occurring at this time
Soft Shell Clams *Mya arenaria*	MD	On-bottom under nets or bags Off-bottom cages	Mainly experimental culture at this time
Sugar Kelp *Saccharina latissima*	NY	Lines suspended from submerged arrays or dropped from moored rafts; nearshore subtidal and offshore subtidal	Multiple pilot scale projects

Aquaculture permitting and authorization process in the Mid-Atlantic

This section provides an overview of the federal and state aquaculture permitting and authorization process in the Mid-Atlantic region, highlighting places in the permitting process where opportunities exist for input on concerns related to adverse effects to MAFMC managed species and habitats from proposed aquaculture activities.

The marine aquaculture permitting process is complex. The specific federal and state agency permits and authorizations an aquaculture project proponent may be required to obtain can vary significantly based on factors such as the species intended to be cultured, the location where the project is proposed, and the scale of the project. Generally, the review and permitting of projects proposed within the EEZ are initiated at the federal level and the review of projects proposed in the coastal zone are initiated at the state level. There are many similarities between the factors state and federal agencies consider when reviewing proposed aquaculture activities and often a high level of coordination between agencies. One important distinction between federal and state authorizations is that, unlike state licenses/or leases which generally grant exclusive use to the cultured organisms within a defined area, federal agencies don't have authority to provide licenses/or leases for aquaculture and only provide permits for the construction and operation of aquaculture facilities.

Federal agency aquaculture permitting and authorization

The specific federal agency permits and authorizations an aquaculture project proponent may be required to obtain generally vary based on the type of operation. The majority of aquaculture projects in the Mid-Atlantic will be required to obtain a permit from the U.S. Army Corps. of Engineers (USACE) under Section 10 of the Rivers and Harbors Act of 1899 for the placement of culture gear or "structures" in the water. A small number of aquaculture activities that involve the placement of fill (shells or other material) may also be required to obtain a permit from USACE under Section 404 of the Clean Water Act. Some aquaculture activities proposing the discharge of pollutants may also require a National Pollutant Discharge Elimination System (NPDES) permit from the EPA (U.S. Environmental Protection Agency; or delegated state agency) under Section 402 of the Clean Water Act. A NPDES permit is required for aquaculture activities that fall under the EPA criteria for Concentrated Aquatic Animal Production Facilities (CAAP). CAAPs generally include aquaculture operations used to rear fish or other aquatic animals which occur in both onshore facilities (hatcheries and land-based fish production systems) and open water facilities (net pens and submerged cages used for fish culture) and meet specific feeding and production thresholds.

USACE and EPA permits each have specific requirements that must be incorporated into the construction and deployment phases of an aquaculture project, as well as day-to-day operation and maintenance activities. Some requirements will apply to all aquaculture operations, while others may be specifically tailored to individual operations. Other federal agencies, such as the U.S. Food and Drug Administration (FDA) and the U.S. Department of Agriculture (USDA), also have oversight of aspects of aquaculture activities such as the use of drugs, pesticides, and biologics and animal health considerations. These agencies have established regulations related to the approval of drugs, pesticides, and biologics used on aquatic animals as well as regulations associated with the source and health of

cultured aquatic animals. The United States Coast Guard (USCG) is the principal authority for establishing and maintaining aids (e.g., safety) to navigation in U.S. waters.

For additional information, please refer to the "Guide to Permitting Marine Aquaculture in the United States (NOAA 2022). This guidance document outlines the key requirements necessary to obtain federal permits to conduct commercial aquaculture activities and provides an overview of federal statutes and regulations governing aquaculture in the United States.

Project review

While the review of projects proposed in the coastal zone are generally initiated at the state level, such projects would require both state and federal agency authorization prior to operation. Projects proposed in the EEZ are only required to obtain federal agency permits; however, coastal states that can demonstrate a potential coastal effect from a project proposed in the EEZ can request to review federal permit applications under their federal consistency authority granted through the coastal zone Management Act (CZMA). Thus, both state and federal agencies are involved with project review at some level, regardless of where they occur.

Beyond the CZMA, federal permitting agencies also coordinate compliance with other related federal laws as part of the review and authorization process. If a federal permitting agency determines a proposed project may have an adverse effect on certain public interests as outlined by federal law, they are required to consult with the federal agencies responsible for the implementation of those laws prior to issuing permits (**Table 2**). This includes consultation with NOAA Fisheries Greater Atlantic Regional Office (GARFO) about projects that may have an adverse effect on areas designated as Essential Fish Habitat (EFH) under the Magnuson-Stevens Fishery Conservation and Management Act (MSA). A summary of the federal laws that federal permitting agencies are required to consider and the associated consultation requirements with each are summarized in **Table 2**. The EFH consultation process is described in greater detail below.

In addition to coordination with federal and state agencies, federal permitting agencies also are responsible for coordinating opportunities for public comment on permitting actions. USACE and EPA each have general requirements related to the timing and extent of public comment opportunities and the level of public review an individual aquaculture project will be required to undergo to obtain permits. While there are similar requirements built into the state agency review process, due to the need for federal permits and authorizations for aquaculture projects proposed in the coastal zone and the EEZ, and the nexus between federal permitting actions and consultation with NMFS under the MSA, it is during the federal permitting and authorization process where formal opportunities for input from the MAFMC and fishing communities/stakeholders on potential impacts to MAFMC species and habitats primarily occur. Some projects deemed to have significant impacts must receive expanded review under the requirements of the National Environmental Policy Act (NEPA) prior to the issuance of federal agency permits. The NEPA process is described in greater detail below.

Table 2. Federal agency review of aquaculture projects and relevant applicable laws.

Consultation or Review	**Description of the Requirement**
Endangered Species Act	Section 7(a)(2) of the ESA requires federal agencies to consult with the NOAA Fisheries, the U.S. Fish and Wildlife Service, or both, before taking any action that may affect an endangered or threatened species or their critical habitat to ensure their actions are not likely to jeopardize any listed species or result in the destruction or adverse modification of designated critical habitat.
Magnuson-Stevens Fishery Conservation and Management Act	The EFH provisions (305(b)(2)) of the MSA require federal action agencies to consult with NOAA Fisheries on all actions, or proposed actions, authorized, funded, or undertaken by the agency, that may adversely affect EFH. As part of the EFH Consultation process, federal action agencies must prepare a written EFH Assessment describing the effects of that action on EFH (50 CFR 600.920(e)(1)). NOAA Fisheries issues conservation recommendations to the action agency based on this assessment.
National Historic Preservation Act	Section 106 of the National Historic Preservation Act (36 CFR Part 800) requires any federal agency issuing a permit to account for potential effects of the proposed aquaculture activity on historic properties, e.g., shipwrecks, prehistoric sites, cultural resources. If a proposed aquaculture activity has the potential to affect historic properties, these details must be provided by the applicant as part of the application package.
Fish and Wildlife Coordination Act	The Fish and Wildlife Coordination Act requires any federal agency issuing permits to consult with the U.S. Fish and Wildlife Service and NOAA Fisheries if the proposed aquaculture activities could potentially harm fish and/or wildlife resources. These consultations may result in project modification and/or the incorporation of measures to reduce these effects.
National Marine Sanctuaries Act	Section 304(d) of the National Marine Sanctuaries Act (NMSA) requires any federal agency issuing permits to consult with NOAA's National Marine Sanctuary Program (NMSP) if the proposed aquaculture activity is likely to destroy or injure sanctuary resources. As part of the consultation process, the NMSP can recommend reasonable and prudent alternatives. While such recommendations may be voluntary, if they are not followed and sanctuary resources are destroyed or injured in the course of the action, the NMSA requires the federal action agency(ies) issuing the permit(s) to restore or replace the damaged resources.

Consultation or Review	**Description of the Requirement**
Marine Mammal Protection Act	The Marine Mammal Protection Act (MMPA) prohibits take, including the harassment, hunting, capturing, or killing of marine mammals, except under certain circumstances. Section 118 establishes the Marine Mammal Authorization Program (MMAP), which provides an annual exemption for the incidental take of a non-endangered and non-threatened marine mammals in a commercial fishing operations having frequent or occasional interactions with marine mammals (listed as Category I and Category II fisheries under the List of Fisheries, LOF, which is published annually and is available on the NOAA Fisheries website and in the Federal Register. To be eligible for the exemption, any commercial vessel or non-vessel gear (e.g., aquaculture facilities) engaging in a Category I or II fishery must obtain a MMPA certificate from NOAA Fisheries. The MMPA does not allow for directed take or harassment of marine mammals. This Certificate must be present on the fishing vessel or on the person during fishing operations at all times. The MMPA also requires that permit holders carry an observer during fishing operations if requested, and that they adhere to all other applicable Take Reduction Plan regulations. Regardless of Categorization (I, II, or III), commercial fisheries must report every incidental death or injury of marine mammals that results from commercial fishing operations (including aquaculture) within 48 hours of returning to port.
National Environmental Policy Act	NEPA requires federal agencies to prepare either an Environmental Impact Statement (EIS) or Environmental Assessment (EA) for any federal action affecting the quality of the human environment, unless it is determined the activity is categorically excluded from NEPA.
Coastal Zone Management Act	CZMA encourages coastal states to develop and implement coastal zone management plans as a basis for protecting, restoring, and establishing a responsibility in preserving and developing the nation's coastal communities and resources. Coastal states with an approved coastal zone management program are authorized to review certain federal actions affecting the land or water uses or natural resources of its coastal zone for consistency with its program. Under the CZMA, a state may review: activities conducted by, or on behalf of, a federal government agency within or outside the coastal zone that affects any land or water use or natural resource of the coastal zone; an application for a federal license or permit; and any plan for the exploration or development or, or production from, any area that has been leased under the Outer Continental Shelf Lands Act for offshore minerals exploration or development. The CZMA requires federal agency activities to be consistent to the maximum extent practicable with the enforceable policies of a state's approved coastal zone management program.

EFH consultation

If EPA or USACE determines during the permitting and authorization process that a proposed aquaculture project may result in adverse effects to EFH, they must prepare a written EFH Assessment describing the effects of the activities on EFH (50 CFR 600.920(e)(1)). The level of detail required in an EFH Assessment is commensurate with the complexity and magnitude of the potential adverse effects of the action, 50 CFR 600.920 (e)(2). For example, assessments for relatively simple actions that may adversely affect EFH are generally brief. Actions that may pose a more serious threat to EFH, or that involve a more complex range of potential adverse effects, justify a correspondingly more detailed EFH Assessment that includes information, such as an analysis of alternatives, the results of on-site inspections, literature reviews and the views of recognized experts.

NOAA Fisheries biologists (GARFO in this region) review the EFH assessment and provide conservation recommendations to federal agencies on means to avoid, reduce, or offset these adverse effects. These conservation recommendations are intended to be included on federal agency permits as special conditions or integrated into the project plans, as appropriate. Conservation recommendations may include provisions for the use of turbidity and erosion controls, time of year (TOY) restrictions, or other specific criteria to minimize adverse impacts on EFH.

National Environmental Policy Act (NEPA) review

While all permitting actions that the EPA or USACE determine may result in adverse effects must undergo some level of agency consultation and public review, the National Environmental Policy Act lays out specific requirements for permitting agencies when they anticipate that an action could significantly affect the quality of the human environment. If a determination of significance is made, the agency must document its consideration of those impacts in an EIS. If the impacts are uncertain, an agency may prepare an EA to determine whether a finding of no significant impact could be made or whether an EIS is necessary. In some cases, federal agencies can determine the level of analysis they will be required to undertake based on how the activities compare to past agency actions or during pre-permitting discussions with partner federal agencies. In other cases, the determination is made after an application is submitted based on considerations raised during the project review process by the permitting agency, the public, and/or consulting agencies.

If more than one federal agency authorization is required, such as in the case of fish aquaculture activities requiring both a Section 10 permit from USACE and a NPDES permit from EPA, a lead agency may be designated to undertake the NEPA review process.

Mid-Atlantic state agency permitting and authorization

The specific state agency review and permits required for aquaculture projects within the coastal zone varies between the Mid-Atlantic states. In some cases, states have developed joint federal/state permit applications for aquaculture activities and the state and federal review process is conducted concurrently under a single application.

New York

The New York State Department of Environmental Conservation (NYSDEC) has permitting and regulatory authority for all types of mariculture activities occurring in the state. Generally, mariculture operations are reviewed and approved through issuance of either a marine hatchery permit or an on/off-bottom culture permit depending on the activity. Given the different jurisdictional and regulatory responsibilities of NYSDEC and the other state and federal agencies with mariculture oversight (USACE – NY District, NYS Department of State's Coastal Management Program), and the local governments administering programs that provide most of the access to underwater lands for mariculture, inter-governmental and inter-agency coordination is necessary.

The most active mariculture access programs include the Suffolk County Aquaculture Lease Program in Peconic and Gardiners Bays (SCALP), the Town of Islip's Bay Bottom Licensing Program in Great South Bay, and the Town of Brookhaven's Mariculture Leasing Program in Bellport and Moriches Bays. SCALP is the most extensive program, with 5- and 10-acre sites potentially available for leasing throughout the program's current 30,000-acre cultivation zone. The Town programs consist of 1 to 5-acre parcels sited within defined areas ranging from 7 to 290 acres. NYSDEC also has its own Temporary Marine Area Use Assignment (TMAUA) program that offers access to 5-acre parcels of state-owned underwater lands of Long Island and Block Island Sounds for off-bottom shellfish culture only (i.e., shellfish cultured in containment: cages, racks, bags, etc.). However, this program is largely inactive since the SCALP and Town programs provide access to the more protected coastal bays most attractive for siting mariculture operations. Private underwater land ownership is one other mechanism by which applicants can gain access for siting certain mariculture operations, whether as the owner or a lessee.

While NYSDEC has done a more comprehensive programmatic evaluation of SCALP based on all available marine resource data collected from throughout the program's cultivation zone, Town programs' sites, TMAUAs and private underwater lands are evaluated individually for any potential conflicts with marine resources, or with other user groups, as part of the permit application review process.

In addition to completing a permit application, applicants must also submit a cultivation/operational plan detailing all aspects of their proposed mariculture activities and documentation of their access to the underwater lands used for this purpose. Additional information on permitting requirements can be found at: https://www.dec.ny.gov/permits/96310.html#Aquaculture and https://www.dec.ny.gov/regs/2494.html.

New Jersey

The focus of aquaculture in New Jersey is on the culture of bivalve shellfish, primarily hard clams and oysters. The basic components of shellfish aquaculture include: on-shore hatcheries where larvae are spawned and raised; leased grounds within the NJ coastal zone for grow out; deployment of maintenance of the gear and product (shellfish); and harvest once the shellfish product reaches market

size. In New Jersey, the Atlantic Coast and Delaware Bay Sections of the Shellfisheries Council have statutory authority to issue a commercial shellfish lease to provide bottom for use in the planting and cultivating of shellfish, including grow out of hatchery reared seed.

The New Jersey Department of Environmental Protection (NJDEP), Bureau of Shellfisheries requires a commercial shellfish license on the Atlantic Coast for the cultivation and harvest of shellfish. Shellfish harvested under a commercial license can only be sold to certified dealers. A commercial shellfish aquaculture permit and hatchery/nursery permit can be obtained through the NJDEP, Bureau of Marine Water Monitoring (BMWM). These permits require the submission of an application through the BMWM as well as an Operational Plan encompassing on-farm activities and harvest or husbandry procedures. An Aquatic Farmer License Application through the New Jersey Department of Agriculture, Office of Aquaculture Coordination for molluscan and bivalve shellfish can also serve as the required Operational Plan. One component of the required Operational Plan is the submission of maps containing currently active leases. Maps for the Atlantic Coast may be accessible through the NJDEP, Bureau of Shellfisheries. Additional information about aquaculture development in New Jersey, including licensing process can be found at: https://www.jerseyseafood.nj.gov/aquaculture.html. Structural aquaculture within an existing commercial shellfish lease area will require additional State permits issued through the NJDEP's Division of Land Resource Protection and a tidelands license through NJDEP's Bureau of Tidelands Management. Federal permits for this activity are required from the USACE.

Pennsylvania

The Pennsylvania Department of Agriculture licenses parties propagating and dealing species which live on or in the water, including but not limited to all game fish, fish bait, baitfish, amphibians, reptiles, and aquatic organisms. More information on aquaculture licensing and regulations in Pennsylvania can be found at: https://www.agriculture.pa.gov/Animals/AHDServices/licenses-certificates/Aquaculture%20Licensing/Pages/default.aspx.

Delaware

The Delaware Bay

The Delaware Department of Natural Resources and Environmental Control (DNREC), Division of Fish & Wildlife (DDFW) has regulatory authority as it pertains to the leasing of shellfish grounds in the of the Delaware Bay. The DNREC advertises, on an annual basis, the general locations of shellfish grounds that are available for lease and are not currently subject to a valid lease. Any person wishing to lease shellfish grounds shall make application to DNREC by way of forms provided by the DNREC. If more than 1 application is received for the same grounds, a competitive sealed process would ensue. The terms of each lease shall begin on January 1 and run through December 31. Leases are to be renewed on an annual basis and any leases not renewed would revert back to available for leasing. Any new shellfish grounds can be no less than 50 acres nor greater than 100 acres in size.

Delaware's Inland Bays

The DNREC, through its DDFW, issues leases for shellfish aquaculture in the state's Inland Bays. Leasing in the Inland Bays is for commercial shellfish aquaculture. Applicants submit applications to the DDFW for up to five combined acres (in whole-acre increments) in Rehoboth and Indian River Bays, and/or an additional 5 acres in the Little Assawoman Bay. Applications and instructions are maintained on the Division's Inland Bays' shellfish aquaculture webpage https://dnrec.alpha.delaware.gov/fish-wildlife/fishing/shellfish-aquaculture/. Also, on this page is a link to a map that shows leases granted, lease acres pending, and areas available for leasing. Leases are granted for a 15 year term and are renewed annually. In the Inland Bays, DNREC has developed Shellfish Aquaculture Development Areas (SADA). Applications for leases within the SADA have expedited permitting with DNREC's Wetlands & Subaqueous Lands Section and USACE, having already undergone some public processes.

Maryland

Prior to conducting commercial shellfish aquaculture activities in Maryland waters, an individual or business entity must apply for and obtain a state lease and federal permit for the proposed shellfish aquaculture activities. Maryland DNR serves as the primary point of contact for applicants in submitting a Joint Application for State Commercial Shellfish Aquaculture Lease and USACE Federal Permit. Applicants who intend to culture shellfish directly on-bottom and not in containers are required to submit an application for a Submerged Land Lease. Applicants who intend to culture shellfish off-bottom and in containers are required to submit an application for a Water Column Lease. The shellfish lease review and approval process includes a comprehensive assessment of legal and resource impacts associated with the proposed project and also requires a public notice and provides an opportunity for a 30 day public comment on the project. In addition to issuing shellfish leases, and depending on the type of shellfish aquaculture activity, an operator may be required to apply for and obtain other permits from Maryland DNR including, shellfish import permit, shellfish hatchery/nursery permit and/or a shellfish aquaculture harvester permit/registration card. More information on aquaculture licensing and regulations in Maryland can be found at: https://dnr.maryland.gov/fisheries/pages/aquaculture/index.aspx.

The Maryland Department of Natural Resources' authority for issuing shellfish leases and other associated permits is granted through the Annotated Code of Maryland, Natural Resources Article, §4-11A (Aquaculture).

Virginia

Aquaculture shellfish (oysters and clams) leases (on-bottom) and aquaculture permits (floats, water column and on-bottom, if no lease) are issued by the Virginia Marine Resources Commission (VMRC; the state of Virginia marine resources agency). Applications for leases up to 250 acres in size can be requested through VMRC. VMRC conducts a public interest review of all lease and permit requests. Leased bottomlands also allow for the placement of bottom cage structures (no more than 12-inches

above the substrate) without any additional permits from the USACE, Norfolk District. Aquaculture activity that requires a permit is handled through a Joint Permit Application (JPA) process (http://leg5.state.va.us/reg_agent/frmView.aspx?Viewid=33ffb005797~5t.pdf&typ=40&actno=005797&mime=application/pdf) with the USACE to provide a single application process for such requests. Bottom leases are valid for ten year terms and are renewable. Permits for aquaculture activity are issued for five year terms and are also renewable. For additional information on permitting requirements visit: https://mrc.virginia.gov/Shellfish_Aquaculture.shtm.

VMRC has not received any request for algae production or fish production within enclosures, but such requests would require a permit through the JPA process through the agencies Habitat Management Division in consultation with the agencies Fisheries Management Division. The agency just recently received our first scallop aquaculture (suspended water column) request, which will also be handled through the JPA process.

It is state policy to avoid impacts to submerged aquatic vegetation (SAV) beds for lease requests and permit activity; however, the agency does have an SAV impacts guideline document that can allow for permitted activity with appropriate mitigation and/or compensation methods.

North Carolina

Aquaculture is considered a form of agriculture and the NC Department of Agriculture and Consumer Services (DACS), NC Wildlife Resources Commission (WRC), and NC Division of Marine Fisheries (DMF) share jurisdiction on various phases and culture of specific species. The Division of Coastal Management (DCM) and the Division of Water Resources (DWR) are also involved in the permitting and monitoring of the siting, construction, and operational impacts of the operations. The DACS regulates production and sale of commercially raised freshwater fish and freshwater crustacean species by issuing aquaculture licenses. The license is for any person who owns or operates an aquaculture facility for the purpose of possession, production, transportation, sale, or commercial grow out. If the species cultured is not on the approved list, then authorization is needed from the WRC in addition to the aquaculture license. Twenty-two species are approved for propagation and production, with no shellfish species listed. Three of the 22 species have specific restrictions that also must be approved through the WRC. The DMF requires permits for any aquaculture operation cultivating marine and/or estuarine species. The DMF, DACS, and WRC work together for issuance of certain aquaculture permits.

The North Carolina General Assembly (GA) supports shellfish aquaculture and encourages shellfish aquaculture development in ways that are compatible with other public uses. The GA established standards that provide for the leasing of public bottom for the cultivation and production of shellfish. The GA gives the Marine Fisheries Commission (MFC) the authority to make rules and take all steps necessary to improve cultivation, harvesting, marketing of shellfish in North Carolina both from public and private beds. The GA also gives the MFC jurisdiction over the conservation of marine and estuarine resources including the regulation of aquaculture facilities which cultivate or rear marine and estuarine resources. The MFC has adopted rules for shellfish leases including addressing adjacent riparian rights,

marking, renewal, reporting, transferring, and terminating shellfish leases. Through this authority, NCDMF regulates live native and non-native marine and estuarine species including aquaculture operations that involve rearing of finfish or shellfish in a land-based facility (i.e., tanks, ponds, raceways) or in any contained structure in submerged waters (i.e., cages, bags, racks). The DMF houses the Shellfish Lease and Aquaculture Program (SLAP) for the purposes of administering shellfish aquaculture within the State of North Carolina.

The SLAP administers shellfish leases in public trust waters for shellfish aquaculture (in brackish and higher salinity waters) which have existed in North Carolina for over 150 years. Public trust resources are land and water areas, whether publicly or privately owned, which are subject to Public Trust Rights as defined under North Carolina law. Shellfish leases are divided into two types: bottom and water column. You must have a bottom lease to have a water column lease. The water column lease can be granted over the entire footprint of a bottom lease, or on a portion of the lease. A shellfish franchise is similar to a bottom lease except that they are recognized submerged lands claims.

In addition to State regulations, shellfish leases are also required to meet federal permitting standards under the USACE Nationwide Permit 48 Regional Conditions for Commercial Shellfish Aquaculture Activities. Once an application is deemed complete, a site investigation is completed to ensure compliance with state and federal laws and MFC rules. Then, a 30 public comment period is followed by a public hearing before a final decision on approval is made.

Aquaculture operations are allowed to cultivate finfish approved by the DMF by means of the Aquaculture Operation Permit issued by the division. It allows Aquaculture Operation Permit holders to possess, sell, purchase, or transport approved finfish species in compliance with all conditions of the permit including record-keeping requirements designed to track the movement of finfish as an aquaculture product from its source to the consumer (https://files.nc.gov/deq/documents/2022-01/FF-10-2022_Finfish%20Aquaculture%20Exemptions_Final.pdf?VersionId=Kt9WzqG4r4YdMjy7zIM5jM_qdCMsFyDW and https://deq.nc.gov/news/press-releases/2022/01/12/new-aquaculture-permit-conditions-facilitate-cultivation-more-finfish-species).

Potential impacts of aquaculture activities on MAFMC-managed species and their habitats

The following summary provides information that has been documented on the potential impacts, both negative and positive, posed by aquaculture activities to MAFMC managed species and EFH, and includes references to various best management practices (BMPs) and the aforementioned regulatory framework used to safeguard coastal resources. It is important to note that the science of marine aquaculture is advancing rapidly and new information and techniques are emerging that can help to improve the understanding of the effects of aquaculture on the environment, including the best means to mitigate negative effects and bolster positive effects. This summary is not an exhaustive literature

review of scientific information on this complex topic. Rather, it is a synthesis of relevant information intended to provide the MAFMC and partners with a general understanding of the environmental effects of marine aquaculture of importance to the interests of the MAFMC.

Summary of impacts

The impacts of aquaculture activities on MAFMC-managed species and their habitats can be positive, neutral, or negative, primarily depending on the system used, the species being cultured, the ecological setting, and the experience level of the operators. For example, excess nutrients, organic matter, and suspended solids from finfish aquaculture effluents can exacerbate eutrophication in nearshore receiving water bodies when nutrient inputs exceed the capacity of natural dispersal and assimilative processes. On the other end of the spectrum, some forms of aquaculture have been used to mitigate eutrophication by sequestering nutrients in nearshore waters (e.g., shellfish and algae culture). In some cases, evaluating whether the impacts from aquaculture activities on EFH will be positive or negative is more complicated. Further, many of the effects are interrelated and can lead to indirect effects on managed species and other ecosystem components. Therefore, the positive and negative effects of aquaculture activities to fisheries and EFH need to be considered concurrently when attempting to provide informed input on proposed aquaculture projects.

Positive impacts

Positive impacts of aquaculture operations include carbon and nutrient sequestration, acidification regulation, improved water clarity, coastal protection, and habitat provisioning (Gentry 2019). The majority of these are associated with shellfish and algae aquaculture, however habitat provisioning associated with equipment used for marine fish culture is widely documented (Gentry 2019). In general, shellfish and algae aquaculture has positive impacts on EFH, providing ecosystem services and habitat related benefits in the estuary including mitigation of land-based nutrients and increased habitat for fish, shellfish, and crustaceans (Shumway 2011). The Nature Conservancy NC has put together a body of research demonstrating that aquaculture can help restore ocean health, as well as support economic development and food production in coastal communities worldwide—if the right practices are deployed in the right places (https://www.nature.org/en-us/what-we-do/our-insights/perspectives/restorative-aquaculture-for-nature-and-communities/).

- Bivalves sequester nutrients from the water column for shell and tissue formation. Both bivalve and algal culture can help reduce eutrophication through the uptake of nutrients, and bivalve aquaculture can help improve water quality through filtration and grazing (Cerco and Noel 2007, Rose et al. 2015). Thus, bivalve and algal culture can control phytoplankton bloom intensity in shallow waters (Gallardi 2014) and may present a viable strategy to mitigate eutrophication caused by agricultural and residential runoff (Petersen et al. 2016).

- Aquaculture gear has been documented to attract structure-oriented species and increase biomass and biodiversity on an otherwise minimally structured bottom. This “reef effect” may result in a localized increase in biomass and local biodiversity at varying trophic levels. For

example, juvenile fish are commonly observed utilizing aquaculture gear as nursery habitat. They in turn serve as a food source to higher trophic levels, including other fish. Suspended mussel culture has been documented to temporarily enhance populations of large macroinvertebrates and benthic fishes, including ecologically and commercially important species (Costa-Pierce and Bridger 2002, D'Amours et al. 2008b, Forrest et al. 2009, McKindsey et al. 2011). For example, lobsters have been found to be attracted to the presence of anchor blocks and mussel farm gear. This increase in lobster abundance may be attributed to increased refuge availability and food supply created by bivalves themselves, as well as other species drawn to the aquaculture gear (D'Amours et al. 2008a). Certain species of kelp have also been found to grow heavily on blue mussel longlines (McKindsey et al. 2006). DeAlteris et al. (2004) found that species diversity around aquaculture gear is equal to that of SAV, and greater than non-vegetated seabed.

In some cases, the effects from aquaculture activities on EFH can be viewed as both positive and negative. For example:

- Cages or cultch associated with aquaculture operations placed on soft sediments may be viewed as habitat conversion, however, conversion may have positive impacts if increased structural complexity is desired at the proposed site due to historic loss of structure from other anthropogenic activities. This issue would have to be considered on a project-specific basis.

- As described above, shellfish and algae culture can help regulate the abundance of phytoplankton in shallow areas which can lead to reduced turbidity and improved light penetration; however, improved light conditions may encourage the growth of nuisance algae (Cranford et al. 2003, Cranford et al. 2006, Gallardi 2014, Kaspar et al. 1985, McKindsey et al. 2006, Newell 2004).

Balancing the potential positive and negative effects of aquaculture activities on fisheries and EFH and incorporating acknowledgement of ecosystem services into the review of proposed projects has the potential to improve environmental performance and sustainable management of aquaculture. However, when possible, conditions designed to protect sensitive habitats and bolster positive impacts should be included in permits issued under state and federal laws and regulations to ensure benefits are not negated by poor management.

Adverse effects

The MSA defines an adverse effect to EFH as any impact that reduces quality and/or quantity of EFH. Adverse effects may include direct or indirect physical, chemical, or biological alterations of the waters or substrate and loss of, or injury to, benthic organisms, prey species and their habitat, and other ecosystem components, if such modifications reduce the quality and/or quantity of EFH. Adverse effects to EFH may result from actions occurring within EFH or outside of EFH and may include site-specific or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions (50 CFR 600.810(a)). Researchers have identified several potential impacts to fisheries and EFH from marine aquaculture, which are described below for finfish and shellfish operations. The individual and

cumulative risk of these specific adverse effects occurring as a result of aquaculture activities, and the magnitude of the impacts when they do occur, will vary by location (i.e., onshore, near-shore, and offshore) and by production format and species (i.e., fish, shellfish, algae). In some cases, the likely impacts from aquaculture activities are well understood and proper siting protocols, standardized operating procedures, and BMPs can be put in place to reduce or eliminate risk. In other cases, the impacts are not well understood and managers are required to err on the side of caution and use their best professional judgment when considering how activities may impact the environment and the most appropriate means to avoid or minimize those impacts.

Marine fish aquaculture activities

Marine fish culture can lead to the range of adverse effects. These include degradation of water quality resulting from the discharge of effluents containing uneaten feed and waste products (including drugs, chemicals, and other inputs); habitat degradation (including alteration of sediment composition and chemistry from settling wastes; alteration to benthic habitats, and changes to infaunal species composition); introduction of invasive species; impacts from the escape of cultured organisms (i.e., trophic and gene pool alterations); and the spread of pathogens and parasites from cultured to wild marine organisms. A significant consideration associated with finfish aquaculture is the potential for impacts on water quality and the seafloor environment adjacent to culture facilities from the discharge of effluents containing unused feed, metabolic fish wastes, and other inputs.

- Net pen and land-based flow through fish aquaculture often requires nutrient rich feeds. Depending on the efficiency of feeding and/or level of effluent treatment, this can introduce excess nutrients into coastal systems, in some cases exacerbating eutrophication. According to global studies, aquaculture's contribution to nitrogen in areas adjacent to net pens ranged broadly from none to significant levels (Price et al. 2013). When nutrient inputs associated with excess feed and waste do occur, they tend to be episodic and limited to the area adjacent to pens (Nash 2003). Beyond ensuring operations are sited in well-flushed locations, other methods for reducing the impact of feed and other wastes on water quality include improved diet formulations and selection of raw materials, treating effluent water, and recovering dead or uneaten fish (Talbot and Hole 1994). Recent advances in technology to monitor and refine feeding rates/feeding delivery could improve feed consumption which in turn could result in a reduction of environmental impacts (Føre et al. 2018, Kumar et al. 2018). Offshore areas may be less susceptible to these impacts because waters are normally nutrient deficient and fish wastes and other pollutants can dissipate more rapidly in deeper and better-flushed offshore areas than they can in nearshore areas (Gentry et al. 2019, Rust et al. 2014).

- Reviews have identified changes to sediment chemistry associated with solid feed and fish waste accumulation on the bottom below and around marine fish aquaculture facilities, if net pens are placed at high densities in semi-enclosed waterbodies with inadequate flushing. An assessment of a coastal Maine site with sandy mud sediments and low current velocity suggested that changes in sediment chemistry were localized to the area under the net pens (Findlay et al. 1995). These impacts can be avoided through proper siting

(Buschmann et al. 2008, Findlay and Watling 1997, Hixson et al. 2014, Klinger and Naylor 2012). Many modern facilities utilize underwater cameras to monitor operations so they can avoid overfeeding and quickly identify and respond to issues (Rust et al. 2014, Herbeck et al. 2013, Talbot and Hole 1994).

- Pharmaceutical drugs, biologics[3] and other chemicals used for the treatment of disease and pests in cultured fish have also been associated with impacts to water quality. The use of pharmaceutical drugs, biologics, and other chemicals for use in marine aquaculture in the U.S. is rare and declining (Rust 2014). This decline is largely attributed to improved husbandry and use of vaccines (Asche and Bjorndal 2011; Forster 2013). Vaccines have been successfully used to prevent a variety of bacterial diseases in finfish and are considered the safest prophylactic approach to management of aquatic animal health as they pose minimal risk to the environment, especially with regards to impacts to fisheries and EFH. All drugs and therapeutic chemicals for use on fish destined for human consumption must be approved by the USDA APHIS and FDA (FDA 2012).

The occurrence and extent of these impacts depends on a variety of factors that should be considered during the review process, including, feed quality, digestion, and metabolism, feeding rate, biomass of fish, and species. In addition, site characteristics such as cage design, depth, currents, existing water quality or nutrient levels, and benthic features also influence nutrient dispersion and impacts (Nash 2003, Rust 2014). Over the last several decades, advances in technology, improved facility siting, better feed management, and stricter regulatory requirements have greatly reduced the risk of impacts to water quality and the seafloor environment from fish aquaculture activities (Price et al. 2015, Rust et al. 2014). Effluent discharges are highly regulated by EPA and aquaculture operators are required to adopt best management practices, including integrating advanced feed management strategies, optimally formulated diets, environmental monitoring, and reporting (EPA 2017).

A regionally relevant example of how best management practices, combined with advances in production methodology, have limited the risk of environmental impacts from marine fish aquaculture can be found in Maine, where Atlantic salmon have been grown in open-net pens since the 1970s. Salmon farmers in Maine worked in cooperation with state and federal regulators and the environmental community to develop a series of BMPs that establish operational and monitoring requirements designed to minimize their environmental footprint. As a result, water quality impairments have been significantly reduced via the use of vaccines and integrated pest management, and the minimal to non-existent use of antibiotics and growth enhancers (Maine Seafood Guide – Salmon 2019).[4] Improvements in feed efficiency have reduced effects on dissolved oxygen, turbidity, and nutrient loading (Price et al. 2015). Thermal baths have largely replaced the use of chemical treatments for sea lice infections, and biological delousing with cleaner fish is also being explored as a preventive treatment for parasites (UNH).[5] In 2016, Maine-raised salmon were upgraded from “avoid”

[3] Biologics include vaccines, bacterins (suspension of killed or attenuated bacteria for use as a vaccine), and probiotics.
[4] https://seagrant.umaine.edu/maine-seafood-guide/salmon/
[5] https://scholars.unh.edu/cgi/viewcontent.cgi?article=2543&context=thesis

to "good alternative" by the Monterey Bay Aquarium Seafood Watch Program,[6] which rates seafood according to whether it supports a healthy ocean.

The use of integrated multi-trophic aquaculture by adding other organisms such as invertebrates and seaweeds to the aquaculture system is also being evaluated to lessen environmental impacts from marine fish aquaculture facilities in New England. These systems are intended to mimic natural trophic relationships, where wastes and excess nutrients from cultured fish are consumed by shellfish or assimilated by seaweed (Buck et al. 2017, Rust et al. 2014).

Marine shellfish aquaculture activities

Impacts to water quality, sediments and benthic habitats from marine shellfish aquaculture have also been documented. The impacts of specific concern to the MAFMC include changes to benthic habitat as a result of pseudofeces deposition, the effects of mechanical harvesting, conversion of soft sediment habitat to hard bottom shellfish reef, displacement of cultured organisms, sedimentation and loading of organic waste to the water column and benthic sediments, and disruption of the benthic community and impacts to SAV located near shellfish aquaculture operations.

- Shellfish release pseudofeces, a byproduct of filtering food from the water column. If allowed to accumulate, the increased deposition of organic matter to the benthos can degrade sediment quality (Forrest et al. 2009, Gosling 2015), increase turbidity, and deplete dissolved oxygen. This is particularly true in areas with poor tidal flushing where organic material can build up under aquaculture sites (Dumbauld et al. 2009). These impacts are likely to be negligible in areas with high tidal flushing where sediment buildup is not localized (Dumbauld et al. 2009).
- The placement and retrieval of off-bottom gear and mechanical and hydraulic harvest methods can result in a release of suspended sediment and organic matter into the water column through increased erosion, transport, and sediment shear and direct physical disturbance. The increased turbidity and physical disturbance associated with these activities may have impacts on benthic communities and demersal fish species (Dumbauld et al. 2009, Forrest et al. 2009, Smith et al. 2006). These impacts are greater for operations located in areas with fine grain sediments that area easily re-suspended into the water column (Chamberlain et al. 2001, Crawford et al. 2003, da Costa and Nalesso 2006, Shumway 2011). Areas with low tidal flushing (~5 cm^{s-1}) are more likely to experience benthic habitat changes due to the accumulation of organic waste and its accompanying effects described above (Crawford et al. 2003).

- Studies have also shown that bivalve aquaculture (via biodeposition, using both suspension and bottom-culture methods) has the ability to alter diverse benthic communities dominated by suspension feeders into one dominated by opportunistic deposit feeders, such as polychaetes, scavengers, carnivores, and hydrogen sulphide-tolerant species. Hydrologic regime, culture density, and culture method influence the magnitude of effects (Callier et al. 2009, Dumbauld et al. 2009, Fabi et al. 2009, Forrest et al. 2009, Fréchette 2012, Gallardi 2014, Hartstein and Rowden 2004, Kaspar et al. 1985). A recent study in Rhode Island assessed the long-term

[6] https://www.seafoodwatch.org/

disturbance from oyster cage aquaculture and found significant differences in the benthic community structures and the presence or absence of opportunistic species between aquaculture sites and sites with no aquaculture present (Duball et al. 2017). However, studies on the effects of hydraulic dredging in nearshore leased shellfish beds in fine to very fine sand in Long Island Sound, Connecticut, showed no significant differences between dredged and non-dredged treatments over a several month period for the benthic community as a whole, nor were there any major effects on sediment biogeochemistry (Goldberg et al. 2012, 2014, Meseck et al. 2014). In a study to better quantify the ecological benefits and impacts of oyster aquaculture in the Chesapeake Bay, VA, researchers sampled water quality, sediment quality, benthic macrofaunal communities , and oysters at four oyster aquaculture sites located on the western shore. Differences in water quality, sediment quality, and macrofauna structure between areas within and outside the farm footprint at each evaluated site were rare. In instances where differences existed, they were small in magnitude and varying direction (i.e., negative versus positive impacts) (Kellogg et al. 2018).

- Habitat conversion can be a concern with some types of shellfish aquaculture, specifically the shift from soft to hard bottom due to the addition of gear or cultch or other fill material. As noted previously, this may benefit certain structure-oriented species (e.g., black sea bass), but harm species that prefer soft bottom (e.g., summer flounder). However, if increased structural complexity is desired at the proposed site due to historic loss of structure from other anthropogenic activities the conversion may be viewed as beneficial (Gallardi et al. 2014).

- SAV is susceptible to damage caused by aquaculture; impacts vary based on gear used for both grow out and harvest. Dumbauld and McCoy (2015) found no change in eelgrass due to the presence of on-bottom oyster beds. Mechanical harvesting commonly associated with bottom culture resulted in significantly less eelgrass coverage along harvested sites compared to unharvested sites. As aquaculture operations have the potential for adverse effects to eelgrass through displacement of SAV habitat and physical disturbance, on-bottom shellfish aquaculture activities should not be conducted on or in immediate proximity to existing eelgrass beds (Ford and Carr 2016); this is an existing best practice in many areas as detailed in the state permitting overview. A buffer between eelgrass meadows and bottom-planted aquaculture sites can limit physical displacement and turbidity effects. Hand-harvest methods were found to be the least disruptive (Dumbauld et al. 2009, Stephan et al. 2000). SAV may also be affected by floating or suspended culture equipment that results in light limitation. Ferriss et al. (2019) found a negative effect of off-bottom aquaculture on eelgrass density, percent cover and reproduction, along with a neutral effect on biomass and growth. Adequate spacing between off-bottom cages, bags, or longlines may mitigate this effect.

While adverse effects to EFH are possible from shellfish aquaculture, the overall risk of impacts to fisheries and EFH can be minimized or eliminated through proper management and siting (Crawford et al. 2003, Dumbauld et al. 2009, Forrest et al. 2009, Gallardi 2014, Gosling 2015, Kaiser et al. 1998, Shumway 2011). Best management practices are now in place for shellfish aquaculture along the U.S.

East Coast (Flimlin 2010) and there is a robust federal and state regulatory process in place designed to limit the specific concerns. This is especially true for the Mid-Atlantic, where many states have established mandatory siting criteria, such as the exclusion of siting new aquaculture sites on sensitive habitats such as eelgrass.

Interactions between MAFMC species and aquaculture activities

If not properly managed, some marine aquaculture activities have the potential to result in direct adverse effects to species managed by the MAFMC, beyond the indirect effects associated with habitat impacts. These include impacts associated with the escape of cultured organisms, the introduction of invasive or non-native species; and the spread of pathogens and parasites from cultured to wild marine organisms (Naylor et al. 2005).

The escape of cultured fish from aquaculture facilities is a significant concern related to aquaculture. The likelihood of escapes from aquaculture operations, and the severity of the impacts associated with escapement, will vary depending on the species being cultured, siting guidelines, structural engineering and operational design, management practices (including probability for human error), adequacy of biosecurity and contingency plans, frequency of extreme weather events, and direct interactions with predators such as sharks and marine mammals that may compromise the integrity of fish enclosures.

- There are substantial concerns that nonnative fish used in aquaculture can escape and become established in the wild, competing with wild fish for food, habitat, mates, and other resources. Most introduced species do not become invasive; however, beyond aquaculture applications, naturalization of introduced non- native species that results in invasion and competition with native fauna and flora has emerged as one of the major threats to natural biodiversity (Bax et al. 2003, D'Antonio et al. 2001, Olenin et al. 2007, Wilcove et al. 1998). Some non-native species have been documented to alter the physical characteristics of coastal habitats and may thus affect population, community, and ecosystem processes (Grosholz 2002). Northeast states, EPA, and USACE highly restrict the use of non-native species in aquaculture, which largely mitigates this concern. One notable exception is the culture of "naturalized" species such as European Oysters and Steelhead Trout that have been present in New England waters for over a century. NOAA Fisheries' Aquaculture policy supports the use of only native or naturalized species in federal waters unless best available science demonstrates that the use of non-native or other species in federal waters would not cause undue harm to wild species, habitats, or ecosystems in the event of an escape.

- Even when native species are utilized, genetic diversity could be affected if hatchery-raised fish spawn with wild conspecifics. 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 (Price et al. 2015). Naylor et al. (2005) suggest that the risks of escaped cultured salmon impacting wild salmon are greater where the populations of farmed salmon are higher than native populations. 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. Large-scale experiments in Norway and Ireland show highly reduced survival and lifetime success rates of farmed and hybrid Atlantic salmon compared to wild salmon (Thorstad 2008). Means of decreasing the genetic risks associated with escapes includes the required use of wild broodstock with a genetic makeup that is similar to local wild populations and the use of sterile fish created through techniques such as hybridization, chemical sterilization, polyploidy (Price et al. 2015). These strategies come with trade-off such as increased production costs and the inability to benefit from selective breeding.

Another concern to MAFMC managed species is impacts from the spread of endemic and introduced pathogens and parasites from cultured populations to wild populations. Risks posed by pathogens and parasites are harder to quantify than those posed by competition or predation, as a single individual transferred to a recipient population can have dramatic consequences. Further, these agents can be spread by water, independent of any escape of cultured individuals. The risk and prevalence of disease in aquaculture operations is influenced by many factors, including immune status, stress level, pathogen load, environmental conditions, water quality, nutritional health, life history stage, and feeding management. The type and level of husbandry practices and disease surveillance will also influence the potential spread of pathogens to wild stocks.

- Cultured organisms are often more susceptible to diseases because they are kept at higher densities, which both increases their rate of contact and may induce stress. Research suggests that fish pathogens may be transferred from farmed to wild fish and that nonnative pathogens may be introduced when fish are moved from different areas (Rust et al. 2014). Effluent treatment and the use of static tanks to hold potentially infected broodstock are effective measures to control the risk of transmission from on shore systems. Nearshore and offshore operations have the greatest potential for exchange of pathogens between cultured and wild organisms as they bring cultured organisms into close contact with their wild cohorts, and a diverse community of potential intermediate hosts to parasites or pathogens. These conditions provide an opportunity for parasites or pathogens with direct and indirect life cycles to proliferate in and near the pen where they may become major causes of disease in both wild and cultured hosts.

- Some studies suggest that high host densities in net pens promote transmission and growth of the parasite sea lice (*Lepeophtheirus salmonis* - a parasitic copepod). The rapid decline of wild populations of pink salmon on the Canadian Pacific Coast in 2002 was hypothesized to be the result of sea lice infections associated with salmon farms in the area (Krkošek et al. 2007). However, Marty et al. (2010) conducted an extensive review of data on farmed and wild populations and found the productivity of wild salmon was not negatively associated with either farm lice numbers or farm fish production, and all published field and laboratory data support the conclusion that something other than sea lice caused the population decline in 2002. In contrast a 2011 study found sea lice abundance on farms to be negatively associated with productivity of both pink and coho salmon in the Broughton Archipelago of British Columbia

(Krkošek et al. 2011). Improved facility design engineering and buffer zones between aquaculture facilities and natural stocks, fallowing periods, and other measures have been employed to reduce the risk of disease transfer between cultured fish and wild populations (Krkošek 2005).

- Shellfish can also carry veterinary diseases that may have adverse impacts on or decimate natural shellfish populations and cultured stocks (Carnegie, 2016). Common shellfish culture practices in the Mid-Atlantic often involve the movement of shellfish between water bodies (hatchery sites, nursery sites, and final planting/harvest site). When moved, shellfish can potentially spread disease to natural populations and cultured stocks in the receiving waters or exacerbate disease levels where the pathogens may already exist. Mid-Atlantic states have specific protocols that must be followed when introducing and transplanting cultured species into wild environments to minimize the incidence of disease transfer. These often include pathogen screening guidelines and certification programs for movement of germplasm, embryos, larvae, juveniles, and broodstock. Some Mid-Atlantic states outright restrict the importation of seed stocks from other states, where others impose geographic restrictions on the source of seed and brood stock. In the case of aquaculture operations in federal waters, the Gulf of Mexico Fishery Management Council specified in their Fishery Management Plan for Regulating Offshore Marine Aquaculture that prior to stocking animals in an aquaculture system in federal waters of the Gulf, the permittee must provide NOAA Fisheries a copy of a health certificate signed by an aquatic animal health expert certifying cultured animals were inspected and determined to be free of World Organization of Animal Health reportable pathogens (OIE 2003) or additional pathogens that are identified as reportable pathogens in the National Aquatic Animal Health Plan (GMFMC 2012).

- While regulatory restrictions and screening can limit the risk of pathogenic transmission, some of the most notable impacts from diseases and parasites are associated with unintentional or deliberate introductions in violation of existing requirements. Burreson et al. (2000) used molecular methods to show that the parasite *Haplosporidium nelsoni* (popularly known as MSX), which has decimated populations of the eastern oyster (*Crassostrea virginica*) along the Atlantic coast of the United States, may have originated from translocations of Pacific oyster, *Crassostrea gigas*, from Japan. However, the means of MSX introduction, whether from illegal introduction of Pacific oysters, fouling of oysters on ship bottoms, or from ballast water, is unknown (NRC 2004).

Potential interactions with other coastal and marine activities

Commercial and recreational fishing and boating activities may be affected by aquaculture activities if they are not sited to avoid productive fishing or vessel transit areas. Generally, an aquaculture lease provides the lessee exclusive rights to permitted organisms within the lease area, but does not restrict other activities. This therefore directly prevents the commercial and recreational harvest of cultured species within the lease area. While this does not directly restrict the harvest of other species within the lease area, many forms of commercial fishing may not be compatible with some aquaculture activities.

For example, the Maine lobster industry requested a temporary ban on new aquaculture leases in 2019 because of concerns that new leases may interfere with their ability to harvest lobster with fixed bottom fishing gear/pots (Bangor Daily News 2019). Rod and reel fishing is generally still possible (e.g., on a kelp or shellfish lease). To avoid conflicts between fishing and aquaculture, baseline environmental surveys of proposed sites are needed to avoid overlap with productive resource areas.

Recreational and commercial boating (i.e., sailing, rowing, water skiing, jet skiing, kayaking, stand up paddleboarding) may be affected by aquaculture operations if the activities are not properly sited. Bottom gear and bottom planting methods are generally not viewed as a conflict with navigation. Power boating, sailboating, jet skiing, and rowing are unlikely to be compatible with floating gear, but kayaking and paddleboarding would generally not be restricted. Depending on the depth of the aquaculture gear, boating may not be affected by suspended culture activities as most configurations are a minimum of 8' below the surface. Through the federal review and authorization process, as well as state review processes, a navigational assessment is conducted and projects with potential conflicts undergo additional review by the USCG and USACE. USACE requires aquaculture activities to be sited outside of federal navigation channels and has established thresholds related to the square footable of floating gear that can be authorized under statewide general permits.

Renewable energy and aquaculture could potentially be co-located. For example, the possibility of siting aquaculture farms within wind farms has been proposed in Germany (Gimpel et al. 2015, Buck et al. 2004). However, the installation of aquaculture facilities may prevent boating and fishing within wind energy areas, depending on the configuration.

References

Asche, F, Bjorndal T (2011). The economics of salmon aquaculture. Wiley-Blackwell.

Bangor Daily News (2019). Maine fishermen ask for temporary ban on aquaculture permits. 3/20/2019. https://bangordailynews.com/2019/03/20/politics/maine-fishermen-ask-for-temporary-ban-on- aquaculture-permits/

Bax N, Williamson A, Aguero M, Gonzalez E, Geeve W (2003). Marine invasive alien species: a threat to global biodiversity. *Marine Policy* 27: 313–323.

Buck, BH, Krause, G, Rosenthal, H (2004). Extensive open ocean aquaculture development within wind farms in Germany: The prospect of offshore co-management and legal constraints. *Ocean & Coastal Management* 47(3): 95–122.

Buck BH, Langan R (2017). Offshore and Multi-Use Aquaculture with Extractive Species: Seaweeds and Bivalves, in Aquaculture Perspective of Multi-Use Sites in the Open Ocean, ed. Buck BH and Langan R (Cham, Switzerland: Springer International, 2017), pages 23-70.

Burreson EM, Stokes NA, Friedman CS (2000). Increased virulence in an introduced pathogen: *Haplosporidium nelsoni* (MSX) in the Eastern oyster *Crassostrea virginica*. *Journal of Aquatic Animal Health* 12(1): 1-8.

Buschmann AH, Hernández-González M C, Aranda C, Chopin T, Neori, A et al. (2008). Mariculture waste management. Pages 2211-2217 in The Encyclopedia of Ecology, Ecological Engineering, Jorgensen SE, Fath BD, eds. Elsevier, Oxford.

Callier MD, Richard M, McKindsey CW, Archambault P, Desrosiers G (2009). Responses of benthic macrofauna and biogeochemical fluxes to various levels of mussel biodeposition: an in situ "benthocosm" experiment. *Marine Pollution Bulletin* 58: 1544-1553.

Carnegie RB, Arzul I, Bushek D (2016). Managing marine mollusc diseases in the context of regional and international commerce: policy issues and emerging concerns. *Philosophical Transactions of the Royal Society B: Biological Sciences* 371(1689): 20150215. doi:10.1098/rstb.2015.0215

Cerco CF, Noel MR (2007). Can oyster restoration reverse cultural eutrophication in Chesapeake Bay? *Estuaries and Coasts* 30(2): 331-343.

Chamberlain J, Fernandes TF, Read P, Nickell TD, Davies IM (2001). Impacts of biodeposits from suspended mussel (*Mytilus edulis* L.) culture on the surrounding surficial sediments. *ICES Journal of Marine Science* 58: 411-416.

Costa-Pierce BA, Bridger CJ (2002). The role of marine aquaculture facilities as habitats and ecosystems. Pages 105–144 in Stickney RR, McVey JP, ds. Responsible Marine Aquaculture. CABI International.

Cranford P, Dowd M, Grant J, Hargrave B, McGladdery S (2003). A scientific review of the potential environmental effects of aquaculture in aquatic systems: Ecosystem level effects of marine bivalve aquaculture. Fisheries and Oceans Canada.

Cranford PJ, Anderson R, Archambault P, Balch T, Bates SS, et al. (2006). Indicators and thresholds for use in assessing shellfish aquaculture impacts on fish habitat. Canadian Science Advisory Secretariat Fisheries and Oceans Canada.

Crawford CM, Macleod CKA, Mitchell IM (2003). Effects of shellfish farming on the benthic environment. *Aquaculture* 224: 117-140.

D'Amours O, Archambault P, McKindsey CW, Johnson LE (2008a). Local enhancement of epibenthic macrofauna by aquaculture activities. *Marine Ecology Progress Series* 371: 73-84.

D'Amours O, Archambault P, McKindsey CW, Robichaud L (2008b). The influence of bivalve aquaculture on ecosystem productivity. *World Aquaculture Magazine*, September 2008: 26–29.

D'Antonio CM, Levine J, Thomsen M (2001). Propagule supply and resistance to invasion: a California botanical perspective. *Journal of Mediterranean Ecology* 2: 233–245.

da Costa KG, Nalesso RC (2006). Effects of mussel farming on macrobenthic community structure in Southeastern Brazil. *Aquaculture* 258: 655-663.

DeAlteris, JT, Kilpatrick, BD, Rheault, RB (2004). A comparative evaluation of the habitat value of shellfish aquaculture gear, submerged aquatic vegetation and a non-vegetated seabed. *Journal of Shellfish Research* 23(3): 9.

Duball C, Stolt MH, Amador JA (2017). Environmental Impacts of Oyster Aquaculture on the Coastal Lagoons of Southern Rhode Island. University of Rhode Island.

Dumbauld BR, McCoy LM (2015). Effect of oyster aquaculture on seagrass *Zostera marina* at the estuarine landscape scale in Willapa Bay, Washington (USA). *Aquaculture Environmental Interactions* 7:29-47.

Dumbauld BR, Ruesink JL, Rumrill SS (2009). The ecological role of bivalve shellfish aquaculture in the estuarine environment: a review with application to oyster and clam culture in West Coast (USA) estuaries. *Aquaculture* 290: 196-223.

EPA (2017). NPDES Aquaculture Permitting. https://www.epa.gov/npdes/npdes-aquaculture-permitting

Fabi G, Manoukian S, Spagnolo A (2009). Impact of an open-sea suspended mussel culture on the macrobenthic community (Western Adriatic Sea). *Aquaculture* 289: 54-63.

FAO (2018). The State of World Fisheries and Aquaculture: Meeting the Sustainable Development Goals. Rome. Licence: CC BY-NC-SA 3.0 IGO. 210p.

FDA (2012). Letter to Aquaculture Professionals. (Available at http://www.fda.gov/AnimalVeterinary/SafetyHealth/ProductSafetyInformation/ucm324048.htm)

Ferriss BE, Conway-Cranos LL, Sanderson BL, Hoberecht L. (2019). Bivalve aquaculture and eelgrass: A global meta-analysis. *Aquaculture* 498:254-262.

Findlay RH, Watling L (1997). Prediction of benthic impact for salmon net-pens based on the balance of benthic oxygen supply and demand. *Marine Ecology Progress Series* 155: 147–157.

Findlay RH, Watling L, Mayer LM (1995). Environmental impact of salmon net-pen culture on marine benthic communities in Maine: A case study. *Estuaries* 18(1): 145-179.

Flimlin G, Macfarlane S, Rhodes E, Rhodes K (2010). Best management practices for the East Coast Shellfish Aquaculture Industry. East Coast Shellfish Growers Association.

Ford KF, Carr J (2016) Eelgrass loss over time in Duxbury, Kingston, and Plymouth Bays, Massachusetts. Final Report. Massachusetts Division of Marine Fisheries. Submitted to Massachusetts Bays Program. 44p.

Føre M, Frank K, Norton T, Svendsen E, Alfredsen JA, et al. (2018). Precision Fish Farming: A New Framework to Improve Production in Aquaculture. *Biosystems Engineering* 173: 176-193.

Forster, J. 2013. A review of opportunities, technical constraints and future needs of offshore mariculture – temperate waters. *In* A. Lovatelli, J. Aguilar-Manjarrez & D. Soto, eds. *Expanding mariculture farther offshore: technical, environmental, spatial and governance challenges*. *FAO Technical Workshop, 22–25 March 2010, Orbetello, Italy*. FAO Fisheries and Aquaculture Proceedings No. 24. Rome, FAO. pp. 77–99.

Forrest BM, Keeley NB, Hopkins GA, Webb SC, Clement DM (2009) Bivalve aquaculture in estuaries: review and synthesis of oyster cultivation effects. *Aquaculture* 298: 1-15.

Fréchette M (2012). Self-thinning, biodeposits production, and organic matter input to the bottom in mussel suspension culture. *Journal of Sea Research* 67: 10-20.

Gallardi D (2014). Effects of bivalve aquaculture on the environment and their possible mitigation: A review. *Fisheries and Aquaculture Journal* 5: 105.

Gentry R, Alleway H, Bishop M, Gillies C, Waters T, Jones R (2019). Exploring the potential for marine aquaculture to contribute to ecosystem services. *Reviews in Aquaculture* 2019: 1-14.

Gimpel A, Stelzenmüller V, Grote B, Buck BH, Floeter J, et al. (2015). A GIS modelling framework to evaluate marine spatial planning scenarios: Co-location of offshore wind farms and aquaculture in the German EEZ. *Marine Policy* 55: 102–115.

GMFMC (2012). Gulf of Mexico Fishery Management Council Marine Aquaculture Policy. https://gulfcouncil.org/wp-content/uploads/Marine-Aquaculture-Policy-1-04-1.pdf

Goldberg R, Mercaldo-Allen R, Rose JM, Clark P, Kuropat C, Meseck S, Pereira J. (2012). Effects of hydraulic shellfish dredging on the ecology of a cultivated clam bed. *Aquaculture Environment Interactions* 3: 11- 21.

Goldberg R, Rose JM, Mercaldo-Allen R, Meseck SL, Clark P, Kuropat C, Pereira J (2014). Effects of hydraulic shellfish dredging on the benthic ecology and sediment chemistry on a cultivated bed of the Northern quahog, *Mercenaria*. *Aquaculture* 428-429: 150-157.

Goldburg RJ, Elliott MS, Naylor RL (2001). Marine Aquaculture in the United States: Environmental Impacts and Policy Options. Pew Oceans Commission, Arlington, VA. 33p.

Gosling, E (2015). Marine Bivalve Molluscs (Second Edition). John Wiley & Sons, Incorporated.

Grosholz E (2002). Ecological and evolutionary consequences of coastal invasions. *Trends in Ecology and Evolution* 17: 22-27.

Hartstein ND, Rowden AA (2004). Effect of biodeposits from mussel culture on macroinvertebrate assemblages at sites of different hydrodynamic regime. *Marine Environmental Research* 57: 339-357.

Herbeck LS, Unger D, Wu Y, Jennerjahn TC (2013). Effluent, nutrient and organic matter export from shrimp and fish ponds causing eutrophication in coastal and back-reef waters of NE Hainan, tropical China. *Continental Shelf Research* 57: 92–104.

Hixson, SM (2014). 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: 1-10.

Kaiser MJ, Laing I, Utting SD, Burnell GM (1998). Environmental impacts of bivalve mariculture. *Journal of Shellfish Research* 17(1): 59-66.

Kaspar HF, Gillespie PA, Boyer IC, MacKenzie AL (1985). Effects of mussel aquaculture on the nitrogen cycle and benthic communities in Kenepuru Sound Marlborough Sounds New Zealand. *Marine Biology* 85: 127-136.

Kellogg M L, Turner J, Dreyer JC, Friedrichs C (2018). Environmental and ecological benefits and impacts of oyster aquaculture: Addendum. Virginia Institute of Marine Science, William & Mary. https://doi.org/10.25773/r01b-tg44

Klinger D, Naylor RL (2012). Searching for solutions in aquaculture: Charting a sustainable course. *Annual Review of Environment and Resources* 37(1): 247.

Krkošek M, Ford JS, Morton A, Lele S, Myers RA, Lewis MA (2007). Declining wild salmon populations in relation to parasites from farm salmon. *Science* 318(5857): 1772-1775.

Krkošek, M, Lewis M, Volpe JP (2005). Transmission dynamics of parasitic sea lice from farm to wild salmon. *Proceedings of the Royal Society B: Biological Sciences* 272:689–693.

Krkošek, M, Connors BM, Morton A, Lewis MA, Dill LM, Hilborn R (2011). Effects of parasites from salmon farms on productivity of wild salmon. *Proceedings of the National Academy of Sciences USA* 108(35): 14700-14704.

Kumar G, Engle C, and Tucker C (2018). Factors Driving Aquaculture Technology Adoption. *Journal of the World Aquaculture Society* 49(3): 447-476.

Marty GD, Saksida SM, Quinn TJ 2nd. (2010). Relationship of farm salmon, sea lice, and wild salmon populations. *Proceedings of the National Academy of Sciences USA* 107: 22599–22604.

McKindsey CW, Anderson MR, Barnes P, Courtenay S, Landry T, et al. (2006). Effects of shellfish aquaculture on fish habitat. Canadian Science Advisory Secretariat, Fisheries and Oceans Canada.

McKindsey CW, Archambault P, Callier MD, Olivier F (2011). Influence of suspended and off-bottom mussel culture on the sea bottom and benthic habitats: a review. *Canadian Journal of Zoology* 89: 622-646.

Meseck SL, Mercaldo-Allen R, Rose JM, Clark P, Kuropat C, Pereira JJ, Goldberg R. (2014). Effects of hydraulic shellfish dredging for *Mercenaria*, northern quahog, on sediment biogeochemistry. *Journal of the World Aquaculture Society* 45(3): 301-311.

Nash CE (2003). Interactions of Atlantic salmon in the Pacific Northwest. VI. A synopsis of the risk and uncertainty. *Fisheries Research* 62: 339−347.

NRC (2004). Non-native Oysters in the Chesapeake Bay. The National Academies Press: Washington, DC. 325p.

Naylor R, Hindar K, Fleming IA, Goldburg R, Williams S, et al. (2005). Fugitive Salmon: Assessing the Risks of Escaped Fish from Net-Pen Aquaculture. *BioScience* 55(5), 427–437.

Newell RIE (2004). Ecosystem influence of natural and cultivated populations of suspension-feeding bivalve molluscs: a review. *Journal of Shellfish Research* 23: 51-61.

NOAA (2019). What is aquaculture? https://oceanservice.noaa.gov/facts/aquaculture.html

NOAA (2022). Guide to Permitting Marine Aquaculture in the United States. https://www.fisheries.noaa.gov/resource/document/guide-permitting-marine-aquaculture-united-states-2022

OIE (2003). Aquatic Animal Health Code and Manual of Diagnostic Tests for Aquatic Animals, sixth ed. Office International des Epizooties, Paris. http://www.oie.int/eng/normes/fcode/a_summary.htm

Olenin S, Minchin D, Daunys D (2007). Assessment of biopollution in aquatic ecosystems. *Marine Pollution Bulletin* 55: 379-394.

Petersen JK, Saurel C, Nielsen P, Timmermann K (2016). The use of shellfish or eutrophication control. *Aquaculture International* 24: 857–878.

Price CS, Morris JA Jr. (2013). Marine Cage Culture and the Environment, NOAA, NOAA Technical Memorandum NOS NCCOS 164, December 2013.

Price CS, Black K, Hargrave B, Morris J Jr. (2015). Marine cage culture and the environment: Effects on water quality and primary production. *Aquaculture Environment Interactions* 6: 151-174.

Rose JM, Bricker SB, Ferreira JG (2015). Modeling shellfish farms to predict harvest-based nitrogen removal. *Marine Pollution Bulletin* 91: 185-190.

Rust MB, Amos KH, Bagwill AP, Dickhoff WW, Juarez LM, et al. (2014). Environmental Performance of Marine Net-Pen Aquaculture in the United States. *Fisheries* 39(11): 508-524.

Shumway SE (2011). Shellfish Aquaculture and the Environment. John Wiley and Sons, Inc. 507p.

Smith R, Boyd SE, Rees HL, Dearnaley MP, Stevenson JR (2006). Effects of dredging activity on epifaunal communities – surveys following cessation of dredging. *Estuarine, Coastal and Shelf Science* 70:207-223.

Stephan CD, Peuser RL, Fonseca MS (2000). Evaluating Fishing Gear Impacts to Submerged Aquatic Vegetation and Determining Mitigation Strategies. Atlantic States Marine Fisheries Commission Habitat Management Series #5. 38p. http://www.asmfc.org/uploads/file/gearImpactsReport.pdf

Talbot C, Hole R (1994). Fish diets and the control of eutrophication resulting from aquaculture. *Journal of Applied Ichthyology* 10: 258-270.

Thorstad EB, Fleming JA, McGinnity P, Soto D, Wennevik V, Whoriskey F (2008). Incidence and impacts of escaped farmed Atlantic Salmon *Salmo salar* in nature. Report from Technical Working Group on Escapes of the Salmon Aquaculture Dialogue, 112 p.

Wilcove DS, Rothstein D, Bubow J, Phillips A, Losos E (1998). Quantifying threats to imperiled species in the United States. *BioScience* 48(8): 607-615.

Selected best management practices

Some of these were referenced to identify best practices in the Council's aquaculture policy.

Charron BT, Miller TL, Riley KL, Morris Jr. JA, Weirich CR. Prevention of Marine Debris from Shellfish Mariculture: Best Management Practices for North Carolina Producers. Developed by the North Carolina Coastal Federation in collaboration with the National Centers for Coastal Ocean Science and North Carolina Sea Grant. https://www.nccoast.org/wp-content/uploads/2018/06/NC-Mariculture-Marine-Debris-BMP-FINAL.pdf

- *This document has useful descriptions of shellfish culture practices, including photos.*

FAO/World Bank (2015). Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture. Policy Brief. Food and Agriculture Organization of the United Nations and World Bank Group Environmental & Natural Resources I5004E/1/09.15. 4p.

Flimlin G, Macfarlane S, Rhodes E, Rhodes K (2010). Best Management Practices for the East Coast Shellfish Aquaculture Industry. East Coast Shellfish Growers Association. 78p.

- *This document has useful descriptions of shellfish culture practices, including photos.*

Global Aquaculture Alliance (2021). Aquaculture Facility Certification, BAP Farm Standard. Best Aquaculture Practices Certification Standards, Implementation Guidelines: Issue 3.0. 73p.

- *This document applies to the farming of finfish, crustaceans, and other aquatic invertebrates, using all production methods, but does not cover bivalve mollusk or net pen salmonid production, or egg/juvenile production for transfer to other aquaculture facilities.*

Global Aquaculture Alliance (2016). Best Aquaculture Practices (BAP) Certification Standards, Guidelines: Mollusk Farms. Version 1. 25p.

Hickey JM, Shields T, Kennedy J, Ford K (2015). Massachusetts Division of Marine Fisheries Shellfish Planting Guidelines, 3rd edition. 15p.

Leavitt DF, ed. Best Management Practices for the Shellfish Culture Industry in Southeastern Massachusetts. Version 09-04a. Developed by Massachusetts shellfish growers in collaboration with the Southeastern Massachusetts Aquaculture Center. SEMAC & Roger Williams University, Bristol, RI. 100p.

Maryland Aquaculture Coordinating Council (2007). Best Management Practices a Manual for Maryland Aquaculture. 44p. https://www.nda.agric.za/doadev/sidemenu/fisheries/03_areasofwork/Aquaculture/AquaDocumentation/BestManagementPracticeGuide/BMP_MarylandAquaculture.pdf

National Marine Fisheries Service. A code of conduct for responsible aquaculture development in the U.S. Exclusive Economic Zone. 44p.

National Oceanic and Atmospheric Administration (2011). Marine Aquaculture Policy. 12p.

The Nature Conservancy. 2021. Global Principles of Restorative Aquaculture. Arlington, VA. https://www.nature.org/content/dam/tnc/nature/en/documents/TNC_PrinciplesofRestorativeAquaculture.pdf

Rutgers Cooperative Extension (2004). Recommended management practices for aquatic farms. N.J. Agricultural Experiment Station, Rutgers, The State University of New Jersey, New Brunswick. 73p.

Tucker CS, Hargreaves JA (editors, 2008). Environmental Best Management Practices for Aquaculture. Wiley-Blackwell. 608p.