Atlantic States Marine Fisheries Commission
Habitat Management Series #16
Spring 2020

Aquaculture: Effects on Fish Habitat Along the Atlantic Coast

Enhancing, preserving, and protecting Atlantic diadromous, estuarine, and coastal fish habitats

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Aquaculture: Effects on Fish Habitat Along the Atlantic Coast

**prepared by the
Habitat Committee**

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Cover Photo Credit: Jay Rutkowski, Atlantic Capes Fisheries

Aquaculture: Effects on Fish Habitat along the Atlantic Coast

This issue of the Habitat Management Series provides a broad description of current and common marine aquaculture (mariculture) practices along the Atlantic seaboard and some potential effects on fish habitats. It should serve as an introduction to the topic and facilitate a discussion of the intersection of aquaculture planning and fishery habitat conservation.

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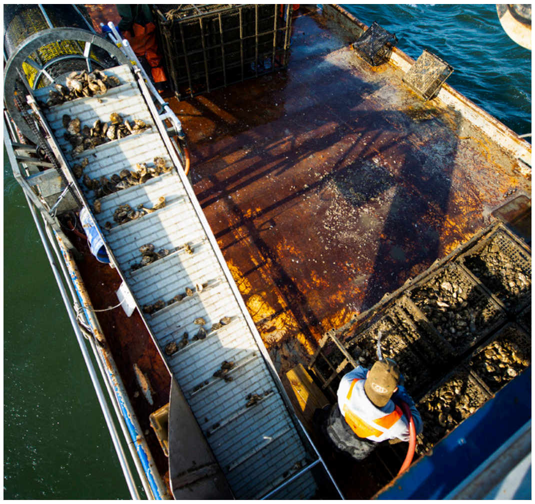


Top: Drone footage of rack and bag grow-out structures at Bay Ridge Oyster Farm, Cape May, New Jersey. Photo credit: Ned Gaine, Bay Ridge Oyster Company.

Center: Cage-cultured oysters being processed aboard FV Stormy Bay, Delaware Bay, NJ. Photo credit: Jay Rutkowski, Atlantic Capes Fisheries.

Bottom: Exposed oyster racks as the tide recedes. Photo credit: Jay Rutkowski, Atlantic Capes Fisheries.

Aquaculture: Effects on Fish Habitat along the Atlantic Coast

Why Aquaculture?

Marine aquaculture, or mariculture, is a potentially vital and sustainable component of seafood production. Half of world seafood was sourced from aquaculture in 2016, and it is the fastest-growing sector in animal-based food production (NMFS 2017, FAO 2018). The current production in the United States is lagging on the world stage, contributing only 20% to U.S. seafood production; however, significant opportunity for aquaculture industry growth exists (NOAA 2019a). The US aquaculture and mariculture industry was valued at $1.4 billion and produced 627 million pounds of meat and 1.2 million jobs in 2015 (NOAA 2019b). This industry creates jobs, supports communities, and promotes secondary industry as well as international trade (Slater 2017, NOAA 2019a). Human population growth means an ever-increasing need for food that may not be sustainable by shifting wild stocks; mariculture can help fulfill that need. In this publication, aquaculture and mariculture are used interchangeably.

Effects on Habitats

WATER QUALITY

The production of finfish and shrimp is often associated with impairment to water quality; however, macroalgae and bivalve culture may improve water quality through the removal of nutrients and suspended solids. On a global scale, marine and brackish water aquaculture cause a net reduction in nutrients (Verdegem 2013). Seaweed and bivalves reduce eutrophication, and bivalves improve water quality through filtration and grazing (Rose et al. 2015, Cerco and Noel 2007) and can control phytoplankton bloom intensity in shallow waters (Gallardi 2014). Fish and shrimp culture can cause nutrient loading in overcrowded, overfed, and poor circulation conditions (Price et al. 2015); placement in deeper waters and stronger currents reduces this risk (Gentry et al. 2016).

Equipment deployed in open and intertidal waters is subject to fouling, and exposed structures to accumulation of bird waste. Antifoulant treatments can contaminate water (Burridge et al. 2010) and physical removal may increase nutrients from bird waste, temporarily deplete oxygen levels as fouling organisms decay, and release toxins if antifoulants were used. There is a need for innovative antifouling strategies that are practical and environmentally responsible (Fitridge et al. 2012).

Top: Shellfish seed are grown in nurseries before they are moved to aquaculture leases for further growout. Photo credit: Florida Department of Agriculture and Consumer Services.

Center: Floating oyster cages. Photo credit: Andrew Button, Virginia Marine Resources Commission.

Bottom: Floating bags are a common gear type for growing oysters in the water column in Florida. Photo credit: Florida Department of Agriculture and Consumer Services.

Crew of the FV Stormy Bay tending subtidal oyster cage in Delaware Bay, NJ. Photo credit: Jay Rutkowski, Atlantic Capes Fisheries.

SEDIMENT

An accumulation of nutrients, wastes, or excess feed can deplete oxygen and impair sediment conditions. Sediment deposition from biodeposits can alter benthic structure. However, accumulation is less likely with adequate flow and good husbandry. Recent investigations into the effects of elevated bivalve culture on the benthos have suggested that impacts are localized and minor by comparison with many other forms of aquaculture (Forrest et al. 2009).

POPULATIONS AND COMMUNITIES

In the marine environment, changes to the water column, benthos, flow, and the introduction of physical barriers/ structure can impact populations and communities. However, they can also attract structure-oriented species and increase biomass and biodiversity on an otherwise minimally structured bottom. Gentry et al. (2019) reviewed ecosystem benefits of mariculture and provided a quantitative method to evaluate these benefits.

Marine life aggregates around structures, including aquaculture gear. Bivalve aquaculture gear can provide substantially better habitat than a shallow, non-vegetated seabed. Biofouling organisms are diverse and include microbes, algae, sponges, hydroids, worms, molluscs, arthropods, and tunicates. Even the animals themselves can create habitat when colonists move into the interstitial spaces on and around cultured oysters and other bivalves. These communities provide a nursery habitat and food source to higher trophic levels, including fish. This "reef effect" may result in a localized increase in biomass and local biodiversity during the production phase. Oyster and mussel mariculture can temporarily enhance populations of large macroinvertebrates and benthic fishes, including ecologically and commercially important species (Costa-Pierce and Bridger 2002, D'Amours et al. 2008, Forrest et al. 2009). Many of the structure-associated fish that are attracted to gear are highly valued for recreational and commercial fishing.

There are other potentially negative biological effects from aquaculture. Disease transmission is a concern for fish, and escapees can outcompete and interbreed with wild fish stocks. Shellfish seed transfer between states may increase the risk of parasite and pathogen transmission if protocols are not established and enforced (see *Bivalve Culture* below for current initiatives). Structures like pens, cages, racks, and bags can exclude or deter resident fauna from their feeding grounds or migration routes. In the Delaware Bay, red knots, a threatened bird, rely on eggs deposited by horseshoe crabs, and research into the effect of shellfish aquaculture on horseshoe crabs and red knots is ongoing. Biocides, used to deter microorganisms in antifoulant treatments, can impact non-target organisms and the antibiotic varieties can lead to antibiotic resistance (Guardiola et al. 2012).

Common Practices

Mariculture along the Atlantic Seaboard includes algae (microalgae and macroalgae), bivalves (oysters, clams, scallops, and mussels), crustaceans (shrimp), and fish (salmon). As of 2016, Atlantic salmon and oysters were the largest components of this market (NMFS 2017). Common practices in this region, along with their known environmental

Hatcheries in numerous states produce shellfish seed. If seed is imported from one state to another, health and genetic testing and Best Management Practices often exist to prevent genetic and disease impacts to local shellfish stocks in the receiving state.
Photo credits: Florida Department of Agriculture and Consumer Services.

effects, are described below. The most common aquaculture practices in each of the ASMFC states are shown in Table 1. Effects depend on the culture method and species, the size of the operation, and the site itself.

TIDAL WATER MARICULTURE

Coastal waters are used for growing shellfish, finfish, and algae. A variety of equipment, locations, and techniques are used to maximize growth and high-quality product.

Bivalve Culture

Bivalve aquaculture typically involves moving immature stock to areas that facilitate grow-out to market size. Juvenile oysters and clams sourced from hatcheries and nurseries are called seed. In areas with a healthy spawning population, newly settled oysters, called spat, can be obtained by laying cultch (typically broken oyster shell) or setting spat collectors just before spawning occurs. For clams and oysters, hatchery-produced seed is now more commonplace than transplanting native set.

Shell planting is an important part of natural oyster stock management programs in most oyster producing states, where it is done on a large scale. Seed and spat may be grown without any gear to house them (i.e. directly on shelled bottom), or in bags or cages to protect the growing organisms and facilitate maintenance and harvest. The timely harvest of cultured oysters has been shown to reduce rates of the pathogen *Perkinsus marinus* (Dermo) in native stocks (Ben-Horin et al. 2018). While only hard and soft shell clams and oysters are currently grown commercially, there is ongoing research into sourcing and growing sea scallops, razor clams, urchins, and surf clams.

Importing seed from other states or other countries may be necessary if local sources are insufficient. Improperly managed seed importation may pose a risk of introducing disease, parasites, and potentially non-native species. Hatchery capacity is already strained in some areas, and those states are seeing significant increases in requests to import seed stock from out-of-state. Many states have developed specific regulations governing the interstate transport of shellfish products, including shellfish seed, to prevent the introduction or spread of diseases and parasites. To reduce this risk, shellfish growers should be familiar with regulations prior to importing seed from other states or regions. As aquaculture efforts expand, importation may become increasingly necessary, so the associated risks must be understood and minimized by managers. Importation protocols, such as the Hazard Analysis and Critical Control Points (HAACCP) standard operating procedure, should be rigorous enough to reduce the risk of introduction of pathogens or invasive species but also practical enough for the aquaculture industry to navigate in a timely manner. An Atlantic and Gulf Shellfish Seed Biosecurity Collaborative effort is underway to increase regulatory compliance and reduce risk of spreading shellfish diseases through transfers. The effort includes a hatchery certification protocol outlining Best Management Practices (BMPs) and disease surveillance which facilitates biosecure interstate commerce.

Habitat managers along with agencies charged with aquaculture development should work cooperatively to encourage the development of regional scale tools (e.g., North Atlantic region, Mid-Atlantic region, and South Atlantic region).

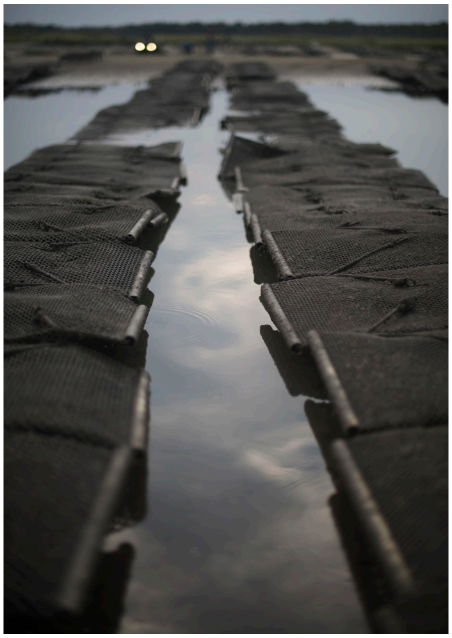
Non-structured/Bottom Planting

Seed or spat can be spread across the bottom without containment (extensive shellfish culture), called non-structured or bottom-planting, in areas that are accessible by boat and conducive to growth, but not already occupied naturally by oysters or clams. Bottom planting reduces the amount of gear maintenance required, but moving stock (relay) and harvesting require the grower to dredge, pick, or tong the product. Predator screening is typically used to cover younger stocks of clams. Planted oysters have been shown to promote biodiversity by attracting settling invertebrates, bottom feeders, and fish (Forrest et al. 2009).

Oystermen in Beaufort County, South Carolina distribute live oysters in order to plant them and encourage oyster reef growth at another site. South Carolina requires commercial shellfish harvesters to replant the grounds from which they harvest in order to keep the state's oyster reefs healthy. Photo credit: South Carolina Department of Natural Resources.

FLUPSYs

Floating upweller systems (FLUPSYs) are a popular way to grow clams and oysters from small seed until they are large enough to be deployed in gear for grow-out (Rivara et al. 2002). Stock is housed in suspended, mesh-bottomed compartments that tidal water circulates through from bottom to top, providing oxygen and algae and removing waste. FLUPSYs are often tied to or built into existing docks or boat slips, making them accessible from shore, and potentially alleviating some permitting concerns (such as total footprints of shading, etc.). FLUPSYs are typically used post-hatchery to raise seed to sub-adults prior to grow-out. There are concerns that waste can accumulate under the FLUPSY if flushing is not adequate. However, low flow areas are often avoided or overcome by the use of electric-powered pumps to provide desired current flow by growers.



Rack and bag oyster culture. Photo credit: Jay Rutkowski, Atlantic Capes Fisheries.

Bags/rack-and-bag/predator nets

Options for intertidal aquaculture are considered intensive shellfish culture, which are grown in cages or bags set on the bottom; or in the water column suspended from a float (often called a Lentz System), attached to a stake, or laid on racks ("rack-and-bag"). Rack-and-bag is the most common of these systems for oysters. Bags or cages are set on racks in the intertidal or shallow sub-tidal zones, where naturally circulating tidal waters provide food and remove waste. Maintenance of bags requires removal of fouling to ensure good flow, typically by scrubbing, scraping, power washing, air drying, and salt dips. As the oysters grow, they are sorted and moved into gear with more space and larger mesh. Commercial clam producers sometimes use predator nets, which are usually attached by stakes under the substrate. Market-sized oysters and clams are easily harvested from bags by taking the entire bag and removing marketable oysters while sub-market oysters are returned to bags. Bags laid directly on the substrate are often secured with stakes and connected with lines to facilitate harvest and husbandry.

Commercial aquaculture bottom gear (cages) used for culturing oysters in South Carolina. Photo credit: South Carolina Department of Natural Resources.

Cages/bottom screens

Oyster cages may be deployed directly on the bottom, typically in sub-tidal areas. This practice may enhance soft-bottom habitat by replacing it with structured bottom that may increase production and biodiversity. Cages become habitat for a variety of species, including juvenile and adult fish (Costa-Pierce and Bridger 2002). The Northeast Fisheries Science Center is studying how reef fish are using these cages (NOAA 2019c).

Suspension culture

Suspended bivalve culture systems include rope culture for mussels (vertical lines within the water column) and trays, bags, or lantern nets, which hang below the surface and shift with the tide. Mussel line culture can be started with hatchery-reared seed or through natural set, depending upon location.

Fish Farming

Open-net pens or cages are used to grow fish in coastal waters. Currents flow through the system removing waste and providing oxygenated water. Feed must be provided.

As described in *Effects on Habitats* above, fish farming can have significant effects on water quality and sediment, and net-pen aquaculture can alter local habits and ecosystems if they are not sited properly (Findlay et al. 1995).

Escaped fish can breed with wild fish and possibly alter genetic fitness or compete with native fish for resources. High population densities increase the chance for transmission of disease, which can then be transferred to wild populations or vice versa.

Informed siting, good husbandry, and regular maintenance are critical to mitigating effects. Siting in deep, well-mixed water reduces the accumulation of wastes that impair water quality and sediment composition (Price et al. 2015). Appropriate stock densities, feeding, and care reduce the risk of release of nutrients, antibiotics, pesticides, and growth enhancers (though not commonly used). Regular maintenance, including removal of fouling, is essential to avoid structural failure. In 2016, hundreds of thousands of non-native salmon were released in the San Juan Islands of Washington state when a heavily-fouled pen collapsed.

Atlantic salmon have been grown in Maine in open-net pens since the 1970s. Water quality impairments have been significantly reduced by 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). Improvements in feed efficiency, escape prevention (Rust et al. 2014), and effects on dissolved oxygen, turbidity, and nutrient enrichment have been seen in this industry (Price et al. 2015). In 2016, Maine-raised salmon were upgraded from "avoid" to "good alternative" by the Monterey Bay Aquarium Seafood Watch Program, which rates seafood according to whether it supports a healthy ocean (Seafood Watch 2019).

Other effects are more difficult to address. Feed is typically wild-caught coastal forage fish. Farms can attract and entangle predators such as cormorants, sharks, and marine mammals. The pens thereby alter predator behavior and subject them to adverse actions (i.e. lethal control measures) by net pen operators. Regular gear maintenance and stock tending result in increased boat traffic and dock use. The implementation of responsible production and husbandry practices as BMPs can mitigate many of these concerns. For example, the use of properly weighted (taut) predator nets have diminished entanglement risk to near-zero for sharks and marine mammals.

Top to bottom: Loading spat on shell onto a barge for planting on private ground. Photo credit: Andrew Button, Virginia Marine Resources Commission. Aquaculture leases in Florida are used for the production of clams, oysters and live rock. Photo credit: Florida Department of Agriculture and Consumer Services.

Seaweed Culture

Seaweeds are a highly nutritious food source, and the world's largest mariculture crop. They are readily grown on longlines in open waters. These autotrophs remove carbon dioxide and nutrients and release oxygen. Seaweed culture has the potential to mitigate ocean acidification, hypoxia, and eutrophication. A review by Kim et al. (2017) found that seaweed aquaculture provides ecosystem services that improve conditions of coastal waters, and that these benefits need further study and better public awareness of the opportunities of this industry.

Integrated Multitrophic Aquaculture (IMTA)

IMTA is a new field of mariculture and is being studied worldwide. Similar to polyculture in terrestrial agriculture, IMTA is the practice of growing multiple species together to reduce environmental effects, provide ecosystem services, and improve profit. The theory behind IMTA is that nutrient inputs are limited as the fish waste serves to promote plant growth. The removal of nutrients by algae and particulates by bivalves provides cleaner water for the other species in the system. Scientists at the University of Maine are researching the use of benthic polychaetes, which can be sold as bait, to reduce impacts from salmon open-net pens (University of Maine 2019). For the marine environment, the greatest potential for IMTA systems is the reduction of space to grow more species. This can limit user conflicts while still yielding environmental and economic benefits.

LAND-BASED MARICULTURE

While state waters are used for grow-out of most marine species, there is a need for land-based systems that provide a more controlled environment. These systems typically include hatcheries and nurseries, though some species, like shrimp, most finfish, and bivalves, can be grown entirely on land. Land-based mariculture facilities are usually sited close to shore for access to seawater (though fresh water from wells can be used with the addition of salts), and produce effluent that may be discharged, accidentally or intentionally, to nearby surface waters. Fish hatchery effluent may be regulated by the National Pollutant Discharge Elimination System (NPDES), and some states require additional permitting. Some states do not require permits for bivalves with the understanding that water quality is not degraded and may even be improved (e.g., due to clearance and filtration by shellfish).

Environmental effects vary widely with the species being cultivated, the location, and the size and type of facility. Organisms lower on the food chain, like algae and bivalves, produce less waste. Pollutants found in aquaculture effluents are similar to those found in effluents from agriculture and municipal wastewater treatment plants, such as nutrients, organic matter, and suspended solids (Boyd and McNevin 2014). Less common effluents include dissolved salts, toxic substances, pesticides, and disease-control compounds.

Hatcheries and Nurseries
Hatcheries house spawning brood stock and produce juveniles of various species. Nurseries are specifically focused on further growth of bivalves prior to deployment in tidal waters. Microalgae is cultured in hatcheries and nurseries as feed for early life stages of fish and shellfish.

Upwellers and Raceways
These systems pass seawater through a series of tanks to then be released into surface waters. Upwellers, common for bivalves, circulate water from bottom to top. Raceways are horizontal rows of tanks. Stock may be moved between raceways for more growing space. Wastewater can contain nutrients and solids that affect receiving waters. If appropriate BMPs are not implemented for health requirements and the containment of nonnative species, there is a possibility of nonnative species and disease being released into the environment.

Transferring fish from an in-tank grader to a small grader. Photo credit: Dr. Wade Watanabe, University of North Carolina at Wilmington.

Recirculation Systems
These systems are similar to flow-through systems in types of effects except that effluent is not released to surface waters. Water is filtered and recirculated, thereby reducing both water usage and the likelihood of effluent release.

Ponds
Ponds are used to grow finfish, shrimp, and macroalgae, among other species. Broodstock are placed in a controlled, closed environment such as a natural or constructed pond to spawn. The larvae and juveniles can be separated by age or size and placed in different ponds for optimal growth. When they reach adult size, they may be kept for broodstock, released in aquatic ecosystems for fishing, or sold to consumers.

Sometimes untreated water is discharged with leftover nutrients and sediments to nearby water bodies which can increase the risk of eutrophication. BMPs can reduce nutrients in effluent and accidental release.

Siting Considerations

Thoughtful spatial planning before aquaculture facilities are sited can mitigate many of the potential environmental impacts, reducing unwanted results and amplifying the benefits of the industry. In fact, proper siting is usually the most important aspect of planning. Understanding the existing environment and how particular aquaculture methods and culture species might affect it is a critical step in reducing conflicts. The implementation of a siting strategy early in the process allows for public involvement and consideration of social benefits. This should include considering novel locations, such as offshore wind farms. As states develop areas for aquaculture, existing and proposed uses, sensitive species and habitats, and carrying capacity of the environment must be considered.

Floating oyster mariculture gear in South Carolina. Photo credit: South Carolina Department of Natural Resources.

MINIMIZING USE CONFLICTS

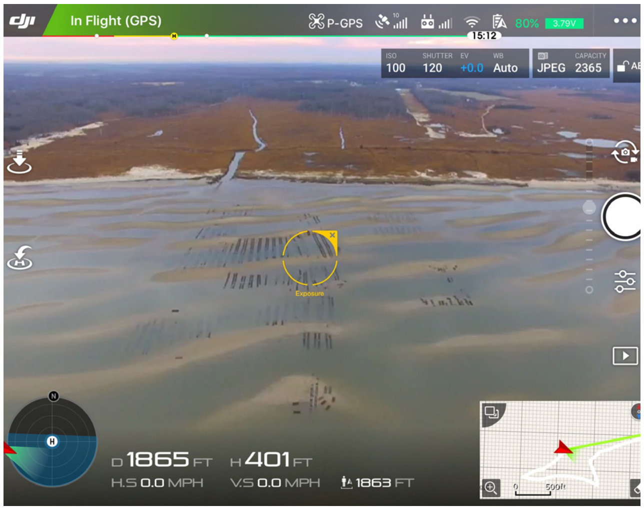
Like any other form of agriculture, marine aquaculture requires space, so it must compete for real estate with other user groups such as boaters, fishers, and landowners in the coastal zone. If uses are not compatible, conflict resolution among users is required. While very few areas will be entirely conflict free, knowledge of how potential aquaculture areas are and will be used is critical to siting.

In some areas, misconceptions exist about impacts of aquaculture on coastal habitats and the safety of farmed seafood, which can lead to conflict with stakeholders. While there are known potential negative effects, the general public is less aware of the potential benefits of aquaculture on habitats, particularly those provided by bivalve culture.

PROTECTING HABITATS

An understanding of the existing resources and siting of potential aquaculture areas is critical to mitigating impacts to fish habitats. Sensitive microhabitats in prospective aquaculture areas should be identified and avoided. Corals, mangroves, and submerged aquatic vegetation (SAV), for example, are valuable microhabitats that are sensitive to nutrient fluxes and disturbance.

Leases should not be sited on existing or historic SAV locations, since the equipment used can cause shading and increased sedimentation. NOAA identifies SAV as an “underwater neighborhood” that is essential habitat for federally managed species. With that being said, not all gear damages SAV (Vaudrey et al. 2009), and in certain circumstances, aquaculture can improve conditions for SAV by reducing turbidity (Dumbauld et al. 2009), adding nitrogen to the benthos, and sheltering new growth from currents (Normant pers. com. 2019). Scientists at the University of North Carolina are studying how aquaculture affects SAV growth (Blackburn 2015).



Left: Drone footage of rack and bag grow-out structures at Bay Ridge Oyster Farm, Cape May, New Jersey. Photo credit: Ned Gaine, Bay Ridge Oyster Company. Right: Loading spat on shell onto a barge for planting on private ground. Photo credit: Andrew Button, Virginia Marine Resources Commission.

In the Delaware Bay there is concern about aquaculture activities interfering with foraging of red knots, a threatened species that relies on eggs deposited by horseshoe crabs. A number of research projects are under way looking at the effect of aquaculture on horseshoe crabs and red knots.

As the mariculture sector continues to grow in both volume and product diversity, it is likely to generate potential disturbances or threats to other important or critical habitats; for example, placement of long lines or net pens in designated right whale critical habitats along the eastern seaboard. Consultations with local, state, and federal permitting agencies during site selection are critical to understanding the nature and extent that new or expanding technologies will impact important habitats.

CARRYING CAPACITY

Another important consideration for siting is carrying capacity, or how much aquaculture a given area can sustain without adverse environmental or social impacts. Too much aquaculture activity in a specific location will create other access and use limitations and erode public perception and support of aquaculture activities in certain areas. Determining optimal densities and spacing is an important aspect of BMPs and should be considered early in the lease siting process. This depends on the type of aquaculture, species in culture, and site-specific conditions. Fish aquaculture is associated with more significant environmental effects than bivalve aquaculture including nutrient loading, sedimentation, lipids, turbidity, oxygen depletion (Pillay 2004, Rust et al. 2014), and rarely to sometimes the use of antibiotics, pesticides, and growth enhancers. Overcrowding and poor husbandry increase the risk of disease transmission and escape.

Conclusions

This document outlined a number of the potential positive and negative impacts that may result from the culture of marine species along the Atlantic Seaboard. Inappropriately sited structures can obstruct migration as well as reduce available habitat for sensitive species. Improperly managed effluents can impair water quality and alter local community dynamics and trophic structure. These impacts, however, are species specific, with bivalve shellfish aquaculture demonstrating minimal detrimental effects (Crawford et al. 2003), balanced with a suite of ecosystem benefits.

Filter-feeding bivalves have been shown to abate eutrophication and algal blooms, enhance the growth of SAV, and benefit benthic macroinvertebrate communities and populations of ecologically and economically important fish. Oysters specifically provide ecosystem services by removing excess carbon, reducing acidification, and improving water clarity and coastal resiliency (Gentry et al. 2019). Research has even demonstrated their potential to moderate disease in wild oyster populations.

The most critical way for habitat managers to avoid direct impacts to marine habitat is through the leasing and site selection process. Site-specific knowledge of sensitive species and habitats, coupled with the establishment of BMPs can mitigate problems like accumulation of food and wastes, disease transmission, water quality impairment, and escape. Research into the carrying capacity of various environments and mariculture practices is still in early stages and remains a critical area in need of support. Supporting research in aquaculture can have far-reaching benefits, particularly in near-shore communities that may be most at risk of the economic effects of climate change and declines in wild fisheries.

Water cannons are used to place clean clam shell (cultch) onto bay bottom. Plantings are done in unison with the wild oyster spawning season in order to recruit setting oysters (spat). Photo credit: New Jersey Marine Fisheries Administration

Current Mariculture Practices by State

CONNECTICUT	Non-structured/bottom planting Bags/rack and bag/predator nets Cages/bottom screens Suspension culture Seaweed culture Flow-through systems	Hard clams and oysters Oysters Hard clams and oysters Oysters Kelp Shellfish hatchery
DELAWARE	Non-structured/bottom planting Bags/rack and bag/predator nets Cages/bottom screens	Oysters Oysters Oysters
FLORIDA	Non-structured/bottom planting FLUPSYs Bags/rack and bag/predator nets Cages/bottom screens Suspension culture IMTA Hatcheries and nurseries Upwellers and raceways Recirculation systems Ponds	Clams Hard clams and oysters Hard clams and oysters Oysters Oysters Numerous species of fish and invertebrates Hard clams and oysters Hard clams and oysters Numerous species of fish and invertebrates Numerous species of fish and invertebrates
GEORGIA	Non-structured/bottom planting Bags/rack and bag/predator nets Hatcheries and nurseries	Hard clams Hard clams Oysters
MAINE	Non-structured/bottom planting FLUPSYs Bags/rack and bag/predator nets Suspension culture Seaweed culture Open net pens and cages Hatcheries and nurseries Recirculation systems Ponds	Hard clams, soft shell clams, and razor clams Oysters Blue mussel Oysters, sea scallops, razor clams, hard clams, blue mussel Sea vegetables Atlantic salmon Atlantic salmon, eel, yellowtail Atlantic salmon, eel, yellowtail Atlantic salmon, eel, yellowtail
MARYLAND	Non-structured/bottom planting FLUPSYs Bags/rack and bag/predator nets Ponds	Soft shell clams and oysters Oysters and striped bass Oysters Striped bass
MASSACHUSETTS	Non-structured/bottom planting Bags/rack and bag/predator nets Cages/bottom screens Suspension culture Seaweed culture Recirculation systems	Softshell clam, oyster, quahog, bay scallop, blue mussel Offshore: blue mussel Inshore: seaweeds (*Gracilaria*, sugar kelp) Pacific white shrimp (*Vannamei* sp.)

Current Mariculture Practices by State

NEW HAMPSHIRE	Non-structured/bottom planting FLUPSYs Bags/rack and bag/predator nets Cages/bottom screens Suspension culture Seaweed culture	Oysters Oysters Oysters Oysters, quahog Offshore: blue mussel, seaweeds (*Gracilaria*, sugar kelp) Offshore: blue mussel, seaweeds (*Gracilaria*, sugar kelp)
NEW JERSEY	Non-structured/bottom planting FLUPSYs Bags/rack and bag/predator nets Cages/bottom screens Upwellers and raceways	Hard clams and oysters Hard clams and oysters Clams and oysters Oysters Hard clams and oysters
NEW YORK	Non-structured/bottom planting FLUPSYs Cages/bottom screens Upwellers and raceways	Hard clams and oysters Hard clams and oysters Oysters Hard clams and oysters
NORTH CAROLINA	Non-structured/bottom planting Bags/rack and bag/predator nets Cages/bottom screens Upwellers and raceways Recirculation systems Ponds	Clams and oysters Clams and oysters Oysters Clams and oysters Numerous species of fish and invertebrates Numerous species of fish and invertebrates
RHODE ISLAND	Non-structured/bottom planting FLUPSYs Bags/rack and bag/predator nets Cages/bottom screens Suspension culture Upwellers and raceways	Hard clams, soft shell clams, and oysters Oysters Oysters Oysters and scallops Kelp, mussels Oysters
SOUTH CAROLINA	Non-structured/bottom planting Bags/rack and bag/predator nets Cages/bottom screens Upwellers and raceways	Clams and oysters Clams Oysters Clams and oysters
VIRGINIA	Non-structured/bottom planting FLUPSYs Bags/rack and bag/predator nets Cages/bottom screens Hatcheries and nurseries Upwellers and raceways Recirculation systems	Clams and oysters Oysters Oysters Clams and oysters Clams and oysters Clams and oysters Clams and oysters

**The methods listed are the same as the categories found on pages 7-12 of the document. For multiple methods in a category (e.g. upwellers and raceways), the state may be carrying out one, some, or all of the method methods listed.*

Resources for Best Management Practices

Atlantic States Marine Fisheries Commission. 2002. Guidance Relative to Development of Responsible Aquaculture Activities in Atlantic Coast States. *http://www.asmfc.org/uploads/file/sr76GuidanceRelativeToDevelopmentResponsibleAquaActNov02.pdf.*

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Florida *https://www.freshfromflorida.com/Divisions-Offices/Aquaculture*

Georgia *https://gacoast.uga.edu/outreach/programs/aquaculture/*

Maine *https://www.maine.gov/dmr/aquaculture/*

Maryland *http://dnr.maryland.gov/fisheries/Pages/aquaculture/index.aspx*

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New Hampshire *https://seagrant.unh.edu/aquaculture*

New Jersey *https://www.nj.gov/dep/fgw/pdf/marine/shellfish_leasing_policy_atlantic.pdf*

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Performing husbandry on a rack and bag oyster culture farm at low tide. Photo credit: Jay Rutkowski, Atlantic Capes Fisheries.

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