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Farmed mussels in the northeastern U.S. Exclusive Economic Zone: An Opportunity Too Good to Ignore

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Abstract

The United States is the top seafood importer in the world. Nevertheless, opportunities to expand national seafood production, such as offshore aquaculture, are restricted by unclear frameworks for licensing, permitting, and regulating new enterprises. Currently, domestic mussel demand is reliant upon international trade but demand could be met by aquaculture within the Exclusive Economic Zone, especially in suitable areas off the northeast coast. With national public seafood preferences pointing towards the need for a larger mussel farming industry, science-based efforts to develop offshore farming will contribute to local economies and domestic supply of high-quality, traceable seafood. Beyond a scientific foundation, perceptions that offshore farming represents environmental and privatization threats instead

of a national economic development and sustainable opportunity, will have to be addressed. The situation will only change when managers decide to include offshore aquaculture as one of the many legitimate activities for New England's ocean waters, so that spatial planning can be done and conservation measures and offshore farming develop in tandem.

American Progress Toward Offshore Aquaculture

Historically, the northeastern United States is a region known as a hub of fishery activities, where a variety of shellfish species are both harvested and cultured. The main harvested species include the sea scallops *Placopecten magellanicus*, Atlantic surfclams *Spisula solidissima*, ocean quahogs *Artica islandica* and hard clams and quahogs *Mercenaria mercenaria* (National Marine Fisheries Service 2018). Eastern oysters *Crassostrea virginica*, hard clam and quahogs, softshell clams *Mya arenaria*, blue mussels *Mytilus edulis* and bay scallops *Argopecten iranians* are the main cultured species (Fairchild et al. 2017), with aquaculture production playing an increasing role in local seafood economies (NOAA 2015). Traditionally performed in coastal areas, shellfish aquaculture has been shifting towards offshore areas, a trend that started internationally.

Research on offshore aquaculture, defined here as aquaculture performed within the federal Exclusive Economic Zone (EEZ; 3 to 200 nautical mi offshore), has recently regained momentum in the northeastern USA fueled by new, *in situ* farming trials and improvement of farming gear. In the midst of discussions about sustainable development of the offshore aquaculture industry in the United States, there is still considerable skepticism, not only among the general public but also within the academic community about the need for a local offshore shellfish industry. Lacking streamlined and objective policy framework for permitting and regulation of offshore aquaculture (Knapp and Rubino 2016; Lester et al. 2018), the United StatesFi falls behind other countries that have long implemented exploratory offshore farming activities, some that developed into successful commercial operations (Buck et al. 2017a; Lester et al. 2018).

Public acceptance of offshore aquaculture in the USA is debatable. Different from the coastal aquaculture that is opposed by costal property owners based upon undesirable visual aspects, offshore aquaculture is performed in the open ocean. Thus, conflicts of use are less likely to come from the public and more often from fishermen against privatization of marine resources. Additionally, the public and environmental groups have expressed concern about interaction between farming practices and wildlife, citing the lack of knowledge and limited experience involving this new activity (Upton and Buck 2010; Fairbanks 2016; Froehlich et al. 2017). Froehlich et al. (2017) stated that the sentiment towards offshore aquaculture was deemed specifically negative in the United States, according to analysis of journal headlines and public comments in the media. A more recent evaluation (Changing Tastes 2019), however, showed a positive perception of offshore aquaculture. This latter study used direct questionnaires with U.S. residents representative of the demographic census (consumers) and a group of food industry purchasers, such as menu and decision makers who choose what to offer consumers (operators). The research showed that Americans perceive farming seafood in the open ocean as the second best practice for the environment. It was thought to produce "cleaner" products than land-based or coastal aquaculture (Changing Tastes 2019). Additionally, the report stated both groups already believed a substantial share (> 5%) of seafood is farmed in open ocean and has already accepted that type of aquaculture.

Nevertheless, discussions among researchers and managers about the still incipient development of this type of aquaculture seem to intensify when the candidate species is the blue mussel (see Mizuta et al. 2019; Mizuta and Wikfors 2019, for discussion about species suitability for offshore aquaculture), a shellfish of *perceived* low economic value, which raises concerns about cost-benefit trade-offs between farming and the uncertainty of risks of interaction with marine life (Price et al. 2017). In the meantime, mussel import trade, fueled by national demand, contributes over US$102 million to the American seafood deficit (National Marine Fisheries Service 2018).

The Real Value of a Prospective Mussel Industry

In 2016, the U.S. seafood trade deficit, considering all traded species, was $14 billion, and that accounted for approximately 90% of quantity of what Americans demanded. The deficit was even higher in 2017, increasing up to $16 billion (National Marine Fisheries Service 2018). In particular, American demand for mussels challenges national production and trade. International statistics show that among bivalve shellfish imported to the USA, mussels were the top species in quantity, in 2016 reaching 35,878 metric tons, of which a considerable amount (13,844 metric tons) is comprised of live, fresh, and chilled products (FAO 2019; Figure 1). In that same year, the national aquaculture production and fisheries landings of mussels supplied together approximately 3,329 metric tons (406 and 2,923 metric tons, respectively), which is a small contribution to the domestic demand (National Marine Fisheries Service 2018). Despite the fact that the import value of mussels is less than other shellfish species, the trade represents a solid "cost," adding to the negative American seafood trade imbalance; particularly because the monetary value of mussels imported is second only to the higher-priced scallops.

Data on the species of mussels arriving in the internal market are scarce, but two genera, *Mytilus* spp. and *Perna* spp., appear in FAO trade statistics (FishStatJ 2019). Among those, blue mussels *M. edulis* and *M. trossulus*, the Mediterranean mussel *M. galloprovincialis*, the Chilean mussel *M. chilensis*, and the Green Lipped Mussel *Perna canaliculus* appear to make up the main species.

Imported mussel products include: fresh and live mussels; frozen; dried; salted and in brine; prepared and preserved; and already prepared dinners. There are differences in product preferences between regions, with New England importing mostly live and fresh mussels, the Mid-Atlantic, south Atlantic, Gulf Coast, and Pacific importing mainly frozen mussels, and inland regions preferring prepared dinners (NOAA 2019). A general overview of the main characteristics of mussel imports are: farmed (especially from Canada); live, namely fresh; and sold mainly in the New England, in the northeastern USA. Wild-caught mussels also are imported, but to a minor extent, and come mainly from New Zealand to be sold to states along the Pacific coast. When different regions of the country are considered, the main import epicenters are the northeastern USA, New England region, followed by the Pacific area (Figure 2).

Most of the imported mussels enter the United States through the northeastern New England region, imported mainly from Canada (NOAA 2019). The proximity of the northeastern USA to Canada's main blue mussel farming region (roughly 80% of the national production) of Prince Edward Island contributes to the ease of this foreign trade (Canadian Aquaculture Industry Alliance 2018). This trade is important because the U.S. mussel farming industry has not grown at the same pace as demand in the northeastern Unites States. Mussel farming started regionally in the early 1970s (Morse and Rice 2010) and has involved mainly off-bottom culture based upon wild spat collection. In 2013 there were only 6 farms in New England (5 in Maine and 1 in Rhode Island) that contributed to the national total of 32 farms, most of which are located in the state of Washington (13 farms). In terms of production value, mussel farming is the third most valuable bivalve aquaculture activity, behind the farming of oysters and the farming of clams, both characterized by a relatively higher number of farms nationally (483 and 375, respectively) and in New England (177 and 52, respectively; USDA 2014).

Regulatory Hurdles to Offshore Aquaculture

The New England area has experience with offshore development of both aquaculture, including attempts with finfish and shellfish farming (Fairbanks 2016) and wind energy (Oteri et al. 2018). On a global scale, much research has been done evaluating co-location of energy production and aquaculture, including suspension culture of seaweed, shellfish, finfish, and multi-trophic projects involving several species (Lapointe 2013; Buck et al. 2017a). Although current offshore mussel farming technology is advanced enough to support the siting and development of a stand-alone aquaculture industry offshore (for a detailed state of art of the offshore aquaculture technology see Buck et al. 2017a), the co-location approach with wind-energy infrastructure would optimize ocean space use by harmonious multiple usage of the same space consistent with both endeavors (see Stenberg et al. 2010; Buck et al. 2017b). Whereas Block Island Wind Farm, the first offshore farm in the United States and located 3.8 mi off Block Island in the state of Rhode Island, promoted interest in the construction of similar infrastructures, incentives for co-locating aquaculture and energy production have not emerged. This is mainly because the arrangement is considered as a one-sided advantage for the mussel farmer, whilst an additional concern to the wind energy operator. Therefore, to date, co-location of energy production and aquaculture has not materialized (Griffen 2011).

For the past 20 years, the New England area has been host to experimental offshore aquaculture research trials that targeted aspects related to the feasibility of mussel culture offshore, such as local spat collection, growth rates, mortality, equipment selection, and longline mooring design (Hoagland et al. 1998; Langan and Horton 2003; Maney et al. 2010). Still, after much investment of governmental funds, initial mussel farming trials in exposed oceanic areas, such as the Open Ocean Aquaculture Project by the University of New Hampshire and community-scale farming initiatives in Rhode Island Sound and Martha's Vineyard (Langan and Horton 2003; Karney et al. 2009; Lindell et al. 2012; Buck et al. 2017a) were concluded with little commercial follow through.

Despite the fact that environmental, market, and aforementioned technical conditions are perceived as good or manageable for offshore farming, the regulatory situation is identified by ocean users and policy actors as a constraint (see Fairbanks 2016). As offshore farming activity in federal waters is new, there are several different agencies in charge of permitting and regulating the activity, such as, but not restricted to: the Army of Corps of Engineers, the National Oceanic and Atmospheric Administration, and the Environmental Protection Agency. Agencies act under different mandates, ranging from water quality, right of use of marine waters, and protected species management, making the legal process difficult for a prospective farmer (Knapp and Rubino 2016).

Recently, new farming trials emerged in the area, such as the Salem State University offshore experimental mussel farm located offshore of Cape Ann in Massachusetts. The experimental farm is to be expanded in size and new scientific approaches are to be performed to collect data for management agencies to facilitate decisions about similar aquaculture permitting in the future. Legal Sea Foods, a major corporation in the food sector, has expressed interest in the commercialization of mussel production, but current permitting does not allow for sufficient profitable expansion.

By contrast, the Catalina Sea Ranch offshore farm located in California, which applied for a permit at the same year as Salem State University (2012; Environmental Law Institute 2015), is currently commercializing mussel production and has plans to expand with other species. Offshore aquaculture in the Atlantic coast of the United States clearly lags behind the Pacific coast in terms of providing a regional product to the national market, an outcome not only attributable to differences in initial project funds but also of considerations in the permitting and regulatory processes. Considering that a national, comprehensive framework for offshore aquaculture has not been established, the process of permitting depends upon different agencies, offices, and consultants, not only at federal, but also regional levels (Fairbanks 2018), and has resulted in distinctly different outcomes.

Previous articles have discussed the regulatory constraints to offshore aquaculture development (Knapp and Rubino 2016; Fairbanks 2016, 2018; Lester et al. 2018) and concluded that offshore aquaculture would be hindered indefinitely if: regulatory frameworks were not clearly defined; fear of negative outcomes continued to overshadow the acknowledgement of positive gains, despite favorable scientific findings (Lester et al. 2018); and initiatives were not allowed to start for adaptive knowledge to be gained (Knapp and Rubino 2016). Spatial planning is sufficient to resolve conflicts of use that could emerge with fisherman, ship traffic and other human users (Tlusty et al. 2018). Nevertheless, offshore farming development in New England seems to be mainly stalled by the uncertainty of farm–wildlife interactions, as the area is used by several species protected under the Endangered Species Act, such as whales and turtles that could potentially become entangled if they approach the submerged mussel ropes in the open ocean (Price et al. 2017). Of pressing concern is the north Atlantic right whale *Eubalaena glacialis* that has a population comprised of a low number of individuals and is not recovering (Pace et al. 2017). Additional obstacles to regulatory language enabling offshore aquaculture development are based upon perceived risk of injuries and entanglements of protected species, but these expectations are based upon fisheries gear (Howle et al. 2018) and extrapolated to mussel offshore aquaculture gear, even when design, area use, operation, and management (of the area/facility) are very different. In contrast, fisheries activities are separately characterized and approached individually in the regulatory context. For instance, recent jury verdicts about the Gulf Aquaculture Plan in the Gulf of Mexico considered “farming activity” as not a “fishing activity,” in conflict with an earlier “fisheries” interpretation based upon the Magnuson-Stevens Fishery Conservation and Management Act (Fairbanks 2018), which is the primary law governing fisheries in U.S. federal waters. In summary, only a clear and streamlined regulatory framework created for offshore farming would simultaneously enable explicit guidelines for marine conservation through existing policies and legislation in the northeastern USA.

Addressing Food Security by Diversifying Food Sources

The seafood consumption footprint of a country, for which a country should be held accountable, is based upon its domestic seafood production and international trade (Guillen et al. 2018). Especially for countries characterized by a trade deficit, sustainability of consumption is dependent upon production beyond national borders and therefore vulnerable to unsustainable practices on a global scale (Guillen et al. 2018). Food security is a flexible concept that encompasses food availability, access, utilization, and stability, the latter accounting for the risks of losing access to food in consequence of sudden transient shocks such as environmental disasters, diseases, and pollution. The concept of food security conveys important messages regarding reliance upon international trade. For instance, Guillen et al. (2018) stressed that increasing income power within developing nations may impose higher demand on seafood, leading to higher prices and decreasing benefits to seafood importing countries, thus promoting shifts in current seafood trading. McClanahan et al. (2013) state that sensitivity (of countries, communities) is measured by the degree of human dependence on marine resources for food, revenue and income and is directly linked to “vulnerability.” In the context of food security, sensitivity may be affected by dependence upon trade at the national level; whereas, at the local level, sensitivity is related to dependence upon resources, such as production and profitability of local fisheries. If aforementioned external shifts in trade are a possibility, a high demand for seafood supported by international trade increases the countries sensitivity and the national food security risk; then precautionary approaches towards diversifying options of seafood sources is a reasonable, if not fundamental, step in management. In that respect, and applying the same line of thought for 'geographic area' instead of 'country', New England should be more responsible for what it demands of seafood and for food security from a national perspective by, for example, increasing its local production and helping to reduce the national trade deficit.

Although the import of processed mussels, such as preserved, canned, or ready meals, are not likely to be replaced by a national processing industry in the foreseeable future, the products that make up a high percentage of imports, as fresh or live mussels, could be met by a competitive home-based farming industry. To illustrate, a recent survey of northeastern U.S. residents showed that participants were willing to pay more for "fresh" and "local" seafood (Atlantic Corporation 2019). This supports the idea behind the logic of using nearby federal waters for mussel culture.

As demand for seafood continues to increase and fisheries are held to maximal sustainable yield, the only way to meet increasing seafood demand, without dependency upon foreign production, is through aquaculture. Nearshore areas of the northeastern USA host predominantly a robust oyster farming industry, but nearshore sites are subjected to increasing conflicts of use (Fairbanks 2016), concerns of potentially degrading environmental quality, and visual impact. By contrast, local federal waters are more spatially available, are environmentally suitable, and can accommodate farming practices to sustain good shellfish productivity and high quality of final product (Langan and Horton 2003; Cheney et al. 2010; Lester et al. 2018). Additionally, mussels, as suspension-feeding bivalves, do not require artificial feeding, and only produce biodeposits resulting from feces and pseudofeces that have minimal effects upon local sediment (Crawford et al. 2003), especially in the high-energy, low-water-residency environment as the open ocean. In this context, it is only a logical and reasonable consequence for the fisheries industry to try to supply demand for mussels by farming where space is available and favorable—that is offshore.

Conclusion

Supported by the increased local demand for mussels, offshore farming in the northeastern United States has good market prospects. It is unquestionable that planning for open ocean farming areas should be performed concomitantly with efforts to safeguard endangered species. Also indisputable is the fact that mussel offshore aquaculture represents an underexplored economic opportunity for American marine farmers. To not develop the offshore mussel industry would mean to neglect the opportunity to create jobs and supply the internal market with traceable, non-fed, domestic seafood (i.e., produced in accordance with the country's sustainability and quality criteria). As a country should ideally produce most of its required food internally, thus contributing to the principles of conscientious local production and consumption and small footprint, it is not reasonable for the USA, with evident potential for offshore aquaculture growth (Kapetsky et al. 2013), to continue to rely upon external sources for commercial mussels. Accordingly, researchers and managers should not linger at continuous discussions about whether or not a regional offshore aquaculture industry is a necessity. On the contrary, they should seek a result-oriented and problem-solving approach on how to accommodate the activity while defining clear frameworks to foster and validate the activity in accordance to existent laws and policies. This will facilitate trust and enable transparency between managers and commercial investors interested in putting the efforts for realizing the nationwide benefits of mussel offshore farming.

The scientific results and conclusions, as well as any views or opinions expressed herein, are those of the author(s) and do not necessarily reflect those of NOAA or the Department of Commerce.

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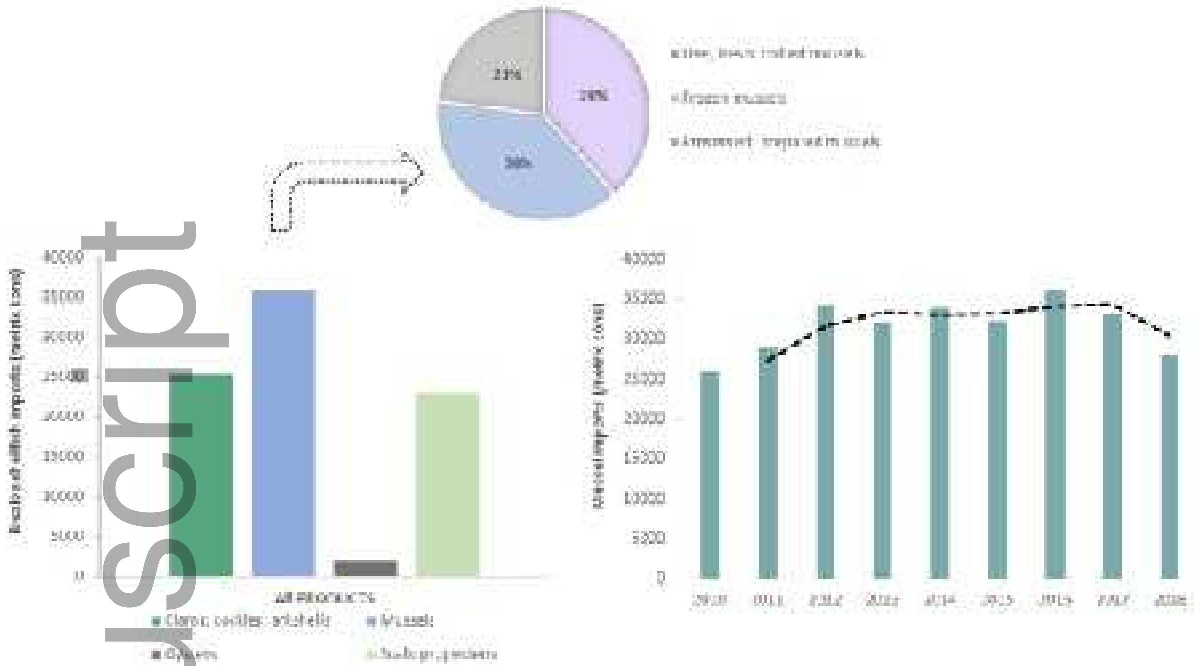
Figure Legends

Figure 1: Breakdown of American imports by main bivalve shellfish group in 2016, types of mussel product imported, and trends in mussel imports in recent years (line indicates moving average per 2 years). Data from FAO (2019).

Figure 2: Imports (kg) of fresh farmed mussels (FF) and fresh wild caught mussel (FW) by the different customs in the United States in 2018. Listed countries represent source of mussel products (including both farmed and wild caught mussels as fresh, frozen, processed, or canned products) imported by custom district. Currently data is cumulative of January through November 2018. Data from NOAA (2019).



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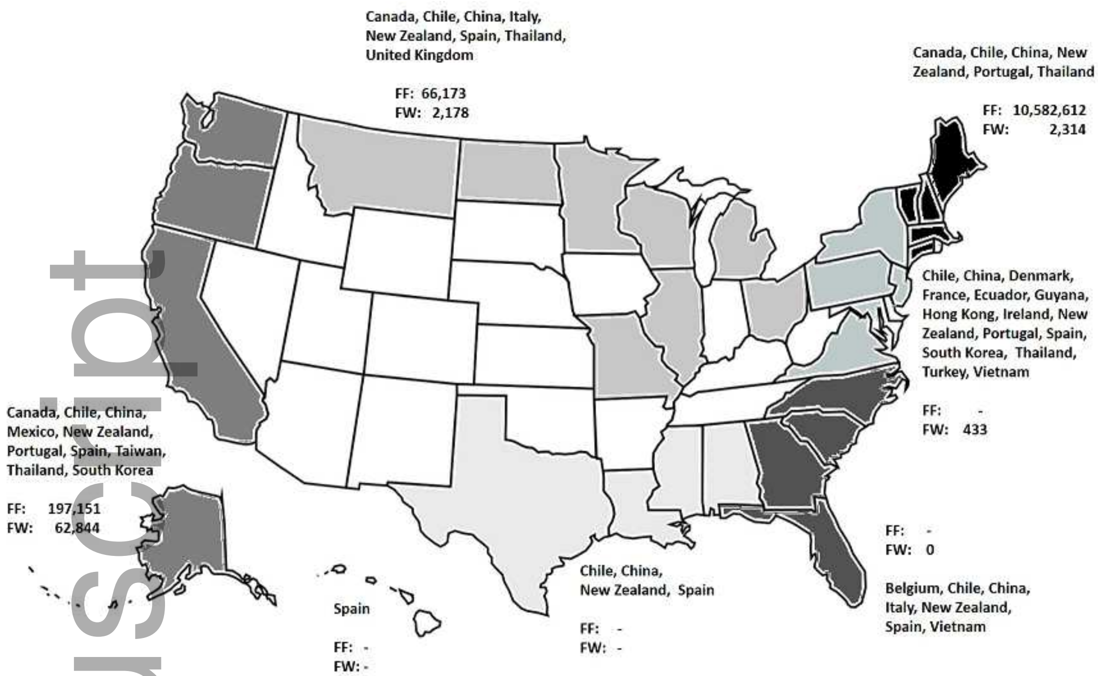

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