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Farming the Oceans:

Opportunities and Regulatory Challenges for U.S. Marine Aquaculture Development

by Arthur R. Wardle
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Reason Foundation

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Executive Summary

In many parts of the world, including the United States, overfishing has depleted wild fish stocks. Several oceanic regions adjacent to the U.S. are already being fished to their maximum sustainable potential. The World Bank projects a nearly 50% increase in worldwide food fish consumption between 2006 and 2030. The U.S. alone will likely need an additional 15 million tons of food fish by the end of the century.

Open ocean aquaculture, also known as mariculture, offers a means of supplementing fish supplies to meet demand and reduce pressure on wild stocks. With new health guidelines recommending increased consumption of fish, many governments have facilitated an aquaculture industry as a means of providing inexpensive, high-quality, year-round protein, benefitting the health of those in low-income households in particular.

Projections for the global seafood industry assume that aquaculture accounts for practically all industry growth to 2030. Yet the United States lags far behind. Aquaculture currently represents 49% of global food fish production, of which the U.S. produces less than 1%.

The greatest impediment to a U.S. aquaculture industry is regulatory. Federal agencies with tenuous claims to the disparate concerns of fish farming, as well as layers of state-level impediments, create a regulatory obstacle course that institutes a de facto ban on aquaculture in the U.S. With these impediments to viable aquaculture businesses, entrepreneurs find capital and insurance impossible to secure, preventing the development of an industry that otherwise might thrive and ensuring the U.S. continues to be a world-leading importer of seafood.

Objections to the development of open ocean aquaculture come from those who benefit from the status quo, such as the capture fishing industry and U.S. environmental groups. While legitimate environmental concerns must be addressed—including water quality, fish escape, disease spread and habitat effects—aquaculture is generally considered to be a low-impact contributor to environmental problems.

For U.S. aquaculture to thrive, federal and state governments will have to remove these regulatory obstacles. Ideally, Congress would create a unified regulatory framework, vested in a single office. The model for this is Norway, whose one-stop permitting process facilitates an expansive marine aquaculture industry. To avoid delays from environmental opposition, priority should be given to the designation of Aquaculture Management Areas in parts of the ocean where aquaculture is less likely to cause environmental harm, a practice advocated by the UN and currently used in New Zealand and Europe.

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Introduction

In many parts of the world, wild fish stocks are under pressure from growing demand and poor fisheries management. Aquaculture, which includes fish farming and underwater plant cultivation, offers a means of supplementing the supply of fish to meet demand and thereby reduce pressure on wild stocks. While aquaculture already supplies a significant proportion of global fish demand, open ocean aquaculture—also known as mariculture—has grown far slower than inland aquaculture and currently represents only a small proportion of total aquaculture in the U.S.

This policy brief begins by reviewing the extent of the overfishing problem and analyzing aquaculture's potential to address that problem. Part 2 summarizes estimates of the economic potential of open ocean aquaculture in the U.S. Part 3 considers the effects of open ocean aquaculture on water quality and other environmental considerations. Part 4 details the regulatory barriers to expanding open ocean aquaculture in the U.S. and offers some possible changes that would reduce those barriers.

Part 1

Aquaculture as a Partial Solution to Overfishing

Dozens of worldwide advocacy groups have identified overfishing as a significant global problem.[1] According to the United Nations Food and Agriculture Organization's most recent biennial State of World Fisheries and Aquaculture report, 28.8% of fish stocks are being fished at an unsustainable level, whereas only 9.9% are being fished below their maximum sustainable yield.[2] Many of the oceanic regions adjacent to the United States are already being

[1] See e.g. World Wildlife Foundation, "Overfishing," <www.worldwildlife.org/threats/overfishing>; Greenpeace, *Overfishing*, <www.greenpeace.org/international/en/campaigns/oceans/fit-for-the-future/overfishing/>; Environmental Defense Fund, "Overfishing: Worse than you might think." <www.edf.org/oceans/overfishing-worse-you-might-think>. Web.

[2] Based on 2011 data. "The State of World Fisheries and Aquaculture: Opportunities and Challenges." Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Department, Rome: Italy, 2014. 37. Print.

fished to their maximum sustainable potential.[3] Given that the World Bank projects a nearly 50% increase in worldwide food fish consumption between 2006 and 2030, this problem is not likely to be solved based solely on demand shifts.[4]

Aquaculture has already been instrumental in handling seafood demand growth. Between 2007 and 2012, for example, worldwide aquaculture production (both inland and marine) grew by 16.7 million tons; capture production increased by only 0.5 million tons.[5] Global fish consumption is not only likely to rise—it is also being encouraged to rise by government dietary recommendations that encourage even more fish intake. Health recommendations for fish consumption cannot be met without growth in aquaculture production.[6] By one estimate, the United States alone will need an additional 15 million tons of seafood by the end of the century.[7] The United States is already one of the world's largest net importers of seafood, and only produces 0.6% of the world's aquaculture product, of which only 5% is maricultured finfish.[8] Aquaculture already comprises nearly 49% of global food fish production, and that fraction is expected to rise.[9]

Markets for aquaculture and wild catch fish interact in a myriad of ways. Most obviously, fish species that are currently produced via aquaculture directly compete with their wild caught counterparts, though conventional fishermen have begun to differentiate their product by marketing it as "wild-caught," diminishing the magnitude of this effect.[10] Additionally, different species of fish act as substitute goods, meaning increased production of aquaculture tilapia, for example, undercuts demand for cod and haddock.[11]

3 Martin, Roy E. "Status of World Fisheries and the Role of Aquaculture," in *Public, Animal, and Environmental Aquaculture Health Issues*, first edition, ed. Michael L. Jahncke et al. Hoboken, NJ: Wiley-Interscience, 2002. 2. Print; Michael L. Jahncke. "Future Considerations of Global Aquaculture," in *Public, Animal, and Environmental Aquaculture Health Issues*, first edition, ed. Michael L. Jahncke et al. Hoboken, NJ: Wiley-Interscience, 2002. 172. Print.

4 "Fish to 2030: Prospects for Fisheries and Aquaculture." Washington, D.C.: World Bank, 2013. xv. Print.

5 "The State of World Fisheries and Aquaculture." Food and Agriculture Organization. 4. Print.

6 Thurstan, Ruth H. and Callum M. Roberts. "The past and future of fish consumption: Can supplies meet healthy eating recommendations?" *Marine Pollution Bulletin* 89, no. 1 (December 2014). 10.

7 Kite-Powell, Hauke L., Michael C. Rubino and Bruce Morehead. "The Future of U.S. Seafood Supply." *Aquaculture Economics & Management* 17, no. 3 (2013). 235.

8 Moffitt, Christine M. and Lubia Cajas-Cano. "Blue Growth: The 2014 FAO State of World Fisheries and Aquaculture." *Fisheries* 39, no. 11 (November 2014). 552–553.

9 Based on 2012 data. "The State of World Fisheries and Aquaculture." FAO. 64; Campbell, Brooke and Daniel Pauly. "Mariculture: A global analysis of production trends since 1950." *Marine Policy* 39 (May 2013). 94.

10 A literature review on the market interaction between aquaculture and wild-caught fish production is available in Fabrizio Natale et al. "Interaction between aquaculture and fisheries." *Marine Policy*. 38 (March 2013). 206–207; Naylor, Rosamond L. et al. "Effect of aquaculture on world fish supplies." *Nature* 405 (June 2000). 1018.

11 Naylor, "Effect of aquaculture on world fish supplies." 1018.

Health recommendations for fish consumption cannot be met without growth in aquaculture production.

Aquaculture has proven useful for the cultivation of numerous fish species that are overfished in the wild. Specifically, aquaculture has been used to farm bluefin tuna, Atlantic cod, and Atlantic halibut.[12] All three of these species are listed in the Monterey Bay Aquarium's *Seafood Watch* consumer information pamphlet as "avoid" for their overfished status.[13] Given the relative ease of domesticating aquatic species and the quick development of new domestications, even more critical species will be open to aquacultural cultivation in the future.[14]

Protein sources in aquaculture feed have historically been comprised primarily of fishmeal and fish oil harvested from schools of small pelagic fish, potentially aggravating overfishing within those populations.[15] However, multiple developments are combating that reliance and protecting the future of small pelagic fish populations:[16]

- Aquaculture feed contains progressively less fishmeal and fish oil as the industry discovers new efficiencies and a better understanding of the dietary needs of farmed fish.
- Growth in aquaculture production of herbivorous fish far outpaces growth in carnivorous fish production. While both categories do require dietary protein, herbivorous species require far less.
- Byproducts from fish processing are increasingly being used for fishmeal production.
- Fishmeal has a number of suitable substitutes such as corn gluten meal, preventing dangerous over reliance on fishmeal as a protein source. Further, animal byproducts of terrestrial animals that have historically been banned from feed products due to

12 Naylor, Rosamond L. "Environmental Safeguards for Open-Ocean Aquaculture." *Issues in Science and Technology* 22, no. 3 (Spring 2006). For more information on how aquaculture helps Bluefin Tuna, see Hayashi, Yuka. "Why Farmed Fish Are Taking Over Our Dinner Plates." *The Wall Street Journal*, November 14, 2014. Web. <www.wsj.com/articles/why-farmed-fish-are-taking-over-our-dinner-plates-1415984616>.

13 Monterey Bay Aquarium, Seafood Watch National Consumer Guide. 2016. <www.seafoodwatch.org/-/m/sfw/pdf/guides/mba-seafoodwatch-national-guide.pdf?la=en>.

14 Duarte, Carlos M., Nùria Marbá and Marianne Holmer. "Rapid Domestication of Marine Species," *Nature* 316 (April 2007). 382.

15 Pelagic fish are fish that spend most of their time in the open ocean. Concerns about this effect are common. See e.g. *Right from the Start: Open-Ocean Aquaculture in the United States* (Washington, D.C.: Ocean Conservancy, March 2011). 24–27. Print.

16 Natale et al. "Interaction between aquaculture and fisheries." 208–210.

concerns about prion transmission could replace some fishmeal in aquaculture feed, as risks associated with prion contamination in mammals are substantially lower among fish.[17] There are also a number of lipid source alternatives to fish oil.[18]

17 Analyses of fishmeal substitutes are available in Olsen, Ragnar L. and Mohammad R. Hasan. "A limited supply of fishmeal: Impact on future increases in global aquaculture production." *Trends in Food Science & Technology* 27, no. 2 (October 2012). 123–126; Hardy, Ronald W. "Utilization of plant proteins in fish diets: effects of global demand and supplies of fishmeal." *Aquaculture Research* 41, no. 5 (April 2010). 772–775; Klinger, Dane and Rosamond Naylor. "Searching for Solutions in Aquaculture: Charting a Sustainable Course." *Annual Review of Environment and Resources* 37 (November 2012). 258–262.

18 Turchini, Giovanni M., Wing-Keong Ng and Douglas R. Tocher, eds., *Fish Oil Replacement and Alternative Lipid Sources in Aquaculture Feeds*. Boca Raton, FL: CRC Press, 2010.; Olsen, Yngvar, Oddmund Otterstad and Carlos M. Duarte. "Status and Future Perspectives of Marine Aquaculture," in *Aquaculture in the Ecosystem*, first edition, ed. Marianne Holmer et al. Dordrecht, Netherlands: Springer, 2008. 306–307.

Part 2

The Economic Potential of Open Ocean Aquaculture

Projections for the global seafood industry predict aquaculture taking up all industry growth to 2030.[19] In the United States, marine aquaculture accounts for only 25% of total aquaculture production and only grows by 1% annually, lagging world growth.[20] Of the marine aquaculture facilities currently operating in the United States, all but one are located in waters regulated predominantly by states. Only a single bivalve shellfish farm exists within

[19] Kobayashi, Mimako et al., "Fish to 2030: The Role and Opportunity for Aquaculture." *Aquaculture Economics & Management* 19, no. 3 (2015). 282.

[20] Measured by value (differs from seemingly similar numbers in section one due to the inclusion of shellfish and crustaceans). Naylor. "Environmental Safeguards for Open-Ocean Aquaculture."

federal waters.[21] Rosamond Naylor, an environmental economist who has written extensively on aquaculture, articulated the necessity of expansion to the ocean for U.S. aquaculture growth this way:

> *The U.S. Department of Commerce has articulated the need to reverse the seafood deficit, and under the leadership of its subagency, the National Oceanic and Atmospheric Administration (NOAA), has a stated goal of increasing the value of the U.S. aquaculture industry from about $1 billion per year currently to $5 billion by 2025. In order to achieve this goal, the Department of Commerce has set its sights on the federal waters of the Exclusive Economic Zone (EEZ), located between the 3-mile state zone and 200 miles offshore, where the potential for aquaculture development appears almost limitless.*[22]

Beyond general economic benefits, aquaculture has benefits for society's poorest members. Aquaculture drives the price of high-quality, year-round protein down, making it more accessible to low-income households.[23]

[21] Welch, Aaron W. *Farming in the Commons, Fishing in the Congress, and U.S. Aquaculture in the 21st Century*. (PhD diss. University of Miami, 2015). 103–104.

[22] Naylor. "Environmental Safeguards for Open-Ocean Aquaculture."

[23] Bostick, Katherine. "NGO Approaches to Minimizing the Impacts of Aquaculture: A Review" in *Aquaculture in the Ecosystem*, first edition, ed. Marianne Holmer et al. Dordrecht, Netherlands: Springer, 2008. 230.

Part 3

Environmental Considerations

As a whole, aquaculture is generally considered to be a low-impact contributor to environmental problems, at least relative to other anthropogenic sources of environmental degradation. In attempting to sum up the extent of aquaculture's environmental impact, Dr. T. V. R. Pillay wrote, "the pollutive effects of aquaculture are comparatively small and highly localized."[24] Still, various researchers have identified a number of environmental factors that might be negatively affected by an expansion of aquaculture. A selection of the most common environmental concerns is covered below.

[24] Pillay, T. V. R. *Aquaculture and the Environment*. Second edition. Oxford: Blackwell, 2003. 21.

Aquaculture is generally considered to be a low-impact contributor to environmental problems.

3.1 Water Quality

Water quality issues associated with aquaculture (and particularly finfish aquaculture) stem from ecological and hydrological effects of fish which are essentially harmless in natural population densities but can cause undue ecological damage in unnaturally dense populations, as is characteristic of aquaculture. Ecological concern with aquaculture's effect on water quality has focused on a few main issues: oxygen depletion, nitrogen overload, phosphorus overload, and water turbidity.

Fish and shellfish both require oxygen to metabolize food. Large concentrations of fish typical of intensive or semi-intensive aquaculture systems thus require a strong water flow in order to replenish oxygen at the aquaculture site.[25] This waterflow is generally enough to negate any effect on surrounding dissolved oxygen levels. In cases where decreases in dissolved oxygen are measurable in the ambient water, they are minor, local, and, in the rare cases where dissolved oxygen does get dangerously low, are only temporary. In these cases, there are a number of mechanical solutions that can re-oxygenate the water.[26]

Because dilution is an effective remedy to fish wastes (which are harmful at high concentrations but naturally occurring and even beneficial at lower levels), the hydrological flushing required to maintain proper dissolved oxygen levels in aquaculture also serves to negate much of the potential waste impact. Unfortunately, it is possible to farm fish in currents that adequately replace oxygen but that still move too slowly for effective waste dispersion.[27]

Nitrogen exits aquaculture systems both when uneaten food floats away and when digestive processes expel nitrogen from the fish in the form of refuse.[28] The largest risk associated with

25 Tett, Paul. "Fish Farm Wastes in the Ecosystem," in *Aquaculture in the Ecosystem*. First edition. Ed. Marianne Holmer et al. Dordrecht, Netherlands: Springer, 2008. 6.

26 Price, Carol et al. "Marine cage culture and the environment: effects on water quality and primary production." *Aquaculture Environment Interactions* 6, no. 2 (2015). 159.

27 Tett. "Fish Farm Wastes." 6.

28 Price, et al. "Marine cage culture and the environment." 153.

high nitrogen levels is eutrophication, an undesirable acceleration in algae and plant life growth that creates unhealthy water quality conditions and throws underwater ecologies off balance, killing off fish. The consequences of eutrophication include the oft-reported danger of harmful algal blooms.[29] Data regarding nitrogen levels surrounding fish farms in marine environments vary widely and are highly contingent on the species being farmed and surrounding hydrological conditions. As an illustrative example, 36% of the nitrogen consumed through feed by salmon and rainbow trout is retained by the fish, 10% falls to the ocean floor in solid waste, and 54% dissolves from excreta into the water column.[30] While uneaten food can potentially act as an additional source of nutrient loading, farmers try to minimize food waste, leading some advanced farms to incorporate computer programs to adjust feeding input based on a number of fluctuating factors.[31] Wild fish surrounding the nets also quickly eat food wastes before they can affect ambient environmental quality.[32] A literature review published by Carol Price et al. in *Aquaculture Environment Interactions* showed that most studied aquaculture facilities have zero or minor effects on surrounding nitrogen levels, but a minority do affect nitrogen levels significantly enough that small shifts could have profound negative impacts.[33]

Owners of aquaculture facilities have an incentive to avoid releasing too many nutrients into the surrounding water column, as the resulting ecological effects that damage native finfish also pose a potentially devastating threat to the farm fish themselves.[34]

Owners of aquaculture facilities have an incentive to avoid releasing too many nutrients into the surrounding water column.

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29 Tett. "Fish Farm Wastes." 7–9.

30 Bouwman, Lex et al. "Mariculture: significant and expanding cause of coastal nutrient enrichment." *Environmental Research Letters* 8, no. 4 (October-December 2013). 2.

31 Pillay. *Aquaculture and the Environment*. 60.

32 Dempster, Tim and Pablo Sanchez-Jerez. "Aquaculture and Coastal Space Management in Europe: An Ecological Perspective," in *Aquaculture in the Ecosystem*. First edition. Ed. Marianne Holmer et al. Dordrecht, Netherlands: Springer, 2008. 93.

33 Price et al. "Marine cage culture and the environment." 154.

34 Bouwman et al. "Mariculture." 4; Tett. "Fish Farm Wastes." 9.

Microbiological growth in marine environments requires a variety of nutrients, and is generally limited by whichever necessary nutrient is scarcest. In a typical marine environment, that nutrient is nitrogen, and thus nitrogen loading is the major concern for preventing eutrophication.[35] However, there are marine environments in which phosphorus is the limiting nutrient, and in these areas, phosphorus release is more concerning than nitrogen.[36] Phosphorus releases vary along the same variables as nitrogen, with species, location, and feed all affecting ambient nutrient density.[37] Price et al. showed that most literature reports minimal or zero effects on dissolved phosphorus levels around finfish cages, though, as with nitrogen, a minority do report significant impacts.[38]

While nutrient loading resulting from aquaculture can have negative effects locally, nutrients released from aquaculture account for only a small fraction of total nutrient introduction, which comes primarily from rivers.[39] For example, in the Danish seas, nitrogen from marine fish farms is said to account for 0.2% of all anthropogenic nitrogen loading.[40] For this reason, even if a given aquaculture facility releases enough nutrients to harm the local marine environment, that facility still will not contribute significantly to macro-level environmental degradation.[41]

Some studies have measured phytoplankton density rather than nutrient density, moving up one trophic level. Many of these studies have found no significant increase in phytoplankton density, and even many of those that have found significant increases have not found levels where eutrophication is a risk. While a few studies have identified potentially dangerous levels of phytoplankton in areas around aquaculture sites, many of them have struggled to isolate the effect of aquaculture from other anthropogenic nutrient sources. In all, phytoplankton overpopulation does not seem to be a common problem with aquaculture.[42] Similarly, there has been little evidence linking aquaculture to harmful algal blooms.[43] In cases showing a potential link between aquaculture and algal blooming, aquaculture farms

35 Pillay. *Aquaculture and the Environment*. 14; Price et al. "Marine cage culture and the environment." 156.

36 Price et al. "Marine cage culture and the environment." 156.

37 Ibid.

38 Ibid.

39 Bouwman et al., "Mariculture." 3.

40 Pillay. *Aquaculture and the Environment*. 22.

41 Dempster and Sanchez-Jerez. "Aquaculture and Coastal Space Management." 94.

42 Price et al. "Marine cage culture and the environment." 161–164.

43 Ibid. 164.

suffered monumental economic losses, giving aquaculture farmers an incentive to avoid causing algal blooms.[44]

Phytoplankton overpopulation does not seem to be a common problem with aquaculture.

Both phosphorus and nitrogen also fall to the ocean floor at aquaculture sites. If these nutrients accumulate too heavily due to less-than-ideal flushing rates, they can be damaging to benthic ecologies.[45] This impact is localized to the aquaculture site; still, some researchers have developed technological remedies that can alleviate the worst cases of benthic nutrient accumulation.[46]

Water turbidity has been a concern for freshwater aquaculture sites, but is not recognized as a major issue for marine aquaculture. While feed and waste particulates can increase water turbidity, the water flushing occurring within aquaculture sites is enough to handle these impacts. In periods of uncharacteristically low flushing rates, turbidity can increase temporarily, but only long-term turbidity poses any real risk to oceanic habitat.[47]

By siting aquaculture facilities in areas with decent flushing rates and away from areas already suffering from eutrophication, water quality issues associated with aquaculture can be avoided.[48] As aquaculture moves farther and farther offshore, these impacts will be even smaller.[49] In fact, with proper site selection, additional nutrient loading can even be beneficial to the surrounding environment.[50] Appropriate sites are likely to be chosen without any government mandate—water quality negatively affects the farmer's fish stocks just as it harms surrounding native environments. Additionally, "fallowing," the practice of rotating

44 Bouwman et al. "Mariculture." 4.

45 Benthic plants are plants that grow in the benthic zone, i.e. the ocean floor and first few feet of ocean substrate.

46 Pillay. *Aquaculture and the Environment*. 46-47.

47 Price et al. "Marine cage culture and the environment." 160–161.

48 Ibid. 164–165.

49 Holmer, Marianne. "Environmental issues of fish farming in offshore waters: perspectives, concerns and research needs." *Aquaculture Environment Interactions* 1, no. 1 (2010). 67; Bouwman et al. "Mariculture." 4; Welch. "Farming in the Commons." 97.

50 Welch. "Farming in the Commons." 100–101.

fish stocks through sites that have been unused for some period of time, can prove beneficial both to farm productivity and to the health of the surrounding marine environment.[51]

By siting aquaculture facilities in areas with decent flushing rates and away from areas already suffering from eutrophication, water quality issues associated with aquaculture can be avoided.

Water quality impacts can be further minimized by combining species of multiple trophic levels together in one aquaculture system. By co-producing finfish with shellfish or seaweeds, waste nutrients that would otherwise float away can be absorbed by shellfish or seaweed, both assisting water quality and increasing farm productivity.[52]

Aquaculture of macroalgaes (i.e. seaweed) and bivalves (i.e. oysters and mussels) even offers water quality benefits. Many coastal areas suffer from dangerously high levels of certain nutrients as a result of agricultural runoff and other human activity. Both macroalgae and bivalve aquaculture can help to alleviate those pressures by filter-feeding those nutrients out of the water.[53] Even non-organic particulate matter that bivalves cannot consume is reduced by bivalve filtering—the shellfish reject it as "pseudofeces," which is mucus-bound. That mucus is aggregated and settles up to 40 times faster than non-aggregated particles, increasing nitrogen content of the sediment.[54] Reduction in phytoplankton and inorganic particle concentration brought about by bivalve filtering results in reduced water turbidity and increased light penetration, which is beneficial to the growth of benthic plants.[55] While these increases in benthic plant mass are often accompanied by decreases in benthic biodiversity, that effect is limited to the surrounding roughly 100m, and even that impact can

51 Pearson, T. H. and K. D. Black. "The environmental impacts of marine fish cage culture," in *Environmental Impacts of Aquaculture*. First edition. Ed. Kenneth D. Black. Sheffield, UK: Sheffield Academic Press; Boca Raton, FL: CRC Press, 2001. 25-26.

52 Troell, Max et al. "Ecological engineering in aquaculture—Potential for integrated multi-trophic aquaculture (IMTA) in marine offshore systems." *Aquaculture* 297, no. 1–4 (December 2009). 3; Price et al. "Marine cage culture and the environment." 165–167; Pillay. *Aquaculture and the Environment*. 79.

53 Newell, Roger I. E. "Ecosystem Influences of Natural and Cultivated Populations of Suspension-Feeding Bivalve Molluscs: A Review." *Journal of Shellfish Research* 23, no. 1 (2004). 57–58; Chopin, Thierry el al. "Integrating Seaweeds into Marine Aquaculture Systems: A Key Toward Sustainability." *Journal of Phycology* 37, no. 6 (December 2001). 977.

54 Newell. "Ecosystem Influences." 52.

55 Ibid.

be mitigated by flushing or dispersion in the surrounding waters.[56] Sadly, many policymakers and advocacy groups simplistically lump together all aquaculture when discussing its impact on water quality, allowing the green aspects of bivalve aquaculture to go uncredited and unnoticed.[57]

Aquaculture of macroalgaes (i.e. seaweed) and bivalves (i.e. oysters and mussels) even offers water quality benefits.

3.2 Fish Escape

Fish escapes from aquaculture facilities can occur in a number of ways. Wear and tear or damage caused by boat collisions can cause small-scale net or pen failures that release small amounts of fish. More catastrophically, extreme weather events can cause structural damage to aquaculture systems that releases all of the farm's fish,[58] though several major storms in areas with aquaculture operations have not resulted in such escapes.[59] In some species of farmed fish (that are not sterile), fertilized egg release from aquaculture nets or cages is yet another route through which farmed genes can enter wild stocks.[60]

Death rates for escapees soon after escape are quite high, but those that do survive can wreak environmental damage, whether the species is native or exotic.[61] For non-native species, escapees can wreak havoc on local ecologies and even become an invasive species. Introduction of new invasive species is of particular concern for aquaculture operations,

56 Howgate, Peter et al. "Aquaculture Associated Public, Animal, and Environmental Health Issues in Nonindustrialized Countries," in *Public, Animal, and Environmental Aquaculture Health Issues*. First edition. Ed. Michael L. Jahncke et al. Hoboken, NJ: Wiley-Interscience, 2002. 47.

57 Shumway, Sandra E. et al. "Shellfish aquaculture—In praise of sustainable economies and environments." *World Aquaculture* 34, no. 4 (December 2003). 15.

58 Cross, T. F. et al. "Detrimental Genetic Effects of Interactions Between Reared Strains and Wild Populations of Marine and Anadromous Fish and Invertebrate Species," in *Aquaculture in the Ecosystem*. First edition. Ed. Marianne Holmer et al. Dordrecht, Netherlands: Springer, 2008. 130; Ferguson, A. et al., "Farm Escapes," in *The Atlantic Salmon: Genetics, Conservation and Management*. First edition. Eds. Eric Verspoor, Lee Stradmeyer and Jennifer L. Nielsen. Oxford: Blackwell, 2007. 361.

59 Upton, Harold F. and Eugene H. Buck. *Open Ocean Aquaculture* (CRS Report No. RL32694). Washington, DC: Congressional Research Service, 2010. 12–13.

60 See e.g. Uglem, Ingebrigt et al. "Extent and ecological importance of escape through spawning in sea-cages for Atlantic cod." *Aquaculture Environment Interactions* 3, no. 1 (2012). 43; Jørstad, Knut E. et al., "'Escapes' of Eggs from Farmed Cod Spawning in Net Pens: Recruitment to Wild Stocks." *Reviews in Fisheries Science* 16, no. 1–3 (2008). 286; Holmer, "Environmental issues of fish farming in offshore waters." 65.

61 Dempster et al., "Recapturing escaped fish from marine aquaculture is largely unsuccessful: alternatives to reduce the number of escapees in the wild." Reviews in Aquaculture. In press (2016). 10.

because many of the characteristics that make a fish species a prime candidate for aquaculture rearing (tolerance for a variety of environments, rapid growth, frequent reproduction) also give species a proclivity toward invading.[62] Even without invading, escaped exotics compete with native populations for food, predate native fishes, and displace native habitat.[63] While aquaculture is only one of many routes for exotic species introductions, its influence is still important.[64]

For escapes of native species, there are still genetic consequences for offspring. When fish are confined to an aquaculture cage or pen, they undergo a process known as "domestication," which alters the fishes' genetics in ways that favor farm, rather than wild, habitat.[65] Mixing genetics tailored for farm survival into native gene pools reduces the fitness of native fish.[66] If farmed fish are drawn from a genetic pool that is substantially unrelated to the local population (though still of the same species), "outbreeding depression" can even result in genetic defects in offspring.[67]

Farming non-native species can have a number of advantages. Advanced aquaculture techniques have only been developed for a small minority of the world's fish. Many suitable aquaculture sites may not be a native home to any of these species. Local fish may not have the characteristics associated with successful aquaculture operations or may simply not be in demand among local customers.[68] While farming exotic species does carry risks, the benefits that can accompany it make an all-out ban on exotic fish farming inadvisable. A significant portion of aquaculture output, including over 70% of aquaculture production in South America and the Caribbean, is already produced with non-native species.[69]

62 Diana, James S. "Aquaculture Production and Biodiversity Conservation." *BioScience*, no. 1 (January 2009). 31–32.

63 *Impacts to Marine Fisheries Habitat from Nonfishing Activities in the Northeastern United States: NOAA Technical Memorandum NMFS-NE-209*, U.S. Department of Commerce. February 2008. 260–261. Web. *www.nefsc.noaa.gov/publications/tm/tm209/tm209.pdf*; Naylor, Rosamond et al. "Fugitive Salmon: Assessing the Risks of Escaped Fish from Net-Pen Aquaculture." *BioScience* 55, no. 5 (2005). 229–230.

64 Lapointe, Nicolas W. R. et al. "Pathways of fish invasions in the Mid-Atlantic region of the United States." *Management of Biological Invasions* 7. In press (2016). 10.

65 To clarify, this process does not require any genetic modification and occurs in entirely "natural" fish. Genetically modified fish pose threats similar to those discussed throughout this section, but genetic modification introduces an entire new host of issues beyond the scope of this paper.

66 *Genetic Risks Associated with Marine Aquaculture: NOAA Technical Memorandum NMFS-NWFSC-119*, U.S. Department of Commerce, National Oceanic and Atmospheric Administration. September 2012. 32. <www.arlis.org/docs/vol1/E/815789406.pdf>

67 *Genetic Risks Associated with Marine Aquaculture*. 33.

68 Pillay. *Aquaculture and the Environment*. 80.

69 Cook, Elizabeth J. et al. "Non-Native Aquaculture Species Releases: Implications for Aquatic Ecosystems," in *Aquaculture in the Ecosystem*. First edition. Ed. Marianne Holmer et al. Dordrecht, Netherlands: Springer, 2008. 156–157.

Farming non-native species can have a number of advantages.

Multiple organizations have released criteria to help weigh the benefits, costs and risks of exotic introductions for aquaculture. In general, these criteria take into account the presence or non-presence of suitable substitute native species, the need for the exotic species, the predicted effect of the exotic on the native habitat, the ability of the exotic to breed with wild native species, the disease and parasite risks associated with the exotic, and the exotic's propensity for invasion.[70]

There are two general strategies for combating risks associated with fish escape. The first is to reduce the ability of the fish to escape in the first place, the second is to control their ability to reproduce in the wild.[71]

Fish escape can never be prevented with 100% certainty, but reasonable precautions can dramatically reduce the risk of most escapes. Siting aquaculture facilities away from areas with frequent destructive storms or aggressive predators can minimize the risk of net pen damage. Additionally, construction of an additional layer of nets provides an extra failsafe and can deter predators.[72] A number of steps can be taken to avoid damage to the nets, such as keeping the net free of biofoulers (see more in section 3.4), frequent inspection, and utilization of proper handling techniques, among others.[73]

There are two general strategies for combating risks associated with fish escape. The first is to reduce the ability of the fish to escape in the first place, the second is to control their ability to reproduce in the wild.

[70] Pillay. *Aquaculture and the Environment*. 85–88.

[71] *Genetic Risks Associated with Marine Aquaculture*. 20–21.

[72] Ibid. 20.

[73] These and more techniques are covered in Moe, Heidi et al. "Technological solutions and operational measures to prevent escapes of Atlantic cod (*Gadus Morhua*) from sea cages." *Aquaculture Research* 38, no. 1 (2007). 97–98.

To minimize the risk associated with fish escape, fish can also be prevented from reproducing in the wild. In rare cases where it is possible, retrieving the escaped fish and removing them from the wild environment is ideal.[74] For anadromous fish, it may be possible to recapture escaped farm fish at the mouth of the spawning river, though this also poses risks to wild populations.[75] Escapee reproduction can be avoided at much lower costs by using sterilized fish.[76] This has the added benefit of avoiding pre-harvest sexual maturation, which reduces meat quality and slows muscle growth and is thus undesirable for fish farmers.[77] By far the most common method of sterilization is by induced triploidy, which adds a third set of chromosomes to the fish, making them infertile.[78] Other methods of sterilization exist, but these are either unviable at a commercial scale or are still in early stages of research.[79] Inducing triploidy into fish can be done with a success rate of >98% on a commercial scale.[80] Triploidy can substantially mitigate or eliminate the genetic risks associated with non-native fish farming.[81]

3.3 Disease Spread

Presence of an aquaculture facility in the ocean introduces new risk for disease and parasite outbreaks among wild populations. Introduction of diseases and parasites can occur merely by the transportation of fish populations, both when fish are introduced to the farm as stock or when smaller fish are introduced as food for carnivorous stocks. Luckily, exotic disease introduction stemming from aquaculture is exceedingly rare, though it can be potentially devastating when it does occur.[82]

74 Naylor et al. "Fugitive Salmon." 433; Dempster, Tim et al. "Recapturing escaped fish from marine aquaculture is largely unsuccessful: alternatives to reduce the number of escapees in the wild." *Reviews in Aquaculture*. In press (2016). 10–11; *Genetic Risks Associated with Marine Aquaculture*. 20.

75 Naylor et al. "Fugitive Salmon." 433; Dempster et al. "Recapturing escaped fish." 10–11.

76 *Genetic Risks Associated with Marine Aquaculture*. 21.

77 Benfey, T. J. "Producing sterile and single-sex populations of fish for aquaculture," in *New technologies in aquaculture: Improving production efficiency, quality and environmental management*. First edition. Eds. Gavin Burnell and Geoff Allan. Boca Raton, FL: CRC Press; Oxford: Woodhead Publishing Ltd., 2009. 144; Piferrer, Francesc et al. "Polyploid fish and shellfish: Production, biology and applications to aquaculture for performance improvement and genetic containment." *Aquaculture* 293, no. 3-4 (2009). 137–140.

78 Naylor et al. "Fugitive Salmon." 433–434; Benfey. "Producing sterile and single-sex populations of fish for aquaculture." 145.

79 Benfey, "Producing sterile and single-sex populations of fish for aquaculture." 153–154; Benfey, Tillmann J. "Effectiveness of triploidy as a management tool for reproductive containment of farmed fish: Atlantic salmon (*Salmo salar*) as a case study." *Reviews in Aquaculture* 7, no. 1 (2015). 2.

80 Benfey, "Effectiveness of triploidy as a management tool for reproductive containment of farmed fish." 4.

81 Piferrer et al. "Polyploid fish and shellfish." 149.

82 *Right from the Start: Open-Ocean Aquaculture in the United States*. 22.

Aquaculture facilities pose a heightened risk for disease spread because the enclosures create high densities of potential carriers, sometimes in environments that cause stress, making fish more vulnerable.[83] High-density fish concentrations can spur evolution in pathogens that increases their virulence, spreading quickly throughout the aquaculture population.[84]

Researchers have identified a number of ways to minimize these risks using fairly basic strategies, such as sanitizing materials between uses and clearing aquaculture facilities of dead fish every few days.[85] Outbreaks of parasites have been successfully dealt with using both chemical treatment and fallowing techniques.[86] Bacterial diseases have been dealt with using antibiotics, which can be included in feed for larger finfish.[87] While viral diseases are more difficult to contend with, vaccination, routine decontamination of facilities and equipment, and eventual development of resistant fish stocks all aid in virus mitigation.[88]

3.4 Drugs, Antifoulants, and Other Chemicals

Chemicals and drugs intended for uptake in fish are not commonly used in marine finfish aquaculture, mainly because of the difficulty of administering treatment. For those that are used, dilution is thought to be an adequate answer to environmental concerns.[89]

Concentrations in aquaculture effluent output have not been tested for all chemicals, but for those that have been tested, output concentrations have been insignificant.[90] For biocidal agents, only localized effects have been observed.[91]

One category of chemicals in common usage among aquaculture facilities is antifoulants. A variety of species—including barnacles, bivalves, and algae—attach to submerged structures

[83] Ibid.

[84] Murray, Alexander G. and Edmund J. Peeler. "A framework for understanding the potential emerging diseases in aquaculture." *Preventative Veterinary Medicine* 67, no. 2–3 (February 2005). 227.

[85] These and other strategies are identified in Murray and Peeler, "A framework for understanding the potential emerging diseases in aquaculture." 230–231.

[86] Jahncke, Michael L. and Michael H. Schwarz. "Public, Animal, and Environmental Aquaculture Health Issues in Industrialized Countries," in *Public, Animal, and Environmental Aquaculture Health Issues*. First edition. Ed. Michael L. Jahncke et al. Hoboken, NJ: Wiley-Interscience, 2002. 81–82.

[87] Ibid. 83–84.

[88] Ibid. 86.

[89] Pillay. *Aquaculture and the Environment*. 69.

[90] Ibid. 19.

[91] Ibid.

and can become burdensome nuisances or even cause structural failures. This process is termed "biofouling." Antifoulants, chemicals applied to underwater surfaces to prevent growth of biofouling communities, are commonly used on aquaculture facility surfaces. Eliminating (or at least reducing) biofouling on aquaculture facilities is critical to maintaining water flow-through, preventing disease spread from biofouling communities to farmed stock, and preventing structural deformation that could cause breakages and lead to fish escape.[92]

Tributyl tin (TBT), which was historically common as an antifoulant, was discovered to be harmful to oyster and finfish health and thus inappropriate for aquaculture use.[93] TBT has since been banned throughout much of the world. Antifouling today is most commonly done with copper oxide, often in combination with a number of other organic biocides or zinc.[94] Copper oxide is not without negative environmental effects and has been demonstrated to harm non-target species, though not as badly as TBT.[95] Some evidence seems to indicate that copper oxide does not bioaccumulate in aquaculture fish, other evidence shows bioaccumulation, but not to dangerous levels.[96] Regardless, the industry still undertakes precautions to minimize copper oxide's risk.[97] Trials of other biocides for use in antifouling are being conducted, and there are extensive global research efforts dedicated to developing an antifoulant that is both "effective and environmentally benign."[98] Researchers are also considering the use of aquatic grazing organisms to control biofouling.[99] Manually dealing with biofouling, either through periodic net replacement or manual removal, is still commonplace in temperate and tropical regions, but is highly costly.[100] Biofouling problems can also be mitigated by siting aquaculture facilities further offshore, where fewer biofouling species grow.[101]

92 Fitridge, Isla et al. "The impact and control of biofouling in marine aquaculture: a review." *Biofouling* 28, no. 7 (August 2012). 655–656.

93 Pillay. *Aquaculture and the Environment*. 69; Howgate, Peter et al. "Aquaculture Associated." 40–41.

94 Guardiola, Francisco Antonio et al. "Risks of Using Antifouling Biocides in Aquaculture." *International Journal of Molecular Sciences* 13, no. 2 (2012). 1543.

95 Ibid.

96 Evidence against accumulation is cited in Fitridge et al., "The impact and control of biofouling in marine aquaculture." 659; evidence for non-dangerous accumulation is in Nikolaou, Marina et al. "Fish-farming and anti-fouling paints: a potential source of Cu and Zn in farmed fish." *Aquaculture Environment Interactions* 5, no. 2 (2014).170.

97 Fitridge et al. "The impact and control of biofouling in marine aquaculture." 659.

98 Ibid. 659–662.

99 See e.g. Atalah, Javier et al. "Potential biocontrol agents for biofouling on artificial structure." *Biofouling* 30, no. 8 (2014). 1008; Prakash, S. et al. "Antimicrofouling properties of chosen marine plants: An eco-friendly approach to restrain marine microfoulers." *Biocatalysis and Agricultural Biotechnology*. 4, no. 1 (January 2015). 120.

100 Fitridge et al. "The impact and control of biofouling in marine aquaculture." 658.

101 Holmer. "Environmental issues of fish farming in offshore waters." 65.

Biofouling problems can also be mitigated by siting aquaculture facilities further offshore, where fewer biofouling species grow.

3.5 Habitat Effects

Wastes and excess feed at aquaculture sites fall into the surrounding water outside the cage. Those discharges attract wild fish, and can result in large population increases around the aquaculture site, especially among benthic species. In general, this is not necessarily a bad thing, though it can have two negative consequences. First, it can interrupt natural movement of fish populations, altering migration routes or even encouraging fish to stay in suboptimal habitat due to the availability of abundant food. Second, the concentration of wild fishes can attract large predators such as sharks or sea lions, which can in turn damage the aquaculture facility and cause fish escapes, discussed above.[102]

[102] Ibid. 63–64.

Part 4

Regulatory Barriers

Given the potential benefits of open ocean aquaculture, one might wonder why it has not yet taken off in the U.S. While small scale aquaculture operations exist in some locations, expansion has been impeded by various regulatory barriers at the federal and state level.

4.1 Lack of a Comprehensive Framework

There is no one regulatory office fully in charge of handling U.S. aquaculture activities. To construct any aquaculture facility in U.S. oceans, a prospective fish farmer needs to fulfill a litany of requirements set up by the Army Corps of Engineers, the National Marine Fisheries Service, the Fish & Wildlife Service, the Environmental Protection Agency, and more.[103] Each of these agencies has the power to completely halt progress on a prospective aquaculture site.[104] A 2005 NOAA-funded study summed it up like this:

> *As presently constituted, federal offshore aquaculture leasing and permitting is governed by an ill-defined framework that regulatory agencies have patched together from a hodge-podge of laws and regulations that only tangentially address aquaculture. As a consequence, the present leasing and permitting framework offers neither predictability nor efficiency.*[105]

The jungle of regulations facing the marine aquaculture industry has been described as a de facto ban, allowing only very small operations and even then only in state-controlled waters.[106] This lack of a central regulatory authority and the resulting mess of semi-related regulations being applied to aquaculture has been identified by numerous researchers as a major (and often the most important) constraint preventing the development of a U.S. marine aquaculture industry.[107] In its comprehensive report, the U.S. Commission on Ocean Policy reported that the regulatory mess meant potential aquaculturists "have no guarantee of exclusive use of space in offshore areas, private capital is difficult to obtain, insurance companies do not provide coverage, and banks are unwilling to accept the unknown risks involved."[108] The FAO has concluded that the permitting requirements in the United States are so strenuous that only large-scale operators that can hire a staff tasked solely with handling regulatory requirements are capable of success.[109]

[103] Engle, Carole R. and Nathan M. Stone. "Competitiveness of U.S. Aquaculture Within the Current U.S. Regulatory Framework." *Aquaculture Economics & Management* 17, no. 3 (2013). 260.

[104] Knapp, Gunnar and Michael C. Rubino. "The Political Economics of Marine Aquaculture in the United States." *Reviews in Fisheries Science & Aquaculture* 24, no. 3 (2016). 218; Upton and Buck, *Open Ocean Aquaculture*. 14.

[105] Cicin-Sain, Biliana et al. *Recommendations for an Operational Framework for Offshore Aquaculture in U.S. Federal Waters*. Technical Report. Newark, DE: Gerard J. Mangone Center for Marine Policy, University of Delaware, 2005. 31.

[106] Welch. "Farming in the Commons." 103 –104.

[107] Firestone, Jeremy. "Offshore marine aquaculture in US waters: Picking up the pieces and painting a picture" in *Aquaculture Law and Policy: Towards principled access and operations*. First edition. Eds. David L. VanderZwaag and Gloria Chao. Abingdon, UK: Routledge, 2006. 465; Welch. "Farming in the Commons." 103; Kite-Powell, Rubino and Morehead, "The Future of U.S. Seafood Supply." 244; Upton and Buck. *Open Ocean Aquaculture*. 2.

[108] *An Ocean Blueprint for the 21st Century*. U.S. Commission on Ocean Policy. Washington, D.C.: Government Printing Office, 2004. 333.

[109] *Environmental impact assessment and monitoring in aquaculture: Requirements, practices, effectiveness and improvements*. Food and Agriculture Organization of the United Nations. Fisheries and Aquaculture Department. Aquaculture Management and Conservation Service. Technical Paper No. 527. Rome: Italy, 2009. 521–522.

The jungle of regulations facing the marine aquaculture industry has been described as a de facto ban.

4.2 Relevant Regulations[110]

Environmental Regulations[111]

The environmental and ecological effects of aquaculture are handled by multiple agencies with varying directives. Aquaculture effluents, discussed in section 3.1, are handled primarily by the Environmental Protection Agency under the Clean Water Act, which requires aquaculturists to furnish pollution permits.[112] Attained through the National Pollutant Discharge Elimination System (NPDES), these permits generally require fish farmers to identify the types of pollution they will contribute to the waters and set rules for concentration limits, management practices, and record keeping.[113] Additionally, the Concentrated Aquatic Animal Production (CAAP) program and Effluent Limitations Guidelines require any net pen facility producing more than 100,000 lbs of fish annually to create a "best management practice plan" to fulfill effluent limitation guidelines, which establish requirements for environmental protection such as solids control, structural maintenance, record-keeping, waste collection, etc.[114] Data reporting required by the EPA under these regulations include drug use, damage reports, spills of feed or pesticides, and much more.[115] Samples are periodically collected from aquaculture facilities to measure water quality indicators like flow, suspended solids, turbidity, nutrient levels, pH, and more.[116]

The EPA's rightful jurisdiction over oceanic aquaculture effluents is far from obvious. The NPDES typically applies only to point source pollution in navigable waters. Whether or not

110 A list of the most significant regulations affecting the U.S. aquaculture industry is available here: Engle and Stone. "Competitiveness of U.S. Aquaculture." 257–260.

111 A comprehensive list of legislation that applies to aquaculture's public health (broadly defined to include environmental) effects available here: Fry, Jillian P. et al. "Offshore Finfish Aquaculture in the United States: An Examination of Federal Laws That Could be Used to Address Environmental and Occupational Public Health Risks." *International Journal of Environmental Research and Public Health* 11, no. 11 (November 2014). 11968–11969.

112 Firestone, "Offshore marine aquaculture in US waters." 469.

113 *Environmental impact assessment and monitoring in aquaculture.* FAO. 336.

114 Ibid. 336–337. 477–478.

115 Ibid. 339.

116 *Environmental impact assessment and monitoring in aquaculture.* FAO. 341.

the various designs of aquaculture facilities count as "point sources" is up for debate, and "navigable waters" does not generally include the open ocean. An additional rule extends EPA's jurisdiction over CAAP effluents, but that rule only applies to "significant contributor[s] of pollution," a designation which may or may not apply to aquaculture facilities. These and other debates have been and continue to be hashed out in the federal court system.[117]

A Section 404 permit may also be required under the Clean Water Act for submarine construction projects. Section 404 gives the U.S. Army Corps of Engineers the authority to consider the ecological effect of any project that will require substantial disturbance to the ocean floor.[118]

Drugs or additives used in fish feed are regulated by the FDA.[119] The FDA requires animal food manufacturers to acquire permits, and that process requires demonstrating that the product will not have major impacts on human or environmental health.[120]

Fishery Regulations

The National Oceanic and Atmospheric Administration has interpreted "fishing" within the Magnuson-Stevens Act to include aquaculture, giving the regional fishery councils set up under the National Marine Fisheries Service jurisdiction to regulate aquaculture activities.[121] These councils are set up to handle wild fish catches, and generally deal with size limitations, seasons, daily catch limits, and other regulations that make no sense in the context of aquaculture, but may still restrict fish farmers' operations.[122] The fishery management councils were originally set up to serve the interests of commercial fishermen.[123] Owing to that construction (which resembles regulatory capture, but cannot properly be called capture since industry's control was intentional), commercial fishermen are essentially given jurisdiction to regulate away their aquaculture competition, with predictable results.

117 Johns, Kristen L. "Farm Fishing Holes: Gaps in Federal Regulations of Offshore Aquaculture." *Southern California Law Review* 86, no.3 (March 2013). 702–706.

118 Boden, Kelly B. and Karen A. Mignone. "The aquaculture permitting process in federal waters." *Trends* 45, no. 5 (May/June 2014).

119 Upton and Buck. *Open Ocean Aquaculture*. 11.

120 Fry et al. "Offshore Finfish Aquaculture in the United States." 11971–11972.

121 Upton and Buck. *Open Ocean Aquaculture*. 14–15.

122 Montañez, José L. "Offshore Aquaculture Regulations Under the Magnuson-Stevens Fishery Conservation and Management Act." *Fisheries* 39, no. 11 (November 2011). 562–563; Firestone. "Offshore marine aquaculture in US waters." 468–469.

123 Welch. "Farming in the Commons." 24–35.

Commercial fishermen are essentially given jurisdiction to regulate away their aquaculture competition, with predictable results.

One regional fishery management council has actually been comparatively welcoming to aquaculture development. The Gulf of Mexico Fishery Management Council (GMFMC) issued a final rule in 2016 setting up a heavily regulated permitting system for future aquaculture operations.[124] The GMFMC permit has a number of restrictive limitations—broodstock can only be sourced from local subpopulations, no genetically engineered fish can be used, harvests must be made using approved equipment and under the supervision of law enforcement, etc. More importantly, the GMFMC permit fails to supercede other federal permitting requirements, making it just another regulatory hurdle rather than a comprehensive framework. A number of stipulations worked into the final rule, including an arbitrarily low “maximum sustainable yield” for aquaculture, seem to be fairly blatant attempts to placate commercial fishermen.[125] These limitations, likely caused by the GMFMC’s inherent conflict of interest, make the council’s aquaculture permitting system unlikely to spur widespread industry development.[126]

Even the final rule for the GMFMC acknowledges the lack of a straightforward jurisdiction for aquaculture. In response to a comment questioning the propriety of assigning a maximum sustainable yield for aquaculture, the agency responded “[T]he Magnuson-Stevens Act was written in part to establish the legal framework for managing wild fisheries resources of the United States, and many of the principles and concepts that guide wild stock management are not generally applicable to the management of an aquaculture fishery.”[127] The response goes on to reiterate the argument for why “fishing” within the Magnuson-Stevens Act has been construed to include aquaculture, but the admittance of questionable regulatory fit is illuminating. In fact, there is reason to believe the fishery management councils may be stripped of this authority in the future—Congress specifically excluded aquaculture from the

124 Fisheries of the Caribbean, Gulf, and South Atlantic; Aquaculture, 81 Fed. Reg. 8. January 13, 2016.

125 Ibid.

126 Ketchum, Brandee. “Splitting Scales: Conflicting National and Regional Attempts to Manage Commercial Aquaculture in the Exclusive Economic Zone.” *Journal of Food Law & Policy* 6, no. 1 (2010). 30.

127 Fisheries of the Caribbean, Gulf, and South Atlantic; Aquaculture, 81 Fed. Reg. 8. January 13, 2016.

2007 reauthorization of the Magnuson-Stevens Act.[128] While the current interpretation has survived a run through federal court, it was not explicitly upheld and may be subject to future litigation.[129]

Navigatory Regulations

Because aquaculture facilities require structures in an open ocean, they are subject to a myriad of regulations intended to prevent oceanic construction from interfering with maritime travel. Jurisdiction over construction in navigable water is held by the Army Corps of Engineers, which requires owners of any oceanic structure to undergo a permitting process.[130] The Army Corps of Engineers' lack of directive for ecological effects has called into question its ability to justifiably issue aquaculture permits, and this issue has resulted in legal action.[131] Additionally, the Coast Guard can require safety measures for problematic structure sites, and the Department of Defense may review proposals that could affect the military's naval activities.[132]

Additional State Regulations

When aquaculture facilities seek to be located in water within three miles of the coast, they need to obtain permits from both the federal and state governments.[133] The exact regulations present in each state will not be covered here, but, as an illustrative example, this report will give cursory attention to Washington's aquaculture-related laws, since it is one of the few states that currently house oceanic net-pen aquaculture.

In Washington, an aquaculture operation would need to attain a Finfish Import and Transfer Permit to ensure fish health, a Hydraulic Project Approval to protect surrounding habitats, a National Pollution Discharge Elimination System Permit (a federal program operated through state offices), a Water Discharge Permit (another state-controlled federal program that protects water quality), an Aquatic Lands Lease to restrict land use, and would also need to fit within the parameters set by the State Environmental Policy Act, which projects environmental as well as "social" impacts of projects, as well as the Shoreline Management Act, which restricts development of state shorelines. In all, these processes involve

128 Johns. "Farm Fishing Holes." 708.

129 Ibid. 711.

130 *U.S. Army Corps of Engineers Regulation of Offshore Aquaculture*. Washington, DC: Environmental Law Institute, March 2015. 6.

131 Johns. "Farm Fishing Holes." 706–707.

132 Upton and Buck. *Open Ocean Aquaculture*. 14.

133 *Environmental impact assessment and monitoring in aquaculture*. FAO. 336.

interfacing with at least three different state-level agencies as well as various local authorities.[134] These regulatory restrictions are in addition to those already existing at the federal level.

4.3 Explaining Why

The lack of an organized regulatory scheme governing aquaculture is well-identified and has plagued the industry for years. Why, then, has nothing been done to address it?

The lack of an organized regulatory scheme governing aquaculture is well-identified and has plagued the industry for years.

One potential solution is for a single agency to take charge and create a comprehensive aquaculture policy on its own. This does not happen for several public choice reasons. Or, in the words of law professor William W. Buzbee, "fragmented political-legal structures that do not match a social ill in cause or effect may be viewed as a regulatory commons and thereby prompt political underinvestment."[135] For a regulator, the cost of drafting large scale regulation that would allow the development of aquaculture in federal waters is high. Research, hearings, and deliberation necessary to draft such a regulation constitutes a large information cost.[136] The risk of being embroiled in lawsuits adds to this cost.[137] Finally, a preference for the status quo, whether caused by monied interests' influence or merely by cognitive heuristics, disincentivizes action.[138] Meanwhile, the benefits of a more workable policy would not only accrue to the agency that took the reform initiative but would instead be spread to all agencies that were previously involved in the fragmented structure.[139] In a

[134] Ibid. 478.

[135] Buzbee, William W. "Recognizing the Regulatory Commons: A Theory of Regulatory Gaps." *Iowa Law Review* 89, no. 1 (2003). 6.

[136] Ibid. 33.

[137] Ibid. 57.

[138] Ibid. 33–36.

[139] Ibid. 30–33.

regulatory commons where no one regulator has a clear directive to centralize control, there is a strong disincentive to promulgating effective regulation.[140]

Another solution is for the U.S. Congress to give unambiguous authority to a single regulator. In fact, a number of bills have come before the floor of both the House and the Senate seeking to do just that; all have failed.[141] Reform failure can be attributed to a number of factors, which Dr. Aaron Welch sums up as "a group of agencies that are indifferent to the idea, a dense and confusing body of regulatory law and code applicable to aquaculture, a generally negative view of fish farming among members of environmental NGOs, and a group of vocal and politically active fishing special interest groups opposed to aquaculture."[142] Government division of property rights to previously public goods (such as fishing and aquaculture rights in the EEZ) has historically been conducted largely to maintain the economic status quo, preventing large amounts of new entrants from flooding into pre-existing markets.[143] There is, after all, a large political incentive to assuage large extant special interests' fears of innovative but unorganized competition. Assisting a fledgling industry with little political clout does not confer the same electoral advantage. With large environmental NGOs entering into the lobbying space opposed to aquaculture, a recognizable "bootleggers and baptists" scenario emerges.[144] "Bootleggers and baptists" is a phenomenon that describes a monied interest (bootleggers during Prohibition) being able to procure regulation to protect their earnings by drumming up political support through an unexpected alliance with a moral impetus (temperance Baptists).[145] Aquaculture interests have not been able to match the political strength of organized commercial fishermen paired with environmentalists.[146]

140 Ibid. 33.

141 Johns. "Farm Fishing Holes." 716–718; Welch. "Farming in the Commons." 115–116.

142 Welch. "Farming in the Commons." 136.

143 Rolph, Elizabeth S. "Government Allocation of Property Rights: Who Gets What?" *Journal of Policy Analysis and Management* 3, no. 1 (1983). 58.

144 Organizations engaging in aquaculture-related lobbying efforts are named in Welch. "Farming in the Commons." 123.

145 Yandle, Bruce. "Bootleggers and Baptists in Retrospect." *Regulation* 22, no. 3 (1999). 5–6.

146 Welch. "Farming in the Commons." 129–131. Also note that this is not meant to imply that environmentalists are unanimously against any aquaculture reform, nor that environmentalists are the only advocacy groups playing the role of "baptist" in anti-aquaculture lobbying efforts. For environmentalists approving of certain pro-aquaculture reform legislation, see e.g. Johns. "Farm Fishing Holes." 718.

Aquaculture interests have not been able to match the political strength of organized commercial fishermen paired with environmentalists.

4.4 Recommendation

Given all the challenges, the best approach would be for Congress to create a unified and reasonably lenient comprehensive aquaculture framework, allowing for widespread industry development. Specifically, Congress should vest regulatory authority over all aspects of aquaculture in a single office. This would bring certainty and efficiency to a currently muddled and amorphous permitting process. In fact, Norway's one-stop permitting process has been credited for the country's expansive marine aquaculture industry.[147]

Congress should vest regulatory authority over all aspects of aquaculture in a single office.

Whichever regulatory authority controls aquaculture, there are a few easy ways that requirements could be streamlined without excessive additional environmental risk. The government could, for example, set a minimum average water flow rate above which further water quality assessments would either not be necessary or at least be far less burdensome, as flow rate measurement can act as a proxy to control nutrient loading, dissolved oxygen levels, and other water quality problems if set at appropriately high levels.

Further, a regulatory agency could help promote speedy aquaculture development by designating Aquaculture Management Areas (AMAs). AMAs are areas for which the government has predetermined that aquaculture can operate without causing undue environmental harm. For fish farmers seeking to begin operations, siting within an AMA can reduce startup costs by eliminating the need for extensive new environmental and navigatory

[147] Engle and Stone. "Competitiveness of U.S. Aquaculture." 263–264.

reviews. This approach is advocated by the United Nations and is currently used throughout the world, including in New Zealand and much of Europe.[148]

With such a unitary and lenient regulatory framework in place, the U.S. aquaculture industry would become competitive with that of other nations as well as domestic commercial fisheries, many of which currently operate under a system of incredibly lax regulatory standards.[149]

A regulatory agency could help promote speedy aquaculture development by designating Aquaculture Management Areas (AMAs).

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[148] *Aquaculture zoning, site selection and area management under the ecosystem approach to aquaculture*. FAO and World Bank. Policy Brief (2015). 2–3; information on worldwide use of AMAs (or similar programs) is covered in Sanchez-Jerez, P. et al. "Aquaculture's struggle for space: the need for coastal spatial planning and the potential benefits of Allocated Zones for Aquaculture (AZAs) to avoid conflict and promote sustainability." *Aquaculture Environment Interactions* 8 (2016). 43–48.

[149] Engle and Stone. "Competitiveness of U.S. Aquaculture." 267–268.

Conclusions

Academics and environmental groups often claim that regulators must choose between permitting marine aquaculture and maintaining pristine, untouched oceans. That is a false choice, yet it has unfortunately colored the discussion of aquaculture regulation, impeding reform.[150] The real question is how to enable the delivery of increased quantities of seafood

150 This misspecification of the trade-off at hand is present in a number of the works cited in Part 3. This is excusable—most of these scholars are interested in environmental protection and studying aquaculture in a vacuum, not social scientists or policy scholars accustomed to conceptualizing problems in wider economic and social context.

while conserving wild fish species and providing adequate protection to other aspects of the marine environment. By refusing to allow aquaculture to develop, regulators remove a potentially important source of sustainable fish that could reduce pressure on wild stocks. (As an aside, gains in aquaculture do not have to come at the expense of fishermen. Both can grow together as demand increases, and, globally, fishermen have been using more and more techniques developed by aquaculture to increase catches.[151] Within the United States, many fish farmers come from commercial fishing families, or even work in both industries.[152])

The real question is how to enable the delivery of increased quantities of seafood while conserving wild fish species and providing adequate protection to other aspects of the marine environment.

This paper has spelled out a possible framework for reform. But reform will not take place unless it is championed, and one obvious champion is the industry that would benefit. Unfortunately, the aquaculture industry in the United States (both inland and marine) is "relatively new, fragmented, diverse, and without a unified well-funded outreach or lobbying organization."[153] That is not the description of an industry well positioned to secure sympathetic political action. In order to drive effective regulatory change, fish farmers will need to assemble a sizeable group of political allies. Since the U.S. aquaculture industry is still small, this may require some creativity, involving the entire aquaculture value chain, as well as interests with similar political goals, such as offshore wind farm operators.[154]

The world in general and the United States in particular have a growing demand for seafood products. Fisheries across the globe are overextended, and aquaculture is already picking up the slack. Whether the United States joins Chile, Norway, and much of Asia as an important player in the worldwide aquaculture market is up to our regulators.

151 Klinger, Dane H. et al. "Moving beyond the fished or farmed dichotomy." *Marine Policy* 38 (March 2013). 370–371.

152 Knapp and Rubino. "The Political Economics of Marine Aquaculture." 221.

153 Ibid. 222.

154 Ibid. 215, 222.

About the Author

Arthur R. Wardle is a policy intern with Reason Foundation. He is also a research associate with Strata Policy, a public policy research center in Logan, Utah, and a research fellow with the Institute of Political Economy at Utah State University, where he is expected to graduate with a bachelor's degree in economics later this year. His research focuses on energy and environmental policy issues.

5737 Mesmer Ave.
Los Angeles, CA 90230
310-391-2245
reason.org