Offshore Aquaculture: A Needed New Frontier for Farmed Fish at Sea

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Offshore Aquaculture and Its Potential Relevance

Aquaculture continues to be the fastest growing food producing sector in the world and it is expected to bridge the future global supply–demand gap for aquatic food.\(^1\) However, this is a great challenge considering that a large proportion of current aquaculture for food is produced in fresh water and this resource is bound to be very scarce and even scarcer under climate change.\(^2\) Today, practically all marine production takes place by the coast or not far from it. Yet, coastal zones are becoming increasingly limiting for aquaculture. Therefore, use of open ocean sites can be a solution for future aquaculture activities.

There is no single universally accepted definition of offshore aquaculture, or equivalently, open ocean aquaculture. In many cases these terms are used for any farming off the coast.\(^3\) Here, the definition proposed in a special publication by the Food and Agriculture Organization of the United Nations (FAO) for offshore mariculture will be used.\(^4\) That is, farming occurring away from the coastline (> 2 km), in waters deeper than 50 m and fully or partially exposed to stronger wave and wind action. The concept opposes that of coastal aquaculture, in as far as coastal refers to nearshore sites, mainly in sheltered places and those located off the coast but in waters not deeper than 40 m and with

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1. Food and Agriculture Organization of the United Nations (FAO), *The State of World Fisheries and Aquaculture 2016: Contributing to Food Security and Nutrition for All* (Rome: FAO, 2016).
2. C.M. Duarte et al., “Will the Oceans Help Feed Humanity?,” *Bioscience* 59 (2009): 967–976.
3. H.E. Froehlich et al., “Offshore Aquaculture: I Know It When I See It,” *Frontiers in Marine Science* 4 (2017): 154. doi.org/10.3389/fmars.2017.00154.
4. A. Lovatelli, J. Aguilar-Manjarrez, and D. Soto, eds., *Expanding Mariculture Farther Offshore—Technical, Environmental, Spatial and Governance Challenges*, FAO Technical Workshop, 22–25 March 2010, Orbetello, Italy, FAO Fisheries and Aquaculture Proceedings No. 24 (Rome: FAO, 2013), 4, http://www.fao.org/docrep/018/i3092e/i3092e00.htm.
easy access. Under such a definition, currently the commercial or experimental production of offshore aquaculture is still minimal.

Most countries cannot expect to develop much further their nearshore marine farming industry because (1) world competition for coastal sites and conflicts over use of space has increased, (2) coastal farming operations have seen their densities increased over the years, often becoming the cause of severe sanitary and environmental disruptions, economic losses, and instability, (3) water quality in those locations is generally getting worse, (4) the cost of coastal marine sites is becoming prohibitive, (5) and coastal communities are increasingly opposing nearshore aquaculture. Therefore, it is certain that in the coming decades, a large portion, if not most, marine aquaculture activities will have to move to open-ocean locations or, alternatively, be done land-based, with pumped water, with or without recirculation.

However, even if offshore aquaculture might have some theoretical advantages, it is yet to be explored in terms of its technicalities, economic efficiency, and environmental and social sustainability. Currently, there are no well-established or standardized offshore aquaculture production methods for marine finfish or other species, which is why offshore farming has very limited coverage thus far. Not many industry players are willing to lead the way, possibly due to the large initial investments, extra costs, and more complicated logistics related to moving offshore, which will require larger production to offset increased outlays.

Where Is the Potential to Develop Offshore Aquaculture?

An FAO publication in 2013, provided a global assessment of the status and potential for offshore mariculture development from a spatial perspective, with an indication of near-future global and national potential for its expansion. Kapetsky et al. concluded that offshore mariculture was limited spatially by the need to tether cages and longlines to the seafloor, and thus, the exclusive economic zone (EEZ) area was either too deep (88 percent), or too shallow or showed stronger currents. With such considerations, only about 1.4 million km² (0.87 percent) of the EEZ area was suitable for offshore cages and longlines.

5 Id.
6 J.M. Kapetsky, J. Aguilar-Manjarrez and J. Jenness, A Global Assessment of Potential for Offshore Mariculture Development from a Spatial Perspective, FAO Fisheries and Aquaculture Technical Paper No. 549 (Rome: FAO, 2013), http://www.fao.org/docrep/017/i3100e/i3100e00.htm.
However, they did not discuss the increasing number of solutions currently being developed for vessel-type devices and self-positioned cages, which do not require mooring, thus amplifying spatial solutions immensely.

Kapetsky et al. also explored the potential production for fed fish in tropical ecosystems (e.g., cobia), in temperate ecosystems (salmon), and blue mussels, a non-fed species also from temperate environments. They showed, for example, that salmon production could be increased by more than one million tonnes using only 5 percent of the offshore aquaculture estimated suitable area (122 km$^2$), while cobia could increase by 48 million tonnes in 5 percent (48,000 km$^2$) of this area. These production numbers are very conservative since some technical restrictions will disappear due to rapid technology advances, e.g., tethering cages deeper than 100 m or not mooring them at all, and even considering floating cages in areas beyond national jurisdiction. Such farming systems may gain acceptability if they prove to be profitable and manageable from a logistics standpoint.

**Investment, Technologies, Human Resources, and Research Needed**

Most current offshore aquaculture production systems are submergible devices, particularly in the case of fish, mainly salmon and cobia. It has been concluded that underwater farming devices such as cages, longlines, etc., can perform better and survive even strong force, category 4 hurricanes. Other non-submergible equipment is also being devised and/or conceived, such as boats of different types (fixed or untethered), and cages and cage-like containers of different sizes and conditions.

The economics of offshore farming has not been well-studied, although it is commonly argued that offshore aquaculture farming devices will require more investment per unit of production than conventional coastal systems. Furthermore, they will be more expensive to operate and maintain. Indeed, it is expected that farms will cost more to run, as they require more sophisticated and expensive equipment and procedures, and correspondingly, highly trained personnel. It is likely that the latter expertise—fewer but very specialized jobs—will not necessarily be drawn from nearshore communities, a fact that might complicate offshore aquaculture's acceptance, though the possible provision of additional fish food in the future at more affordable prices may counter such concerns. Additionally, there is a need for much more research and development along the production process and value chain.

To offset higher investment costs and more complicated logistics, the average size of an offshore farming operation would likely exceed that of coastal
farms. This fact limits for now the idea of small-scale offshore farming units, and makes large-scale operations the only ones with probable feasibility (economically, technically, and otherwise) in the near future.

Offshore Aquaculture: Environmental Implications

Compared with nearshore aquaculture, environmental risks associated with offshore aquaculture can be smaller, especially those associated with nutrient and organic enrichment of sediments and modification of benthic communities, eutrophication of water bodies, release of chemicals used to control water conditions and diseases, and competition for and, in some cases, depletion of resources (e.g., water).\(^7\) Indeed, considering much deeper sites with higher currents, it is unlikely that organic matter will significantly affect the seabed, generate local eutrophication, or cause other cumulative impacts. However, appropriate oceanographic modeling to forecast potential impacts to the surrounding ecosystem and to the farm itself is essential, as well as close environmental monitoring to follow up on potential impacts. Offshore aquaculture operations could increase the danger of generating local conditions that could trigger phytoplankton blooms or attract/foster jellyfish outbreaks.

Risks that could increase from offshore aquaculture might relate to biodiversity and ecosystem losses due to escaped fish.\(^8\) Even if fish cages are much more resistant today, weather conditions in offshore and open seas could be very rough, and escape risks will always be present. Considering much larger cages, as will be the case, massive numbers of fish could escape under extreme conditions. Given that cages will be comparatively far from the coast, chances for fish species such as salmon or mussels to interact with local biodiversity and/or establish a population could be low, but there is not enough information to ascertain the same for other species such as cobia, considering that species in this genus (\textit{Rachycentron}) spawn in open seas.

Clearly, any offshore aquaculture development requires adequate risk-based spatial planning.\(^9\) In an open-sea environment it is much more difficult

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\(^7\) See Duarte et al., *supra* note 2, and Lovatelli et al., *supra* note 4.

\(^8\) E.B. Thorstad et al., *Incidence and Impacts of Escaped Farmed Atlantic Salmon* \textit{Salmo salar in Nature}, Report from the Technical Working Group on Escapes of the Salmon Aquaculture Dialogue, NINA Special Report 36 (World Wildlife Fund, 2008), http://oldsalmon.ca/docs/uploads/impacts-escapes-2008.pdf.

\(^9\) J. Aguilar-Manjarrez, D. Soto and R. Brummett, *Aquaculture Zoning, Site Selection and Area Management under the Ecosystem Approach to Aquaculture: A Handbook* (FAO, Rome, and World Bank Group, Washington, DC, 2017), http://www.fao.org/3/a-i6834e.pdf;
to establish boundaries of impacts, and there is as well a need for very carefully
designed and implemented monitoring systems for environmental conditions
and biotic interactions in the farm’s estimated area of influence.

**Governance Issues and Needs**

The poor image of aquaculture in many places, the fact that there is no previ-
ous or well-established history of offshore farming, and the likelihood that its
initial development will involve huge projects, suggest that it will be resisted by
many. Therefore, contacts with authorities, local communities, fishers and oth-
er ocean users will be necessary to make this new production system accepted
and well-established.

In general, there is no special legislation regarding prerequisites to install
and run new offshore fish farms, or to address the ways they should relate to
local fisheries and traditional fishing grounds, ports, local communities, and
tourism, etc. This is also the case regarding potential conflicts in areas where
wild fish stocks, whales, and other marine mammals are known to forage, mi-
grate, reproduce, or where it is believed that farming might put fragile ma-
rine environments at risk. In most cases, all new aquaculture activities are
framed by national norms and regulations that tend to be more relevant to
coastal aquaculture. Also, there is a legal vacuum over regulating mariculture
operations in areas beyond national jurisdiction (ABNJ), leading to a series of
potential controversies that could arise from such activity.\(^\text{10}\) Further, according
to Lovatelli et al., coastal states are entitled to legislate in order to protect facili-
ties and installations within the territorial sea, and they must properly inform
about their laws and regulations under the 1982 United Nations Convention on
the Law of the Sea.\(^\text{11}\) International law does not impose other general restric-
tions on how coastal states manage mariculture within their territorial seas.
Most of the above-mentioned matters could benefit from an international ap-
proach to develop the main framework within which offshore farming should
conform, especially if the activity is moved into ABNJ.

Safety at sea is and will be a matter of high priority for offshore fish farm
operators. The same applies to fish escapes, predators, robberies, fish diseases,

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\(^{10}\) See Lovatelli et al., *supra* note 4.

\(^{11}\) Montego Bay, 10 December 1982, 1833 *U.N.T.S.* 3.

*FAO, Aquaculture Development. 4. Ecosystem Approach to Aquaculture, FAO Technical
Guidelines for Responsible Fisheries No. 5, Suppl. 4 (Rome: FAO, 2010), http://www.fao.
docrep/013/i1750e/i1750e.pdf.*
and the use of antibiotics and other pharmaceuticals, while the environmental effects of unused feed and fish faeces also have to be addressed. Treatment of fish mortalities and maintenance and repair procedures will also have to be dealt with under appropriate management. Clearly, a full set of regulations is needed worldwide to get offshore farming established, well-organized, and able to receive social acceptance, an extremely relevant goal.

We are certain that open ocean aquaculture is bound to become one of the most used production procedures in the coming decades in many parts of the world, and more increasingly so, as freshwater resources become scarcer. Therefore, careful and more intense consideration should be given to this novel and promising food production system, both at national and international levels.