Challenges and market trends in the offshore aquaculture industry

EVANGELOU P.[1*] and LYRIDIS D.V.[2]

[1 2] *Laboratory for Maritime Transport, School of Naval Architecture and Marine Engineering, National Technical University of Athens (NTUA), Athens, Greece*

*corresponding author:
e-mail: panosevangelou@gmail.com

Abstract In this paper the global market trends and design challenges in the offshore aquaculture industry will be presented, focusing on the use of innovative materials for the construction of fish cages. Newly designed cages offer sustainable and environmentally friendly solutions for offshore cage systems, effectiveness in the intended environmental conditions, as well as advanced fish production compared to traditional coastal aquacultures, in order to satisfy the changes in the consumer preferences and the continuously growing feeding demands of the world population. At the end of this paper, a short presentation of the MATISSE project (Study of the appropriateness and the adequacy of modern materials for offshore fish cage and nets – numerical and experimental investigation in realistic loading conditions) and its key results will be performed.

Keywords: offshore, aquaculture, fish, environment

1. Introduction

Moving fish cages from coastal areas to offshore locations is a very challenging process. The challenges of the offshore aquaculture are divided into economic, spatial, environmental and design.

Furthermore, there has been a significant change in the demand and consuming preferences for seafood globally. The market trends and opportunities created by these changes will be documented.

The application of innovative practices reduce the operating costs and increase the profit margins for the existing and the newly introduced units. These units offer steady growth of productivity as a result of the offshore setting of the fish farms and the stability offered by the new designed fish cages and their nets.

2. Market Analysis And Trends

Since the 1980s the world production of farmed fish for human consumption has increased almost 12 times, with an average annual growth rate of 8.8%. Aquaculture has been the engine of growth in total fish production since the 90's and in 2014 for the first time, the supply of fish for human consumption from aquaculture was higher than that from catches (Pascal Raux P. 2020).

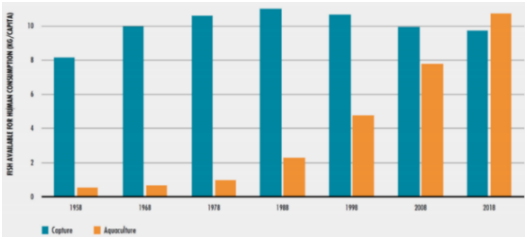

Figure 1. Contribution of Aquaculture and Capture Fisheries to Fish Available For Human Consumption (FAO 2020)

In addition, from 1961 to 2017, the average annual growth rate for global fish consumption has been 3.1% and the consumption per person grew from 9.0 kg in 1961 to 20.3 kg in 2017, a growth rate of 1.5% a year (Cherabier P., 2020).

China remains by far the largest fish-producing country in the world (15% of the total global captures) (FAO, 2020) and at the same time China is the largest aquaculture producer, responsible for over the 60% of the global production (O'Shea et al., 2019), while a significant percentage of the global production is comes from the rest of Asia.

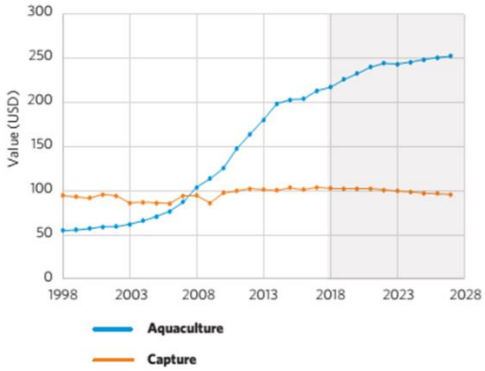

Figure 2. Global aquaculture and wild capture market value since 1998 and projections to 2027 (O'Shea et al., 2019)

Aquaculture production is expected to continue to grow at an average rate of 2.1% per year over the next decade. Aquaculture production for food consumption (80 million mt) now exceeds that of wild capture, focusing to higher-value products, which is also reflected to the aquaculture's market value per unit, being 180% greater than that of wild-capture (O'Shea et al., 2019).

It is evident that fish farming is one of the fastest growing sectors of the food industry. Undoubtedly, in the future, controlled fish production in fish farms will be key solution in tackling the rapid decline in fish natural stocks due to the uncontrolled fishing and the growth of the human population. According to the Food and Agriculture Organization (FAO) of the United Nations, 70% of the world's salmon population has been overfished (Kapetsky J. et al., 2013), putting many species at risk. As a result, fish farming must be in position to meet the growing demand for fish consumption, creating the optimal conditions for the growth and prosperity of the fish farming industry.

The seafood market is an intensively globalised sector. Aquaculture products are being traded between countries and continents all around the world. The EU is the largest market where the world fish production is directed, with imports exceeding the 60 billion dollars (Figure *3*).

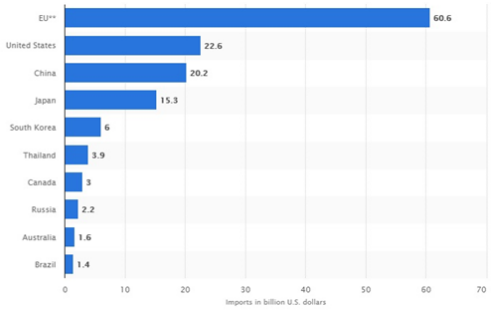

Figure 3. Imports of fish farming products per region in billion dollars (M. Shahbandeh, 2019)

According to the Nature Conservancy and Encourage Capital report 2019 (O'Shea et al., 2019), the key drivers and methods to positively influence the change of the aquaculture environmental impact are investments in production systems, changes in farm siting, improvement of farm management practices, the species selection and the use of improved technology.

In this context, pilot projects aiming to develop or improve technologies for operation in real exposed conditions should address the following aspects towards the development of (Basurco, 2000):

- less expensive offshore structures
- economic and resistant workboats and platforms for offshore operations
- remote-control systems for offshore units
- more resistant nets more resistant chains and mooring systems
- environmentally friendly net anti-fouling systems
- monitoring techniques for the control of environmental impact
- systems to protect stock against environmental disasters, such as oil spills, plankton blooms, etc.

3. Offshore Aquaculture Challenges

Offshore fish farming faces a number of economic, spatial, environmental and design challenges, in some cases common with coastal units.

3.1. Economic Challenges

The profitability of offshore units depends heavily on economies of scale, while a large amount of investment is required to build them. In combination with the high cost of materials used to build these units, the initial investment cost is further inflated. In addition, investments are required in onshore production processing facilities as well as the creation of pre-fattening units.

Increasing the production of offspring must be based on the course of demand in order to control oversupply which in return reduces the prices of products and intensifies the environmental costs of production. Poor management of aquaculture units may lead also to degradation of the ecosystem in the exploitable area of the units.

3.2. Regulatory Framework

An important obstacle to the development of offshore units is the lack of an appropriate legal framework for the construction and operation of offshore units, the acquirement of the necessary licenses and the overall planning and regulatory framework of the offshore aquaculture production.

Furthermore, spatial planning of marine areas is necessary for the development of the offshore production and it should take into account local, regional, environmental and social factors.

3.3. Environmental Challenges

Regarding the environmental challenges of the offshore aquaculture, the sea depth at the unit installation site affects the growth and the mortality rate of the fish species produced. In very shallow sea depths the fish cages units offer limited production of fish.

Fish farms (near-shore or offshore) generate wastes. Therefore, proper and responsible waste management is essential, as polluting fish farming practices and the lack of waste management procedures will result the disruption of the local marine ecosystem.

Moreover, aquaculture can pose a risk to corals, reefs or marine areas through ecosystem destruction or degraded water quality but also present risks for human health. Fish farms increase the load of bacteria to the marine environment below the cages and at a distance of 100 meters around the facilities (O'Shea et al., 2019). If aquaculture units do not follow strict protocols and hygiene standards then the deterioration of the fish quality in the cages and their diseases can be extremely dangerous to the public health.

In addition, Fish farms also release fish food into the environment that is rich to nitrogen and phosphorus,

causing eutrophication of the algae, since they act as fertilizers and lead to degradation of the sea bottom.

3.4. Design Challenges

Regarding the design challenges in the construction of the offshore fish cages, an important aspect is the control of the fish escape risk and the consequent genetic interaction with the free fish population that may present serious consequences to the marine ecosystem.

In addition, the offshore floating and flexible fish cages often have plastic collars. Synthetic plastic is a material that is widely used in coastal fish farming offering satisfactory resistance to loads caused by waves and the marine environment in general, nevertheless displays wear problems, due to the relative movement between the frame and the net of the cage.

Lastly, the floating and inelastic offshore fish cages are designed to withstand the loads of the marine environment. As a result, they become expensive constructions and are characterized by large size.

4. Offshore Aquaculture Advantages

In general Offshore Aquaculture may be defined as taking place in the open sea with significant exposure to wind and wave action, and where there is a requirement for equipment and servicing vessels to operate safely in severe sea conditions from time to time (Drumm, 2010).

Offshore fish farming offers the potential for a viable and scalable alternative to the traditional coastal net pen (CNP) aquaculture and is likely to constitute a significant drive of the sector's overall development. The most important advantages of the offshore fish cages regarding the problems identified in coastal units are as follows:

- Open sea means more favorable conditions and clean water
- High capacity (up to 6000 m3) and correspondingly high production capacity (up to 150 tons) (O'Shea et al., 2019), offering significant commercial profits, including the potential for economies of scale, and process automation.
- availability of more unit installation sites
- proximity to markets and improved product quality
- Easy fish handling, boarding and service
- Modern fish farms are of special components and offer higher performance while the by-products produced are much less
- Increased environmental performance and advantages in comparison to the traditional aquaculture, including improvements in Feed Conversion Ratio, improved control of contagious diseases and reduced breeding interactions with other species.
- Opportunities for significant investments in research and development. Each country can invest in species that suit its environmental conditions and market
- Collaborations with oil and gas companies with experience in offshore construction
- Minimum staffing needs
- Ability to move the cages in different locations
- Better results in the breeding process
- Low fish mortality
- Improved security conditions
- Opportunities from state-funded projects

5. Investments in Offshore Aquaculture

Offshore aquaculture systems offer improved environmental performance but have largely failed to attract private capital at a sufficient scale to reach their full commercial and impact potential. Ways to promote financial investments by taking measures to optimize capital structures and mitigate operational risks must be discovered. At the moment, offshore aquaculture may indicate a higher level of risk but it also shows a strong capital intensity (Figure 4).

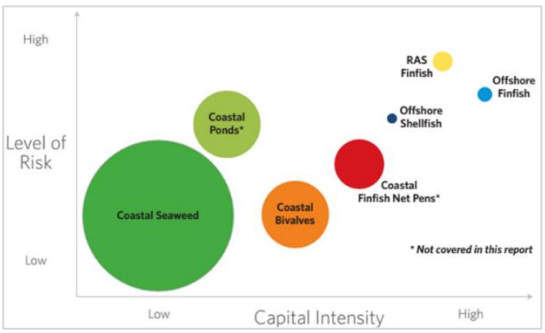

Figure 4. State of aquaculture industrialization – Risk and capital intensity (circle size indicates current scale of production) (O'Shea et al., 2019)

Offshore fish farming is a rapidly growing industry which is generally funded by the largest companies of the industry. Offshore fish producers are often affiliated entities of larger companies and most of the projects for the development of offshore cage systems are the result of joint ventures with oil and gas companies (Asche F. et al., 2011).

Norway is the world leader in the production of salmon from fish farms and has invested significant capitals for the development of advanced offshore fish cages designed to withstand the difficult conditions of the Baltic and Northern Sea. Most of the investments in this type of aquaculture units comes mainly from Norwegian companies.

The Norwegian Fisheries Agency has set up a development and licensing program, funding large-scale projects for the construction and operation of offshore fish cages. The program resulted in 104 projects and by July 2018, 53 operating licenses had been issued in 8 of these projects (O'Shea et al., 2019).

China is also promoting a similar strategy, with a view to building fully modernized fish farms in offshore marine areas. China's growth strategy is taking into account the rapid growth of domestic seafood demand and aims to directly increase production in the fisheries sector, including that of the offshore farms.

The Chinese Ministry of Agriculture in an effort to increase fish production by 15.4 million metric tons by 2025, evaluated cases of large-scale fish production. The De Maas SMC Company operating in the field of offshore oil and gas extraction, in cooperation with local Chinese government, proceeded with a project worth of 151 million dollars, for the construction of an offshore farm consisting of 5 semi-sinked cages with a central pole that functions as a storage-supply space (SSFF150 Semi-Submersible Spar Fish Farm). In addition, China is expected to invest in joint ventures of mainly Chinese state-owned companies to build state-of-the-art fish farming facilities worth of $ 955 million (CEA 2018).

Finally, additional investments in research and development of offshore farms are taking place in Japan, Europe, South and North America. Panama holds the record for offshore production using an underwater fish farm system managed by Open Blue Company, raising 2,000-3,000 tons per year of cobia. In Mexico, Earth Ocean Farms Company uses submersible Aquapods cages with a characteristic spherical shape, made by Innovasea Company. Turkey has 425 sea farms, the vast majority of which are located offshore. The total offshore production in 2016 was 150,000 tons, while every year over 50 new units are added to the available farm infrastructure (CEA 2018).

6. The MATISSE Project

MATISSE is a 3 year pilot project on the offshore aquaculture, funded by the Greek Programme EPAnEK, attempting to address some of the aforementioned challenges of the aquaculture industry. The project that started in June 2019, aims to study the adequacy of modern materials for fish cage and nets to be used in systems of offshore aquacultures where the future of aquaculture lies.

The project shall constitute a valuable contribution toward the promotion of fish farming in deeper water fields, given that aside from the traditional lab testing for the adequacy of modern materials for fish cages and nets, will go a step further proposing the overall investigation of their characteristics in realistic conditions. To this end, the research team will design a complete offshore aquaculture system, together with its mooring system, in installation sites that have been already selected.

A unique set of experiments shall be performed using proper similitude factors of the expected realistic conditions. Thus, the project will develop a complete pilot study for the technological guidance of relevant projects of offshore aquacultures which are the future in fish breeding.

In addition, a detailed business plan for the commercial exploitation of the developed fish cage system will be developed, including the sales strategy and the marketing strategy for the introduction of the newly designed product in the offshore aquaculture market.

7. Conclusions and Future Research

The main challenges that the aquaculture industry faces today are relevant to the local character of the nearshore facilities and the limited production capabilities due to the small scale of fish cages. Problems like the organic matter pollution due to overload of food, faeces, etc., pollution due to chemical (antifouling), treatment drugs and waste, environmental issues caused by escapees and newly introduced species causing degradation of natural habitats as well as conflicts on land use can be solved with the use of the new and advanced offshore fish cages using innovative materials and advanced livestock management practices based on the different species cultivated.

Modern offshore fish cage systems incorporate innovative ideas from other industries, such as temperature sensors, wave sensors, oxygen sensors and remote control systems, which allow the producer to collect computing data and manage efficiently the storage units from afar.

References

Asche F. et al., The Economics of Salmon Aquaculture, John Wiley & Sons, 2011, ISBN1119993377, 9781119993377

Cherabier P. 2020. Trends and challenges towards a sustainable aquaculture in the Mediterranean

Drumm, A. (2010). Evaluation of the promotion of offshore aquaculture through a technology platform (OATP) (p. 46)

FAO. 2020. The State of World Fisheries and Aquaculture 2020. Sustainability in action. Rome. https://doi.org/10.4060/ca9229en

Kapetsky J. et al., A global assessment of offshore mariculture potential from a spatial perspective, FAO Fisheries and Aquaculture Technical Paper, Rome, 2013

M. Shahbandeh, 2019, Top importers of fish and fishery products worldwide

O'Shea, T., Jones, R., Markham, A., Norell, E., Scott, J., Theuerkauf, S., and T. Waters. 2019. Towards a Blue Revolution: Catalyzing Private Investment in Sustainable Aquaculture Production Systems. The Nature Conservancy and Encourage Capital, Arlington, Virginia, USA

Offshore Finfish Aquaculture, Global Review and U.S. Prospects, California Environmental Associates (CEA), ©2018 The David and Lucile Packard Foundation

Pascal Raux. 2020. CASE STUDIES - Innovative solutions for addressing aquaculture challenges and conditions for promoting their capitalization. University of Western Brittany (UBO)

Scott, D.C.B., Muir, J.F., 2000. Offshore Cage Systems: A Practical Overview. Mediterranean Offshore Mariculture (CIHEAMIAMZ), vol. 17–21. Zaragoza, Spain, pp. 79–89