Sustainable Marine Structures
https://journals.nasspublishing.com/index.php/sms

EDITORIAL

Offshore Fish Farming: Challenges and Recent Advancements

Lin Li*

Department of Mechanical and Structural Engineering and Materials Science, University of Stavanger, Stavanger, 4021, Norway

ARTICLE INFO

Article history
Received: 5 September 2023
Accepted: 17 September 2023
Published Online: 24 September 2023

The current marine-based aquaculture primarily utilizes nearshore waters by means of fish cages. Over the past few decades, enormous types of fish cages have evolved, and the technology converges to a few optimized designs of cages that balance capital costs and fish welfare. The prevailing technology for fish farming is the flexible gravity-type open-net cage, which comprises a floating collar made of high-density polyethylene (HDPE), flexible net enclosures for fish containment, a bottom ring, bottom weights, and interconnecting wires or ropes. These cages can have diameters exceeding 50 m and depths of over 20 m. A modern commercial-scale farm can consist of up to ten or more such cages, and a complex grid mooring system is required. Such a system includes bridle lines, frame lines, anchor lines and buoys. The whole system is highly flexible and resilient against exposure to wave and current forces. However, due to biofouling, wear and tear caused by environmental forces and operation, regular maintenance is needed to keep the system in good condition. Feeding is facilitated through feeding tubes, operated either from the control room aboard a barge or remotely from shore. Such fish farms are known for their cost-effectiveness and resilience, typically situated in sheltered environments, like fjords or nearshore areas.

The sustainability of nearshore aquaculture faces several critical challenges, including threats to wild stocks from fish escape, issues with parasites, water pollution, harmful algal blooms, impacts from climate change, etc. Additionally, the limited availability of sheltered locations is also a driving factor to move the aquaculture industry toward more exposed seas, notably offshore fish farming. Currently, there is no agreed definition for offshore or exposed fish farming [1]. In general terms, it refers to fish farming conducted in remote and unsheltered locations

*Corresponding Author:
Lin Li,
Department of Mechanical and Structural Engineering and Materials Science, University of Stavanger, Stavanger, 4021, Norway;
Email: lin.li@uis.no

DOI: http://dx.doi.org/10.36956/sms.v5i2.949

Copyright © 2023 by the author(s). Published by Nan Yang Academy of Sciences Pte Ltd. This is an open access article under the Creative Commons Attribution-NonCommercial 4.0 International (CC BY-NC 4.0) License. (https://creativecommons.org/licenses/by-nc/4.0/).

characterized by high-energy currents and waves comparable to those of the open ocean but located relatively close to the coast [2].

The potential advantages of offshore farming are significant. They include access to ample open sea space for achieving better economies of scale, reduced exposure to pollution from human-induced sources, minimized conflict with other nearshore activities, improved water exchange within the farm, better control of fish parasites, reduction in negative environmental impacts both on water quality, the substrate and associated benthic organisms, etc. However, new challenges emerge as the industry transitions to exposed locations. These challenges, owing to their complexity, are not yet clearly defined, or extensively researched. Generally, the key challenges are associated with structural design, remote operation, and ensuring fish welfare in the face of harsh environmental conditions and the remoteness of offshore sites. These result in extra costs that need to be matched by benefits in production. Addressing these challenges demands innovation in both technology and strategies to adapt current practices to effective offshore farming.

In recent years, numerous offshore fish farm concepts have been proposed, and some have been successfully constructed and deployed. A comprehensive review of these concepts can be found [1]. From a structural design perspective, the novel offshore fish farms tend to feature more rigid and robust supporting frames and submerged cages in contrast to the prevailing flexible floating cage technology. The design aims to endure the stronger wave and current loads in an offshore environment while minimizing deformation and ensuring adequate cage volume. Two prominent offshore fish farm units, namely Ocean Farm 1 and Havfarm, are the pioneering examples among various designs, and they are already in full-scale operational phases off the Norwegian coast.

Ocean Farm 1 has been considered as the first full-scale offshore fish farm operating in exposed sea since 2017. With a diameter of 110 m and a volume of 250000 m^3, the cage can accommodate over 1 million salmon. In contrast to the flexible collar cage in sheltered waters, this offshore facility is a dodecagonal semi-submersible unit composed of a rigid frame structure with steel columns, pontoons, and braces to resist excessive environmental loads. Stiff net materials are attached to the frame structure to minimize cage deformation. The design significant wave height for such a structure is about 5 m and the design current velocity is 0.75 m/s [3].

Havfarm, on the other hand, is recognized for its vessel-like design, and the first unit has been in operation since 2020. It is a 385 m steel construction equipped with a weathervane mooring system. The entire farm comprises six separate cages along the vessel, and the volume of the whole farm is 414000 m^3, with a capacity to host 10000 tons of salmon [4]. The nets in the upper part of the cages are attached to the rigid frame structure. The farm is dimensioned to withstand a significant wave height of up to 10 m.

The development of the above advanced technologies for exposed and offshore farming has been heavily based on established practices in the offshore oil and gas sector, given many similarities between the engineering methods within these industries. While it is feasible to design and manufacture enduring offshore structures as proven by the oil and gas industry, offshore fish farm structures face additional challenges in ensuring the well-being of the fish. Offshore conditions characterized by strong currents and waves, can significantly impact the fish's behaviour, potentially leading to health and welfare concerns. These considerations impose limitations on the design and site selection of offshore farms. Consequently, offshore farms are currently situated in locations that are either partially sheltered or relatively close to land, rather than fully exposed open sea areas.

Offshore fish farm development is still in its early stages. The cost of establishing offshore farms significantly surpasses that of nearshore fish farms. The elevated cost is primarily driven by the necessity for more robust and expensive structures which also have much higher maintenance costs, as they are subjected to accelerated wear and tear from harsh weather conditions. As an example, Ocean Farm 1 faced a deficit of over 100 million NOK in 2022, largely attributed to major maintenance and upgrading costs. As a result of these challenges, the full-scale development of offshore fish farms remains limited to a few countries such as Norway and China. To facilitate industry growth, well-structured financing is thus imperative. The feasibility of offshore fish farming may be achieved by embracing the development of multi-functional and autonomous infrastructure from the oil and offshore industry. Co-locating offshore renewable energy systems with offshore fish farms has the potential benefits of integration and shared services while reducing operational time and costs. Meanwhile, research and development of the technology require more cross-disciplinary collaboration to take care of engineering and biological challenges, as well as social and environmental aspects.

Conflict of Interest

There is no conflict of interest.

References

[1] Chu, Y.I., Wang, C.M., Park, J.C., et al., 2020. Review of cage and containment tank designs for offshore fish farming. Aquaculture. 519, 734928.

[2] Morro, B., Davidson, K., Adams, T.P., et al., 2022. Offshore aquaculture of finfish: Big expectations at sea. Reviews in Aquaculture. 14(2), 791-815.

[3] Jin, J., Su, B., Dou, R., et al., 2021. Numerical modelling of hydrodynamic responses of Ocean Farm 1 in waves and current and validation against model test measurements. Marine Structures. 78, 103017.

[4] Mobron, E., Torgersen, T., Zhu, S., et al., 2022. Design of Havfarm 1. WCFS2020, proceedings of the second world conference on floating solutions, Rotterdam. Springer: Singapore. pp. 99-111.