BLUE ECONOMY
COOPERATIVE RESEARCH CENTRE

Australian Government
Department of Industry, Science, Energy and Resources

AusIndustry
Cooperative Research Centres Program

SHORT SUMMARY

1.20.005 Review of Fish Pen Designs and Mooring Systems

INTRODUCTION

This study reviewed the literature for offshore/ high energy fish pen designs. The study identified operating envelopes, failure modes and knowledge gaps, and present recommendations for future studies. The study also reviewed the performance of existing inshore fish pens, assess their suitability for offshore/high energy application, and identify opportunities for improvement in their current environment. The study considered failure modes, maintenance requirements, environmental compatibility, and end-of-life strategies.

KEY POINTS

- A definition of offshore fish farming is given.
- Challenges for offshore fish farming are identified.
- Fish pen designs are reviewed, categorized and their advantages and disadvantages discussed.
- Types of mooring system and anchor foundation for fish pens are reviewed.
- Fish pen designs and future of offshore fish farming are discussed.
- Knowledge gaps and future research topics are identified.

Figure 1. Selected offshore fish pens for modifications and fusion to produce suitable offshore fish pen designs for BE CRC.

THE CHALLENGE

The challenge is to identify offshore fish pen designs for modifications and fusion to suit the BE CRC partners' energetic sites. So far, only a few offshore fish pens have been constructed (such as Ocean Farm 1, Shenlan 1 and Havfarm 1) and they are still in the testing stage.

This nascent stage of offshore fish farms poses challenges in establishing the robustness and durability of the fish pen designs over their lifespan, during which they would be exposed to many instances of severe weather conditions. Another challenge is the lack of guides and design standards for offshore aquaculture systems and mooring systems in Australia and New Zealand. This means that BE CRC designers have to develop guidelines in tandem with the research and development of offshore fish pens.

THE OPPORTUNITY

As offshore fish farming is still in its infancy, there are great opportunities to develop novel offshore fish pens with their mooring systems. Such offshore fish farms with spacious and pristine water allow unprecedented fish production levels to meet the ever-increasing demand for high quality fish products. A game changing collocation/ integration of fish farms and offshore renewable energy production and storage plants will provide synergetic benefits to both aquaculture and offshore energy industries. Some of these benefits include better utilization of sea space, reduced service and maintenance cost by combined labour and transport, integrated operations and process engineering synergies, integrated disaster management, joint monitoring and control, combined product lifecycle management and shared platforms and mooring systems.

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OUR RESEARCH

Definition of Offshore for Fish Farming
This scoping study project focused on identifying potential opportunities and challenges between the energy and aquaculture sectors, by reporting on novel MPOP concepts and pilot projects recently developed worldwide. All such initiatives seek to address the challenges of offshore seafood and energy production, and enable leveraging the benefits of co-location, vertical integration, infrastructure, and shared services. This study also aimed at shedding light on the limitations of structural reliability analysis methods employed for assessing the structural safety of novel MPOPs. It discussed the current status and future directions for structural reliability analysis of a novel MPOP, considering Australia's unique environment.

Offshore Fish Farm Design Challenges
There are seven major environmental challenges (water depth, current speed, wave action, seabed condition, adverse weather and storms, biofouling, pathogens and predators) that affect two functional criteria (conducive environment for fish welfare and infrastructure & economic sustainability for operations including accessibility) for offshore fish farms.

Types of Fish Pen Designs
By adopting the categorization of pen designs by the nature of the structures for supporting the holding net and the pen containment methods, fish pens may be divided into the open-net pen system and the closed containment tank system.

The open-net pen system may be further categorized into six types (floating flexible pens, floating rigid pens, semi-submersible flexible pens, semi-submersible rigid pens, submerged pens, bottom-resting pens) and the closed containment tank into two types (rigid closed containment systems and flexible bag containment systems.

Examples of each type of fish pen design and key observations are given in the Report.

Mooring Systems for Fish Pens
A mooring system includes several components such as mooring lines, floaters, buoys, shackles, chains, ropes, wires, windlass, fairlead, anchors, sinkers and anchor chain. Mooring lines must withstand and transmit forces. Floaters, net and mooring components of a fish pen system should be designed together and mechanically linked. Therefore, pens and mooring design shall be "site specific" to survive major storms.

Two main types of mooring system are used for fish pens: multi-point mooring (i.e., spread moorings) and single-point mooring (i.e. catenary anchor leg mooring).

Pen Designs and The Future of Offshore Fish Farming
Floating flexible pens have not been deployed in highly exposed sites that are expected to cause a large deformation of the floater, damage of stanchion and connectors, and contraction of net space under severe wave actions.

Floating rigid pens may be deployed at some exposed offshore sites where the occurrence of extreme storms is rare. Semi-submersible rigid pens have become the most popular type due to their submergibility and robust structure against harsh environmental conditions.

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Semi-submersible flexible pens and submerged pens may be deployed at more exposed sites. In general, the volumes of these types of pens are relatively small. So far, it is not known if there are any semi-submersible flexible pen and submerged pen being deployed in offshore sites.

Floating closed containment tanks face sloshing problems and hence they have not been used offshore.

The feasibility of offshore fish farming may be achieved through adoption of new development of multifunctional, modularity for ease of construction and autonomous infrastructure that has been validated in oil and offshore industry. By co-locating offshore renewable energy systems and floating platforms (that can accommodate feed silos, equipment, harvesting cranes and nets, waste treatment plant, desalination plant) with offshore fish farms, it is possible to leverage the benefits of colocation, vertical integration and shared services and to reduce operating time and cost. Also, the use of offshore renewable energy helps to decarbonize the fish farming industry.

Shortlisted Offshore Fish Pen Designs
Shortlisted offshore fish pen designs for modification and fusion are the Ocean Farm 1, COSPAR, Havfarm 1, Zhenyu Aquaculture Platform and the GIEC's Penghu Open Sea Aquaculture Platform. An example of such a modified Havfarm 1 is the SeaFisher, which is described in the Report.

Knowledge Gaps and Future Research Topics

- Making aquaculture systems storm proof (more robust fish pens and mooring systems, mobile or submerged, use of floating breakwater systems)
- Enabling feasibility of offshore fish farming (colocation with renewable energy production facility, modification of nearshore aquaculture systems for energetic sites)
- Developing analysis tools for offshore fish pens and mooring systems (analysis of nets with biofouling, aero-hydrodynamic analysis of integrated fish pen and wind turbines)
- Developing closed containment systems for fish farming in exposed sites (minimize sloshing).

OUTCOMES

The scoping study has revealed the challenges in offshore fish farming, different types of fish pen designs and mooring systems for nearshore and offshore sites, the lack of Australian guides and design standards for offshore fish pen designs, the kinds of analysis performed and software packages used in pen designs, and knowledge gaps. Several existing offshore fish pen designs have been shortlisted for modification and fusion with the view to produce suitable offshore fishpen designs tailored for application in the identified offshore sites in Australia and New Zealand. COSPAR and SeaFisher are two offshore fish pen designs that have been proposed by members of the scoping study team for further research.

NEXT STEPS

Research and development on novel offshore fish pens will be conducted in a proposed general project; by modifying and fusing shortlisted existing and proposed offshore fish pen designs for energetic sites, as identified by BE CRC fish farm operators.

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PROJECT TEAM

- The University of Queensland: Chien Ming Wang,
- Yunil Chu, Johannes Wiegerink, Tom Baldock, David Callaghan, Martin Veidt, Michael Heitzmann
- Griffith University: Hong Zhang, Dong-Sheng Jeng, Joerg Baumeister
- University of Tasmania: Nagi Abdussamie
- CSIRO: Mark Underwood, Andrew Martini
- East China Sea Fisheries Research Institute: Lumin Wang,
- Shiming Peng
- SINTEF Ocean: Hans Bjelland,
- Universidad Austral de Chile: Cristian Cifuentes
- Advanced Composite Structures Australia: Rowan Paton, Michael Vuong, Rodney Thomson
- BMT: Chris Shearer, Trevor Dove
- Tassal Group: Bradley Evans
- Huon Aquaculture: Matthew Whittle, David
- Morehead
- The New Zealand King Salmon: Mark Preece

PROJECT REPORTS/PUBLICATIONS

Wang, C.M. et al. (2020). Review of Fish Pen Designs and Mooring System, P.1.20.005 – Final Project Report. Launceston, Tasmania, Australia: Blue Economy Cooperative Research Centre.

Wang, C.M, Wiegerink, J. and Leow, B.T. (2020). Opportunities for floating closed containment systems for fish farm. Journal of Aquaculture & Marine Biology, 9(4), 122-127.

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