Bull kelp is one of the seaweed species the BECRC is investing in research.

New offshore horizons for future seafood production

Words by Dr Chris G Carter

Seafood and aquaculture

The importance of aquaculture in future food production for global food and nutrition security cannot be underestimated. As was recently outlined by Antonia Guterres as Secretary-General of the United Nations, there needs to be "invest[ment] in sustainable ocean economies for food, renewable energy and livelihoods".[1] Aquaculture will make an increasing contribution to seafood production and can be done using different systems and locations that contribute to meeting the sustainability challenges the world's seas face.

Whilst the majority of aquaculture is from polyculture of carp species in Chinese freshwater ponds, marine aquaculture is large, increasing and provides many opportunities. In addition to animals, aquatic plants contribute about a quarter of aquaculture production. Nine of the top fifteen aquaculture species are marine and include five seaweed species, whiteleg shrimp, oysters, carpet shells and Atlantic salmon.[2]

New marine horizons are being explored around the world to increase seafood production and offshore locations are often envisaged as critical to seafood futures. A functional definition of offshore that emphasises the exposed and high energy nature of the environmental conditions, rather than only the distance from the shore,[3] provides an effective way to encapsulate the local conditions as well as the vision and challenges.

The Blue Economy Cooperative Research Centre (BECRC) has taken the challenge further to focus on both offshore sustainable seafood and renewable energy. Integration is a founding principle and reflected by opportunities for co-location of renewable energy with seafood production. Integration also operates at different levels which encompass co-location of multiple aquaculture species and systems, integration of nutrient cycling among them and even extends to wild fisheries that might associate with offshore structures.

The BECRC brings together more than forty partners from ten countries to grow the blue economy for offshore seafood and renewable energy production. Seafood and Marine Products is one of five research programs and aims to develop offshore aquaculture systems that provide viable and sustainable growth opportunities. The Seafood and Marine Products Program will support existing industries' move offshore and develop, test and evaluate innovative product, production and processing systems for a range of seafood species. There are exciting opportunities such as using established aquaculture species, identifying a new white-fleshed marine fish, establishing seaweed aquaculture, and systems that promote aspects of the circular economy.

Australia presents an excellent location - it has the world's third largest Exclusive Economic Zone, nearly 60,000km of coastline, multiple climates, and is recognised to offer access to offshore locations with significant but unrealised potential for aquaculture.[4] There are established species and markets, and consumers know Australian grown seafood with Atlantic salmon at the top of the menu that includes oysters, yellowtail kingfish, barramundi and prawns.

Tasmania is Australia's largest seafood producing state by value which is mainly attributable to farmed Atlantic salmon aquaculture: in 2019/20 Atlantic salmon accounted for well over half of Australian aquaculture (55% value, 62% production) and 29% of the value of all Australian seafood.[5] All Australian states have some aquaculture and there are exciting prospects in the northern tropical regions as well as from mussel, Chinook (King) salmon and oyster aquaculture in New Zealand.

Which aquaculture species and systems?

What seafood might the consumer expect to come from offshore aquaculture? There are lots of species to consider from the many already farmed globally, but far fewer offer realistic choices. Meeting market needs as well as critical biological and technical production criteria are crucial for any species to be successful, offshore locations add criteria around meeting environmental challenges of open ocean locations for both the species and the production systems.

Strong contenders the BECRC will

consider are seaweeds, extractive species that take food from the environment such as filter feeding bivalves (oyster and mussels), high value shellfish (lobsters, abalone, sea cucumbers) and the best few from many different species of finfish that need formulated feeds. These will be considered as single and multiple species systems and for different climates and regions.

With our partners in successful aquaculture industries the BECRC is already exploring offshore aquaculture for salmon and oysters. Globally, the location of salmon farms and matching production schedules are changing to move on land and offshore. Successful salmon farming will most likely be based on sophisticated adaptive integration of both; using land-based recirculation aquaculture systems (RAS) to increase the size and condition of salmon before they are moved to offshore and high energy seawater sites. High energy seas pose considerable technological challenges as well as unknown questions about salmon production biology. Fortunately, a large amount of information that can be applied locally is rapidly accumulating around the world.

Engineering offshore structures is clearly critical for success, the two distinct approaches are for large and very robust surface structures built to withstand the waves and storms or for submersible structures that can be lowered out of harms way. Semi-enclosed systems have additional advantages which are being explored. For example, they might offer protection for fish from disease, parasites and other harmful organisms as well as offer the opportunity to recycle wastes into valuable by-products. There are a range of options for contributing to the circular economy that include recycling nutrients within multispecies systems, using non-human food ingredients and deriving value from biofouling.

The BECRC has the opportunity and intent to build on current knowledge about best practices for environmental sustainability for offshore industries. This is inherent in the BECRC structure and a holistic approach across programs will support managing the environmental footprint of offshore infrastructure, aquaculture systems and renewable energy generating systems that will be used by different offshore industries.

New technologies to support sustainable aquaculture emphasise the critical nature of accurate and appropriate data to minimise both environmental impact and the impact of the environment on aquaculture, as this maximises sustainable production. Autonomous systems for environmental monitoring will be crucial for operating remote offshore locations, including projects that are developing and linking sensor networks with autonomous underwater vehicles (AUV), autonomous surface vehicles (ASV) and drones.

New data gathering systems will be covered by marine spatial planning (MSP) tools incorporating resource potential, operational logistics and risks (particularly to the environment) into a decision support tool for locating offshore industries. Site choice will maximise the offshore advantage for horizontal dispersal of wastes so that they can be continually processed on the seafloor. The impact and benefits of such systems must be quantified so we are developing novel approaches to measuring any depositional footprint and then incorporating this information into MSP.

Other technology projects include developing novel offshore structures such as pens for holding fish and structures for anchoring seaweeds as well integrating seaweed and other aquaculture with renewable energy production. There are further opportunities for renewable energy supporting aquaculture operations such as hydrogen powered vessels. Decarbonising aquaculture operations as well as understanding how aquaculture can contribute to decarbonisation and increased nutrient sequestration are also being explored.

Seaweeds are likely to contribute and to be key species in multi-species systems as discussed below. Further, the number of examples of how to co-locate aquaculture with renewable energy infrastructure is increasing across the world.[6] The vital consideration of building social licence to operate, which necessarily includes environmental sustainability, is part of the research portfolio.[7] Thus, the BECRC is investing in R&D for environmentally sustainable aquaculture at multiple levels.

Achieving an aquaculture industry at scale for white-fleshed marine fish would be a major advance and arguably essential for future Australian seafood. For almost fifty years, Australian research has aimed to address this local gap using species like barramundi, cobia, mulloway, snapper, striped trumpeter and yellowtail kingfish. The success of Australian Atlantic salmon provides a model, as it has a range of excellent biological characteristics that make it suitable for aquaculture[8] and the product is underpinned by strong markets. Although local production is currently small, marine fish are farmed successfully. Barramundi, mulloway and yellowtail kingfish may provide the starting point for new offshore finfish aquaculture. Characteristics required for offshore farms will be developed and applied alongside the standard aquaculture species selection criteria.[8]

Seaweed aquaculture is only very recently emerging as a potential industry in Australia and New Zealand. Seaweeds might be used as a quality human food, as a source of high value extractives, for nutrient sequestration, and potentially for hydrodynamic attenuation in high energy and offshore sites.

There is a real need to correctly understand and then promote the values that farmed seaweeds might have. For example, the economics of seaweed products is still to be determined and the role of seaweeds in decarbonisation needs to be evidence based. Consequently, R&D

to underpin establishing a seaweed aquaculture industry requires a broad range of R&D ranging from establishing production technology to ensuring an appropriate legal and governance structure is in place.

After two years of the United Nations Decade of Ocean Science for Sustainable Development (2021-2030) it is apparent that throughout the world, countries with expertise and interest in aquaculture are developing offshore aquaculture systems.[9] Through the BECRC, Australia has invested in seeking to combine renewable energy production with sustainable offshore aquaculture. The BECRC partnership aims to increase sustainability, regional economic growth and community trust to deliver multiple impacts across seafood and renewable energy.

References

1. ANON. 2022 Guterres outlines four recommendations to help us all 'Save Our Ocean'. UN Ocean Conference. 27 June 2022. Speech to Conference by UN Secretary-General António Guterres].[cited 21.10.2022]; Available from: https://news.un.org/en/story/2022/06/1121402.
2. FAO. 2022. The State of World Fisheries and Aquaculture 2022. *Towards Blue Transformation*. FAO, Rome, Italy. 266 pages.
3. Buck, B.H., M.F. Troell, G. Krause, D.L. Angel, *et al*., 2018. State of the art and challenges for offshore integrated multi-trophic aquaculture (IMTA). *Frontiers in Marine Science*. 5: 00165 doi 10.3389/fmars.2018.00165:
4. Gentry, R.R., H.E. Froehlich, D. Grimm, P. Kareiva, *et al*., 2017. Mapping the global potential for marine aquaculture. *Nature Ecology & Evolution*. 1: 1317-1324. doi 10.1038/s41559-017-0257-9:
5. Steven, A.H., M. Dylewski, and R. Curtotti. 2021. *Australian Fisheries and Aquaculture Statistics 2020*. Canberra, Australia. doi.org/10.25814/0wzy-re76:
6. Aryai, V., R. Abbassi, N. Abdussamie, F. Salehi, *et al*., 2021. Reliability of multi-purpose offshore-facilities: *Present status and future direction in Australia. Process Safety and Environmental Protection*. 148: 437-461. doi 10.1016/j.psep.2020.10.016:
7. Garavelli, L., M.C. Freeman, L.G. Tugade, D. Greene, *et al*., 2022. A feasibility assessment for co-locating and powering offshore aquaculture with wave energy in the United States. *Ocean & Coastal Management*. 225: 106242 10. doi 10.1016/j.ocecoaman.2022.106242:
8. Le Francois, N.R., M. Jobling, C. Carter, and P.U. Blier, eds. 2010. *Finfish Aquaculture Diversification*. CAB International. 681 pages.
9. Novaglio, C., N. Bax, F. Boschetti, G.R. Emad, *et al*., 2022. Deep aspirations: towards a sustainable offshore Blue Economy. *Reviews in Fish Biology and Fisheries*. 32: 209-230. doi 10.1007/s11160-020-09628-6:

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