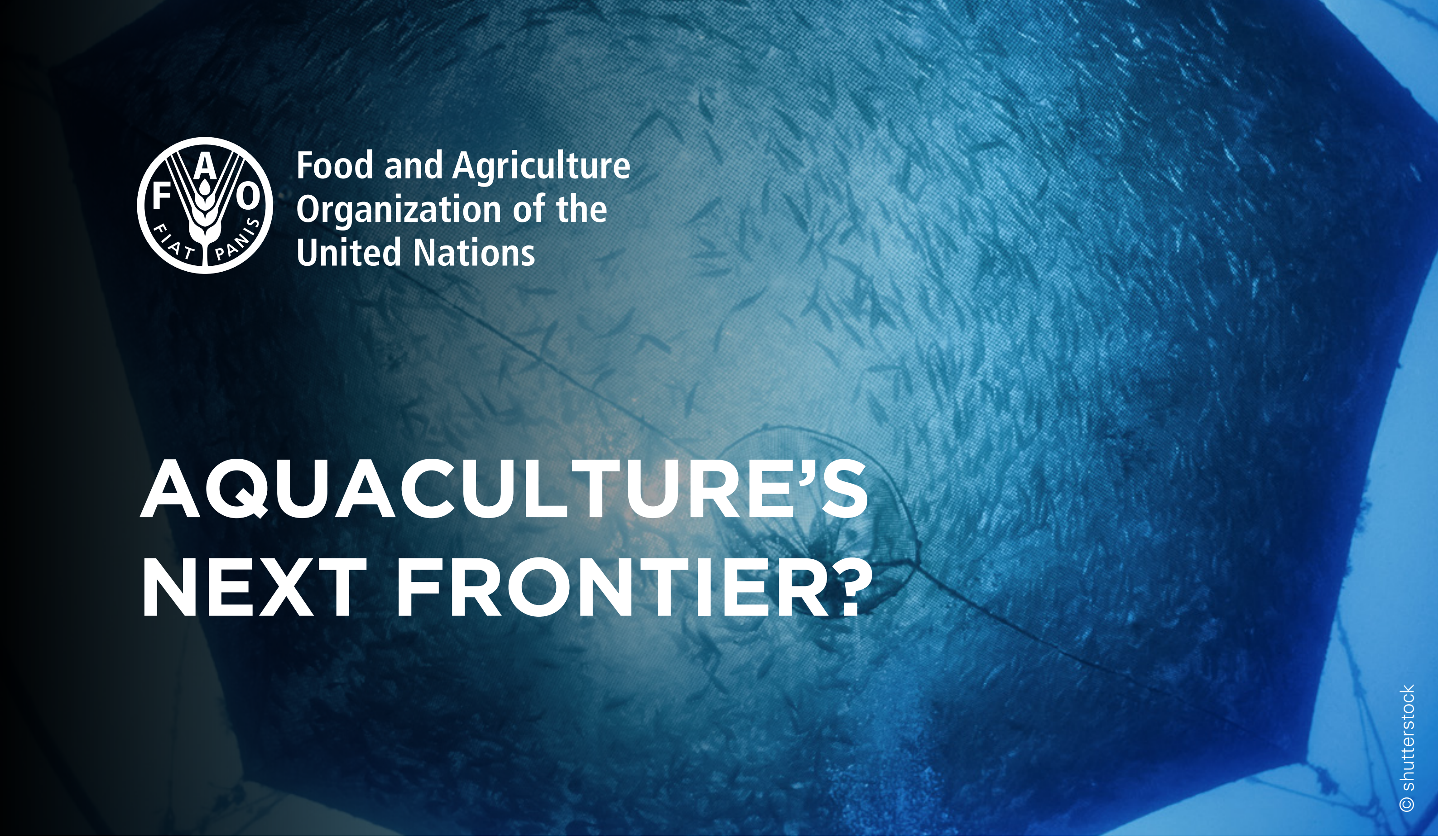

Food and Agriculture
Organization of the
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AQUACULTURE'S NEXT FRONTIER?

While aquaculture's roots are in freshwater and coastal systems, as competition for these resources increases and technology advances, farmers are increasingly looking for opportunities further offshore from the coast.

Aquaculture has traditionally been carried out in sheltered, low-energy waters. The earliest accounts of the sector refer to the culture of carps in ponds in China and pond farming still dominates global finfish aquaculture production figures. However, over time, farmers have succeeded in producing aquatic animals in increasingly high-energy locations and exposed locations – driven by the evolution of new techniques and technologies; the belief that offshore aquaculture locations can avoid many of the biological issues plaguing inshore waters; and by a host of other growing pressures on aquaculture in inland and coastal waterways (Froehlich *et al.*, 2017).

These pressures include competition for space from other users, issues with disease and poor water quality in areas which have reached their biological carrying capacity, or problems caused by runoff carrying nutrients and pollution from agricultural, industrial and urban areas.

As a result of these factors, increasing numbers of companies and research institutes are looking to develop systems that can withstand high-energy locations. Until recently these efforts were hampered by the expense of creating effective systems and by issues related to legislation (Lester *et al.*, 2018). However, due to the rising costs of aquaculture production in some conventional systems – for example due to parasites, algal blooms and disease – and the lack of space for the sector to expand in its traditional areas with increasing land prices, the incentive to look further offshore from the coast has been increasing.

TECHNIQUE AND APPROACH USED

There are now several companies and initiatives that are looking to produce lower trophic species in offshore locations. Examples include a company that produces blue mussels (*Mytilus edulis*) up to 24 km off the south coast of the United Kingdom of Great Britain and Northern Ireland, while another company was doing the same off the coast of California before it was declared bankrupt in 2020. Some seaweed-farming companies are also looking to produce species such as kelp (*Laminaria* spp.) further from the shore. However, most offshore aquaculture systems to date have been designed for the production of high-value marine finfish and Atlantic salmon (*Salmo salar*).

A company based in the United States of America has been developing submersible offshore aquaculture systems for finfish for several decades and their designs have been deployed by producers of a range of marine finfish species – such as totoaba (*Totoaba macdonaldi*), amberjack (*Seriola* spp.), striped bass (*Morone saxatilis*) and cobia (*Rachycentron canadum*) – in offshore locations including Hawaii, Mexico, Panama, Former Canal Zone and the Republic of Korea. However, the hopes of establishing a thriving offshore aquaculture sector in the United States of America have, so far, been thwarted by a lack of supportive legislation for the sector.

While the legislative system for aquaculture in US federal waters is currently being debated, the two countries that are now dominating the drive towards offshore aquaculture are China and Norway. In Norway the drive for offshore production of Atlantic salmon was catalysed by the government's development licence initiative. Launched in 2017, it encouraged salmon producers to think outside the box and to develop ground-breaking production systems in a bid to move away from the conventional net pen systems that have dominated production since the industry was established in the 1970s.

While a wide range of designs was produced by salmon farmers keen to increase their production allowance, a significant proportion of the plans was for structures that were designed for offshore locations. These designs included submersible farms that could be sunk below sea level if conditions became too rough on the surface; mobile farms that could be moved to avoid extreme weather events or biological threats; and huge industrial structures designed to withstand all weather conditions – based around technology developed for the offshore oil and gas sector.

The only one of these offshore designs that has been constructed on a commercial scale and stocked with fish is a heavy duty steel structure forming a cage, which is 68 m deep and has a diameter of 110 m. However, after two production cycles – in which a total of 10 000 tonnes of salmon were produced in the system – the two companies involved have pledged to invest more in offshore aquaculture research and development. While their designs were initially intended for use in Norway's salmon sector, the companies have expressed international ambitions for the longer term.

China is seen as developing into another possible hub for offshore aquaculture – as the government looks to make up for the reduction in growth of its traditional, freshwater and coastal aquaculture sectors, as well as the stagnation of its capture fisheries landings. China has manufactured some of the structures used by Norway's offshore aquaculture sector. However, China's domestic offshore sector is still embryonic and it is difficult to find reliable information on how the sector is developing.

As well as the structures themselves, extensive research and development is ongoing for the systems that will help farmers operate farms sited in remote and environmentally extreme locations. In particular, given the difficulty of accessing offshore sites – especially during extreme weather – there has been a drive to automate systems and also to develop the means to operate them remotely.

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A submersible cage for totoaba and red snapper grow-out in Mexico, designed for use in offshore locations.

SCOPE AND SCALE OF APPLICATION

It is clear that aquaculture in genuinely offshore locations has taken off more slowly than predicted by its early proponents. But the potential of the offshore aquaculture sector to grow in many parts of the world is both considerable and improving, due to the constraints on conventional systems, developments in the new technologies and the sheer scale of offshore waters that could – in the long term – be available for aquaculture development.

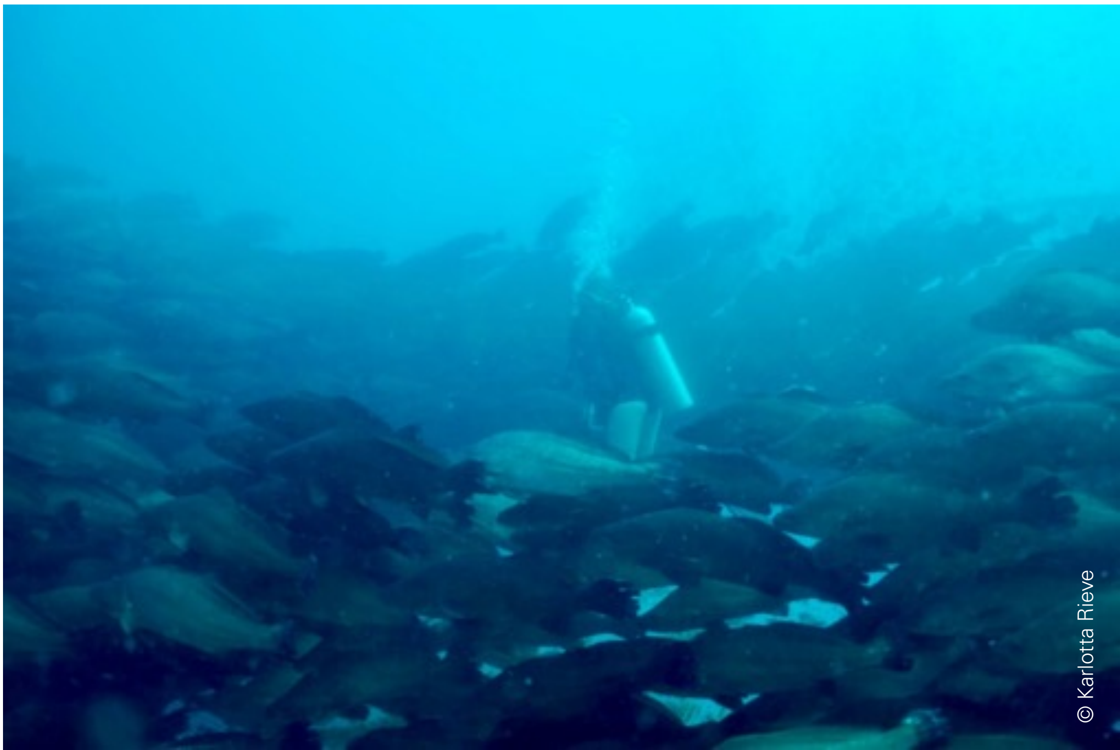
A recent report by Rabobank, for example, suggested that 10 percent of farmed salmon could be produced in offshore systems by 2030 and that Norway alone could produce 100 000 tonnes of salmon in offshore systems by that time (Rabobank, 2021). This drive and investment from the salmon sector is likely to accelerate the adoption of offshore technology for producing other species.

ACCESSIBILITY

Offshore farming systems are still evolving. While various existing offshore systems have demonstrated their resilience in extreme weather conditions, the cost of setting up and running them – in particular those housing finfish – has made them prohibitively expensive for most individuals, companies and organizations.

According to one of the larger players in the sector, establishing an offshore all-weather farm capable of producing 1 000 tonnes of finfish a year would require an initial outlay of USD 15 million to USD 20 million in capital, with annual operating cost of about USD 10 million. It is these issues of capital and operational expenditure, as well as legislative hurdles, and proving that offshore aquaculture production systems will be environmentally benign – that are seen as the biggest obstacles facing the sector.

While capital outlays are always likely to be higher for offshore aquaculture systems, operational costs have been predicted to decrease over time. Investment costs for offshore shellfish and seaweed production systems should be substantially lower and more accessible, although these will still require considerable investments in equipment, such as the vessels used for harvesting.



A diver inspects totoaba in a submersible grow-out pen at an offshore location in Mexico.

OUTCOME AND BENEFITS

The offshore aquaculture sector is still at a nascent stage and developers have struggled to translate the theoretical benefits into the construction of economically viable farms. However, offshore systems are likely to offer one means of increasing aquatic food production and potentially easing pressure on waterways and inshore coastal areas that have already reached, or exceeded, their carrying capacity for aquaculture production.

Whether the offshore aquaculture sector can produce a significant volume of aquatic produce in the medium term remains to be seen, but – as research and development in this field continues – these systems are likely to improve, while the cost of producing each unit should decline.

Equally, some of the technologies being developed for use in the sector will almost certainly have applications in more conventional aquaculture production systems. In particular, technologies related to remote operation and increasing automation will have the potential to improve the efficiency of many forms and scales of aquaculture production. Whether these technological advances will reduce or improve employment opportunities in the sector remains to be seen.

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