



Boom in Aquaculture: Where and why aquaculture is thriving?



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Executive Summary

Aquaculture is about to overtake capture production of fish and seafood products, and is expected to grow at a rate of 1.0% p.a. over the next decade. The strongest growth is expected within developing nations where the sector is forecast to expand at a rate of 1.2 % p.a.

Aquaculture is an extremely varied sector with a wide range of marine and freshwater species being cultivated across the globe. There are important emerging investment opportunities within the Aquaculture sector, especially within the Middle East as countries in the region are investing heavily in aquaculture as a means of ensuring food security. New technology is being commercialised and a wider range of species are being cultivated as wild fish stocks decline.



Introduction

According to the OECD, 2023 will be a landmark year for the aquaculture sector, as fish and seafood production from capture fisheries is overtaken by aquaculture for the first time. In this report, we will consider where this growth in aquaculture sector has come from, and where the specific opportunities within Europe, the Middle East and Africa are.

Global Production

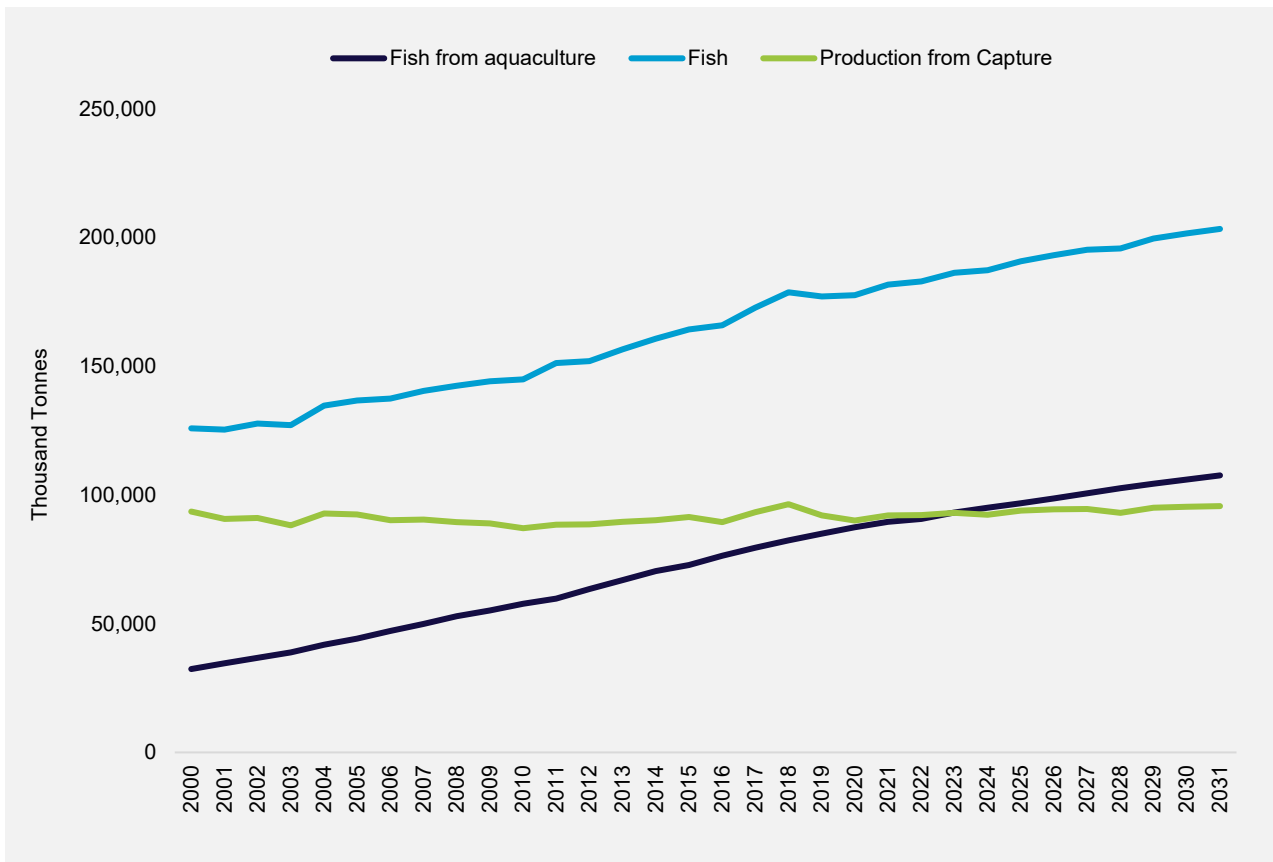
Aquaculture will account for 53% of all fish production by 2030, according to the OECD. Declining wild fish stocks and concerns over the sustainability of capture fisheries are driving growth and interest within aquaculture. Total fish production is expected to grow at a rate of 0.6% p.a. production from aquaculture is forecast to grow at a rate of 1.0% p.a.



	2016	2021	2026	2031	5 YR CAGR % p.a.	5 YR CAGR % p.a. F
Production from Capture	89 498	92 189	94 496	95 745	0.3%	0.2%
Production from Aquaculture	76 506	89 606	98 702	107 659	1.6%	1.0%
Total Production	166 003	181 795	193 198	203 403	0.9%	0.6%
% From Aquaculture	46%	49%	51%	53%		

Source: OECD¹

Global Aquaculture and Capture Fisheries Forecasts



Source: OECD²

The total fish supply is forecast to increase from 166 million tons in 2016 to 203 million tons in 2031, with aquaculture entirely responsible for the increase. The fastest aquaculture growth is expected for tilapia and shrimp, while the largest expansion is expected in India, Latin America and the Caribbean and Southeast Asia. Rapidly growing seafood for seafood in China and

elsewhere represents a critical opportunity for global fisheries and aquaculture to improve their management and achieve a sustainable seafood economy³.

Opportunities and market impacts

The bulk of aquaculture production occurs in Asia, with China the dominant country (60% of global production) for both freshwater and marine aquaculture.



Forecasts for Aquaculture Production

	2016	2021	2026	2031	5 YR CAGR % p.a.	5 YR CAGR % p.a. F
World	76 506	89 606	98 702	107 659	1.6%	1.0%
Developed Countries	4 602	4 857	5 277	5 616	0.5%	0.8%
Developing Countries	71 904	82 632	93 426	102 042	1.4%	1.2%
OECD	6 324	7 191	7 892	8 566	1.3%	0.9%
BRICS	52 237	59 162	66 859	73 334	1.3%	1.2%

Source: OECD⁴

Global Situation

The overwhelming majority of aquaculture production by volume is within developing countries, where aquaculture production has been growing at a rate of 1.9% p.a. over the last five years⁵. Fish are an important protein source for people in many developing countries. Approximately 200 million people in Africa derive high-quality and low-cost proteins from fish. However, the consumption of fish is not fully exploited to combat the “triple burden” of malnutrition—obesity, undernutrition, and micronutrient deficiencies which are the leading causes of poor health in developing countries.

Globally aquaculture contributes 8% of animal protein intake to the human diet, and per capita consumption is increasing faster than meat and dairy consumption⁶. The most-farmed fish species around the world are catfish, tilapia, Atlantic salmon, flatfish, trout, seabass, tuna, and cod, but other types of farmed species include mussels, oysters, shrimp, and eels. In tandem with the growth in seafood production, the aquafeed market is also expected to grow.

Consumption Trends

The global average for fish consumption is 17.97 kg per capita per annum and is growing at a rate of 0.8 % p.a., however there is a wide variation between countries and regions. In 2022, the top three countries in terms of annual per capita consumption are Korea (49.2 kg), Malaysia

(47.9 kg) and Norway (44.3 kg)⁸. In terms of per capita consumption growth, the fastest growth rates are developing countries where it is growing at a rate of 1.0% p.a., whilst growing at 1.7% p.a. in the BRIC nations.

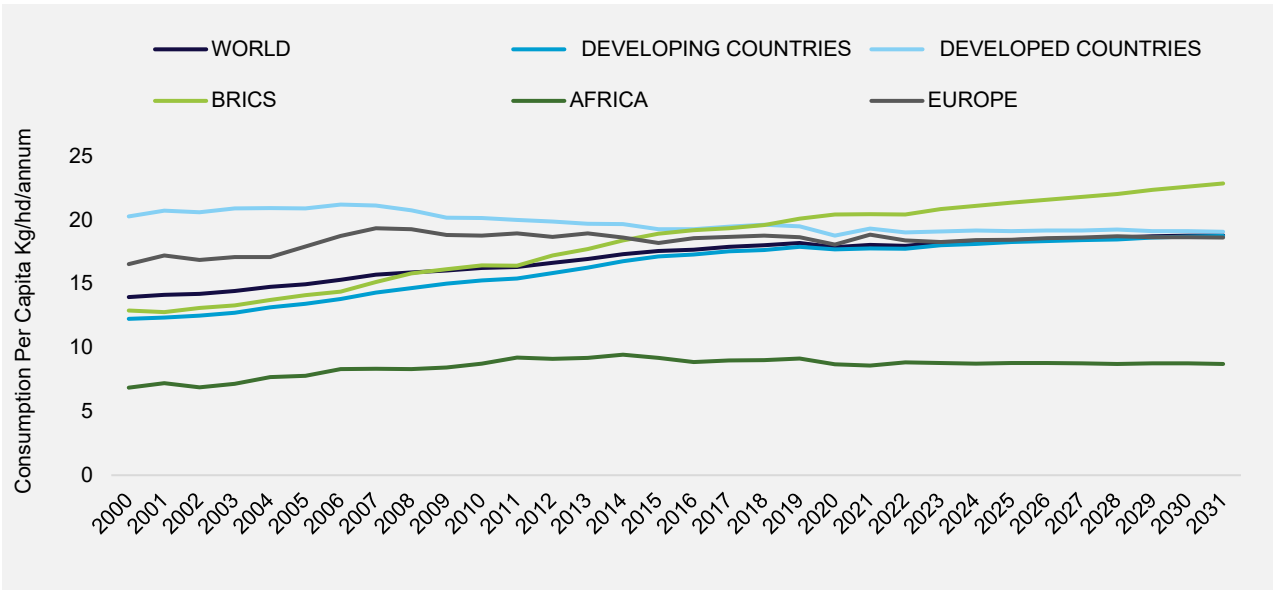
According to a new report from GM insights, aquafeed is expected to achieve a 4.1% compound annual growth rate (CAGR) this year and each year up to 2026 globally.

Asia dominates the global aquaculture sector accounting for 92% of all production. China (57 million tonnes) and Indonesia (13 million tonnes) are the main producers, together with India, Vietnam, and the Philippines. The main marine species are seaweed and oysters; freshwater species consist mainly of various carp species, especially grass, silver, and common carp species.

Over the past 20 years, the aquaculture sector has evolved from having a niche role in seafood production to playing a mainstream part in the global food system. The aquaculture literature reflects the increased attention to food system outcomes, with consumers, value chains, and sustainability criteria progressively shaping the direction of the industry⁷.



Global Fish Consumption Trends



Source: OECD⁹

Consumer perceptions of seafood

Part of the growth in demand for fish and other seafood is due to consumer perceptions of these products as sustainable and healthy. They are low in fat and high in protein, many with high Omega fatty acid and vitamin content as well. In terms of greenhouse gas emissions, aquaculture is among the lowest in carbon emissions compared to all other types of livestock¹⁰.

Increased seafood consumption is being driven by increased availability, increased disposable incomes, urbanization, price competitiveness with other proteins, and the perceived health and nutrition benefits of fish¹¹.

There is however a growing consciousness and awareness within the aquaculture value chain about sustainability and preventive health and this is impacting the whole value chain and not just primary aquaculture¹².





Regional Focus

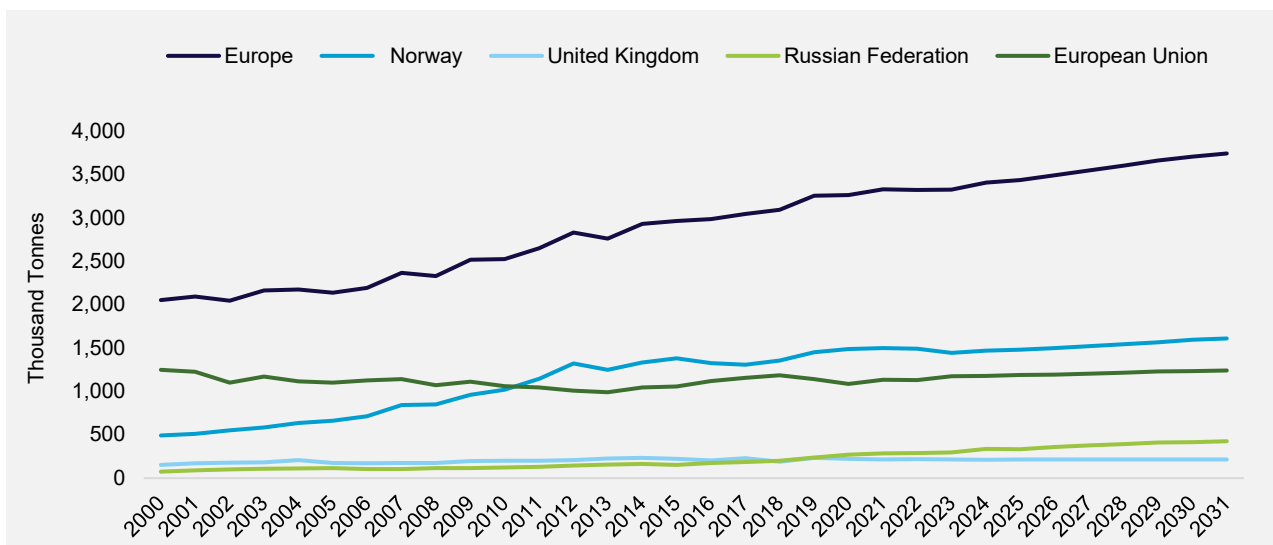
Whilst the bulk of aquaculture production occurs within Asia, there are opportunities for high-value aquaculture within Europe, the Middle East and Africa.

Europe

Overview

Aquaculture production in Europe is growing at a rate of 1.1% p.a. and is expected to continue at a rate of 0.5% p.a. over the next five years.

European Aquaculture Production



	2016	2021	2026	2031	2016-2021 CAGR % p.a.	2020-2026 CAGR % p.a.
Europe	2 988	3 330	3 493	3 746	1.1%	0.5%
European Union	1 120	1 134	1 195	1 241	0.1%	0.5%
Norway	1 326	1 500	1 500	1 611	1.2%	0.0%
United Kingdom	205	215	214	216	0.5%	-0.1%
Russian Federation	173	285	357	426	5.1%	2.3%
Other countries	164	196	227	252	1.8%	1.5%

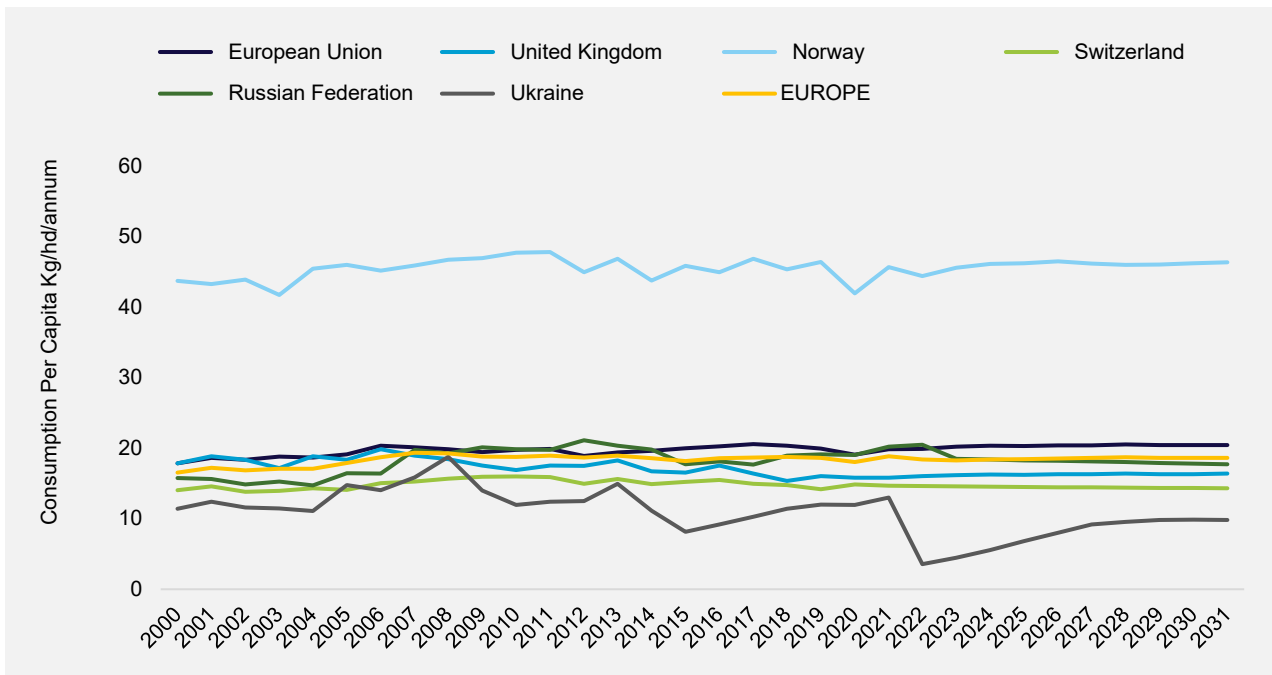
Source: OECD¹³

Aquaculture in Europe is diverse, with a wide range of species produced across several countries. Norway is the largest aquaculture producer within Europe, with production growing at a rate of 1.2% p.a., but this growth is expected to stall going forward. Bivalve molluscs (mussels, oysters, and clams) are dominant in Spain, France, and Italy. The Norway and UK sectors focus on salmon, while Greece produces mainly sea bass and sea bream¹⁴.

Aquaculture in Europe has long been described as a stagnant sector. With a total production of just 1.3 million metric tons (MT), Fish farming continues to be hampered by lengthy licensing procedures, considerable regulatory red tape, and environmental considerations¹⁵.



European Fish Consumption



Source: OECD¹⁶

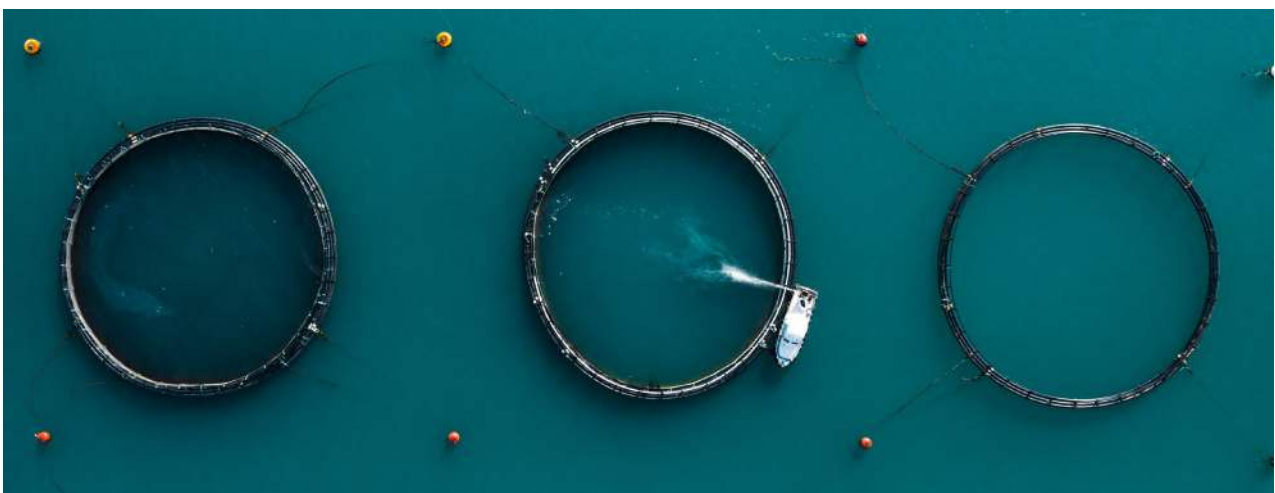
Europe is highly import-dependent in seafood, and traditional aquaculture facing challenges to expand output¹⁷. Consumption of fish per capita is high in global terms, however, is forecast to remain stagnant with little growth over the next few years according to the OECD¹⁸.

In 2016 the EU aquaculture sector was made up of around 12,500 companies, which were mostly micro-businesses employing less than 10 employees. The total number of employees was 73,000 in 2016, a figure that has remained stable for several years. However, one major change is a significant growth in the number of full-time equivalent people employed, which rose from 36,000 in 2013 to just under 44,000 in 2016¹⁹.

The main species in terms of value were Atlantic salmon, rainbow trout, and European sea bass.

The UK (Scotland) and Norway dominate Atlantic Salmon production, Greece for 47% of the value of sea bream and sea bass.

Trout production within Europe was dominated by Italy (19%), Denmark (17%) and France (14%). Carp, an important species in Eastern Europe, was mainly produced in Poland (24%), Czechia (23%) and Hungary (14%). In the shellfish sector, France and Spain were the most important countries in terms of production volume and value. France accounted for 86% of oyster production, Spain for 45% of mussel production, and Italy for 80% of clam production. In terms of the number of businesses, Portugal was the leading country, while Spain registered the largest number of employees²⁰.



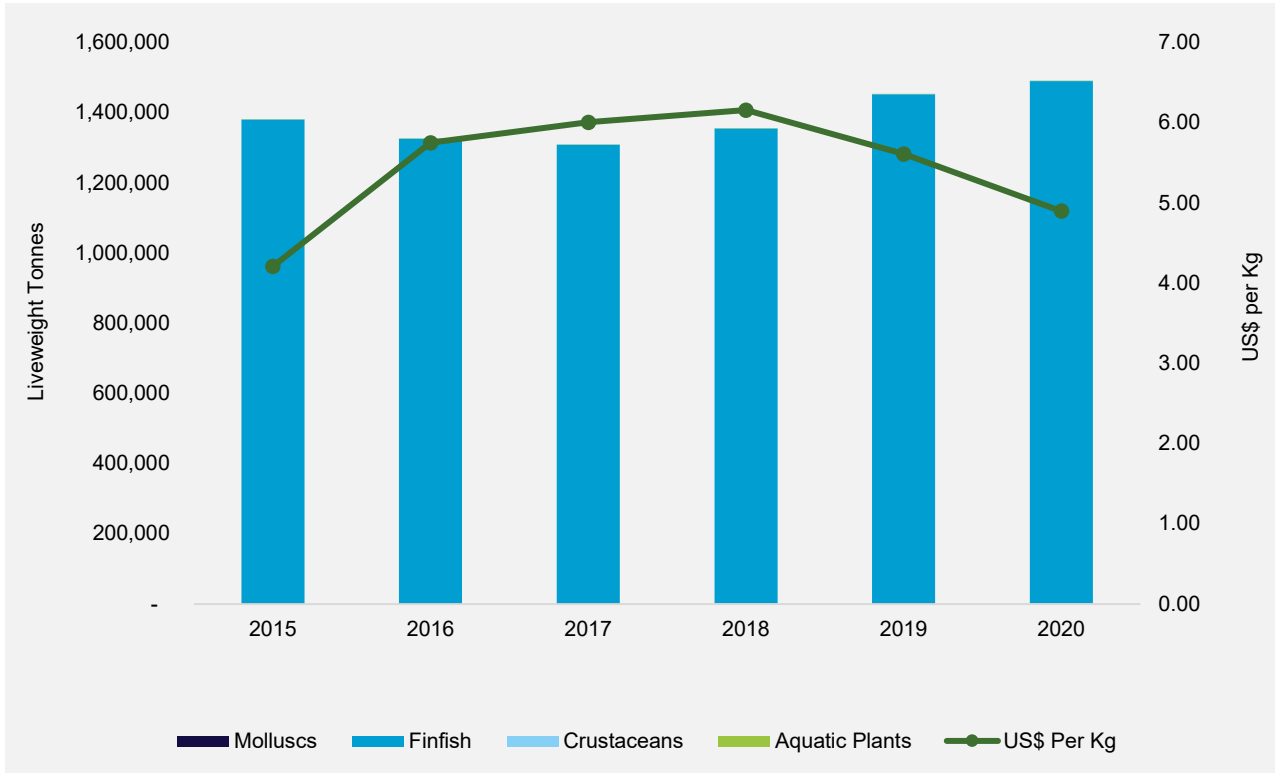


Norway

Norway is the largest aquaculture producer within Europe and accounts for 45% of European production by volume. The sector is dominated by

finfish production with Atlantic Salmon and Rainbow trout being key species. Blue mussels are also produced, along with some crustacean and aquatic plant species.

Norway Aquaculture



Source: FAO FishStats²¹.

After achieving record-high revenues in 2019, the Norwegian sea farming subsegment saw its revenues go down in 2020. This was despite a 2.9% growth in sold harvested volumes in 2020 compared with 2019. As such, the explanation for the revenue reduction was simply a lower sales price of salmon²².

The availability of licences is a key issue for the sector. Due to the fast growth that the market is currently experiencing, licensing and permits will be vital in maintaining market growth. This limit

on sea-based fish farming is driving interest in land-based fish farming. However, there is still significant room for growth in the sea-based sector, which takes a great deal of pressure off land-based operations²³.

In the longer-term, new farming concepts and technologies can contribute to decreasing the industry's environmental impact and will also lead to the release of new areas for aquaculture in the fjords and open ocean²⁴.

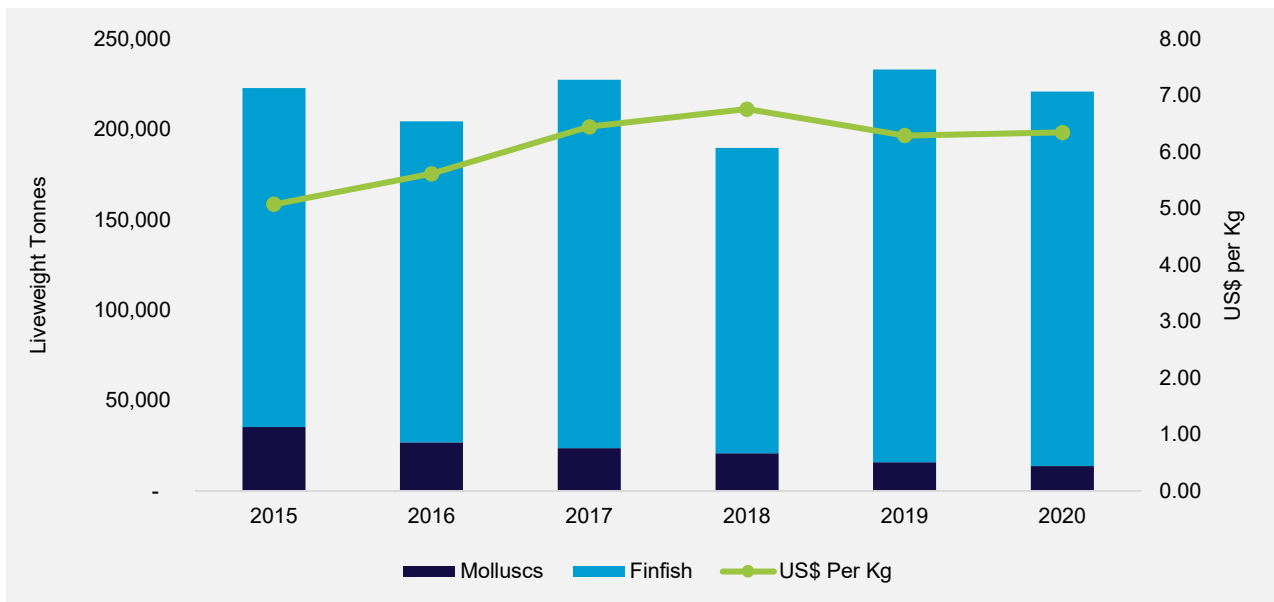
The UK

UK aquaculture production is mainly based within Scotland and the salmon sector which accounts for over 85% of production by volume, and 60% of employment within the sector²⁵. Aquaculture has grown in the last 40 years to be a vital component of the UK seafood sector. The UK fish and seafood market is currently dominated by imports (43%) and capture fisheries (40%) with aquaculture making up only 17% of domestic

supplies²⁶. The main export markets for UK salmon are the USA (34%), France (23%) and China (12%)²⁷. However, there are plans for UK salmon production to increase significantly. The Scottish aquaculture industry, supported by the Scottish Government, has set targets to develop the industry over the short to medium term. Production targets of 300–400 '000 thousand tonnes of fish and 21 thousand tonnes of shellfish are proposed for 2030²⁸.



UK Aquaculture



Source: FAO²⁹

Projections for 2030 could be in the range of 300,000 to 400,000 tonnes per annum for finfish production. In shellfish production, there is the potential to reach 21,000 tonnes of mussels per annum by 2030 and to significantly increase the value of oyster production³⁰. A production figure of 350,000 tonnes of salmon would double aquaculture's current economic value of £1.8 billion to the Scottish economy, to £3.6 billion³¹. Reaching this tonnage from current levels would require year-on-year production growth of less than 5%.

The sector directly employs over 4,500 people in its supply chain. An increase in finfish and shellfish production to approximately 300,000–400,000 tonnes and 21,000 tonnes respectively in 2030 could increase the number of jobs in the sector to approximately 18,000, with a move from production-only jobs towards job creation in the supply chain³².

Key factors driving the market include:

- Strong government support for the Scottish aquaculture industry has contributed to its growth and ongoing plans for expansion up to 2030. Aquaculture policy is devolved, and the framework differs in detail in each administration of the UK where aquaculture schemes and operations are conducted. Policy is much more fully established in Scotland than elsewhere in the UK – an effect of the concentration of the UK aquaculture industry in Scotland.

- Increasing demand for seafood for export and, domestically, a limit to the expansion of capture fisheries, and the development of technology that will reduce the environmental impact and increase the social acceptance of aquaculture.
- Climate change, energy prices, government policy and social acceptance of aquaculture will shape how aquaculture develops in the next 50 years.

There is significant potential for aquaculture to further develop within the UK, especially in semi-contained recirculating aquaculture systems (RAS) on both land and sea, and in offshore cage aquaculture. It is clear that aquaculture has a critical role to play in protecting and strengthening Scotland's rural communities and economy, both now and in the decades to come.

Challenges for the UK aquaculture sector

The global market share of Scottish salmon has fallen from around 10% in 2005 to less than 7%, as other aquaculture nations raise productivity. A variety of factors have slowed production growth in Scotland these include the lack of an industry-led, all-stakeholder growth strategy; issues around consenting for aquaculture sites and the application of planning policy; workforce issues; access to finance; and the limitations of Scotland's rural infrastructure³³.

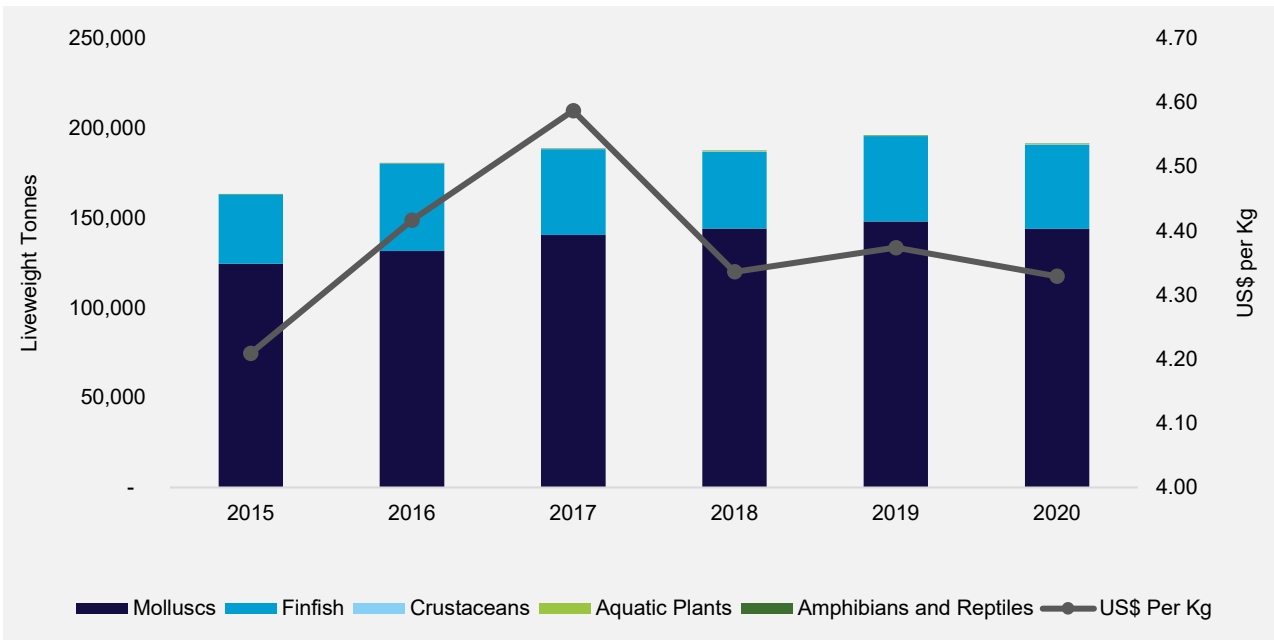


France

French aquaculture is dominated by mollusc and finfish production, with small volumes of

crustaceans, aquatic plants, amphibians, and reptiles. The key mollusc species produced are pacific cupped oysters and blue mussels, whilst rainbow trout are the main finfish species farmed.

France Aquaculture

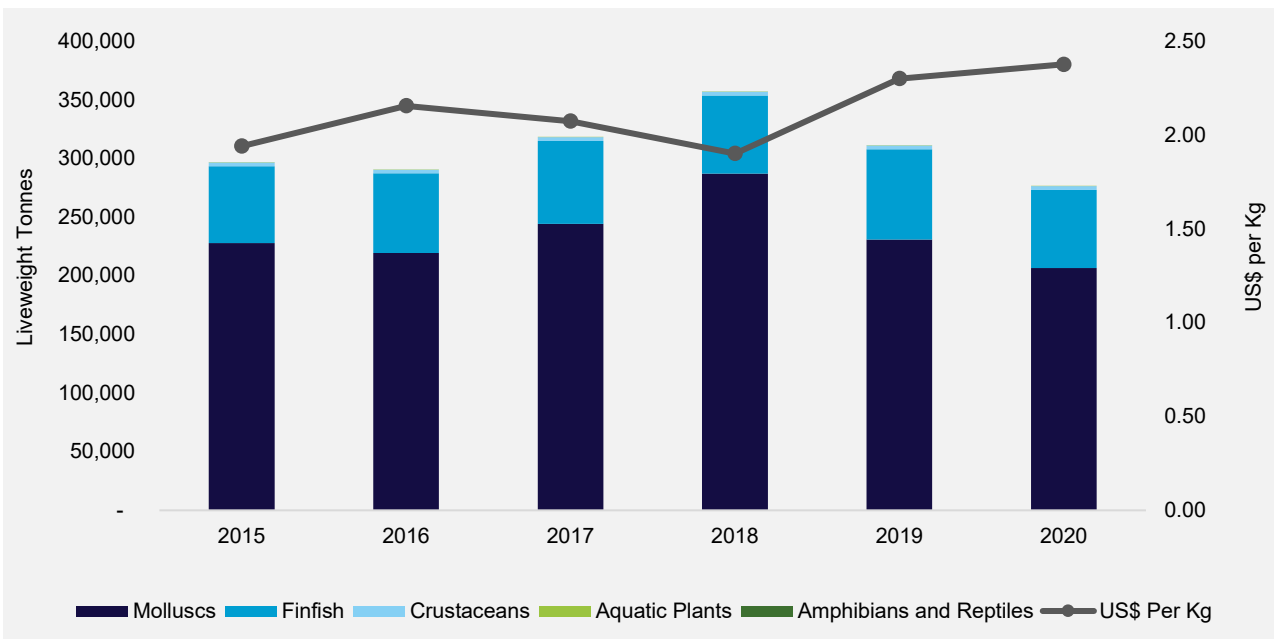


Source: FAO³⁴.

Spain

Key finfish species farmed in Spain include rainbow trout, European sea bass and turbot. Sea mussels dominate mollusc production.

Spain Aquaculture



Source: FAO³⁵.



What are the Challenges facing European Aquaculture?

The European Aquaculture sector faces several significant challenges, these include:

- High feed and labour costs mean that many aquaculture producers in Europe are uncompetitive;
- Concerns over the environmental impact of aquaculture on marine ecosystems;
- Climate change, depletion of natural resources, loss of biodiversity, food security and safety, environmental pollution and waste represent important sustainability challenges for further expansion of European aquaculture;
- Increasingly strict environmental regulations, mounting bureaucracy, and the impacts of climate change have led to a lack of investment and innovation, and to limited product diversity;
- Marine aquaculture, in the Mediterranean has not progressed significantly over the last decade, due to several factors impacting on the performance of the main fish species;
- The replacement of fish meal feeds with ingredients from plant origin has influenced FCR³⁶s, presence of mycotoxins in feed and micro ingredient deficiency. Many breeding, health and welfare issues remain unresolved and impact on productivity;
- Complicated administrative procedures related to national and regional environmental regulations were constraining aquaculture development in many EU-Mediterranean states. Fragmented approach to marketing of mariculture products requires a cooperation of different actors across the Mediterranean.

What are the opportunities for European Aquaculture?

Despite stagnant growth, there are still several growth areas within the European aquaculture sector.

Growing demand for locally produced seafood.

One in four of every seafood product consumed in Europe comes from aquaculture. However, most of the seafood consumption is covered by imports, making up around 60% of the total supply. There is a sizeable market growth potential for businesses in this sector, given that only 10% of EU seafood consumption comes from EU aquaculture.

New technologies and Species

There are opportunities in farming new and novel fish species, for example Atlantic cod.

Land-based fish farming increases in relevance

An increasing number of large-scale land-based projects have managed to raise sufficient capital and start the construction phase. Despite the progress, there are still challenges that these first movers must overcome – the industry is experiencing that things take time, challenging investor confidence. We still believe that we will see increasing salmon production volumes from land-based facilities in the years to come, but it is still uncertain at what pace this will be.

Seaweed cultivation sees significant potential for growth

Norwegian seaweed cultivation experienced rapid growth in 2020. Norwegian seaweed farmers believe that volumes can quite easily be increased by utilizing more of the current licenses. However, the industry is still characterized by unstandardized production technologies and low volumes. Farmers are waiting for the market to demand more Norwegian seaweed, whereas the market is waiting for farmers to produce larger and more stable volumes. Increased demand for plant-based seafood products may help drive demand in this market segment.





The Middle East

Overview

The aquaculture industry in the Middle East (ME) is still relatively new compared to other parts of the world, making this region highly dependent on

other countries for food and feed. Key aquaculture-producing countries within the region include Saudi Arabia, Turkey, and Iran, however many other countries such as Oman and the UAE are investing in and expanding aquaculture in a drive for sustainable food production.

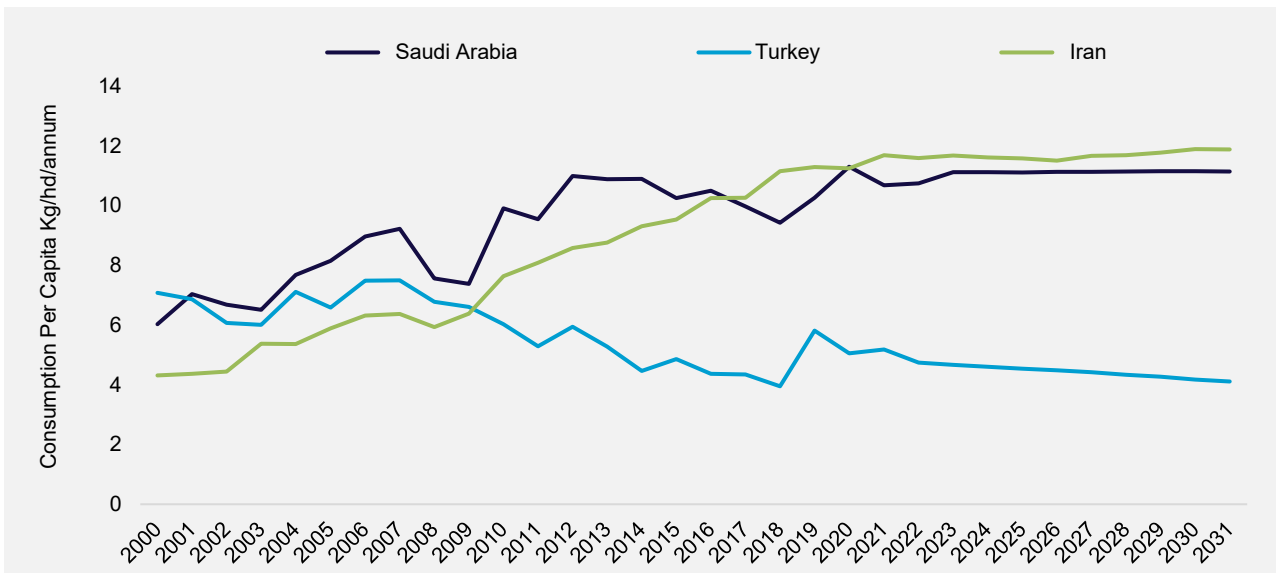
	2016	2021	2026	2031	2016-2021 CAGR % p.a.	2021-2026 CAGR % p.a.
Saudi Arabia	40	110	123	137	10.7%	1.2%
Turkey	253	450	412	390	5.9%	-0.9%
Iran	398	500	536	596	2.3%	0.7%

Source: OECD³⁷

Overall, small pelagic fish such as sardines and mackerel and large pelagic fish such as tuna and barracuda are the most highly consumed species throughout the Middle East³⁸. Freshwater species such as tilapia and Nile perch are also popular and consumed significantly by the Egyptians, Iranians, and Iraqis. The richer oil producing GCC states highly value their local demersal species such as grouper, travelly, emperor and pomfret. Imports of high-value seafood

products such as scallops, shrimp, lobsters, and caviar have increased due to a growing economy and tourism sector. As in other parts of the world, consumers in the Middle East are increasingly purchasing their seafood from supermarkets and shopping malls. Though not widely available, online fish retail stores are also a growing market presence and work to deliver seafood directly to households in metropolitan cities such as Dubai³⁹.

Middle East Fish Consumption



Source: OECD⁴⁰

A large section of consumers prefers wild caught due to the perception that it is more natural, fresher, tastier, and healthier. Another emerging trend is consumer interest in sustainability⁴¹. In the UAE, the government launched a campaign in partnership with the WWF entitled “Choose Wisely,” educating consumers on the sustainability of fish. Like other

sustainability guides, the campaign provides consumers with a colour-coded system to provide information about which species are over-exploited, considered sustainable or good alternatives. These colour codes have been placed in fish retail areas and on restaurant menus in the UAE

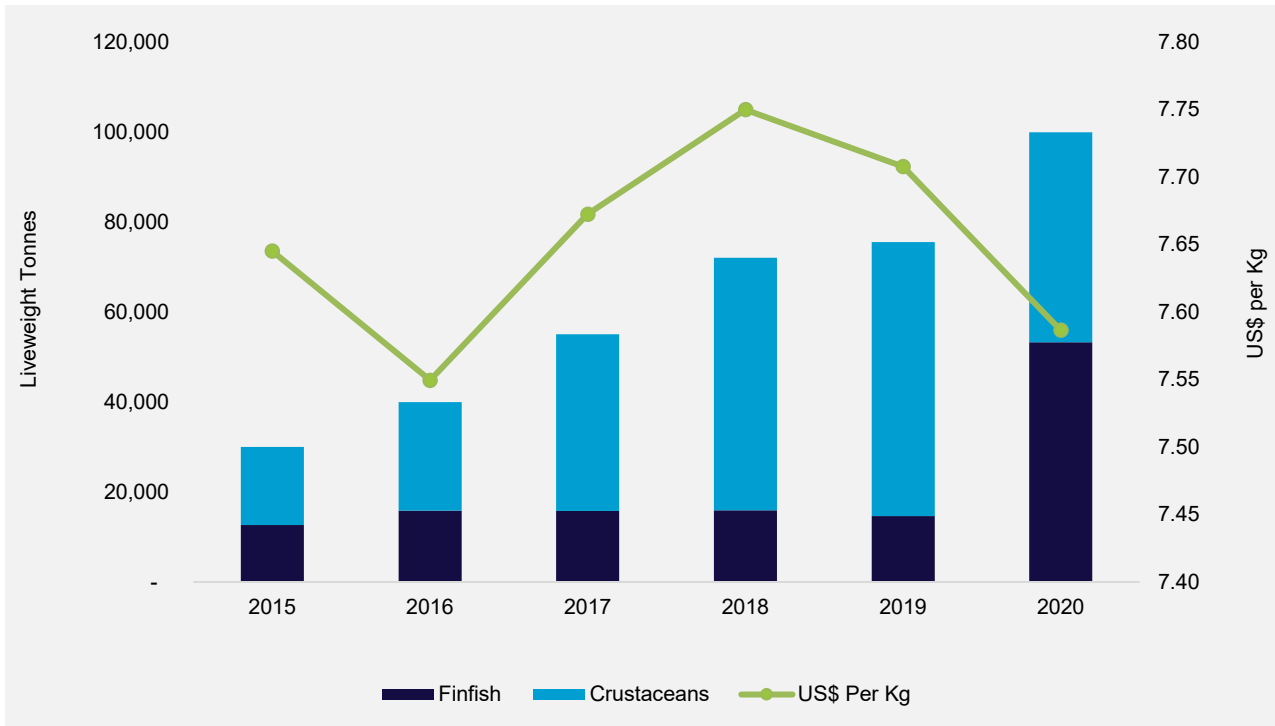


Saudi Arabia

There has been rapid growth in the Saudi Arabian aquaculture sector over the last 5 years – with production growing at a rate of 10.7% p.a. However, the OECD forecast that over the next

five years growth will fall to 1.2% p.a. A wide range of finfish species are farmed within Saudi Arabia including, tilapias, carp, barramundi (giant seaperch) and catfish. Crustacean production is also growing rapidly, with the sector dominated by whiteleg shrimp.

Saudi Arabia Aquaculture



Source: FAO⁴².

Saudi Arabia's megacity project Neom and Tabuk Fish Company signed an agreement to develop the Middle East and North Africa's biggest fish farm as the kingdom diversifies its economy⁴³. The agreement aims to expand local aquaculture production and apply the latest fish farming technology. The kingdom is developing several new projects including Neom, a \$500 billion futuristic project consisting of a nature reserve, coral reefs, and heritage sites on about 50 islands off the Red Sea coast.

Under Neom's new agreement with Tabuk Fish Company, the hatchery will operate with a capacity of 70 million fingerlings, making it the largest in the region. The hatchery will focus on improving the production of local fish species in the Red Sea to contribute to fulfilling the kingdom's goal of producing 600,000 tonnes of fish products by 2030. Seafood consumption in the kingdom is projected to grow 7.4% annually, with sustainable aquaculture growth key to meeting local and global demand for seafood.

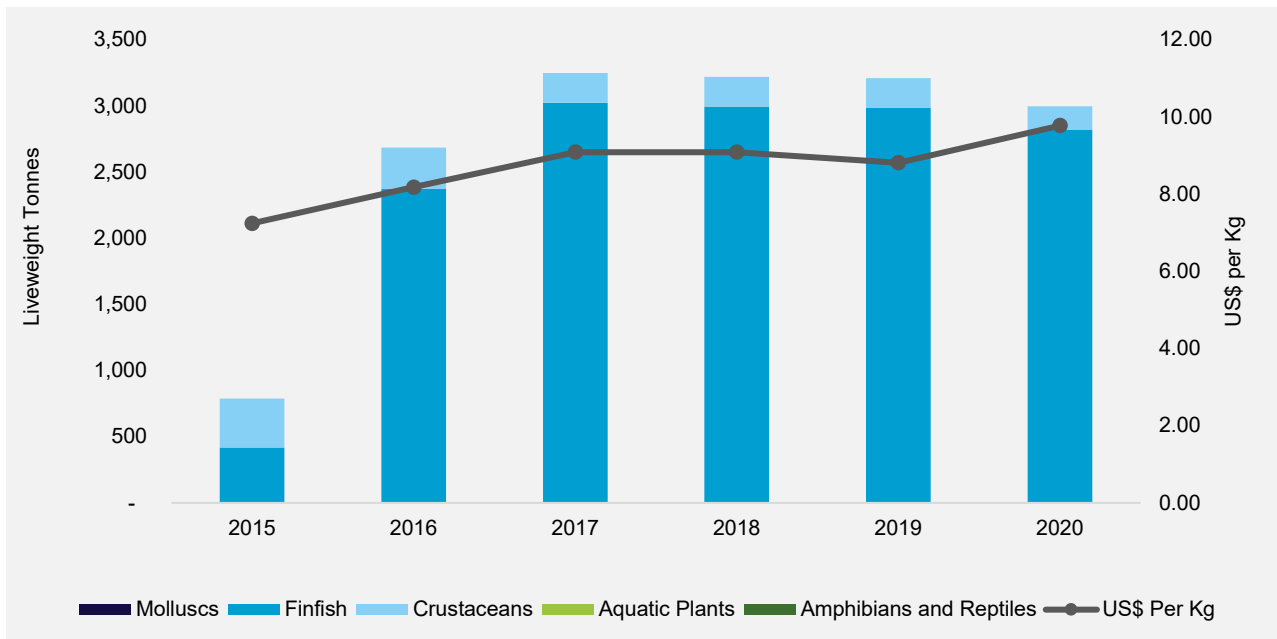
UAE

The UAE Fisheries and Aquaculture Market is projected to register a CAGR of 4.7% during 2022-2027⁴⁴. The UAE aquaculture sector produces a diverse range of species, including Atlantic salmon, Orange Spotted-Grouper, European Seabass and Gilthead Sea bream. Crustaceans (Indian White Prawn) and a small volume of molluscs are also produced.

The COVID-19 pandemic had a minor impact on UAE fisheries and the aquaculture market. The country has faced temporary export and import challenges due to lockdown restrictions. To overcome this, the government has dedicated specific trips through national carriers to fish-producing nations such as Turkey and Greece to import seafood. It has also taken the initiative to develop internet sales of fish and home delivery to consumers.



UAE Aquaculture



Source: FAO⁴⁵.

The UAE government is focusing on increasing aquaculture projects as it is a viable source for improving the region's food security which is the major concern in the country. Rapid growth and development and the diverse population of the UAE, coupled with the rising consumption of seafood, are likely to be the major factor that is driving the fisheries and aquaculture sector. The tourist visits and lower-income disparity among the population increased fuel consumption, thus driving the market.

With the pivotal role fisheries and aquaculture play in achieving self-sufficiency and meeting

human protein needs, the government is focusing on the development of the industry, which has led to the establishment of the marine research centre. Freshwater aquaculture in the country is limited only to a few irrigation channels, ponds, and tanks located near agricultural farms.

Expansion is likely as people are becoming aware of the dual benefits of rearing fish such as tilapia in such facilities, which will not only produce fish but also fertilize the irrigation water. All these factors are likely to drive the fisheries and aquaculture market in the UAE.



1Aquaponics in the UAE

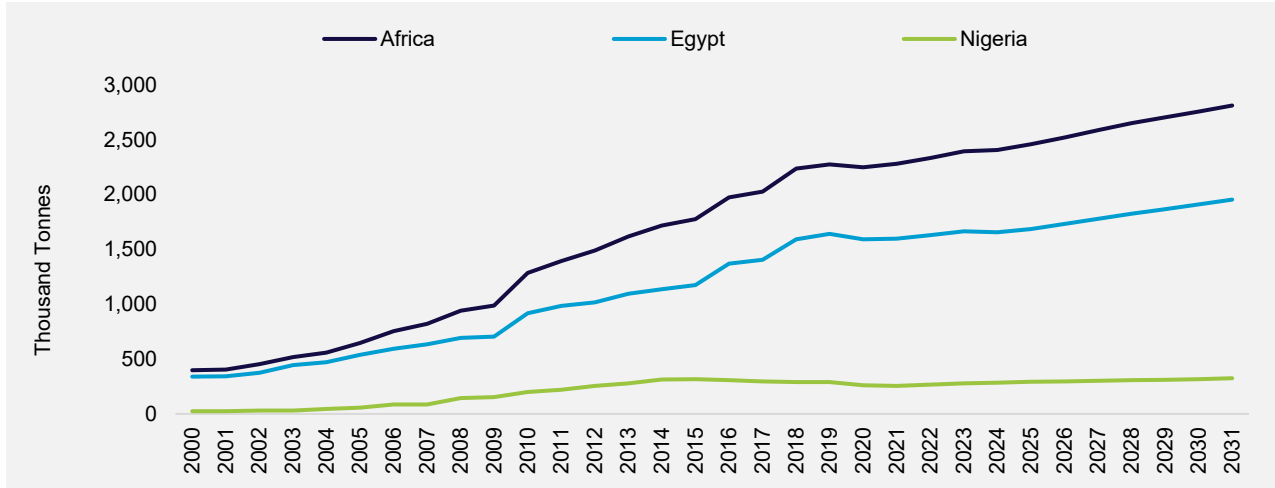


Africa

Aquaculture production across Africa is growing at a rate of 1.0% p.a. driven by a rising population, economic growth, and demand for

protein. Egypt is the largest producer followed by Nigeria. Other countries in the region where aquaculture is expanding rapidly include Ethiopia and South Africa.

African Aquaculture Production

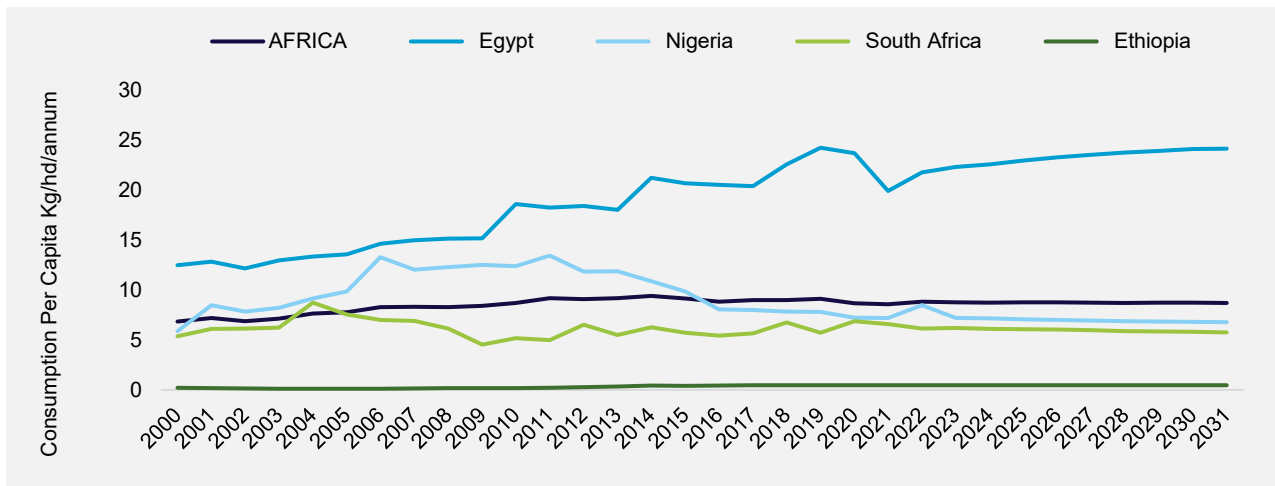


Source: OECD⁴⁶.

	2016	2021	2026	2031	2016-2021 CAGR % p.a.	2021-2026 CAGR % p.a.
Africa	1 977	2 283	2 523	2 815	1.4%	1.0%
Egypt	1 371	1 600	1 732	1 955	1.6%	0.8%
Nigeria	307	255	297	324	-1.8%	1.5%
Ethiopia	0	1	1	2	18.8%	6.0%
South Africa	6	7	10	12	2.4%	3.0%
Other countries	294	420	483	523	3.6%	1.4%

Source: OECD⁴⁷

African Fish Consumption



Source: OECD⁴⁸.



Rising population growth and income levels imply that the region will need 2.49 million tonnes of fish to fill the demand-supply gaps.

Freshwater and marine aquaculture have extensive growth potential all across Africa and could contribute to feeding the continent's rapidly increasing population. However, the challenge is to find solutions to ensure seafood farming expands sustainably in the next years⁴⁹.

Aquaculture was first introduced to Africa over 50 years ago, but it has not reached its full potential yet when it comes to food security and economic growth. At the moment, Africa contributes around 2.5% to the world's aquaculture production, although there has been an increase in investments in recent years, especially in Egypt,

Nigeria, Uganda and Ghana. The majority of production is from inland freshwater systems and is mostly dominated by tilapia and African catfish, although seaweed and shellfish are emerging sectors.

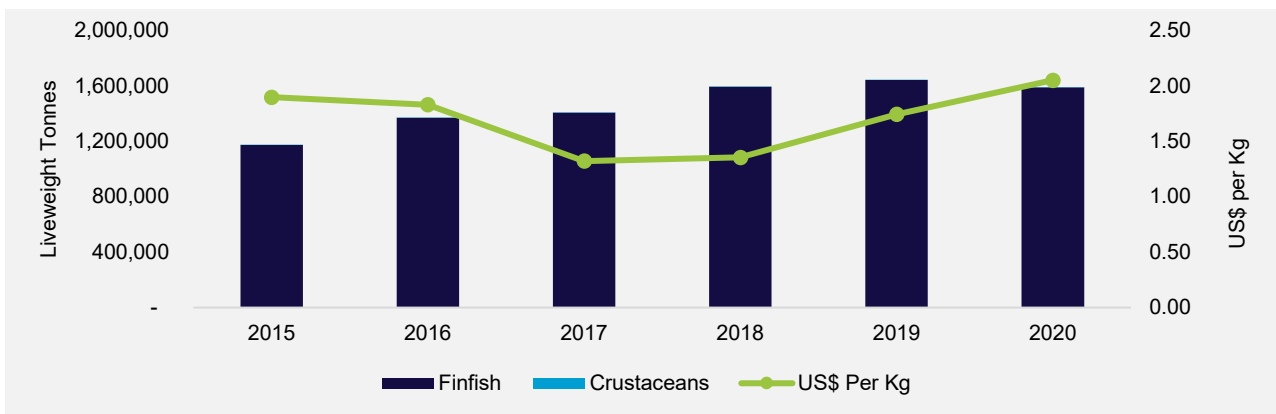
Fisheries and aquaculture make a critical contribution to food security and livelihoods in Africa and could do more to meet development goals with well-designed policies and investments. Continued rapid population growth combined with robust income growth will fuel strong increases in demand for fish through the projection period analysed in this research. Given a limited potential for growth in African capture fisheries, the rapid expansion of aquaculture will be needed to meet this increased fish demand⁵⁰.

Egypt

Aquaculture has been practised in Egypt for millennia, but modern approaches have only

recently been adopted to maximize its output⁵¹. Finfish production dominates, with key species being tilapias and carp.

Egypt Aquaculture

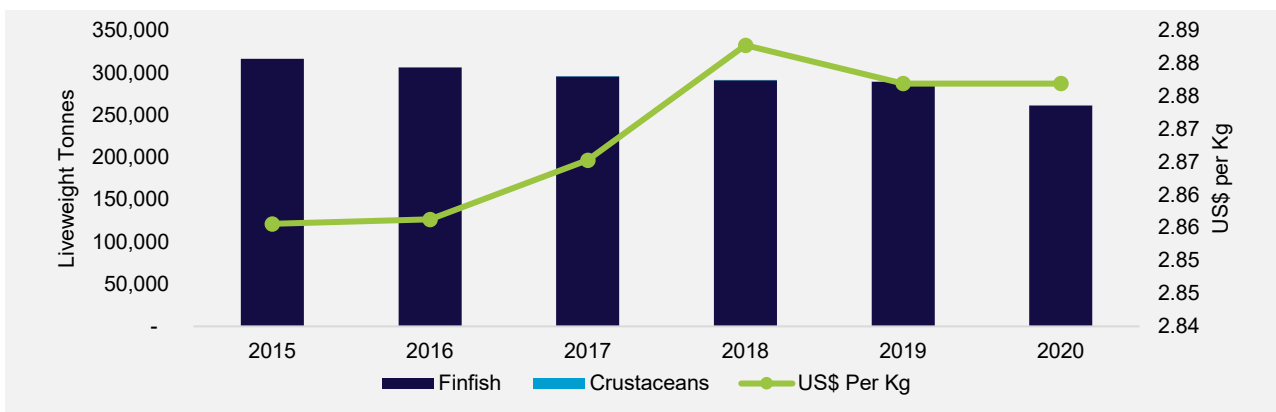


Nigeria

Aquaculture in Nigeria is a growing industry, which is expected to continue due to the need to meet up with a large deficit (over a million tonnes)

between fish production and consumption. The aquaculture industry in Nigeria is restricted to inland freshwater aquaculture, despite abundant marine water resources only a few species such as catfishes, tilapia and carp are being cultured⁵².

Nigeria Aquaculture



Source: FAO⁵³.



What are the Challenges facing African Aquaculture?

Despite rapid growth the aquaculture sector in Africa faces several important challenges:

- There is poor access to quality fish feed, eggs, and fry, in some developing countries including those within Africa⁵⁴. For example, the Kenyan aquaculture sector still suffers from an inadequate supply of certified quality seed fish and feed, incomprehensive aquaculture policy, and low funding for research⁵⁵.
- According to Innovate UK the aquaculture sector within Africa faces needs to scale up production, improve genetics and the health and welfare of farmed fish⁵⁶.

Scaling Up

Many farmers in Africa operate on a small scale, either farming for their own family or selling locally. For them to scale up, there needs to be a huge improvement in infrastructure and access to markets. To grow, the industry requires investments which enable producers to scale up production. This would give access to

sustainable, affordable inputs which will support the delivery of high-quality fish, shellfish, and seaweed to the whole of Africa and enable an increase in export. This needs to be in combination with a policy framework that enables commercial aquaculture production, trade, and investment.

Genetics

Producing fish that grow rapidly, are hardier and more disease resistant can help small-scale farmers get a greater return on their investment and can reduce prices for resource-poor consumers. Improved strains can offer a more sustainable approach to providing healthy and nutritious food.

Genetics in African aquaculture is underdeveloped and there is huge growth potential, not just in fish species but in shellfish and seaweed. In the 1980s, WorldFish and partners produced the Genetically Improved Farmed Tilapia strain (GIFT) which has benefitted millions in Africa and across the world⁵⁷. This successful project is an example of how selective breeding can transform aquaculture in Africa and change lives for the better.





Health and welfare

Aquaculture systems are complex and prone to issues with disease, which in turn affects health and welfare. With increased regional and international trade comes an increased risk of disease spreading and a growing need for surveillance, diagnosis, and testing. Transfer of knowledge and expertise is particularly important in health and welfare as the African Aquaculture industry grows and is at risk of introducing new diseases.

Feed still stands out as aquaculture's primary production expense – and the sector is on the lookout for ways to use it more efficiently. For industry insiders, adopting “precision nutrition” – or feed that is formulated to unlock the potential of fish and crustacean DNA, microbiomes, and metabolic responses to prevent disease and grow efficiently is the next farming milestone⁵⁸. Like other areas of the industry, nutrition experts are turning to tech and research advancements to bring precision nutrition strategies online.

New protein sources, for both non-carnivorous and carnivorous fish, will allow the aquaculture industry to grow more sustainably. Examples of new protein sources include sugarcane waste converted to oil by microalgae, insects and bacterial protein made from natural gas. New feed is required as the traditional sources of fish oil and fish meal are diminishing, with more species going directly to human consumption.

Automation will minimize the requirement for people in high-risk operations and enable remote

control. One application is the shift from on-site to a more off-site feeding control regime, where the operator is located on a nearby feed barge or onshore. This approach reduces the potential for safety-related incidents, especially during harsh weather conditions.

There is potential for Remote Operated Vehicles (ROV), operating inside the cage to ensure net integrity and perform net cleaning. Towards 2030 we will see the use of more sensors, technologies to monitor fish health, and technologies for counting and treating lice on salmon. Uncrewed vehicles have already been used to support coastal aquaculture in undertaking the following⁵⁹:

- Site Planning – gathering data to better inform decisions regarding the environmental feasibility of starting a coastal aquaculture operation at a particular location;
- Cage/Net Inspection – detecting flaws in aquaculture cages/nets to proactively mitigate risks associated with a broken cage/net, such as fish escaping or predatory species entering the system;
- Environmental Monitoring – keeping track of environmental conditions, such as temperature, salinity, algal concentrations, etc., to predict the health of the organisms and inform if intervention is needed;
- Disaster Assessment and Risk Reduction – inspecting an area post-disaster to give insight.





Integrated multitrophic solutions aquaculture.

Local ecosystems can be created to maximize the use of valuable input resources and minimize unwanted environmental impacts. This requires more complex setups than traditional aquaculture and combines farming of complementary organisms at different levels in the food chain, with waste from one species acting as a food source for another. One example of such an integrated production setup could include Atlantic salmon (open cage), combined with kelp (inorganic nutrient uptake), and scallops (organic filter feeder). This recycling of nutrients reduces the waste products in the marine environment, including the ocean floor. However, due to high costs, it does not seem likely that these setups will be installed at scale in offshore waters in the next decade.

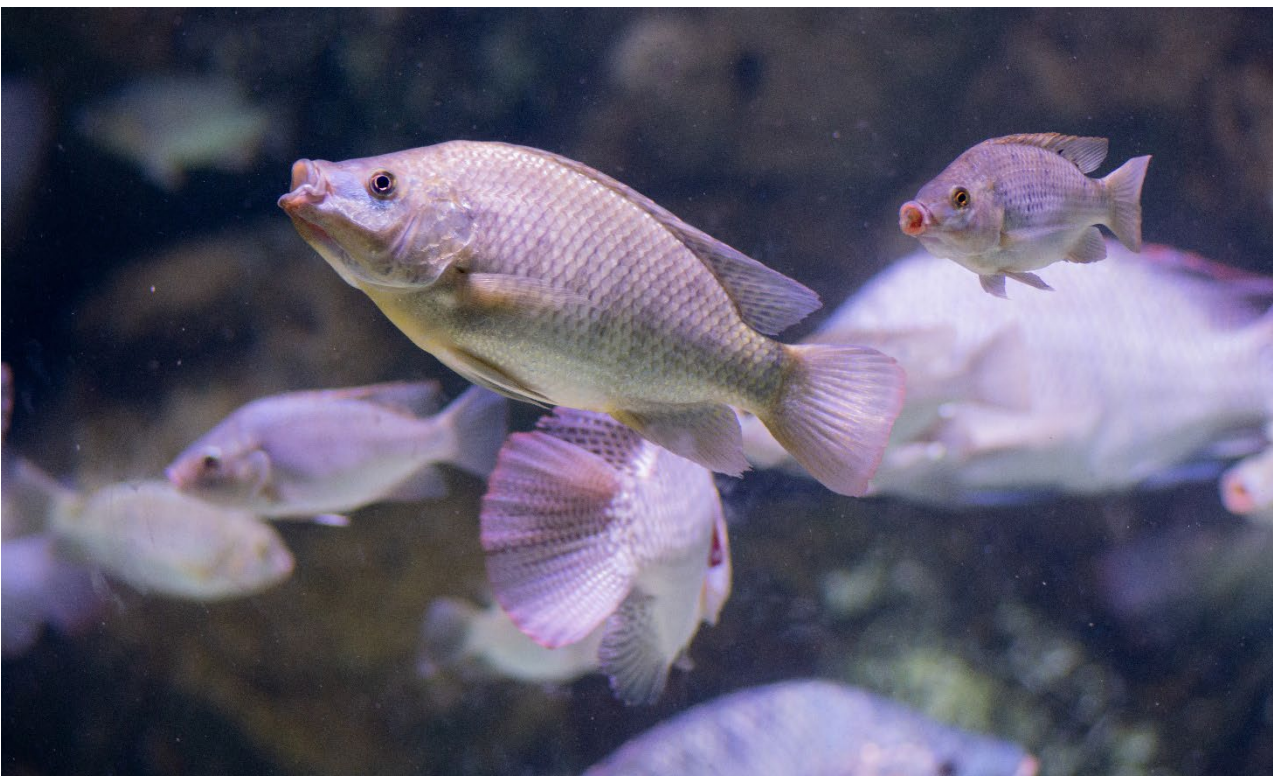
Offshore fish farming

Recent studies have highlighted the vast potential for food production in offshore areas. Most coastal countries could develop domestic marine aquaculture markets that would meet the full seafood consumption requirements of their population. For example, should Indonesia utilize 1% of its ocean area for fish farming, it could increase the supply of fish to its population sixfold⁶⁰.

Technical solutions are being developed to move fish farms offshore to more exposed areas with

harsher environmental conditions. The fish farm shall still cater for the generic tasks such as transport and transfer of fish; feed delivery, feeding; biomass control; fish health monitoring; water quality monitoring; asset integrity; limit the effect on the surrounding environment; treatment of diseases and parasites; removal of dead fish; and removal and transport of fish slaughter. This means that fish farms should be designed to handle the increased wave heights, larger environmental loads, larger currents, loads from larger vessels, and more complex logistics. In addition, fish welfare must be maintained in the more challenging environmental conditions. Therefore, the units will be larger and more capital intensive compared to conventional fish farms with a more challenging logistics chain and a tighter weather window for access to the installations. Innovations in this area benefit from learnings from the shipping and offshore oil and gas sectors.

The drivers for moving towards farming in more exposed areas or further offshore are coastal/inshore area competition, the need to reduce environmental loads from farming, and the wish to increase the distance between sites to limit exposure to diseases and parasites from neighbouring farms. Aquaculture in exposed marine and offshore areas restricts the range of potentially farmable organisms. Some early movers have started fish farming in rougher areas offshore, representing the first steps towards the next-generation aquaculture and we expect an increased deployment towards 2030.





Recirculating aquaculture systems (RAS)

Recirculating aquaculture systems (RAS) will be a game changer for some parts of the aquaculture industry. The technology makes it possible to grow fish in places where water is scarce. Secondly, RAS systems can grow larger fish in tanks and establish a full-growth cycle. A series of treatment processes are used to maintain water quality. After leaving the vessel holding fish the water is first treated for solids before entering a biofilter to convert ammonia, next degassing and oxygenation occur, often followed by heating/cooling and sterilization. These processes can be completed by using a variety of different methods and equipment but

are all needed to ensure a healthy environment that maximizes fish growth and health. High capital costs as well as high operating cost costs due to electricity and system maintenance has held back the development.

RAS installations can be delivered as turn-key installations, with the possibility of adjusting production capacity by adding modules. RAS technology can also be used to produce fish close to key urban markets. Therefore, there will be increased roll-out of RAS during the coming decade, benefitting both onshore and offshore aquaculture producers. However, many hazards need to be controlled, such as animal welfare, persistent infective diseases, and water quality.



Recirculating Aquaculture System (RAS)



Risks and Uncertainties

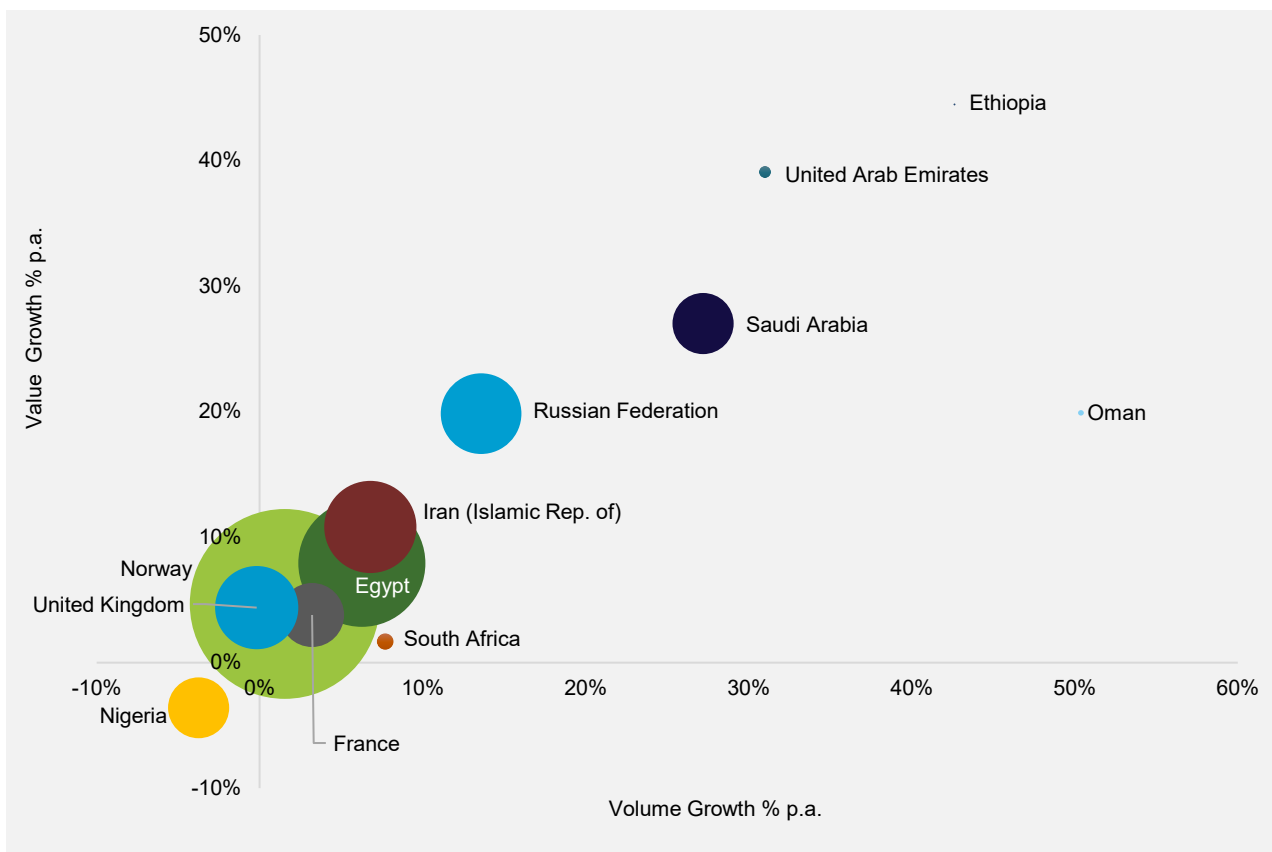
Whilst many innovative technologies are responses to increased risks and challenges within the aquaculture sector some new technology is also introducing new risk elements through bigger sites and more complex systems.

The regulation of aquaculture is also complex. Regional planning, spatial planning, industrial development, and environmental issues all impact on the ability of aquaculture to expand. Beyond zoning considerations, public regulation also includes requirements that such operations address concerns with environmental issues, work safety, fish welfare, and production volumes. Without commitment from national administrations growth within the sector will be hampered.

Conclusion

Whilst the aquaculture sector is rapidly expanding within the Middle East driven by government policies aimed at promoting sustainable food production, the sector remains minor compared with major aquaculture producers such as Norway, the UK and France where expansion is limited by environmental concerns, and the availability of site licenses.

Country Summary Volume Growth Versus Value Growth



Source: FAO⁶¹.

Aquaculture is a rapidly expanding sector driven largely by declining wild capture fish production, and increased demand for protein, especially in developing and emerging countries. In addition,

new technology is providing opportunities leading to the growth in the use of land-based and offshore fish farming systems, precision technology, and advances in nutrition.



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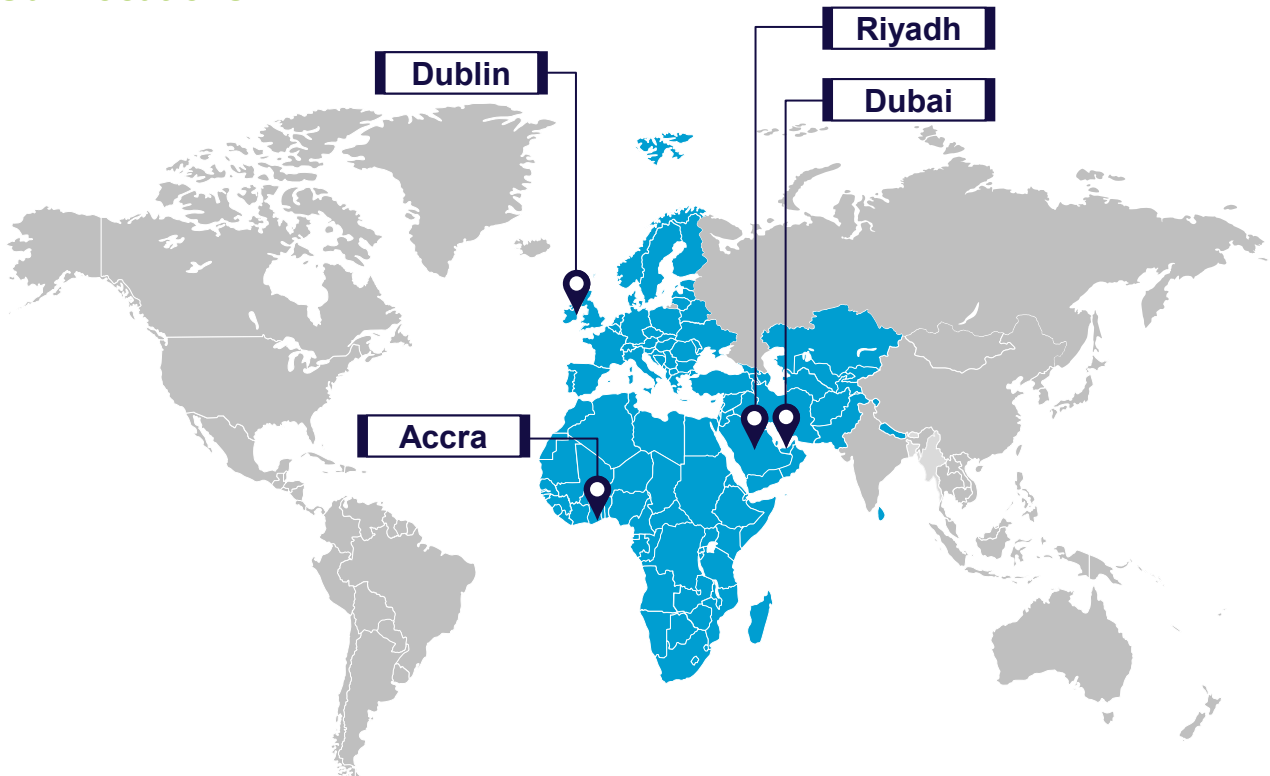
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