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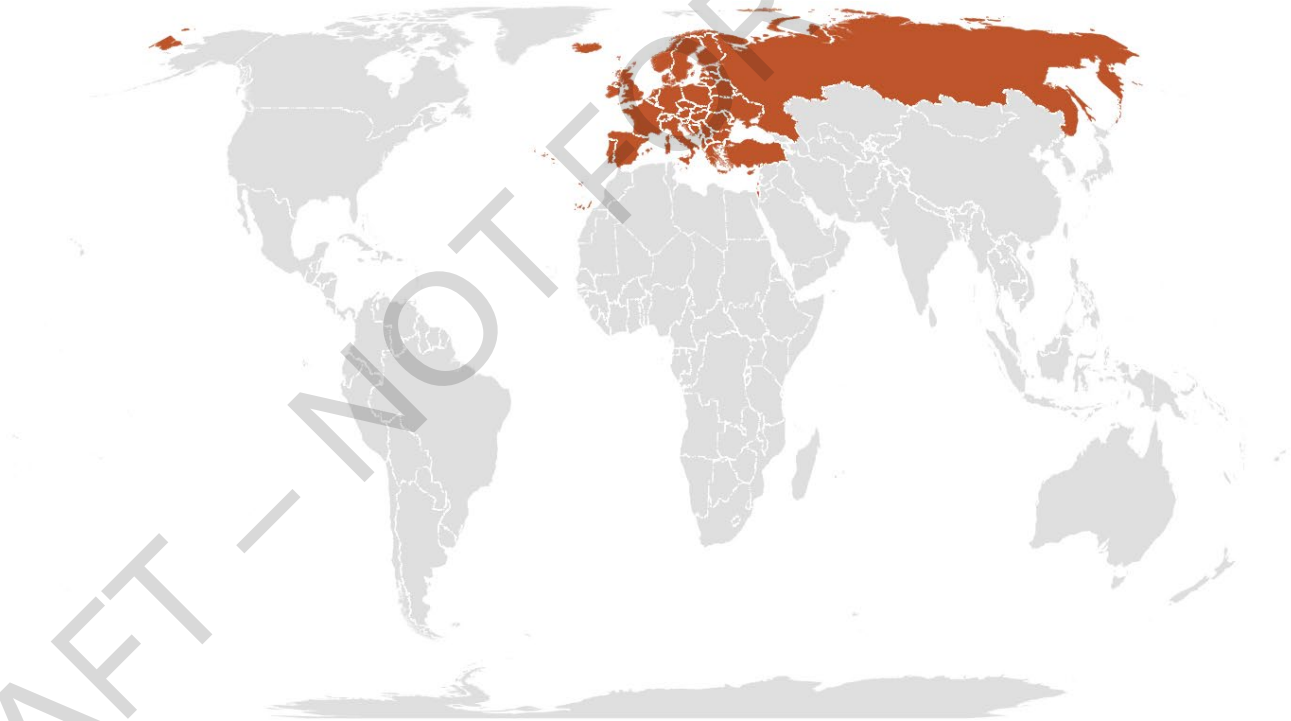

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REGIONAL REVIEW ON STATUS AND TRENDS IN AQUACULTURE DEVELOPMENT IN EUROPE – 2020

by

Courtney Hough
FAO Consultant
Former General Secretary of the Federation of European Aquaculture Producers
Belgium

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Preparation of this document

Continuing the FAO's traditional aquaculture regional and global review process, six regional reviews on aquaculture were compiled in 2020 and were published in 2021. This is the fourth review in the series, the first, second and third having been published in 2006, 2011 and 2017 with the 2017 publication covering the period to 2015 (FAO, 2017a) while similar global and regional aquaculture reviews were developed in 1995, 1997 and 2000. Previous reviews, along with recordings of the aquaculture review webinars held 26–29 October 2020, can be found here: www.fao.org/fishery/regional-aquaculture-reviews/aquaculture-reviews-home/en/

Data used in this regional aquaculture review are 2018 data that derive mainly from FAO fisheries and aquaculture statistics (FishStat sources), including the FAO Yearbook Fishery and Aquaculture Statistics, accessible through online query panels and FishStatJ. A briefdescription on the collection and consultation of FAO statistical data is provided in Annex 1.

This Regional Review of European Aquaculture was prepared by Courtney Hough, who recently retired from his professional positions with the Federation of European Aquaculture Producers and the European Aquaculture Technology and Innovation Platform. Significant data and inputs for the markets and trade section were prepared by Felix Dent (Globefish consultant). The author acknowledges and appreciates the specific and long-term contributions of many experts and colleagues active in European aquaculture who have assisted in the provision of data, suggestions and views before and during the preparation of this review, including:

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Abstract

This review reports on aquaculture development trends and challenges during 2000–2018 in the European Region covering 51 countries including European Union member states. Aquaculture production in the European Region is composed of marine molluscs and diadromous, marine and freshwater fish. It reached 3.4 million tonnes in 2018, while having a value of USD 16.6 billion. Atlantic salmon and rainbow trout combine to give nearly two million tonnes, with molluscs providing 0.7 million tonnes; marine fish species supplied 0.4 million tonnes and freshwater fish 0.3 million tonnes. In Europe, the strongest aquaculture growth has been seen in non-European Union states (e.g. Norway, Turkey, Russian Federation) while several European Union states have diminished production (e.g. France, Netherlands, Italy). The growth in value (5.8 percent) is higher than production (0.9 percent), which is now dominated by salmonids (nearly 60 percent), primarily Atlantic salmon. Mediterranean marine fish farming is mainly for gilthead seabream and European seabass. European cyprinid production in freshwater has increased slightly, where the Russian Federation, Czechia and Poland are the biggest producers. Mussels are the principal shellfish reared, led by Spain, followed by oysters in France and clams in Italy. While publicly quoted companies have led salmon development in Northern Europe, elsewhere aquaculture is done, with few exceptions, by SMEs and micro-enterprises. Mechanisms for financial support exist for aquaculture development throughout Europe but these have not been matched by anticipated results. When unpredictable and time-consuming licensing procedures are combined with extreme competition for space and strict environmental regulations, both growth and investments are discouraged. Technology development focus has been given to structures appropriate for marine off-shore or 'open ocean' operation. The use of recirculating aquaculture systems (RAS) for large operations has also developed, both for hatcheries and for farms. Treatment for diseases and parasites remains problematic. Use of the same vaccines, veterinary treatments and disinfectants is not standardised, restricting the best health and welfare practices. Access to appropriate and efficient ingredients for formulated feeds remains a key issue for European fish farming, directly influencing productivity and profitability. The European Union is the world's largest single market for seafood and the most important destination for European aquaculture production. With preferences declared for wild products vs. farmed, the habits of the European consumer have been studied, indicating evolving influences on purchase decisions. These include the use of additives, food miles, climate change, acceptance of manufacturing practices, cost and access as well as health benefits. Adapting aquaculture production to consumer preferences and sensitivities means being able to provide stable and sustainable production, giving safe and high-quality food at affordable prices, and will require sectoral communication to improve public perception. Aquaculture policy development at the European level has been positive in many cases but has rarely been translated into visible development actions in certain nations. Aquaculture development strategies have been made throughout Europe, to support production increase, and address stagnation and reduction in performance. However, competition for space, licensing and public acceptance are blocks to predictable growth. Nonetheless, leading European public aquaculture, feed and equipment companies are active at the global level. International cooperation actions have been achieved or are ongoing to support European interests in the global development of aquaculture.

Key words: *aquaculture development, Europe, production trends, value, markets, major commodities, consumer preferences, technology developments, external pressures, governance, policies, strategies*

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Abbreviations and acronyms

AAC	Aquaculture Advisory Council
AAGR	Average Annual Growth Rate
APR	Annual Percent Rate: average annual compounded growth rate in percent
ASC	Aquaculture Stewardship Council
AZA	Allocated Zone for Aquaculture
CAGR	Compound Annual Growth Rate
CFP	Common Fisheries Policy
EATiP	European Aquaculture Technology and Innovation Platform
EBIT	Earnings Before Interest and Taxes
EC	European Commission
EFSA	European Food Safety Authority
EIFAAC	European Inland Fisheries and Aquaculture Advisory Commission
EMFF	European Maritime and Fisheries Fund
EMPA	European Mollusc Producers Organisation
EPA	eicosapentaenoic acid
EU	European Union
EUROFISH	International Organization for the Development of Fisheries and Aquaculture in Europe
FAO	Food and Agriculture Organization of the United Nations
FEAP	Federation of European Aquaculture Producers
FEI	Future Expectations Indicator
FLAG	Fisheries Local Action Group
FTE	Full Time Equivalent
GDP	Gross Domestic Product
GFCM	General Fisheries Commission for the Mediterranean
ICES	International Council for the Exploration of the Sea
IMTA	Integrated Multi-Trophic Aquaculture systems
IUCN	International Union for the Conservation of Nature
LC-PUFAs	long-chain polyunsaturated fatty acids
LSR	Large Scale Retailers (Supermarket chains)
OECD	The Organisation for Economic Co-operation and Development
PAP	Processed Animal Protein
PEF	Product Environmental Footprint
PPP	Purchasing Power Parity
RAS	Recirculating Aquaculture Systems
R&D	Research and Development
SAM	Scientific Advice Mechanism
SRIA	Strategic Research and Innovation Agenda
STECF	Scientific, Technical and Economic Committee for Fisheries
UN	United Nations

Executive Summary

This review reports on aquaculture in the European Region that has been examined for the period 2000–2018. This covers 51 countries and areas, sub-divided into four geographic zones (northern, southern, western and eastern), each including member states of the European Union.

The European population is 10.9 percent of the world and the annual growth rate in population in the last decade has been around 0.3 percent compared to 1.1 percent globally, with several states showing negative population growth. Most of Europe is wealthy and while considerable inequalities exist, Gross Domestic Product (GDP) per capita has grown positively in most European states. Sustainable development prospects appear to be influenced by climate change, environmental degradation and the inefficient use of natural resources.

Aquaculture production in the European Region is composed principally of marine molluscs and diadromous, marine and freshwater fish. It reached 3.4 million tonnes in 2018 which is 4.8 percent of the global total for aquaculture fish and shellfish, while having a value of USD 16.6 billion. Ten European states produce more than 50 000 tonnes annually. The growth in value (5.8 percent) is higher than production (0.9 percent), which is now dominated by salmonids (nearly 60 percent), primarily Atlantic salmon. The financial share is taken principally by northern Europe (65 percent) followed by southern Europe (20 percent), while western and eastern Europe represent seven percent each. In 2018, the non-European Union, European countries accounted for 55 percent of production, 41.5 percent of export volume and 15.1 percent of imported volume.

The European Union is the world's largest single market for seafood and the most important destination for European aquaculture production. In 2017, supplies were 14.6 million tonnes worth USD 38 billion with a trade deficit of USD 24.5 billion. Apparent consumption in the European Union was 24.35 kg per capita of which 6.35 kg (26 percent) was from aquaculture. In the European Region, apparent consumption is lower at 19.9 kg per capita.

In Europe, the strongest aquaculture growth has been seen in non-European Union states (including Norway, Turkey and Russian Federation) while production has diminished several EU states such as France, Netherlands and Italy meaning that European Union aquaculture production fell by an average of 0.2 percent per year between 2000 and 2018.

Production of Atlantic salmon and rainbow trout combined amounted to nearly two million tonnes in 2018 (60 percent of regional 2018 production), with molluscs providing 0.7 million tonnes (20 percent) marine fish species supplying 11 percent (0.4 million tonnes) and freshwater fish nine percent (0.3 million tonnes).

Norway leads Atlantic salmon production, totalling nearly 1.6 million tonnes in 2018, when the northern European sub-region supported 51.5 percent of all European aquaculture production. Significant salmon production also takes place in the United Kingdom of Great Britain and Northern Ireland, the Faroe Islands and Iceland.

Marine fish farming in the Mediterranean basin is mainly for gilthead seabream and European seabass. Diversification efforts indicate that meagre and flatfish are developing slowly and the ranching of bluefin tuna continues, mainly in Spain. Turkey, Greece and Croatia are the leading Mediterranean fish producers. European cyprinid production in freshwater has increased slightly after a long period of stability, where the Russian Federation, Czechia and Poland are the biggest producers. Mussels are the principal shellfish reared, led by Galicia in

Spain, followed by oysters in France and clams in Italy. After a long period where shellfish aquaculture diminished, production levels have increased in recent years.

While publicly quoted companies have led salmon development in Northern Europe, in the rest of the European Region aquaculture is done, with few exceptions, by SMEs and micro-enterprises. Employment appears to have been stable in the EU, with an increase in full-time equivalents of the estimated 12 500 operating companies. Nonetheless, the contribution of aquaculture to national economies and jobs is rarely important in Europe. Only the farming of salmon, seabass and seabream have grown significantly since 2000 and the success of diversification efforts has been limited.

Declarations of positive strategic intent and mechanisms for financial support exist for aquaculture development throughout Europe but these have not been matched by anticipated results, particularly in the EU. When unpredictable and time-consuming licensing procedures are combined with extreme competition for space and strict environmental regulations, both growth and investments are discouraged. While common issues and goals have been identified for aquaculture in many areas of Europe, national responses and actions have been slow.

Success in European aquaculture has been led by salmon in northern Europe, attaining new markets with affordable products adapted to consumer preferences. Often related to the development of this sector, breeding programmes, improved feeds and technological improvements have made strong contributions and these approaches are being adapted to other sectors.

European fish farming has been dominated by five species whose market price has reduced over time, changing economic profitability and leading to a search for diversification options. New species impact has been rare, limited mainly to freshwater sturgeon for caviar production. For marine fish, the most successful have been meagre, turbot and sole but their production levels remain limited.

Inland aquaculture in ponds in central Europe is a traditional activity providing live fish to seasonal markets. The effects of predation and disease have been numerous, negatively affecting financial viability. Diversification towards multifunctional uses and acknowledgement of the ecosystem services provided options for the future of this activity.

In respect of technology development, particular focus has been given to structures appropriate for marine off-shore or ‘open ocean’ operation. In recognising the difficult operational conditions and risks, investment potential appears to be restricted to large companies where pilot and commercial activities have been started using a range of different technologies including submersible cages and ship-based containment.

The use of recirculating aquaculture systems (RAS) for large operations has also developed, both for hatcheries and for farms. A range of conditions have stimulated RAS developments, including effective parasite control actions (for example, sealice), water availability and temperature influence. Also of interest is the approach of integrated multitrophic aquaculture (IMTA) where technical advances have been made for the joint cultivation of fish, molluscs, algae and plants. Nonetheless, progress is limited by spatial competition and inappropriate licensing conditions. Land-based investments in marine aquaculture, using RAS technology, are seen to have significant potential in Europe and elsewhere and several large projects have been initiated for Atlantic salmon.

Treatment for diseases and parasites remains problematic since there is little harmonisation on access conditions to veterinary pharmaceuticals for professionals. Use of the same

vaccines, veterinary treatments and disinfectants is not standardised, restricting the best health and welfare practices.

Access to appropriate and efficient ingredients for formulated feeds remains a key issue for European fish farming, directly influencing productivity and profitability. While significant improvements have been seen for salmonids, these are less evident for other marine species. Access to insect-based raw materials for feeds gives promise, while additional initiatives, such as measuring the Product Environment Footprint of both feeds and aquaculture products, are being developed for the measurement of sustainability.

New technologies have been accompanied by improved monitoring and control systems, which have led to novel approaches to data management and analysis geared to the development of precision farming. While significant benefits could be achieved, there are many challenges for smaller businesses to adopt such solutions.

Views on the environmental integrity of European aquaculture depend on the culture system and species reared. The pond farming of cyprinids is seen as environmentally friendly and of benefit to the local ecosystem. On the other hand, more intensive aquaculture in coastal areas is often the subject of criticism. Many monitoring systems have been put into place for the measurement of negative effects such as escapes and pollution. The use of evidence-based monitoring using decision-support models can support not only the measurement of environmental integrity but also licensing systems based on observation and knowledge.

The consumption of seafood per capita is highly variable in Europe, often dependent on geography, historical access to fishery products and age. While aware of the health and wellness benefits of seafood consumption, price remains a significant barrier for the public where 68 percent would increase consumption if prices were lower.

In terms of European aquaculture, the key trade movements involve salmon, trout, seabass, seabream, mussels and oysters. Imports of aquaculture products from outside of Europe are primarily tropical shrimp, pangasius and tilapia products.

With preferences declared for wild products compared to farmed, the habits of the European consumer have been studied, indicating evolving influences on purchase decisions. These include the use of additives, food miles, climate change and the acceptance of manufacturing practices. Negative attention and effects require responses that are effective and transparent. Coordination of such actions has been difficult.

To expand its markets, it is important that aquaculture understands generational changes in food preferences and factors that influence purchase decisions. These include cost and access as well as health benefits and sustainability. Social media have become an important influence in the shaping of preferences and successful marketing.

Labels and certification have become reference points for many consumers although the plethora of labels has given rise to a degree of mistrust. The harmonisation or centralisation of references is seen as being necessary for long-term trust by the consumer. Adapting aquaculture production to consumer preferences and sensitivities means being able to provide stable and sustainable production, giving safe and high-quality food at affordable prices. Such adaptation also imposes sectoral communication to improve public perception, referencing issues that reflect sustainable and responsible development of the sector.

The economic indicators used in the European Union indicate improvements in both the financial turnover and employment in the aquaculture sector. How these will be affected by the effects of the COVID-19 pandemic and Brexit is yet to be determined.

External pressures on European aquaculture are numerous with climate change and its serious effects on the different culture environments, ranging from increased heatwaves and storm risks to freshwater drought and the eutrophication of coastal waters. Several projects have examined response scenarios, developing decision support frameworks based on observed variables. While effects may be common to European aquaculture, adaptation strategies will vary throughout the sector.

Coordinated governance of European aquaculture is supported by the multi-stakeholder Aquaculture Advisory Council (AAC) in the EU and two bodies of the FAO, the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC) and the General Fisheries Commission for the Mediterranean (GFCM). The International Organization for the Development of Fisheries and Aquaculture in Europe (Eurofish) also gives significant support through its different information services and conferences while the European Aquaculture Society provides important support for researchers through its annual Aquaculture Europe conference. Professional representation is assured within both the European Union and the European Region with dedicated associations and federations that cover different production sectors, feeds and feed ingredients. Coordinated research support is provided through several organisations which communicate with European and national agencies and research entities.

Aquaculture policy development at the European level has been positive in many cases but has rarely been translated into visible development actions in certain nations. Although the effects of the 2008 financial crisis were long-lasting, notably for financial loans, obtaining licences for operation remains a key barrier to the expansion of European production.

The Scientific Advice Mechanism of the European Commission reported on 'Food from the Oceans' in 2017, giving policy recommendations on how to increase the amount of food obtained from the oceans while maintaining healthy marine and coastal ecosystems. Sustainable marine aquaculture, including shellfish and algae culture, including the potential for feed development, was highlighted.

European aquaculture contributes to several of the United Nations (UN) Sustainable Development Goals (SDGs) and the European Union has initiated different actions that provide visible support to these, notably with Food 2030, based on assuring food and nutrition security, and the Blue Growth initiative that looks to unlock the potential of seas and oceans. Providing safe and nutritious food from European fisheries and aquaculture was identified as one of the best opportunities of these initiatives.

Aquaculture professionals are aware that the encouraging broad European agendas and strategies are often less adapted to local or national positions. The promotion and development of interest platforms that can communicate on and participate in actions relating to individual activities is important for well-coordinated growth and development actions. The European Aquaculture Technology and Innovation Platform (EATiP) has encouraged the creation of national and local mirror platforms to this end.

Aquaculture development strategies have been made throughout Europe, ranging from the European dimension to local areas. Although production has increased in certain states, stagnation and even a reduction in performance has been seen in several European countries. Competition for space, licensing and public acceptance are blocks to predictable growth. Nonetheless, leading European public aquaculture, feed and equipment companies are active at the global level. International cooperation actions have been achieved or are ongoing to support European interests in the global development of aquaculture.

1. Social and economic background of the region

1.1 STATUS AND TRENDS

1.1.1 Location and Definitions

For this regional review on aquaculture development, the term "European Region" covers the geographic sub-regions of northern Europe, southern Europe, eastern Europe and western Europe as detailed in Table 1.

Many of these are member states of the European Union and are subject to associate legislation. The review also considers specific economic information on the Eurozone states, those using the Euro currency. Unless otherwise specified, the data and statistics presented cover the complete European Region. Note that geographical coverage of this Europe regional review includes Cyprus, Israel and Turkey, and is therefore wider than the M49 standard coverage of the UN Statistics Division (UN, 2021).

TABLE 1. Countries and territories within the sub-regions of Europe

Northern Europe	Southern Europe	Eastern Europe	Western Europe
Channel Islands	Albania	Belarus	Austria°⁂
Denmark°	Andorra	Bulgaria°	Belgium°⁂
Estonia°⁂	Bosnia and Herzegovina	Czechia°	France°⁂
Faroe Islands	Croatia°	Hungary°	Germany°⁂
Finland°⁂	Cyprus°⁂	Republic of Moldova	Liechtenstein
Iceland	Gibraltar	Poland°	Luxembourg°⁂
Ireland°⁂	Greece°⁂	Romania°	Monaco
Isle of Man	Israel	Russian Federation	Netherlands°⁂
Latvia°⁂	Italy°⁂	Slovakia°⁂	Switzerland
Lithuania°⁂	Malta°⁂	Ukraine	
Norway	Montenegro		
Svalbard and Jan Mayen Islands	North Macedonia		
Sweden°	Portugal°⁂		
United Kingdom of Great Britain and Northern Ireland°	San Marino		
	Serbia		
	Slovenia°⁂		
	Spain°⁂		
	Turkey		

° = member state of the European Union; ⁂= member of the Eurozone

1.1.2 Population

The population of the European Region was 826 million in 2018, equivalent to 10.9 percent of the global figure. This is a decrease from 12.8 percent in 2000, and the average annual growth rates for different periods are given in Table 2.

While the total growth of the world's population was 24 percent over the period 2000–2018, that of the European Region was much less, recorded as 5.2 percent, and the European Union was 5.1 percent.

TABLE 2. Comparison of the average annual population growth rates for the World and Europe, 2000–2018 (percent)

	Average Annual Growth Rate (AAGR)		Total Growth
	2000–2010	2010–2018	2000–2018
World	1.1%	1.1%	24.2%
European Union	0.3%	0.2%	5.1%
European Region	0.2%	0.3%	5.2%

Source: World Bank, 2020.

Within the European Region, the highest population growth rates over the period 2000–2018 were registered for Luxembourg and Israel (33 percent), followed by Turkey (24 percent) and Ireland (22 percent). Turkey also has the highest percent of the population aged 14 or under (more than 26 percent).

Of note is the population reduction in many European states, as indicated in Table 3. This position reflects the impacts of labour migration and diminishing birth rates.

TABLE 3. European Region states with no or negative population growth from 2000 to 2018 (AAGR, percent)

State	AAGR	State	AAGR
Germany	0.0%	Albania	-0.4%
Portugal	0.0%	Croatia	-0.5%
Greece	0.0%	Ukraine	-0.5%
Poland	0.0%	Bosnia and Herzegovina	-0.7%
Russian Federation	-0.1%	Romania	-0.8%
Hungary	-0.2%	Bulgaria	-0.8%
Belarus	-0.3%	Latvia	-1.1%
Estonia	-0.3%	Lithuania	-1.3%

Source: World Bank, 2020.

1.1.3 Wealth

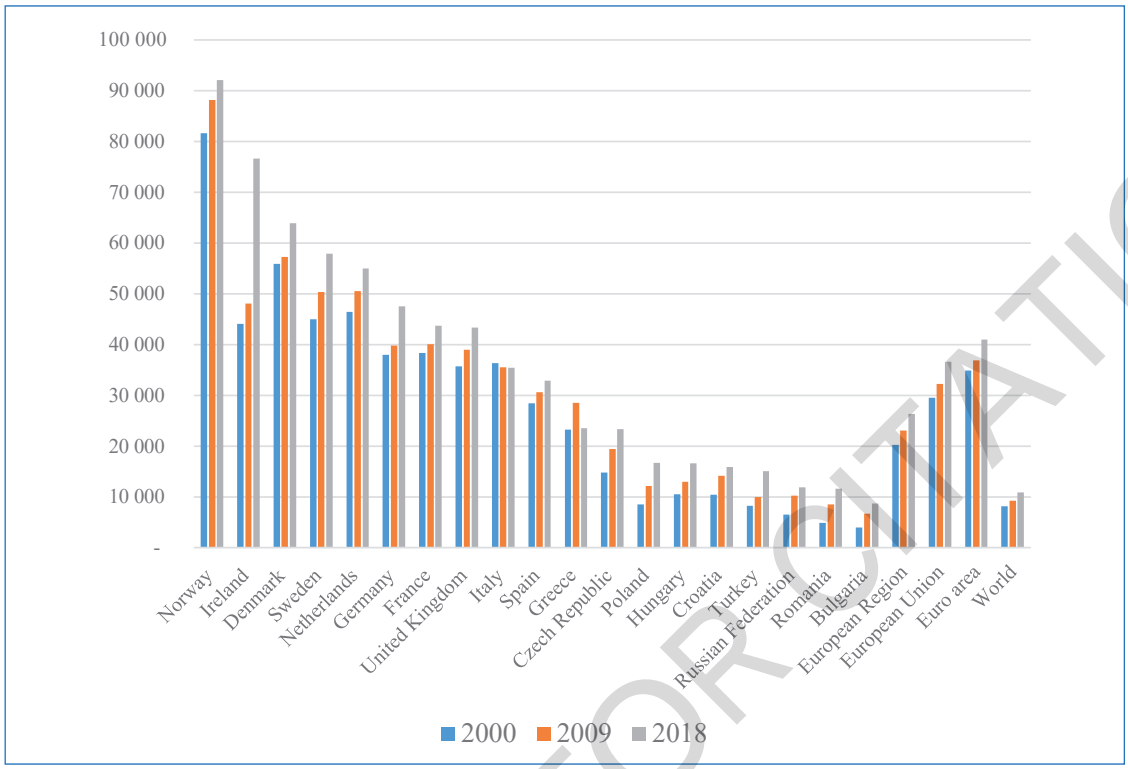
Most of the states in the European Region are wealthy but there are considerable inequalities including income and wealth, access to basic services, education and infrastructure within both the European Union and non-European Union countries. Figure 1 indicates the Gross Domestic Product per capita (in constant USD 2010) for selected states in the region (chosen on the basis of aquaculture production importance). This figure shows the affluence of many of the northern European states, while the figures for southern and eastern Europe are much lower. The decline of Italy and Greece is to be noted while the other states indicate different levels of growth in wealth during the period 2000–2018.

For the period 2000–2018, the European region GDP grew by an average of 1.46 percent per year, while European Union GDP grew by 1.2 percent per year and the Eurozone area by 0.95 percent per year. This compares to a world GDP average annual growth rate of 1.63 percent over the same period.

None of the countries in the European Region is on the 2018 FAO list of Low-Income Food-Deficit (LIFDC) countries.

When GDP is reflected in terms of purchasing power parity (PPP), an economic theory that allows comparison of the purchasing power of various world currencies to one another, the picture changes slightly. The differences between states become less marked since allowance is made for the cost of living and inflation rates within the different states. The Northern and

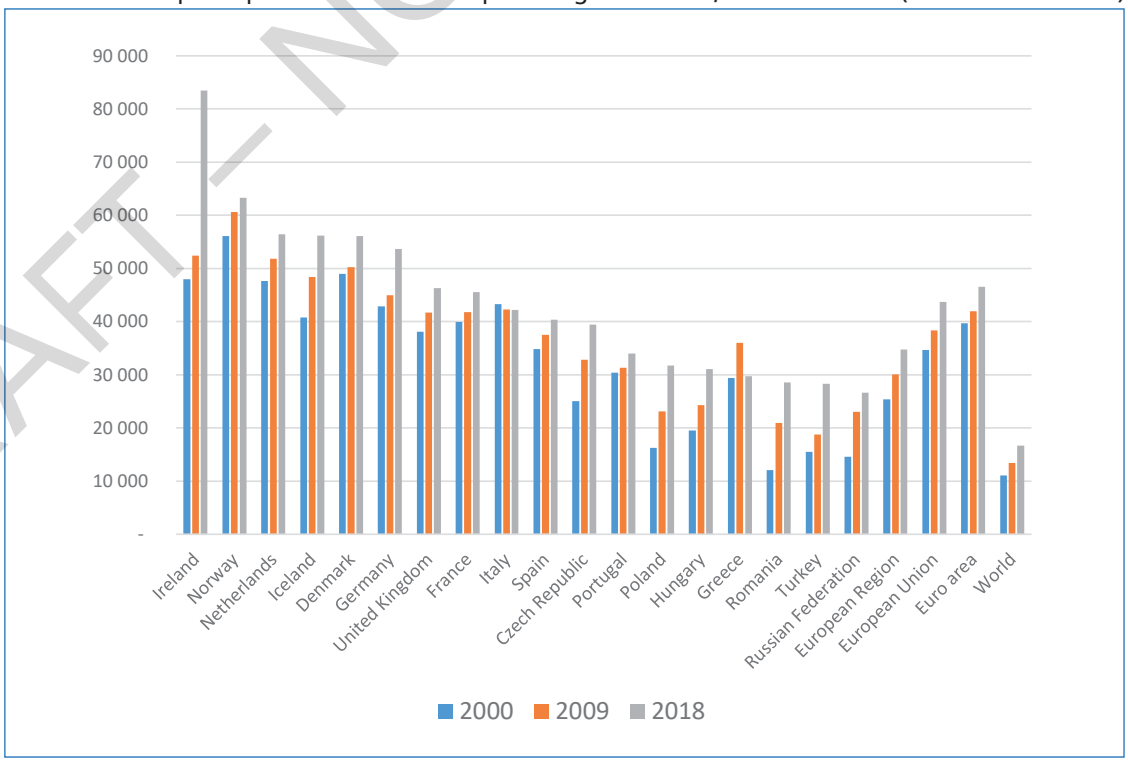
FIGURE 1. GDP per capita of European Region states with significant aquaculture sectors in 2000, 2009 and 2018 (constant USD, 2010)



Source: World Bank, 2020.
No data available for Faroe Islands.

Western sub-regions have the strongest positions, followed by the Southern and Eastern areas (Figure 2). The PPP analysis highlights the strength of the Turkish and Russian economies when compared to the global figures, while confirming declines in Italy and Greece.

FIGURE 2. GDP per capita PPP for the European Region in 2000, 2009 and 2018 (constant 2017 USD)



Source: World Bank, 2020.

As reported in the 2015 European Region aquaculture review (FAO, 2017a), Cyprus, Greece, Portugal, Spain and Ireland each received financial support from the eurozone bailout fund following the financial crisis that affected Europe generally. The return to economic growth of Ireland and Portugal allowed their exit from the bailout programmes in 2014 and a steep recovery of Ireland between 2009 and 2018. Increased GDP per capita PPP was recorded for most countries, as well as the European Union and at the global level, while economies in Italy and Greece receded.

Adverse economic effects, accompanied by diminished labour markets, have been seen in the entire European Region. Within the Eurozone, unemployment levels reached 27 percent in Greece and Spain, while rates were even higher in some non- European Union states, including North Macedonia and Bosnia and Herzegovina.

In the European Union, the European Financial Stability Facility (EFSF) and the European Stability Mechanism (ESM) were two financial measures introduced after 2010 to provide financial support to allay the crisis in member states.

1.2 SALIENT ISSUES

While the population of the European Union is foreseen to increase from 513 million in 2018 to 520 million by 2070, the working age population (15–64 years of age) will reduce from 333 million to 292 million (EC, 2018a). Assumptions used for this forecast include fertility rates, life expectancy and migration flows. This change means that the number of working-age citizens per person over 65 in the European Union is projected to fall from 3.5 to 2, while the labour supply of those aged between 20 and 64 is projected to fall by 9.6 percent and labour shortages are likely to be a major issue for many primary production activities, including aquaculture.

Advanced European economies have focused on addressing increased labour shortages by lifting restrictions on the participation of women in the labour force, strengthening social policies and redesigning tax systems. Workers over the age of 64 will also increase in number.

On the other hand, migration from troubled zones into Europe, including asylum seekers and economic migrants, has been termed a crisis since 2015 when asylum applications peaked at 1.4 million, falling to 1.3 million in 2016.

Migration to the European Union from non-European Union countries reached 2.4 million people in 2017 (Eurostat, 2019) contributing to a total of 22.3 million non- European Union citizens living in the European Union at the end of 2017. Within the European Union, 1.3 million European Union citizens moved to a different European Union state while a further 1.0 million European Union nationals returned to their European Union state of citizenship. In 2017, the United Kingdom of Great Britain and Northern Ireland accepted 243 000 European Union nationals and 321 000 non- European Union citizens, while Germany received 395 000 European Union nationals and 392 000 non-European Union citizens, and Spain, Italy and France also had immigration totals between 340 000 and 530 000.

In destination European Union states, international migration may contribute to solving specific labour market shortages. A similar situation is observed in other European states, notably in the Russian Federation, where legal and illegal workers from former Soviet republics (Ukraine, Uzbekistan, Tajikistan, Azerbaijan, Kyrgyzstan, Armenia and Republic of Moldova) constitute a significant percentage of the labour force, notably for manual tasks. Nonetheless, migration alone will almost certainly not reverse the ongoing trend of population ageing seen in many parts of Europe.

The effects on European aquaculture of the 2007–2009 financial crisis were felt long afterwards where access to long-term and short-term financing remained difficult. This was most visible in the Mediterranean seabass and seabream sector, where restructuring following bankruptcies or company purchases led to consolidation and larger corporate structures, specifically in Greece, Spain and Turkey (FEAP, 2017). Stiff market competition and a lack of confidence in maintaining adequate product prices has undermined investor confidence since that time.

Family-based micro-enterprises face an additional challenge where the owner-operator is ageing, having started business in the 1970s or1980s. If none of the family wish to take over the business, it became difficult to sell during and immediately following the financial crisis. Bureaucracy and red tape are also seen as major discouraging factors, specifically for obtaining licences to operate. This situation has affected freshwater fish farms (for example trout and carp) and shellfish (mussels) and has led to some farm closures. The phenomenon of urban migration by the younger population has also affected rural communities in Europe, leading to localised labour shortages and reduced services.

1.3 THE WAY FORWARD

The European Union economy expanded significantly in 2017 after many years of crisis. Accommodative monetary policy encouraged growth in both the Eurozone and European Union areas, helped by mildly expansionary fiscal policies and a recovering global economy. GDP growth in the European Union is projected to remain strong and historical data is provided in Table 4. Nonetheless, the Organisation for Economic Co-operation and Development (OECD, 2019) and European Commission forecasts indicate that the pace of structural reforms within member states is not fast enough (EC, 2019a).

TABLE 4. Average annual GDP growth rates in the European Region, 2000–2018 (percent)

	Average Annual GDP Growth Rate				Average Annual GDP Growth Rate		
	2000-2005	2006-2011	2012-2018		2000-2005	2006-2011	2012-2018
Ireland	5.3%	-0.5%	8.9%	Serbia	6.4%	2.4%	2.1%
Turkey	4.8%	4.0%	5.5%	Denmark	1.3%	-0.3%	2.1%
Romania	5.6%	1.7%	4.5%	United Kingdom	2.8%	0.2%	2.0%
Moldova	7.1%	3.4%	4.5%	Spain	3.3%	-0.0%	2.0%
Iceland	4.2%	0.5%	4.3%	Switzerland	1.5%	1.7%	2.0%
Georgia	7.3%	4.9%	3.9%	Croatia	4.5%	-0.5%	1.8%
Poland	3.1%	4.5%	3.6%	Netherlands	1.3%	1.0%	1.8%
Hungary	4.4%	-0.6%	3.6%	Germany	0.5%	1.2%	1.8%
Montenegro	2.8%	2.7%	3.6%	Portugal	0.9%	-0.1%	1.6%
Lithuania	7.6%	0.9%	3.3%	Norway	2.2%	0.7%	1.6%
Estonia	7.3%	-0.7%	3.2%	Cyprus	4.0%	1.8%	1.6%
Latvia	8.2%	-1.5%	2.9%	Belgium	1.9%	1.3%	1.5%
Slovak Republic	5.0%	3.8%	2.9%	Austria	1.8%	1.2%	1.4%
Czechia	3.9%	1.4%	2.8%	France	1.7%	0.8%	1.3%
North Macedonia	2.0%	3.4%	2.8%	Finland	2.6%	0.6%	1.1%
Bulgaria	5.7%	2.4%	2.8%	Russian Federation	6.1%	2.8%	0.8%
Albania	5.9%	4.6%	2.7%	Italy	0.9%	-0.5%	0.4%
Slovenia	3.6%	0.9%	2.7%	Belarus	7.5%	6.4%	0.3%
Bosnia and Herzegovina	5.7%	1.9%	2.6%	Greece	3.9%	-3.3%	0.0%
Sweden	2.6%	1.5%	2.5%	European Region	2.4%	1.0%	1.9%

Source: World Bank, 2020.

When planning sustainable growth for a social Europe, it has been recognised that major challenges need to be addressed to ensure a protective, competitive, fair and sustainable environment for European citizens (EC, 2019b). These challenges include low productivity growth, persistent gender differences in participation, significant investment shortfalls, high energy and housing costs as well as the substantial burden of public and private debt.

The 2019 European Commission review on choices for the future of social Europe (EC, 2019b) concluded that climate change, environmental degradation and the inefficient use of natural resources also weigh on sustainable development prospects in the European Union and the world. European citizens are increasingly demonstrating a keen awareness of these challenges and of the importance of addressing together all three dimensions of sustainability; economic, social and environmental.

Greece and Italy have implemented anti-poverty schemes to ensure minimum household incomes, policies that remain the subject of discussion in several European states.

Norway faces a major challenge in sustaining the high levels of economic output and comprehensive public services that are key to Norway's wellbeing because its scope for growth in public spending may be compromised by slower growth in its wealth fund. Low productivity growth remains a concern since the Norwegian economy requires a high-productivity business sector to be competitive in a high-wage, high-tax situation. The OECD (OECD, 2020) notes that Norway is generally well placed to harness the next generation of digital technology and research and development (R&D) activity is increasing. These considerations are reflected in the Norwegian aquaculture sector, which has incorporated new technologies and skills and is supported by universities, institutes and private R&D companies.

Turkey's GDP growth averaged nearly 7 percent during 2010–2018, reflecting strong performance of a dynamic but fragmented business sector; however, inflation rates were high. Fast economic growth was accompanied by strong levels of investment, but the OECD considered this to be overly funded by debt, not profits. There were significant differences in the education, skills and earning capacity of individuals in the workforce, while infrastructure quality and corporate productivity also varied significantly. While many Turkish business activities rely on domestic demand, Turkey, like Norway, has built its aquaculture business on export markets. It has, however, invested in developing national markets in recent years. However, none of the OECD or European Economic reviews mention aquaculture specifically.

2. General characteristics of the sector

2.1 STATUS AND TRENDS

2.1.1 Regional production and value

Aquaculture production in 2018 for the European region and sub-regions is reported in Table 5. Total European production was 3 409 288 tonnes which compares to a global total of 114 508 042 tonnes (FAO, 2020a) Aquaculture activities were restricted to fish and mollusc production as aquatic plant and crustacean rearing were negligible, and production was dominated by coastal marine activities. Sub-regional differences were significant, with wide differences in the culture systems used throughout Europe while marine aquaculture was particularly underdeveloped in Eastern European countries.

TABLE 5. Aquaculture production (tonnes) and production shares (percent) in Europe and its sub-regions (2018)

Sub-Regions	Aquaculture production 2018			
	Tonnes	Share of Europe Total (%)	Share of World Total (%)	Share of World Fish/ Shellfish (%)
Eastern Europe	360 568	10.6%	0.31%	0.50%
Northern Europe	1 756 994	51.5%	1.53%	2.45%
Southern Europe	1 013 750	29.7%	0.89%	1.41%
Western Europe	277 976	8.2%	0.24%	0.39%
EUROPE Total	3 409 288	100.00%	2.98%	4.75%

Source: FAO, 2020a.

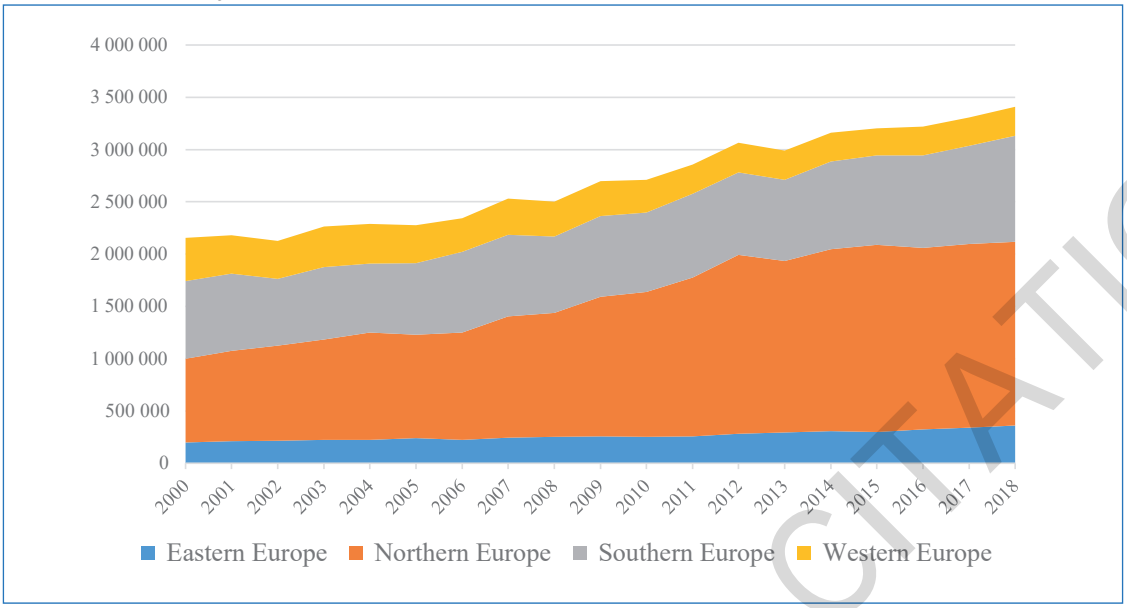
Although the number of aquatic organisms reared in global aquaculture increased from around 70 species items in the 1950s (Teletchea, 2019) to more than 600 species items in 2018, only a few represent major production levels. Some 85 percent of the production volume of each aquaculture group were made by 18 fish, four crustacean, seven molluscan, four amphibian and reptilian and five aquatic plant species items (FAO, 2020a).

European aquaculture focuses on fish and shellfish, with extremely low production levels for aquatic plants and crustaceans and eight species or groups contributed 93 percent of total production in 2018. These comprise five finfish species; Atlantic salmon (*Salmo salar*), rainbow trout (*Oncorhynchus mykiss*), European seabass (*Dicentrarchus labrax*), gilthead seabream (*Sparus aurata*) and common carp (*Cyprinus carpio*) and three shellfish groups; mussels (mainly blue and Mediterranean mussels (*Mytilus edulis* and *M. galloprovincialis*)), oysters (mainly Pacific cupped oysters (*Crassostrea gigas*)) and clams (mainly Japanese carpet shell *Ruditapes philippinarum)*..

Northern Europe made the largest contribution to global aquaculture through salmon and trout production, followed by southern Europe's shellfish, marine fish and trout supplies. Most of the countries represented in eastern and western Europe, especially the landlocked countries, depend on freshwater aquaculture as the major activity, France being the notable exception with oyster culture.

Figure 3 shows the total pattern of development in the European region and sub-regions between 2000 and 2018. The progress of the northern European area, growing from 37 percent to 51.5 percent, can be compared to a reduction of the western European contribution that dropped from 19 percent to 8.2 percent.

FIGURE 3. Development of aquaculture production in the European Region and sub-regions, 2000–2018 (tonnes/yr)



Source: FAO. 2020a.

Except for salmon production, which itself increased by 60 percent since 2008, only modest sectoral growth (31 percent) has occurred in the last decade for other marine aquaculture species and the freshwater sector. The salmon sector dominates European finfish aquaculture, mainly in Norway, where publicly quoted companies have led development. Elsewhere, European aquaculture, with a few exceptions, is carried out by SMEs and micro-enterprises, often with part-time labour.

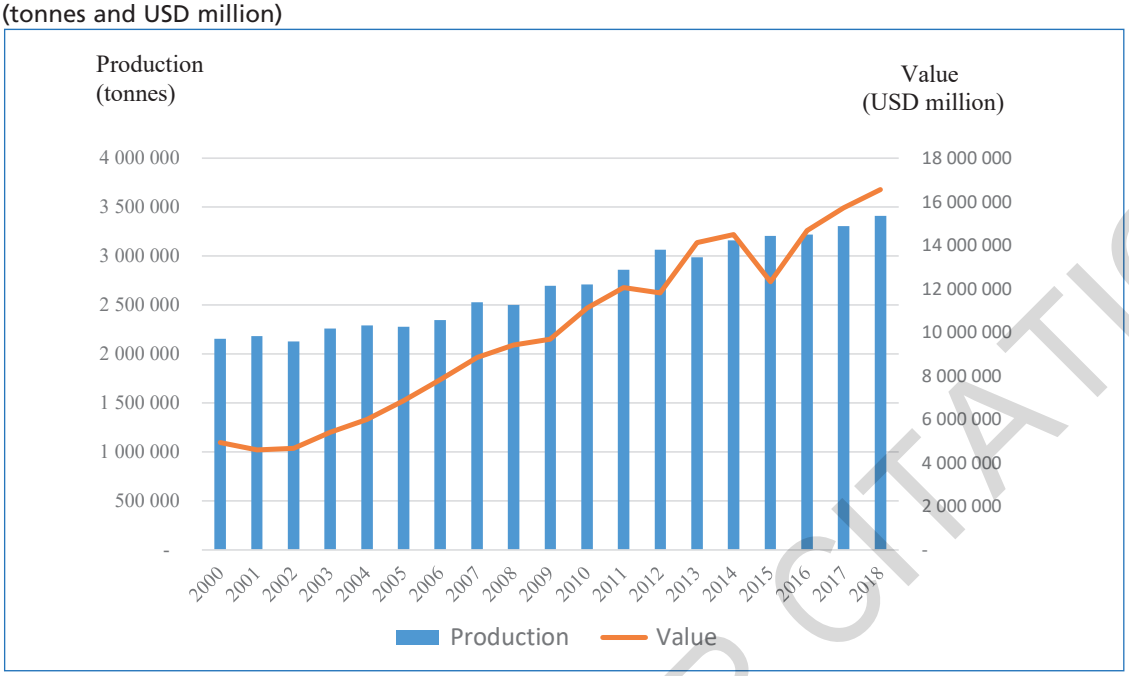
The European Union is home to some 12 500 aquaculture enterprises, mostly micro-businesses employing less than 10 employees. Employment has remained stable in terms of total employees (73 000) but has significantly expanded in terms of full-time equivalents FTEs), from 36 000 in 2013 to almost 44 000 in 2016. This development implies that aquaculture firms are providing more stable employment opportunities.

This positive trend is likely to continue throughout the European Region. With investment being significantly higher than depreciation, the sector has a positive perception about its future development.

Figure 4 shows that, in 2018, regional production was 3.4 million tonnes of which 60 percent (2 million tonnes) were diadromous fish species, principally Atlantic salmon (1.57 million tonnes) and rainbow trout (0.4 million tonnes). Marine species provided 11 percent, led by European seabass (0.20 million tonnes) and gilthead seabream (0.17 million tonnes) which together represent 96 percent of this figure. Marine molluscs represented 20 percent (0.68 million tonnes), where mussels dominated production with 0.53 million tonnes, followed by Pacific cupped oysters and carpet shell clams were the other major molluscs reared. Freshwater fish dominated inland aquaculture in Europe and provided 628 000 tonnes, where rainbow trout (48 percent) and common carp (27 percent) remained the core species reared, although some diversification has been seen.

Production in the last decade (2009–2018) increased by 36 percent in volume but by 76 percent in value. Annual growth rates have been variable but the compound annual growth rate (CAGR) for the same period was 3.1 percent for volume and 5.8 percent for value, with an average value, for all aquaculture products combined, of USD 4.86/kg.

FIGURE 4. Production and value of aquaculture in the European Region, 2000–2018 (tonnes and USD million)



Source: FAO. 2020a.

In the European Union, the production growth rate (CAGR) was only 0.9 percent for the decade with the value increasing by 1.3 percent per year while the average value of aquaculture products was USD 3.98/kg. While the 2018 European Union production volume was 3.3 percent lower than in 2000, global production increased by 166 percent over the same period. Global aquaculture statistics indicate a CAGR of 5.0 percent for volume and 8.7 percent for value, with an average value of USD 2.30/kg (FAO, 2020a).

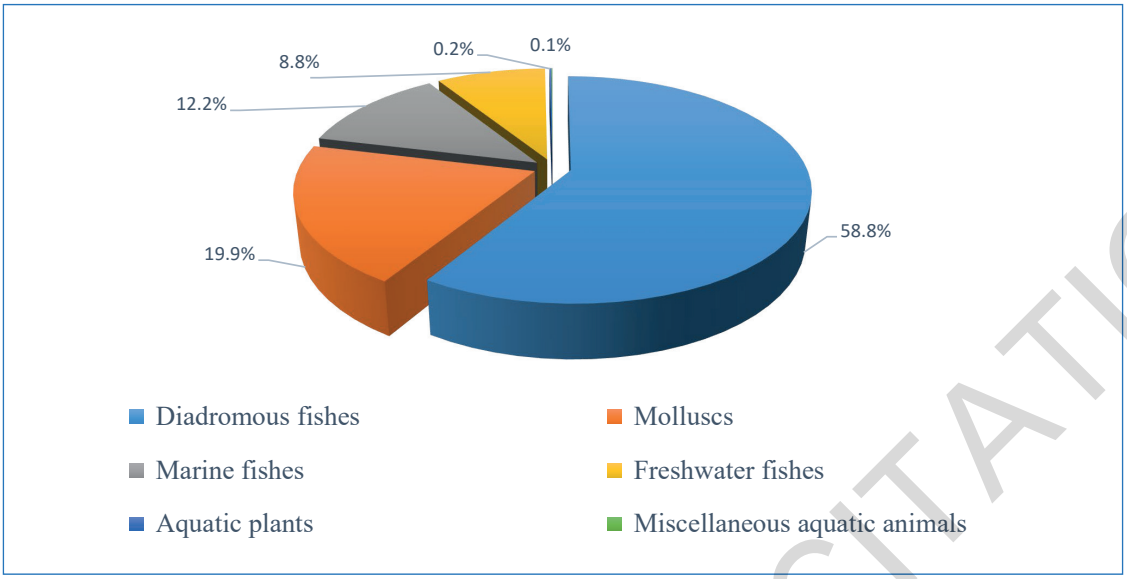
For the European Region, the higher increase in value compared to production volume reflects the growth of the northern European salmon and Mediterranean marine fish sectors. During the same period, production of lower value molluscs decreased significantly to 0.55 million tonnes in 2012–2013 before recovering to previous levels, around 0.7 million tonnes, in 2017–2018 (Guillen *et al.*, 2019).

The total value of aquaculture in the European Region was USD 16.56 billion in 2018, indicating a CAGR of 5.8 percent in the period 2008–2018. Aside from minor production components such as aquatic plants (USD 10.9 million), crustaceans (USD 4.2 million) and miscellaneous aquatic animals (USD 16.4 million), the value of salmon and trout exceeded USD 11.8 billion, followed by marine fish with USD 2.35 billion and molluscs with USD 1.4 billion. As indicated, fish (80 percent) and mollusc (19 percent) species items are the core of European aquaculture. Within the production value, Atlantic salmon dominates with a total of USD 10 billion in 2018, while the other major species (fish and shellfish) combined to provide USD 6.5 billion. Salmon alone provided 60 percent of the total value of European aquaculture in 2018. The division and share of the main groups comprising European aquaculture are shown in Figure 5.

Figure 6 shows the growth in value of Atlantic salmon compared to that of all other fish and mollusc species produced in the European Region.

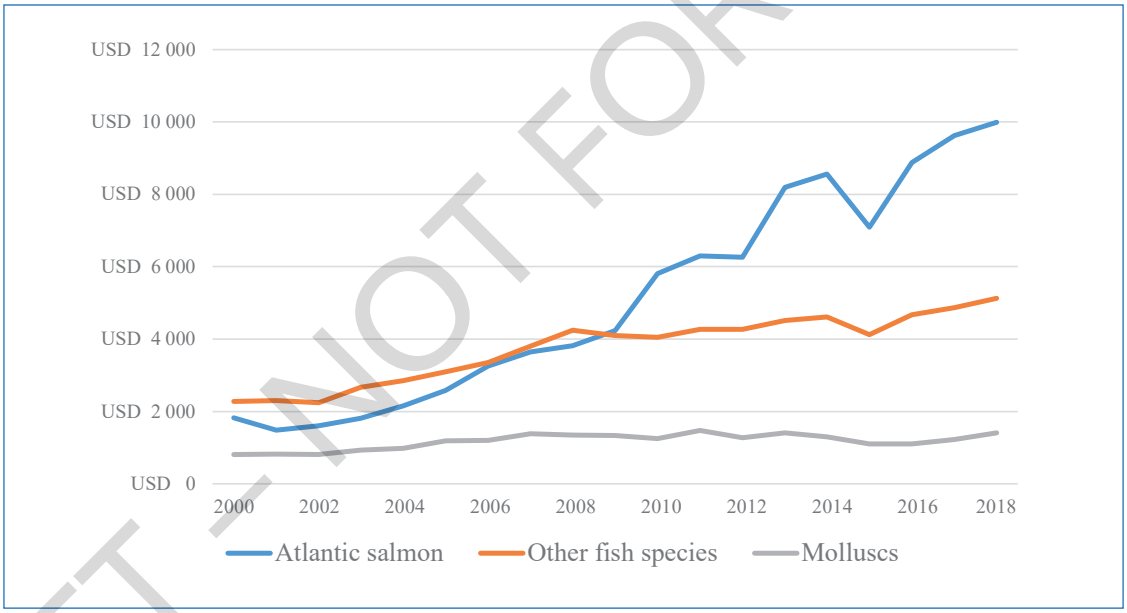
Figure 6 also shows that the value of salmon production has grown rapidly while that for other species has grown slowly or stabilised in the case of molluscs. The combined value and details of the main species or groups, excluding salmon, is indicated in Figure 7.

FIGURE 5. Division and share of 2018 aquaculture production in the European Region (percent)



Source: FAO. 2020a.

FIGURE 6. Production value of Atlantic salmon and other major aquaculture products in the European Region, 2000–2018 (USD million)

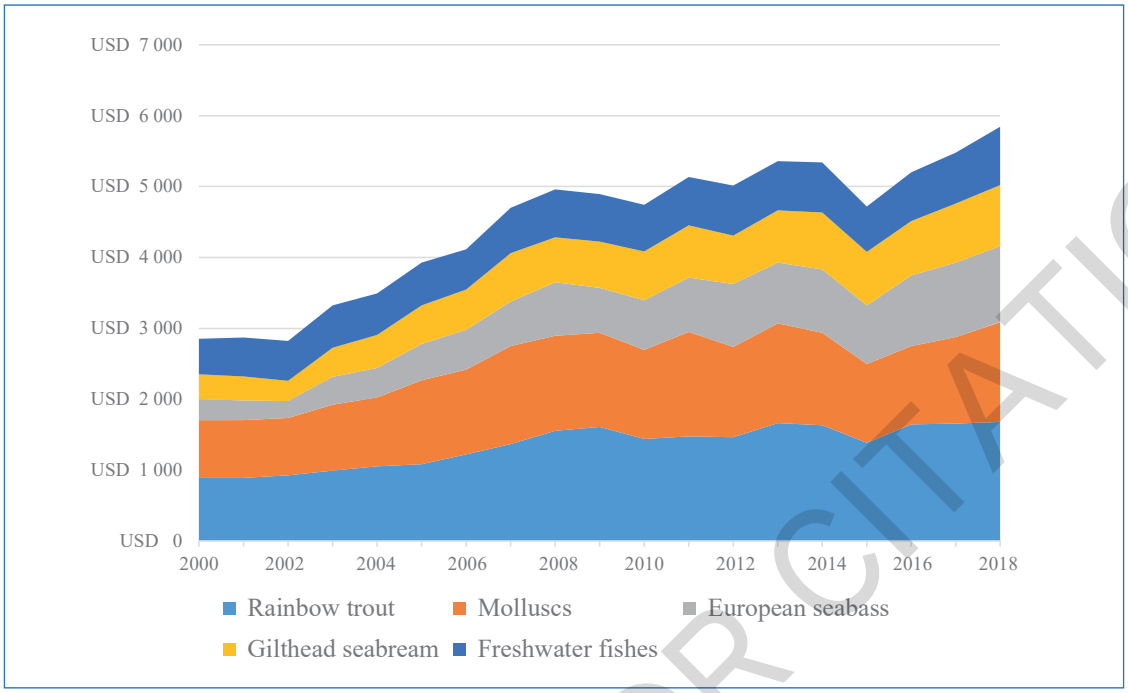


Source: FAO. 2020a.

Figure 7 shows an overall increase of 19.5 percent in value for the main species and groups between 2008 and 2018, which has come from freshwater fish species (23.5 percent), European seabass (70 percent), gilthead seabream (32 percent), while rainbow trout (4.3 percent) and molluscs (5.7 percent) increased more slowly.

The sales price recovery for finfish aquaculture products that started in 2015 has been confirmed in recent times, particularly for salmon and other marine fish, while shellfish values have remained low. As will be discussed further, the major concerns in European aquaculture remain market conditions, licensing and assuring aquatic animal health.

FIGURE 7. Value of major European aquaculture products, excluding Atlantic salmon, 2000–2018 (USD million)

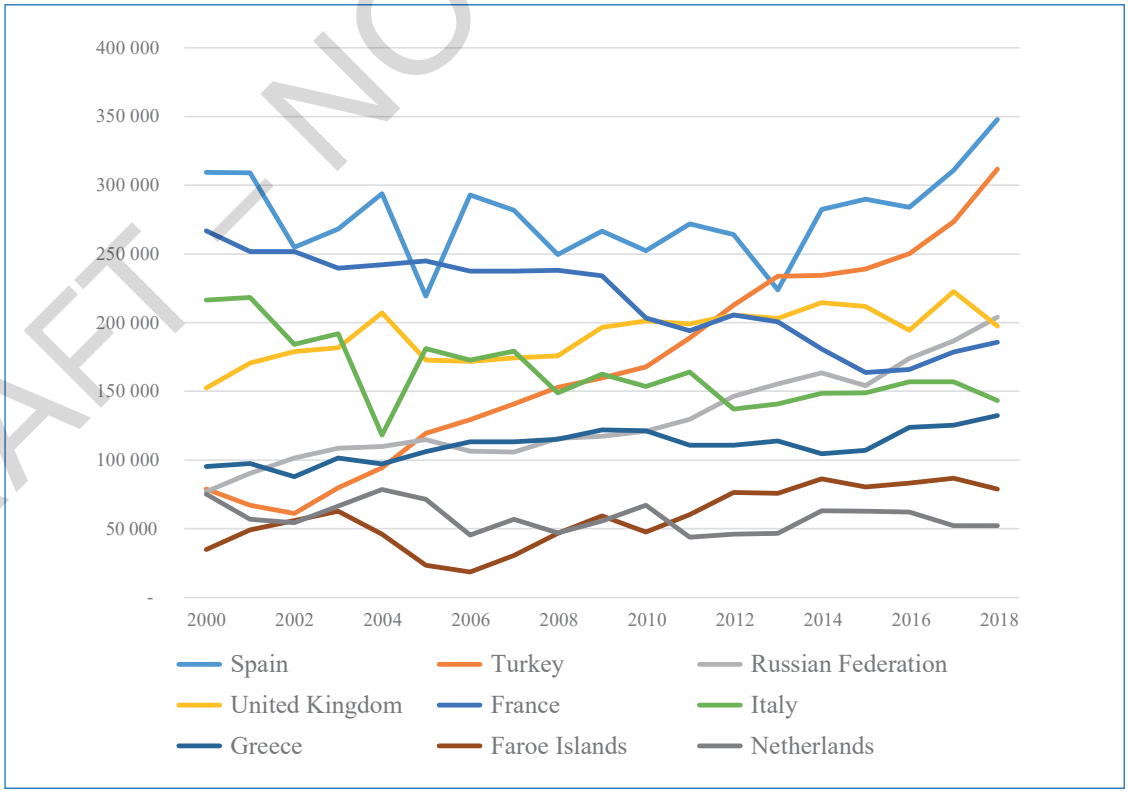


Source: FAO. 2020a.

2.1.2 Performance of main aquaculture-producing countries

As well as Norway, there are nine European countries that have produced more than 50 000 tonnes per year of aquaculture products during the period, 2000–2018 (Figure 8).

FIGURE 8. Aquaculture production in European states with aquaculture sectors >50 000 tonnes , excluding Norway, 2000–2018 (tonnes/yr)



Source: FAO. 2020a.

The strongest annual percentage rate (APR) growth for this 18-year period has been reported for Turkey (7.9 percent), followed by the Russian Federation (5.6 percent) and the Faroe Islands (4.6 percent). Negative developments for France, Italy and the Netherlands are to be noted, while the other countries showed more modest growth.

When the position of all areas included in the European Region is examined for this period, nine states show significant reductions in aquaculture production volume, while the strongest growth was recorded for states having modest production levels (Table 6).

TABLE 6. Development of aquaculture by state in the European Region, 2000–2018 (percent APR)

	Negative growth			Positive growth			
Rate	> -5.0	-2.5 --> -5	0 --> -2.5	0-->2.5	2.5-5.0	5.0-10.0	>10
Nº	1	2	6	10	10	7	5
Area	Belgium	Ukraine	Finland	Austria	**Faroe Islands**	Iceland	Albania
		Germany	Israel	Greece	Lithuania	Bulgaria	Moldova
			Denmark	Hungary	Belarus	Estonia	Malta
			Ireland	**United Kingdom**	Slovenia	**Turkey**	
			France	Romania	Switzerland	Channel Islands	
			Netherlands	Poland	Portugal	**Norway**	
			Italy	**Spain**		Russian Federation	
				North Macedonia		Croatia	
				Czechia		Latvia	
						Slovakia	
						Sweden	

Source: FAO, 2020a.
Note: Countries in bold Italics produce more than 50 000 tonnes/annum.

Of those countries that produce more than 50 000 tonnes annually, Norway and Turkey have shown the greatest growth in production for the period 2000–2018, their prime export market being the European Union.

In Norway, the production of Atlantic salmon and rainbow trout continued to grow until 2015, when it stabilised at between 1.2 million and 1.3 million tonnes per year. Over the last 20 years, the number of companies involved in salmon farming has dropped from 467 with 799 licences to 174 companies with 1 160 licences (DoF, 2019). Corporate consolidation combined with drives towards improved equipment and productivity also led to the major companies being listed on the stock exchange and expanding with international investments in salmon farming, processing and marketing. Chile, Canada and Australia are examples of this.

Direct employment in on-growing production increased from 2 500 people to 6 000 over the period 2000–2018, while hatcheries and juvenile production account for a further 1 800 jobs. The addition of personnel for processing and the supply and service sectors (around 14 000) means that the sector provides significant employment with economic and social added value in coastal communities.

Consistent growth of aquaculture in Turkey is reflected in the expansion of the freshwater farming of rainbow trout, rising from 44 000 tonnes to 112 000 tonnes over the last 18 years while European seabass and gilthead seabream farming in the Aegean has grown from 33 000 tonnes in 2000 to over 193 000 tonnes in 2018, making Turkey the leader of this sector in the Mediterranean (Eurofish, 2016). However, the use of subsidies to support Turkish

aquaculture growth led to the application of European Union countervailing duties between 2014–2019 (EC, 2021a).

The Faroe Islands has also participated in the growth of Atlantic salmon aquaculture and, after dropping from 52 500 tonnes in 2003 to only 13 000 tonnes in 2006, production increased to 87 000 tonnes in 2017. Priding itself on strict veterinary controls, limiting each production site to one generation and fallowing after harvest, the Faroe Islands also has one of the best sanitary records in global fish farming, using cleaner fish as the main solution for sea lice control.

The Russian Federation has increased its investment in aquaculture, with development in both salmon and trout farming that increased from 6 100 tonnes in 2000 to over 59 000 tonnes in 2018, when rainbow trout was the major product (59 percent of total production). Cyprinid production also grew from 63 000 tonnes to 126 000 tonnes over the same period. A ban on imported food from Norway and the European Union was imposed in 2014, at which time a federal law promoting aquaculture was approved and the development of aquaculture sites was accelerated. Ambitions to triple aquaculture production by 2030 have been published, with hopes to attract private investment to support this objective while the need for adequate support services and skilled staff have also been highlighted (Stupachenko, 2018).

Netherlands has a long-standing history of blue mussel production, which has stabilised at around 50 000 tonnes. Diversification, often using recirculating aquaculture systems (RAS), for eel (*Anguilla anguilla*) and north African catfish (*Clarias gariepinus*) production has experienced mixed fortunes; after reaching their highest levels in the mid-2000s (5 000 tonnes of eels, 4 500 tonnes of catfish) their production has steadily reduced. Therefore, any aquaculture growth recorded from Netherlands is entirely due to shellfish production.

Spain has the largest mussel production in Europe, localised in Galicia and characterised by multiple small family enterprises. There are nearly 4 800 farms that are responsible for 280 000 tonnes of production (average around 50 tonnes per farm). In 2000, around 33 000 tonnes of rainbow trout were grown in Spain but by 2018, this dropped to 10 500 tonnes. The main reasons were a highly competitive export market within the European Union and a weak local market, dominated by marine species as opposed to freshwater, leading to bankruptcies. Meanwhile, marine farming of European seabass and gilthead seabream in Spain has grown over this period to reach a combined production level of 35 000 tonnes. Diversification has raised meagre (*Argyrosomus regius*) production to nearly 4 000 tonnes in recent years and there are several producers of sturgeon (*Acipenser* spp.) for caviar. Spain leads turbot (*Scophthalmus maximus*) production in Europe with 8 000–9 000 tonnes reported recently. The latest figures for Atlantic bluefin tuna (*Thunnus thynnus*) farming indicate over 1 500 tonnes reared on the Mediterranean coast.

The United Kingdom of Great Britain and Northern Ireland's aquaculture development is entirely due to salmon in Scotland, which increased from 129 000 tonnes in 2000 to a high of 203 000 tonnes in 2017. Trout aquaculture is stable at 13 000 tonnes while shellfish (oysters and mussels) contributed 17 142 tonnes in 2018, falling from a high of over 35 000 tonnes in 2009.

Negative growth has been recorded for Italy and France, states which have been characterised by strong aquaculture sectors in the past.

Aquaculture in France provided 267 000 tonnes in 2000 which fell to 164 000 tonnes by 2015, recovering recently to 186 000 tonnes due to higher shellfish harvests. During this

period, trout aquaculture diminished from around 49 000 tonnes to around 26 000 tonnes while the production of marine fish, such as European seabass, gilthead seabream, turbot and meagre, also reduced to a total of 4 190 tonnes from a high point of 6 749 tonnes. Shellfish aquaculture reached a peak of around 195 000 tonnes in 2005 falling to around 125 000 tonnes in 2017. Oyster production almost halved over this period, principally due to disease issues. However, the recent rise observed is mainly due to higher oyster yields.

In 2001, Italian aquaculture peaked at around 218 000 tonnes, comprising 48 000 tonnes in freshwater, including eels, rainbow trout and sturgeon while marine aquaculture supplied 21 000 tonnes of mullet, European seabass and gilthead seabream. The bulk came from shellfish with 149 000 tonnes of mussels and clams. By 2018, trout production had remained stable at around 33 000 tonnes and a similar position seen for the marine fish sector at around 13 500 tonnes. However, shellfish production has been volatile, with variable clam and mussel harvests that have stabilised at around 31 000 tonnes and 63 000 tonnes, respectively. Nonetheless, total Italian shellfish aquaculture production has dropped by around 50 000 tonnes since 2000.

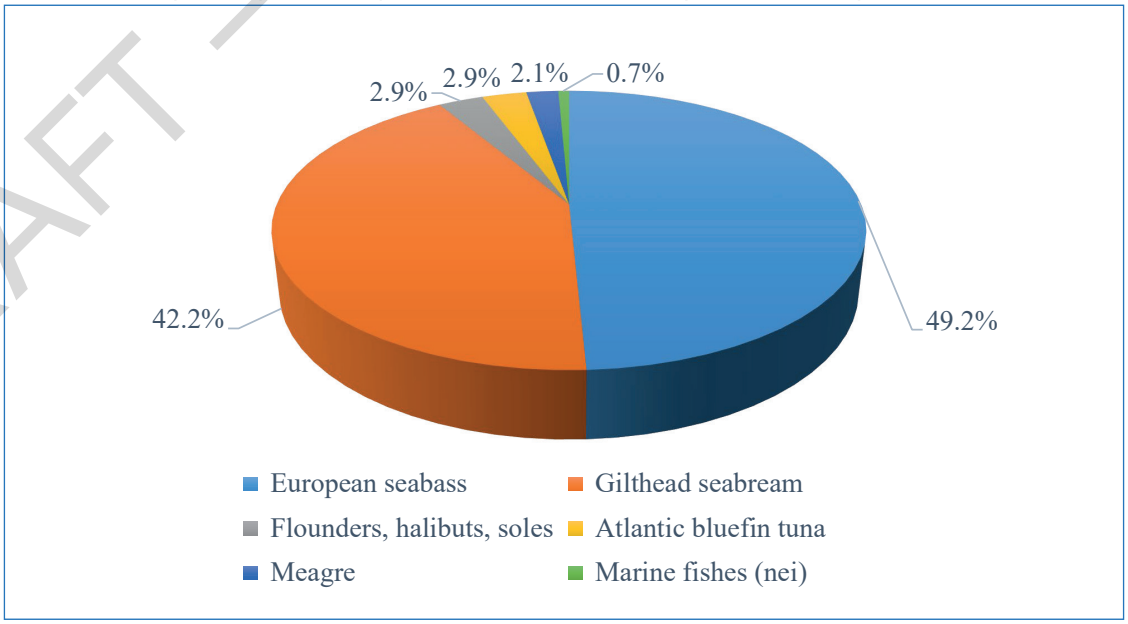
2.1.3 Marine aquaculture species

European seabass and gilthead seabream are the main marine finfish species cultivated, whose combined total of 376 000 tonnes in 2018 equalled 90 percent of marine fish species production (Figure 9). Cage farming of these species dominates Mediterranean aquaculture where Turkey and Greece are the major producers by volume but only Turkey, Spain, Croatia and Cyprus reported significant growth in the last decade.

The aquaculture of turbot, halibut *(Hippoglossus hippoglossus)* and, more recently, sole *(Solea solea)* has given a boost to flatfish production, although combined production is limited at around 12 000 tonnes. Production peaked at 15 400 tonnes in 2017 and the failure of one big company accounted for the reduction in 2018.

Market instability and uncertainties have stimulated diversification efforts, particularly in the Mediterranean sector, where the emergence of meagre, red porgy (*Pagrus pagrus*) and other seabreams was recorded, albeit in minor volumes.

FIGURE 9. European aquaculture production of marine fish species in 2018 (percent)



Source: FAO. 2020a.

Of note is the complete disappearance of Atlantic cod (*Gadus morhua*) that peaked at 23 000 tonnes in 2009–2010 in Norway. While on-growing activities have ceased, several cod hatcheries reopened to produce cleaner fish including ballan wrasse (*Labrus bergylta*) and lumpfish (*Cyclopterus lumpus*) for biological control of sea lice in the marine cage production of salmon. Nonetheless, recent reports indicate optimism for a return of the cod farming sector in the future, notably by the Norcod consortium.

The production of cleaner fish for sea lice control has become an important economic activity, with over 30 million juveniles produced in 2016, and is the third highest value product in Norwegian aquaculture after salmon and trout. At an average price of USD 3.34 for a 50 g lumpfish specimen, this equated to a market value of USD 100 million.

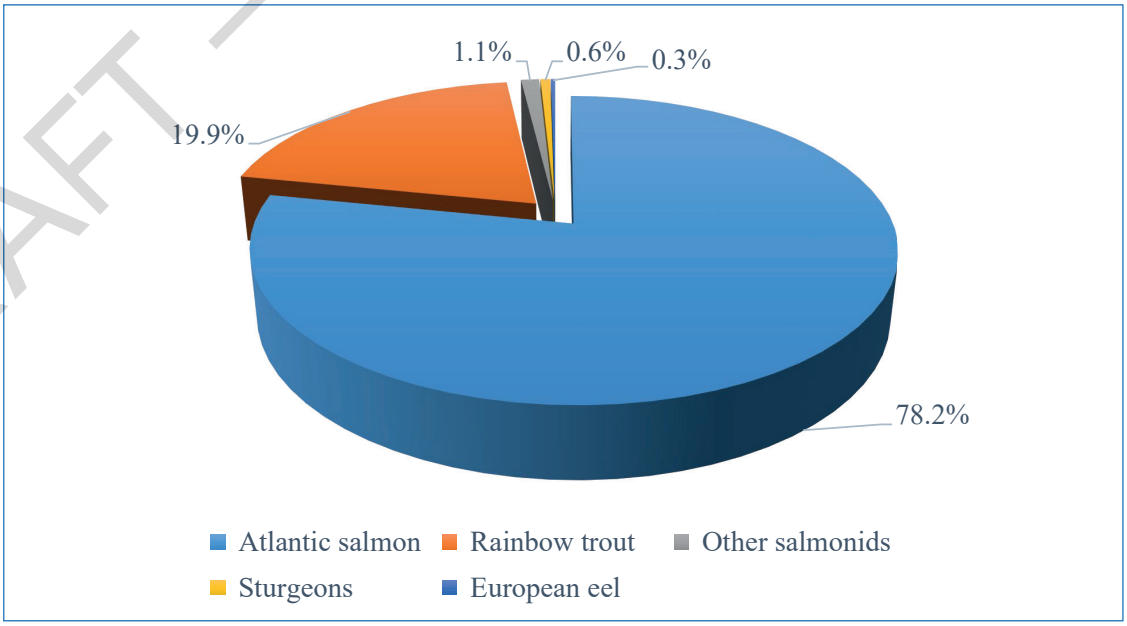
Market and price instabilities, combined with production difficulties, have characterised the last decade in the Mediterranean, where Greece and Turkey both experienced lengthy financial crises. Bankruptcies and corporate consolidation created uncertainty throughout the sector, hampering investment and growth. After several years of negotiation, it was only in late 2019 that the merger of the three major Greek companies (Andromeda, Selonda and Nireus) was completed, following extreme financial difficulties encountered by Selonda and Nireus in 2014. In 2019, the new organisation, Andromeda Group, includes operations in Spain and had a combined production of over 75 000 tonnes and combined sales of around USD 475 million.

In Turkey, Kılıç Deniz A.Ş.is the largest aquaculture company, rearing European seabass, gilthead seabream and rainbow trout. The company has also invested in feed production, fish processing and distribution. The Kiliç Group has the capacity for over 65 000 tonnes of production, large hatcheries and over 200 000 tonnes of feed manufacture. In 2017, Turkey was reported to have produced nearly 100 000 tonnes of European seabass and 61 000 tonnes of gilthead seabream, more than double its production of ten years earlier.

2.1.4 Diadromous fish species

Atlantic salmon (78 percent) and rainbow trout (20 percent) are the main diadromous fish species cultivated in Europe (Figure 10). While diversification efforts have focused on production of arctic char *(Salvelinus alpinus)*, brook trout *(Salvelinus fontinalis)* and

FIGURE 10. European production of diadromous fish species in 2018 (percent)



Source: FAO. 2020a.

grayling (*Thymallus thymallus)*, these have had little impact on development and remain very minor. On the other hand, a recent trend is the move of freshwater trout producers away from portion-size (250 g–450 g individual size) to larger sizes (>1.2 kg), facilitating marketing as a replacement for salmon (FEAP, 2017).

Increasing with an APR of 5.8 percent since 2000 and with a combined production approaching 2 million tonnes, salmon and trout remain the prime products farmed in Europe accounting for 99 percent of diadromous fish production.

In 2018, Norway led production development of diadromous fish species, increasing to 1.35 million tonnes, followed by United Kingdom of Great Britain and Northern Ireland (0.18 million tonnes) and the Faroe Islands where production has risen rapidly in recent years to 78 900 tonnes. The Russian Federation reported 20 566 tonnes of Atlantic salmon production in 2018, after peaking at 22 500 tonnes in 2013.

Rainbow trout is a ubiquitous aquaculture product in Europe, being reported by 37 different countries, with total 2018 production of 400 979 tonnes. Turkey leads freshwater production (112 427 tonnes) while Norway's on-growing production is marine-based (68 216 tonnes). Denmark, France, Italy and the Russian Federation each produce around 30 000 tonnes.

The presence of six different sturgeon species in production statistics reflects the production of caviar. Stimulated by the ban on international trade of wild caviar, investments in sturgeon aquaculture have been made throughout Europe, where the Russian Federation is the largest producer. Italy and France are the leaders of European Union caviar supplies.

The on-growing of European eel *(Anguilla anguilla)* remains stable at between 5 000 tonnes and 6 000 tonnes where several farmers and associations participate in restocking actions, responding to controversies on fishing and international trade in glass eels. The Sustainable Eel Group has supported actions to block illegal eel trade and remove impediments to the migration of mature (silver) eels, including creating passes.

2.1.5 Freshwater fish species

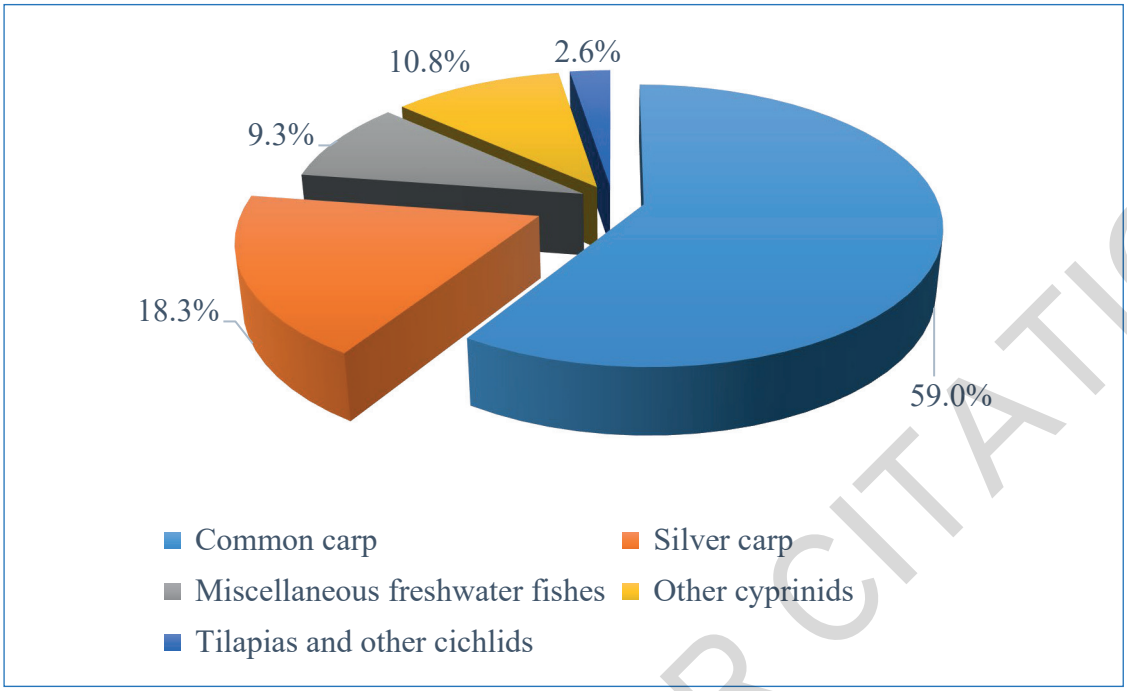
Carps and other cyprinids are the main freshwater species reared in the European Region, where common carp, silver carp *(Hypophthalmichthys molitrix)* and grass carp *(Ctenopharyngodon idella)* are the key farmed types (Figure 11). Total cyprinid production has increased slightly, principally due to a rise in silver carp production while common carp production has been stable at around 170 000 tonnes in recent years.

While large farms are dedicated to carp aquaculture in the Russian Federation, Poland, Czechia and Hungary, there are also many smallholder farms which have very small annual production (under ten tonnes) that cater to local seasonal sales. In the European Region, 23 countries reported carp production in 2018.

The Russian Federation is the most important carp producer (around 65 000 tonnes), followed by Czechia and Poland which each rear 18 000 tonnes, while Hungary (12 000 tonnes), Belarus (8 000 tonnes) and Ukraine (9 600 tonnes) are the remaining producers of importance.

Small increases in catfish production were reported, including channel catfish (*Ictalurus punctatus*) and wels catfish (*Silurus glanis*). North African catfish production has also risen, raised in heated water and RAS systems. Tilapia (*Oreochromis* spp.), once seen as an alternative species in such systems, is mainly produced in pond culture in Israel, production being stable at around 7 500 tonnes.

FIGURE 11. European production of freshwater fish species in 2018 (percent)



Source: FAO. 2020a.

Perch *(Perca fluviatilis)* and pike-perch *(Sander lucioperca)* have been of interest to farmers for several years, often for rearing using RAS technology, but production figures indicate only minor increases (under 1 000 tonnes for each species) that reflect continuing technical issues.

The APR for freshwater fish species over the period 2000–2018 was 1.5 percent, where silver carp (1.9 percent) and grass carp (10.3 percent) production developed more strongly than common carp (1.1 percent).

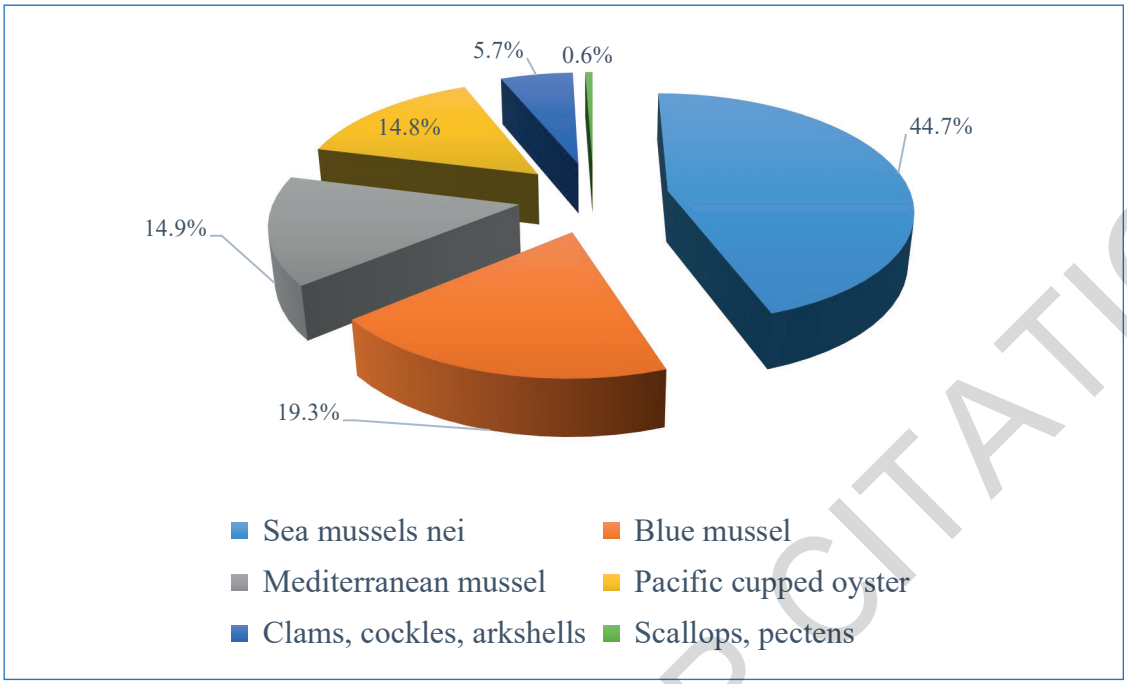
Stocking fish for recreational angling is another aspect of European freshwater aquaculture, although accurate data on production and economic aspects are difficult to isolate. The stocking of freshwater rivers, lakes and reservoirs is often from aquaculture (including rainbow trout, carp and other coarse fish species) and several traditional freshwater pond farms have turned to angling tourism as an important activity component. While angling is recognised as being an important social and recreational activity, there are few socio-economic data at the European level and the European Anglers Alliance has called for a regular study on the contributions of this activity (European Anglers Alliance, 2021).

2.1.6 Mollusc species

In terms of volume, the blue mussel *(Mytilus edulis)* and the Mediterranean mussel *(Mytilus galloprovincialis)* are the dominant mollusc species with a total of 533 000 tonnes produced in 2018 (Figure 12). Although this reflected a reduction of 60 000 tonnes compared to 2000, annual yields have been increasing since 2013. Similarly, oyster aquaculture diminished from a high of 149 000 tonnes in 2000 to a low of 83 500 tonnes in 2015, recovering to 106 000 tonnes in 2018.

European clam culture, mainly of Japanese carpet shell *(Ruditapes philippinarum)* and grooved carpet shell *(Ruditapes decussatus)*, peaked in the mid-2000s and then production dipped in the middle part of the last decade, but has recovered to around 40 000 tonnes.

FIGURE 12. European production of mollusc species in 2018 (percent)



Source: FAO. 2020a.

Total mollusc aquaculture in the European region peaked at 783 000 tonnes in 2000, dropping to a low of 541 000 tonnes in 2013 and recovering to 681 000 tonnes in 2018, for an APR of minus 0.8 percent between 2000 and 2018.

The sensitivity of all mollusc production to environmental influences and pollution is well noted and, as filter feeders, they can be strongly affected by algal blooms, including red tides, and pollution. Only scallops showed positive growth during the period (13.0 percent) with production of 3 900 tonnes in 2018.

Mussels are the most important mollusc aquaculture product in Europe, being produced in Atlantic and Mediterranean waters, with Mediterranean mussel and blue mussel being the principle identified species reared while unidentified sea mussels are the most important sub-category (from Spain). While Spain was the leading supplier with around 50 percent of production in 2018, the Netherlands, France, Germany, Ireland, the United Kingdom of Great Britain and Northern Ireland, Italy and Greece each have significant supply levels.

Mussel farming is characterised by multiple small-scale family businesses, using different aquaculture techniques, for example, "bouchot", rafts, longline ropes and bottom culture methods.

While mussel farming has been a long-established activity, a strong downward trend in production was seen in the European Region until 2013, after which the volume of European production increased, primarily in Spain to a total of 533 000 tonnes in 2018.

France has always dominated oyster production, being the prime supplier of Pacific cupped oyster in Europe, supported by Ireland which has shown slow production growth. According to FAO statistics, oyster aquaculture production has almost halved in the last 20 years, where the incidence of 'summer' mortalities has been compounded by mass mortalities of oyster spat from 2008 onwards (EC, 2015). The European Food Safety Authority (EFSA) has addressed causal effects and official reports indicate ostreid herpes virus to be a principle factor. EFSA also highlighted that the discharge of untreated seawater from depuration and oyster holding facilities could contribute to disease spread.

Improved stocks from hatcheries have improved the position, providing seed for use within and outside of Europe and where some 50 percent of oyster farmers use such stocks (Bruno Guillaumie, European Molluscs Producers Association, personal communication). Production in 2018 was 106 000 tonnes, a reduction from 149 000 tonnes in 2000. However, the lowest levels were around 83 000 tonnes in 2015–2016 and the APR for 2000-2018 was minus 1.9 percent.

Italy dominates clam rearing, principally of the Japanese carpet shell, delivering 95 percent of European production within annual production levels of 40 000 tonnes to 45 000 tonnes. While France, Spain and Portugal reported production in the early 2000s, none has reached the output of Italy. Italy has well-established companies, whereas clam farming in Portugal and Spain is characterised by family-based micro-enterprises with small capacity and part-time operation. As with other mollusc production in the European Region, clam aquaculture had a negative APR of minus 3.1 percent for 2000–2018, heavily influenced by output drops in Italy.

2.1.7 Aquaculture development in the European Region

While European aquaculture consists mainly of private enterprises of widely different production capabilities, its control and direction have multifarious influences that include local, national and international bodies.

The FAO has two commissions that address the sustainable development of aquaculture, in addition to fisheries, in the European Region; the General Fisheries Commission for the Mediterranean (GFCM) which includes the Black Sea and covers the states bordering these seas and the European Inland Fisheries and Aquaculture Advisory Commission (EIFAAC).

As defined within their missions affecting aquaculture, each has the following roles:

- Providing advice, information and coordination.
- Encouraging enhanced stakeholder participation and communication.
- The delivery of effective research.

Both commissions have active national members and achieve projects of importance, often reported in their official annual meetings. Many of these projects address issues affecting aquaculture sustainability.

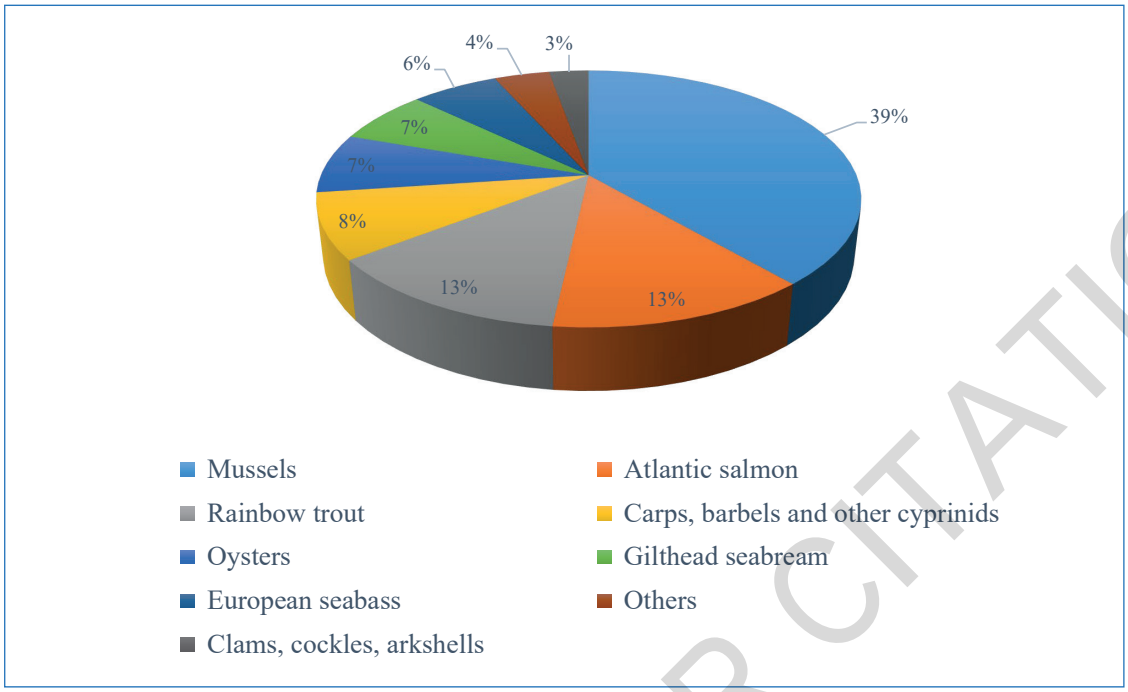
For the European Union, the European Parliament and the European Commission have limited roles, compared to fisheries, since member states individually govern licensing and operational legislation affecting aquaculture.

As will be detailed later in this review, the European Union developed a strategy (EC, 2002) and guidelines (EC, 2013) that focused on the sustainable development of European aquaculture, taking positions and recommendations to promote growth. However, during the period 2000–2018, a negative APR of minus 0.2 percent was seen for European Union aquaculture production while considerable developments were seen in Norway, Turkey, the Faroe Islands, the Russian Federation and Iceland, all non-European Union states.

Over the same period within the European Union, the aquaculture production of Atlantic salmon and Mediterranean finfish (European seabass, gilthead seabream, turbot and tuna) were positive, while cyprinids were stable but shellfish and rainbow trout production diminished.

Apart from higher rate increases in smaller states (including Malta, Cyprus, Estonia), only a few of the larger producing countries in the European Union obtained significant growth, with Greece leading (2000–2018 APR of 1.8 percent), although production has been between 110 000 tonnes and 130 000 tonnes annually since 2006.

FIGURE 13. Distribution of European Union aquaculture production by species in 2018 (percent)



Source: FAO. 2020a.

Figure 13 indicates the distribution by volume of the main species reared in European Union aquaculture in 2018, where shellfish provide 46 percent of the total amount, Atlantic salmon and rainbow trout had a combined yield of 30 percent, while combined European seabass and gilthead seabream contributed 13 percent.

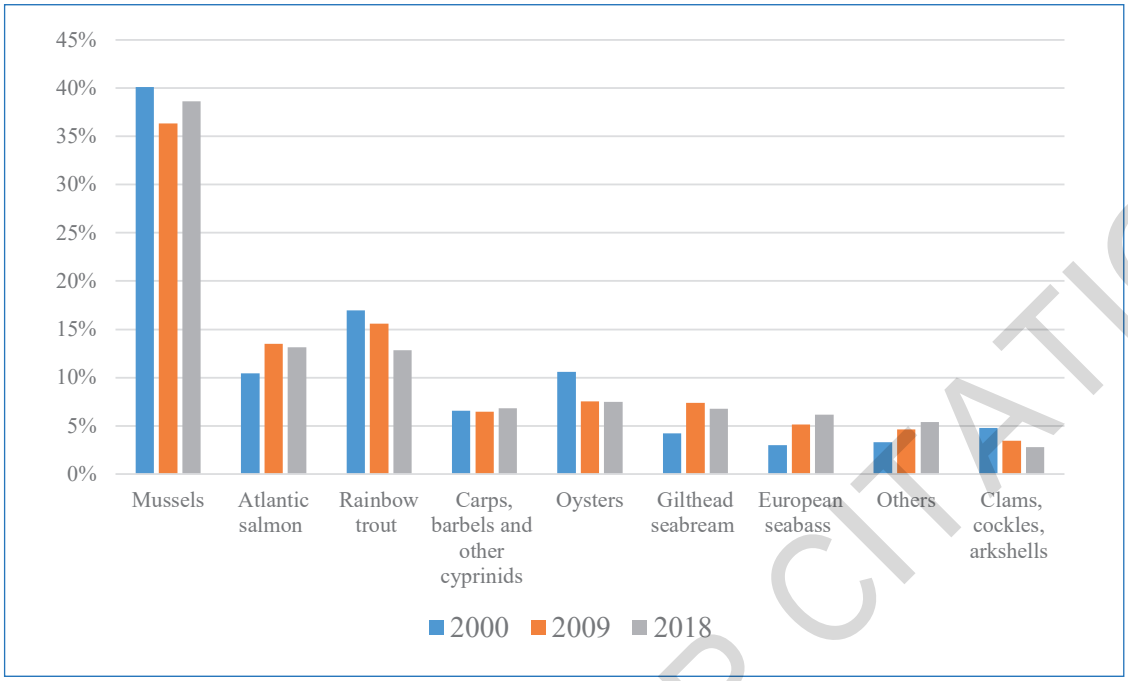
When the development for the period 2000–2018 is examined, only salmon, seabass and seabream aquaculture have shown growth, alongside a higher contribution of 'others' (four percent), a descriptive term that also includes diversification efforts to introduce 'new' or alternative species.

Several constraints to the development of freshwater aquaculture are noted by the European Market Observatory for Fisheries and Aquaculture Products (EUMOFA, 2021) where the low diversity and seasonal supply of products, combined with a lack of investment and successful innovation, are more specific to this sector. The contribution of freshwater aquaculture to local communities, traditions and cultural heritage is seen as important.

Figure 14 compares the percentage distribution of species in European aquaculture and shows how this has changed between 2000 and 2018.

The disparity between official expectations and results within the European Union has been the cause of much debate. There is no doubt that the financial crisis affected the performance of many of the companies involved in European aquaculture and, more specifically, the Mediterranean area, where Greece, Italy and Spain, as eurozone countries, received significant financial bailouts. Nonetheless, access to banking and financial facilities to assist aquaculture growth became, and still is in some countries, extremely difficult. In the last decade, several groups have analysed the reasons for this situation, including different Advisory Committees at European level and the European Aquaculture Technology and Innovation Platform (EATiP). EATiP prepared a Strategic Research and Innovation Agenda (SRIA) in 2012 (EATiP, 2012), following extended multi-stakeholder consultation, that addressed issues and solutions; a review of the SRIA was published in 2017, accompanied by a new Position Paper in 2019 (EATiP, 2019).

FIGURE 14. Distribution of species in European Union aquaculture in 2000, 2009 and 2018 (percent)



Source: FAO. 2020a.

Amongst the key issues identified were:

- A common strategy for the sustainable growth and development of European aquaculture is obstructed by the absence of a level legal playing field for allocating aquaculture licences. EATiP recommended that a pan-European review of existing regulations be made to develop a predictable, scientific and evidence-based licensing system that could be applied within Europe and beyond.
- Addressing public perceptions of aquaculture and engagement with citizens were two items identified to ensure the public licence to operate commercial aquaculture
- Assuring the best health conditions of livestock, guaranteeing effective animal welfare, should focus on moving from a treatment-based approach to using preventive measures, including vaccination, selective breeding and best management practices.
- Raising efficiency and control though high-precision farming technologies
- Promoting entrepreneurship, building capacity and training facilities, and improving dialogue.

The Aquaculture Advisory Council (AAC) provided a detailed position paper on the issue of obtaining a level playing field for European aquaculture compared with its competitors in the European market, covering a range of challenges that included consumer issues, food safety, feed ingredients, environmental measures and animal welfare. The AAC noted that the key challenge for European aquaculture is to achieve responsible and sustainable growth while restoring predictable profitability following the period of financial instability within the European Union.

During the period 2000–2014, the European Union invested USD 1.52 billion of structural funds in the aquaculture sector and agreed to provide USD 2.24 billion for 2014–2020 through the European Maritime and Fisheries Fund (EMFF). Production was forecast to increase through support for new farms and diversification activities while also investing in environmentally friendly technologies and adapting to new legislative conditions (Guillen *et al.*, 2019).

The 2016 Scientific, Technical and Economic Committee for Fisheries (STECF) Economic report on aquaculture observed the following:

- Providing a better legal framework (including licensing and environmental requirements) for the aquaculture industry is by far the most important limiting factor to be addressed to lay the foundation for future growth in the European aquaculture sector.
- Administrative issues are far more important to solve than the technical ones.
- Environmental regulations, difficulties in the licensing process due to multi-level governance and competition for space, both on land and in the coastal zones, continue to be the most important areas to be addressed to support and increase growth in the European Union aquaculture sector

The European Parliament made an own-initiative report in 2018 which confirmed many of these issues and that the expectations of the European strategies have not been met (EP, 2017). It highlighted broad areas for action, including:

- Unlocking the potential of European Union aquaculture and increase the sector's contributions to food nutrition and security.
- Simplifying administrative procedures, addressing specifically local and regional authorities.
- Establishing equity in interaction with other sectors in coastal and rural areas.
- Adapting legislation to aquaculture's realities, specificities and needs.
- Enhancing competitiveness with imported seafood products.
- Improving communication and consumer information.
- Supporting research and innovation, accompanied by appropriate training actions.

It was noted and supported by the conclusion of the European Court of Auditors, that the European Fisheries Fund (EFF) did not effectively support the sustainable development of aquaculture. The complexity of application processes, combined with a lack of complementary state funding, has been blamed by the production sector. The financial crisis also meant that bridging loans, needed to achieve and pay for agreed investments before liberation of EFF/EMFF funds, were very difficult to obtain.

The AAC indicated that the main reasons for the lack of growth were the failure by public authorities to address key challenges and insufficient implementation by those authorities of the strategic guidelines. In 2019 and 2020, the AAC provided recommendations and a comprehensive list of actions for European Union member states and the European Commission for consideration by these authorities in pursuit of the sustainable development of European Union aquaculture.

The shared views included that licensing procedures for aquaculture are time-consuming and unpredictable which, when combined with competition for coastal or rural space and strict environmental regulations, restrict and discourage aquaculture investments and growth. The paradox is that high-level European documents have supported the principles for growth and the sustainable development of aquaculture but that this has not been translated into visible progress within the European Union sector.

Furthermore, in 2017 the GFCM adopted the "Strategy for the sustainable development of Mediterranean and Black Sea aquaculture" (GFCM, 2018), providing a framework for GFCM member states to foster responsible sectoral growth. The strategy has three main targets, in line with Sustainable Development Goal (SDG) 14, which are:

- Build an efficient regulatory and administrative framework to secure sustainable aquaculture growth.
- Enhance interactions between aquaculture and the environment while ensuring animal health and welfare.
- Facilitate market-oriented aquaculture and enhance public perception.

It must be observed that the different commissions and committees that address aquaculture development in Europe agree on many common issues and goals but integration of these into efficient national actions is slow.

The TAPAS project (TAPAS, 2020) aimed to provide tools for measuring carrying capacity categories of freshwater and marine aquaculture in terms of regulation, policies and sustainability indicators while applying the ecosystem approach to aquaculture. Recently finished, the application of project results remains to be assessed. It is hoped that their use will help to reduce the licensing time for new and existing aquaculture operations, while enhancing the public image of aquaculture and providing a better understanding of the sustainability of aquaculture in Europe. This project complemented work on sustainability indicators in the Mediterranean by Fezzardi *et al.* (2013).

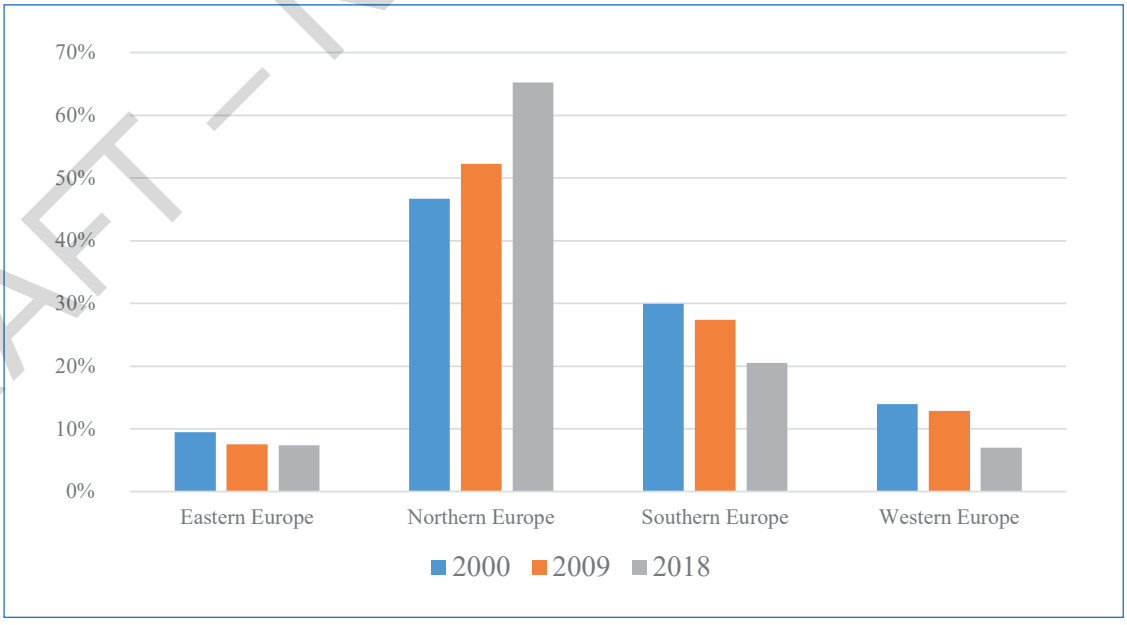
2.1.8 Financial performance

The value of aquaculture trade in the European Region was USD 16.56 billion in 2018 (FAO, 2020a), indicating an APR of 7.0 percent for the period 2000–2018. The sub-regional share of this value is detailed in Figure 15.

For the major products, Atlantic salmon production fared best with an APR of 9.9 percent over the period 2000–2018, followed by European seabass with 7.4 percent and gilthead seabream at 5.1 percent. Rainbow trout had an APR of 3.6 percent, while freshwater fish followed with 2.8 percent. The value of mollusc production increased by 3.1 percent over the period, where oysters (5.4 percent) and mussels (2.3 percent) performed best.

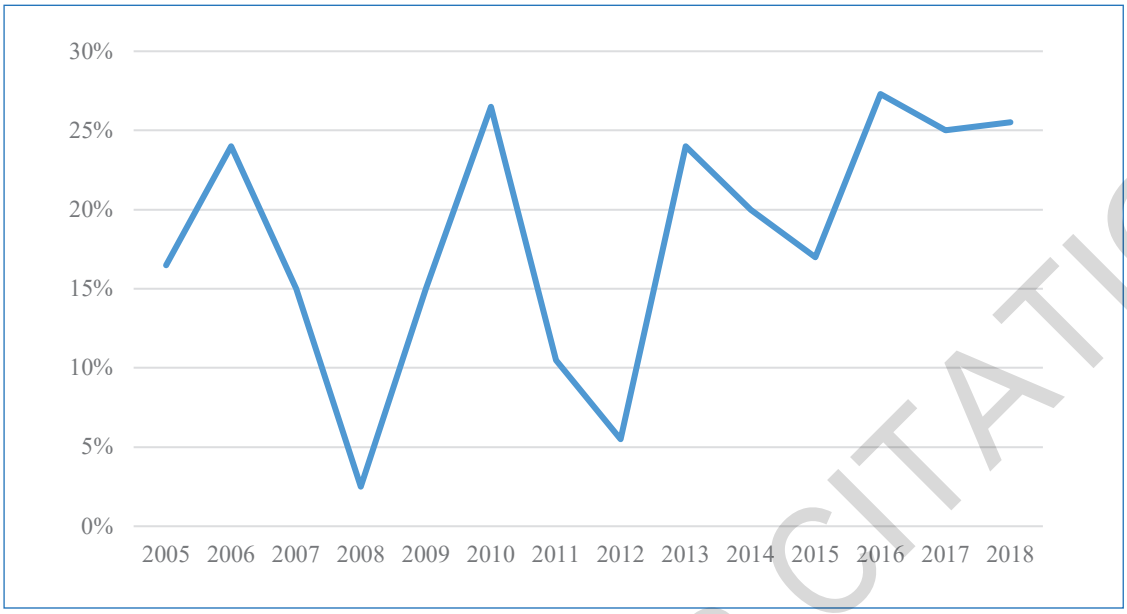
From European Union member state reports, the total first sale value was estimated at USD 4.41 billion in 2016, an increase compared to previous years and a result of rising prices across the different sub-sectors. Profitability increased as well for the complete European Union aquaculture sector (STECF, 2018) while earnings before interest and taxes (EBIT) was reported to be 15.7 percent, almost double the 2014 estimate.

FIGURE 15. Share of the value of European aquaculture by sub-region in 2000, 2009 and 2018 (percent)



Source: FAO. 2020a.

FIGURE 16. Earnings Before Interest and Taxes (EBIT) for the 20 largest Norwegian salmon companies, 2005–2018 (percent of total revenue)



Source: Berge, 2017.

In Norway, the 2018 EBIT analysis of the salmon and trout farming sector indicates continuing profitability with 20 companies having EBITs of 35 percent to 50 percent (Figure 16). Although cyclic, this sector has shown outstanding financial performance in the last five years.

The STECF report provides an overall Future Expectations Indicator (FEI), a measure of whether a sector is investing more than the depreciation of its current assets. An overall figure of 3.1 percent was reported for European Union aquaculture enterprises, much improved from the negative minus 5.8 percent of 2014. However, several important producer states have weak FEI figures (Denmark 0.4 percent, France minus 1.4 percent, Greece 0.1 percent, Spain minus 0.6 percent) which do not reflect particularly positive prospects.

2.2 SALIENT ISSUES

2.2.1 Aquaculture production

Salmon has been the consistent success story of European aquaculture in the last decade. Growth has continued, not only in Norway but also in the Faroe Islands and Scotland, and prices have been very good, allowing continued profitability even with the additional costs of sea lice treatment.

Mowi, formerly known as Marine Harvest, is the largest aquaculture company in the world, harvesting 436 000 tonnes for a turnover of USD 3 700 million and an operational EBIT of USD 600 million in 2019 (MOWI, 2019). The company serves 20 percent of the global demand for salmon and employs 14 500 people in 25 countries (MOWI, 2019).

By comparison, the largest company in the Faroe Islands, Bakkafrost, harvested 57 200 tonnes in 2019, representing 65 percent of the country's total aquaculture production; Bakkafrost also owns the Scottish Salmon Company in the United Kingdom of Great Britain and Northern Ireland and is quoted on the Oslo Stock Exchange (Bakkafrost, 2021).

The Norwegian aquaculture sector is backed by research institutes, universities and private companies, where many research activities are targeting environmental and economic solutions to the challenges facing the sector. The Norwegian Seafood Research Fund, a state-

owned company, is financed by an export levy on Norwegian seafood of 0.3 percent of value and supports industry-based R&D projects. The larger Norwegian companies also achieve own-initiative development actions including the use of RAS to produce larger smolts, meaning less time in sea cages, and speedier attainment of harvest sizes. Closed containment marine facilities are also being investigated as are technological solutions to the multiple challenges facing the sector (see also Murray *et al*., 2014).

Before being farmed, fresh salmon was a luxury, an expensive and seasonal product, usually sold as a whole, gutted fish or prepared as cuts by a fishmonger, the only added-value item being smoked salmon. Today, affordable boneless fillets and multiple fresh cuts are offered alongside a wide range of ready-to-cook preparations, with year-round availability. This represents the major European aquaculture success story since 2000.

The first research-based selective breeding programmes on salmon started in Norway in the 1970s, although selective trout breeding had started much earlier. By common agreement with the Norwegian Aquaculture Association, a 1985 joint venture that pooled the original Atlantic salmon and trout families, collected originally in Norwegian rivers in 1971, became AquaGen in 1999.

Breeding programmes have been established for faster growth, late sexual maturity, fillet colour, disease resistance (for example, to Infectious Pancreatic Necrosis and Pancreas Disease), resistance to gill parasites and sea lice. Advanced selection techniques, using DNA analysis to find quantitative trait locus (QTL) genetic markers associated with different traits, can give more rapid and accurate selection. Similar programmes have been established for trout in Denmark, the United Kingdom of Great Britain and Northern Ireland and France, and for common carp in Belarus. Combined with better feeds and management, the time from egg to harvest for both salmon and trout has been much reduced, providing larger fish containing more meat.

The Mediterranean sector started later in this aspect, working mainly on European seabass and gilthead seabream, where the larger companies and hatcheries have invested in selective breeding programmes. Research in this area has also been supported by the European and national research programmes.

The largest salmon companies have invested in advanced infrastructure and equipment and have access to sophisticated logistics and supply chains. Similar actions have been seen in the Mediterranean sector, notably in Turkey and Greece. The integration of hatcheries and feed manufacture by some companies, accompanied by final product processing and packaging, accounts for full vertical integration of the aquaculture chain.

There are few comparable stories in freshwater aquaculture, but Aqualande (France) is one such. The company started as a cooperative of trout producers in southwest France. Following diversification with hatcheries and processing units, Aqualande entered marine fish production and feed manufacture. Specialised in selective breeding of trout and marine fish, the company has become the leading producer-processor of trout in Europe with a turnover of USD 130 million in 2018 and employing 945 people (Aqualande, 2018).

2.2.2 Aquaculture products

Product trends have followed consumer preferences and market demands that reflect an increased offer of packed fillets and processed products, including ready-to-cook meals. This has been compounded by the reduction of fishmonger outlets and fresh fish counters in supermarkets. Larger individual fish sizes, improved bone removal and modified-

atmosphere packing that prolongs shelf-life account for the omnipresence of salmon fillets and cuts throughout Europe.

In Western Europe, production of portion-size trout (250–450 g), traditionally marketed fresh, has reduced with producers moving to larger sizes, acting as a complementary product to salmon, for filleting, smoking and processing. Similarly, packed shellfish (mainly mussels) are more commonplace and popular in northern European countries. The increased availability of ready-made meals that use fish and shellfish as ingredients is also to be noted.

In Central and Eastern Europe, fishmongers and farm shops play an important role supplying live and fresh fish for local and regional markets. For example, in Romania 25 percent of farmed fish is sold through farm shops and some 60 percent through fishmongers.

2.3 THE WAY FORWARD

2.3.1 Salmon farming in the European Region

Salmon farming had expanded to 1.5 million tonnes in Europe by 2012, with production stabilising at around this level since then. The slowdown in growth was seen first in Norway, the production leader. Concerns about sea lice infestation, the potential environmental effects of escapes and the other impacts of aquaculture on the environment led to the introduction of stricter controls and tighter licensing conditions.

These issues led to the proposals for salmon farms to move offshore or use marine closed-containment systems and RAS-based farms on land. While each approach has advantages and disadvantages, it will be the response of the sector to such local and public concerns that will govern acceptance of the activity. Bolstered by high product values, the European salmon sector has some space to establish solutions to its challenges but immediate growth appears unlikely, except where rearing conditions and effects satisfy the local legislator.

2.3.2 Species diversification

Unstable product pricing has affected most European aquaculture sectors at some point and attempting the production of new or different species has been an option for many involved in professional aquaculture.

The production of Atlantic cod grew mainly in Norway, reaching 21 000 tonnes before competition with fisheries eliminated the sector. Interest in flatfish, including sole and turbot, has been longstanding but, except for a few individual farms, it has not expanded to become a product of high European importance. Uncertainty in the Mediterranean marine sector caused multiple attempts to farm alternative species to European seabass and gilthead seabream, with FAO statistics reporting a range of bream species such as common pandora *(Pagellus erythrinus)* and red porgy. However, the only species to have exceeded 1 000 tonnes of production are meagre, flathead grey mullet *(Mugil cephalus)* and red porgy. Meagre has proved to be a viable production option, reaching around 7 000 tonnes but still with a limited market.

In freshwater, the production of varied trout species for angling purposes can be noted. The Russian Federation reports development for species such as silver carp and channel catfish, while African catfish *(Clarias gariepinus)* is now produced, albeit in small quantities, throughout the European Region. Attempts to rear European perch and pike-perch, although of high interest, have not translated into commercial success.

TABLE 7. Caviar production in the European Region in 2017 (tonnes)

Country	Caviar (tonnes)	Country	Caviar (tonnes)
Russian Federation	49	Turkey	3
Italy	43	Greece	2
France	37	Hungary	2
Poland	20.4	Belorussia	1.8
Germany	16.1	Switzerland	1.7
Bulgaria	8	Ukraine	1.6
Israel	5.5	Netherlands	1
Spain	5	Austria	1
Belgium	3.8	United Kingdom	0.5
Finland	3.5	Estonia	0.4
Latvia	3	Lithuania	0.4
Romania	3	Cyprus	0.1

Source. Bronzi *et al*., 2017.

The rearing of sturgeon for caviar has become widespread in the European Region (Table 7), benefitting from the CITES ban on international trade on caviar from wild sturgeons. In 2002, sturgeon production was limited to the Russian Federation and Italy, with small levels of production in France, Poland and Spain (FAO, 2020a). By 2017, a further 20 countries in the European Region reported sturgeon production (Bronzi *et al*, 2017).

The European Region has 30 percent of the commercial sturgeon farms in the world. While China dominates sturgeon biomass and caviar production, the European Region provided some 213 tonnes of caviar to the market in 2017. Sturgeon meat is a minor product within the European market but is well developed within the Russian Federation, together with minor production of coloured sturgeons as ornamental fish. Over 20 different species, crosses or hybrids are reared, where Siberian sturgeon *(Acipenser baerii)* and Russian sturgeon *(A. gueldenstaedtii)* dominate those used for caviar production. The caviar market was traditionally focused on cruise ships and airlines and high-level seasonal consumption. The expansion of production appears to be higher than demand and prices have dropped, which has led to seasonal product presence in certain supermarkets. The long-term success of this sector will depend on the maintenance of the image and quality of the caviar presented but at values that will be acceptable for market growth.

Diversification of production away from the main aquaculture products of the European Region has been encouraged but with few success stories. The DIVERSIFY project looked to identify the biological and socio-economic potential of several new or emerging fish species for aquaculture. These include meagre and greater amberjack for warm-water marine cage culture, wreckfish *(Polyprion americanus)* for warm- and cool-water marine cage culture, Atlantic halibut *(Hippoglossus hippoglossus)* for marine cold-water culture, flat-head grey mullet, a euryhaline herbivore for extensive pond culture, and pike-perch (DIVERSIFY, 2021).

The improved performance of strains of existing species, through selective breeding technologies, that have established production protocols and markets appears to be a more viable option for immediate development opportunities.

2.3.3 Certification of aquaculture

Branding for supermarkets was a major marketing influence for food suppliers in the 1980s. This evolved towards independent quality schemes, such as “Label Rouge”, which were the first form of certification for aquaculture. This approach was followed later by organic, environmental and welfare programmes.

Each certification direction adopted imposes production and processing conditions that have to be followed by the producer that are subject to control inspections and audits to allow that producer to be certified and allowed to use the associated labels. Programme controls are not necessarily achieved by the scheme promoter and programme auditors are often independent companies.

Defining and certifying organic aquaculture has posed specific challenges to both the formulated feed manufacturers and the production sectors, notably those dependent on hatchery supplies of organic juveniles. While organic aquaculture exists in Europe, production and transition from 'conventional' remains below 5 percent (see Section 5 of this review for more details).

Nonetheless, increased consumer awareness of the nature of food production and geographic origin and sensitivity to issues such as food miles, fair trade and encouragement of local production are influencing consumer behaviour. Sustainability is now referenced often in branding actions but, without defined criteria, is complex to address for certification purposes and when communicating with the public. Defining and obtaining agreement on the terms and conditions for sustainability when certifying is extremely challenging.

The encouragement of local, sustainable aquaculture would provide considerable opportunities to microenterprises in freshwater aquaculture, although this would involve investment in processing, marketing and distribution, which may deter many. The use of cooperative structures or producer organisations would provide alternative solutions to those with insufficient individual financial resources.

Application of the Product Environmental Footprint (PEF) has been promoted within the European Union as an important component of the single market for green products, requiring the development and agreement of specific category rules for production and operation (EC, 2012). This effort was a reaction to the increasing number of certification schemes whose impact and efficiency has been questioned. Pilot schemes have been developed, including one for animal and fish feeds. Measuring the impact and success of such measures by the professional industry remains an issue to resolve.

3. Resources, services and technologies

3.1 STATUS AND TRENDS

3.1.1 Background

The technologies applied by aquaculture operators in Europe varies with the scale of the enterprise and its investment capacity. Little has changed in recent times in shellfish culture while temperature extremes and reduced freshwater resources have encouraged governments to support the adoption of RAS and other innovations in production of freshwater fish in Europe.

Major changes have been within the marine cage farming sectors where significant improvements in equipment, technologies and management systems have occurred. The driving force behind these developments has been productivity improvements.

On the other hand, as reported in the 2015 FAO Regional Review, growth in European aquaculture cannot be achieved without licenses for farm location and site operation. The conditions and time required for farm licences in Europe have been recognised as a major constraint for development in the European Union. Marine site licences are often linked to production capacity and thus provide limitations on unplanned growth. Freshwater farm licences are increasingly dependent on limiting nitrogen and phosphorous release, affecting production and feed profiles.

3.1.2 Offshore marine aquaculture

The model of 'offshore' or 'open ocean' aquaculture has been promoted as a new component of the 'Blue Revolution', which reflects the intense growth in the worldwide aquaculture industry from the mid-1960s to present. The concept of relocating coastal sites to 'offshore' locations has been encouraged, often due to opposition to pollution and competition for marine coastal space, for example, from tourist and fishing areas. For the salmon sector, concerns about sea lice infestation dominate the sector's public acceptability and impose new approaches to sustainability. Offshore conditions improve self-cleaning of production sites and, potentially, fish health (Ross *et al.*, 2013).

However, most investments have been for developments within exposed areas rather than fully offshore. Farm design challenges include infrastructure resistance to storms, logistics for feed supplies and workers, and effectiveness of remote management systems that combine to impose higher investment and operating costs. Nonetheless, offshore developments have been made, notably in the countries where marine aquaculture is important, albeit at a smaller level of adoption than traditional coastal farming.

Norway has led European investment in this area, with several major companies making substantial commitments to offshore farming, which have featured different engineering solutions. Fully or semi-submersible cages and ship-based containment projects have been promoted, with organisations making significant investments in both pilot and commercial stages. Offshore structures have been estimated to be as much as six times the cost of existing coastal farms, which limits the investment potential to large companies. These moves need to be accompanied by new regulations to give a clear and predictable operating regime for offshore aquaculture to move forward significantly.

3.1.3 Freshwater pond aquaculture

Aquaculture in central and eastern Europe is dominated by cyprinid culture, principally common carp, that is not only achieved in large ponds and waterways but also by many smallholder farmers who maintain a few ponds for harvesting at festive periods. Up to nine fish species may be used in pond stocking formulas and there is increasing recognition of the ecological benefits of the extensive culture system, contributing to the conservation of biodiversity and providing local social and cultural benefits, including sport angling in larger man-made reservoirs or natural lakes. Native species supported through culture-based fish hatcheries managed by private farmers, angler associations or government, are harvested by sport fishers and almost exclusively consumed locally in tourist restaurants or at home. Major demand is during Christmas and Easter holidays. Unfortunately, data on inland sport fishing supported by aquaculture is often lacking.

The surrounding areas are also considered highly appropriate for Natura2000 sites, and provide habitats for a wide variety of birds, plants and animals. In developing the concept of ecosystem services provided by these aquaculture infrastructures, which include nutrient retention, water cleaning and flood protection, high economic values have been estimated, often more than the value of the food produced by aquaculture (Turkowski, 2018).

Economically, this sector's market is challenged by changing consumer preferences, competitive products and supply restrictions due to seasonal harvests. Stock losses to predators such as cormorants and disease including koi herpes virus (KHV) have been significant and there have been recurrent extreme weather events (high summer temperature and drought) in recent years (COST, 2015). Questions remain on the long-term viability of this sector and the multi-functional environmental services of the large pond infrastructure appear to be important to its long-term future.

Innovative solutions to production constraints, coupled with higher societal recognition of environmentally sustainable fish production, need encouragement. Product diversification and adaptation to consumer preferences also requires attention (EUMOFA, 2021)

3.1.4 Resources

Optimising resource use is of the highest concern for assuring the sustainability of aquaculture and covers different topics, including infrastructure, freshwater and electricity, feeds and their ingredients, and the control of disease and infections.

Regular access to adequate water supplies is a barrier for the development of all freshwater aquaculture in Europe. Low volumes combined with high summer temperatures can have considerable impacts on harvest quantities, due to low feed regimes and temperature stress. Severe weather episodes are becoming more frequent in the European region and have impacts on both live stocks and infrastructure. Drought, heavy rains and flooding combined with extreme temperatures affect many aquaculture species.

Concerns that extreme climate effects would become the norm and could have severe effects on European aquaculture and fisheries led to two large European projects, Climefish and CERES (ClimeFish, 2021; CERES, 2021). These projects examine how climate change can affect aquaculture and fisheries and provide tools and strategies to plan for adaptation.

Each project has published the results of case studies, accompanied by fact sheets covering marine and freshwater aquaculture in European geographic regions. Generally, while certain freshwater and marine species would grow more quickly in higher temperatures, there is concern that the highest temperatures will cause mortalities and extreme climatic events will damage infrastructure.

Each case study includes an analysis of risks and opportunities, adaptation strategies and potential socio-economic outcomes. An evolving decision support framework (DSF) is being developed for use by stakeholders. Strong cooperation and collaboration between all stakeholders including industry, academia and administrations is a clear recommendation and both Climefish and Ceres are collaborating with the European Climate Adaptation Platform.

3.1.5 Integrated Multi-trophic Aquaculture (IMTA)

The EATiP Strategic Research and Innovation Agenda (EATiP, 2012) identified the potential of integrated multi-trophic aquaculture, where lower trophic level aquatic organisms, such as shellfish and algae, can benefit from the organic waste and nutrient enrichment from adjacent fish farming. As pointed out in FAO (2017a), such systems are common in Asia but their integration within the more intensive commercial aquaculture models in Europe is challenging. In addition, as IMTA is primarily a coastal activity, few legal and licensing frameworks exist to accommodate such developments, which have been largely experimental.

The goals of the European project IDREEM (Increasing industrial Resource Efficiency in European Mariculture) were to develop and demonstrate new IMTA technologies and systems (IDREEM, 2016). It was completed in 2016 with its final report indicating seven activities in place. Two large IMTA projects were initiated in the last decade. The KOMBI project (KOMBI, 2021) in Denmark and Ocean Forest in Norway, the latter promoted by the Leroy Seafood Group and the Bellona Foundation (Bellona, 2021). In France, an inter-regional project (INTEGRATE, 2020) on IMTA reported on experiences in five IMTA facilities and observed that multi-skilled operators are needed to master the different IMTA components (fish/shellfish/algae). In Italy, the project RemediaLife, operative from 2017 to 2021, aims to develop an IMTA system using a new set of bioremediator organisms whose action is more effective than the use of molluscs only. The European project "IMTA-Effect" aimed to generate knowledge for designing IMTA strategies for fish farmers in marine and freshwater aquaculture systems. The project combined experimental and modelling approaches to provide knowledge on the nutrient and energy efficiency gains generated by associating different aquatic species of different levels in the food web. Multitrophic marine systems were studied in Portugal, France and Greece and freshwater polyculture systems in Romania and France. The different IMTA case studies revealed that adapted management of the interaction between species of different trophic groups allows improvement of the aquaculture system, increasing productivity of other products and services that would not be obtained in monoculture. Nutrient recycling is important and is accompanied by the regulation of carbon dioxide and oxygen and the reduction of nitrogen and phosphorus concentrations.

While these efforts have been appreciated and are generating interest, the legal conditions for operation remain important challenges to wide-scale adoption. As an example, there is no integrated process at present for licensing IMTA sites. Overall, the uncertainties on licensing, spatial competition and questionable financial returns from secondary products including algae and/or shellfish are major barriers to immediate growth of this sector in Europe.

3.1.6 Formulated feeds

Nutritional advances are evident, especially for the salmonid sector, and food conversion ratios remain one of the most important factors determining the profitability of finfish aquaculture. Many of the improvements in feeds have come from feed manufacturing companies although academic research continues on this topic, more specifically on alternative ingredients. The commercial sector in southern Europe, rearing European seabass and gilthead seabream, has stated that its sector has not seen the same progress as made in salmonids, an issue highlighted in the joint EATiP-EAS workshop held in 2014. The recommendations of this meeting led

to two important European research and innovation projects, Performfish (2017–2022) and MedAid (2017–2021), whose common aim is to explore and address the underlying causes behind the stagnation of Mediterranean fish farming (PerformFish, 2020). Feeds and feeding technology are amongst the top subjects, accompanied by selective breeding, juvenile quality and investigations into health and welfare.

Following the bovine spongiform encephalopathy (BSE) crisis where a neurodegenerative disease of cattle was spread to humans following consumption of infected meat products, resulting in Variant Creutzfeldt-Jakob Disease, land animal proteins were banned from fish feed formulations in Europe. This led to concerns about the impact of the growth of carnivorous fish aquaculture on the populations of forage fish used for fishmeal supplies.

The Aquaculture Advisory Council (AAC) communicated on this topic in 2019, stating that 'marine raw materials used in aquafeeds for aquaculture product consumed in Europe should be expected to achieve standards based on responsibly managed resources where that material is available, according to the FAO Code of Conduct for Responsible Fisheries. This should include imported aquaculture products, as well as those produced in Europe'. Noting that both IFFO (The Marine Ingredients Association) and the Marine Stewardship Council (MSC) have international standards, the AAC anticipates that the sustainable management of resources for feeds is the collective responsibility of all stakeholders (MSC, 2021).

Carnivorous fish have a nutritional requirement for the omega-3 (n-3) long-chain polyunsaturated fatty acids (LC-PUFAs) docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), as do humans. If limitations occur on LC-PUFA supplies from fish oils, alternative sources are needed for carnivorous fish diets.

Alternative plant oils have been the topic of large-scale investigation but, despite intense research, few alternatives appear to be feasible, although the incorporation rate of fish oils in feeds is now about 30 percent of that in 2010. As reported in the 2015 regional review, the use of algal genes in transgenic camelina *(Camelina sativa)* shows clear potential as a replacement source of EPA. Nonetheless, since it is clear that the European authorities discourage the development and use of genetically modified organisms (GMOs), it is unlikely that this route will be followed in Europe.

For protein supplies, plant resources (soy, sunflower rapeseed, wheat and corn) have been commonly used in the culture of cyprinids and are used increasingly for omnivorous and carnivorous species, while recycling fish processing offcuts is commonplace. Processed animal proteins (PAPs) have been treated to allow their direct use as a feed or as an ingredient in a feed for animals, including fish. While approved for use in fish feeds in the European Union, consumer sensitivity following the BSE crisis means that PAPs are little used.

Since 2017, insect meals have been allowed for use in fish feeds and commercial feed companies have investigated their potential use and acceptance (OJ L, 2017). Trials have given positive results but consistent and adequate supplies, combined with lower prices, will be required for widespread use. The approach of rearing insects on food waste corresponds to the circular economy concept, encouraging sustainability, although only plant-based feedstocks can be used at present. The International Platform of Insects for Food and Feed has over 50 members that are engaged with insect production for human consumption and feed formulation, and reported that 6 000 tonnes of insect protein were produced in 2019 (IPIFF, 2020).

Other alternatives under examination include microbial and single cell proteins and, while all these options are promising, it appears that they are niche components at present.

3.1.7 Services

Services to aquaculture professionals are varied and cover all aspects of the different production technologies. While feed suppliers and veterinary services are long established, new innovations have entered the active European service supply sector.

Within the European Region, progress and innovations are communicated through different events. The annual scientific conference 'Aquaculture Europe' is organised by the European Aquaculture Society and covers research progress as well as being accompanied by a trade show (EAS, 2021). 'AquaNor' is held every 2 years in Trondheim (Norway) and combines conference activities with demonstrations and a tradeshow. Drawing around 28 000 visitors and with around 700 exhibitors in 2019, AquaNor is the largest meeting place for professionals and service suppliers in Europe and is the most important regular global event on aquaculture and technologies. In the Mediterranean area, 'AquaFarm' is an international conference and tradeshow on aquaculture that is held annually in Pordenone (Italy) and is becoming an important event in the region.

These events provide showcases on research and innovation in all service areas that support professional aquaculture.

EIFAAC has increased its regional projects related to freshwater aquaculture, for example on problems of cormorant predation in fish farms and a publication on "Welfare of fishes in aquaculture" (Segner *et al.*, 2019).

3.1.8 Technologies for aquaculture

For suppliers to aquaculture operators, the last decade has seen the development of larger and stronger cages for marine operation, accompanied by better mooring systems, automated feed distribution and monitoring technology. These improvements are essential for productivity, assuring worker safety and environmental monitoring while minimising the risk of escapes. Improved feeds and health have long been the focus of research in aquaculture since these are the key issues for economic profitability and the long-term sustainability of the profession.

Labour-saving devices are ubiquitous in the European fish farming sector, notably for fish feeding, counting, grading and harvesting. Automation and remote-distance monitoring are essential features of modern marine and freshwater cage aquaculture and important efforts are being made to improve the means of measurement and monitoring of farm activities.

Improving farm operational procedures, stock movement and performance data have long been addressed through computerised assistance of stock management. Stock traceability is increasingly important, not only when improved genetic lines are used but also for referencing disease treatment and feed usage. On-farm data collection is done regularly, often using automated sensors and communication tools, and a range of software solutions have been developed to support monitoring and predictive efficiency. Leaders in this area are AKVA, which integrates their software with other control measures including feed management, Mercatus and AquaManager.

Additional cloud-based systems, linked to data-mining facilities, have been developed to allow highly detailed performance analysis, what-if functions and predictive analysis. Nonetheless, for smaller farms with limited human resources, data management and analysis is a challenge. The FindIT project determined that virtually no aquaculture farms employed a professional data manager although the financial benefits obtained through minor levels of stock management improvement would pay for this (FindIT, 2021).

While fish farming has long been served by journals such as Fish Farming International or Fish Farmer, the growth of web-based publications during the last decade has been notable. Intrafish led the way, achieving global coverage after starting as a weekly fax-based initiative in 1996. Specialised information on aquaculture is in demand not only by the farmers but by all related to the profession, including seafood product buyers, investors, bankers and other stakeholders. Usually subscription-based, these information services are integral to awareness on news, issues and developments for all professional farmers.

EUROFISH International Organization, formerly a project of FAO's GLOBEFISH and part of the global FISH INFO network, prepares detailed reports on aquaculture sectors of its 13 member countries, for publication on the web and in its 'Eurofish' Magazine. These reports focus on markets and trade but also include information on aquaculture production in Europe.

At the Mediterranean and Black Sea level, the GFCM launched two Aquaculture Demonstration Centre units (ADCs) in Romania and in Turkey, which could be replicated in other countries in the region. These centres have proven to be effective in sharing knowledge and innovations among countries.

Beside the importance of online or printed publications, a key role in knowledge-transfer and capacity development could be played by farmers organizations across the region. Their role should be strengthened (Rad *et al*, 2014) and synergies promoted between research programmes at the national level.

3.2 SALIENT ISSUES

3.2.1 Expansion of Recirculating Aquaculture Systems (RAS)

The use of systems to treat and recirculate water in land-based aquaculture is not new but has always been hampered by higher investment and operating costs when compared to traditional flow-through structures. Maximising water use while eliminating contaminant materials, solid and dissolved, is the core consideration. Stricter environmental controls on farm effluents, particularly in northern Europe, stimulated technological developments on more efficient and cost-effective installations. Initially reserved for hatcheries, with their higher biological turnover and product value, investments in on-growing have increased, most recently for land-based Atlantic salmon farming. Extension of RAS technology to tropical or warm water species has occurred but with variable commercial results in Europe (for example, for shrimp, eel, pike-perch, tilapia).

As noted by FAO (2017a) the optimism about RAS success has been countered by many failures, often due to underestimating investment and overestimating performance. One major success was the FAO installation of a RAS system in Armenia. The system is fully functional and the installations are used a model farm for training. Investment in RAS systems in Eastern and Central Europe by freshwater fish farms has been limited to commercial enterprises for higher-value products like sturgeon and rainbow trout, as the investment payback is inadequate for smallholder farmers or carp producers. The success of smolt and post-smolt production in RAS systems in Norway has been notable. Within the last decade, more than 40 such units have become operational, usually managed with the strictest hygienic conditions (Rabobank, 2019). These systems allow the supply of larger post-smolt fish for cage culture, significantly reducing the time to harvest. This also means less exposure to the risk of sea-lice infection and allows cage usage that is closer to maximum capacity.

Extension of RAS systems to on-growing operations has been problematic, but higher product values for salmon in recent years has returned optimism. Rabobank identified 50 RAS salmon projects proposed for investment, noting that salmon was the focus as opposed to other species produced in Europe. Foreseeing an additional 250 000 tonnes to be produced by 2030, through investments in Norway and northern Europe, the report indicates projects of between 5 000 and 35 000 tonnes capacity (Rabobank, 2019).

Atlantic Sapphire initiated a RAS salmon project in Denmark, followed by the world's largest RAS salmon farm in Florida (US), aiming to supply the American market (Atlantic Sapphire, 2021). At the end of 2019, the company was valued at more than USD 1 billion on the Oslo Stock Exchange, reflecting high investor expectations. While only in its first generation of production, success will lead to significant investments in this area.

3.2.2 Aquatic animal health and biosecurity

The FAO has encouraged the adoption and dissemination of the Progressive Management Pathway approach to improve aquaculture biosecurity and other aquatic animal health issues (FAO, 2019a). At the Mediterranean and Black Sea level, regional cooperation activities address transboundary issues and challenges related to aquatic animal health and welfare. These include applying effective health management measures based on epidemiological knowledge, early diagnosis of pathogens, application of effective biosecurity measures at the farm level, adaptive management responses and a harmonized approach to surveillance systems.

For the salmon sector, and more specifically Norway, sea lice infestation and obtaining efficient non-chemical treatments have been dominant issues for sectoral operations and a focal point of research for many years. Losses of salmon exceeded USD 340 million and treatment costs were estimated at between USD 0.10/kg and USD 0.20/kg of harvested salmon. In 2017 Norway introduced a zonal 'traffic-light' system, where each of 13 zones is allocated a green, amber, or red light, based on the number of sea lice. Within a green-light area, farmers may be accorded production growth (up to 6 percent), amber means the situation stays the same but a red-light imposes reduction. In 2019, following national monitoring, Norwegian authorities indicated that a red-light option would be applied in 2020.

Optical counting systems for use in cages have been developed to monitor infections, even combining this with killing sea lice with a laser. Chemical treatments, in baths or medicated feeds, have not proved fully effective and can have negative effects. The use of cleaner fish, such as lumpfish or ballan wrasse, is widespread, the rearing of these fish being a new form of aquaculture. Mechanical delousing systems are also employed, combined with thermal or freshwater treatments to remove lice. In the long term, research into vaccines and selective breeding are indicating promising results. Whether any of these approaches are 100 percent effective remains debatable and research continues.

Within the European Union, there is little standardisation on the availability and access by professionals to the same vaccines, veterinary treatments and disinfectants in different member states. The AAC recognised this situation in its position paper (AAC, 2019) on establishing a level playing field for European aquaculture operators, requesting a review of comparable measures to assure the best welfare practices throughout Europe.

3.3 THE WAY FORWARD

3.3.1 Precision farming

Big Data and Advanced Analytics (BDAA) is widely seen as an opportunity for the food production sector to respond to the challenges of attaining sustainability. Examples are given in Table 8.

TABLE 8. BDAA responses to challenges in food production

Opportunity	Challenge	BDAA Response
Optimise farming operations	More and better food required globally	Precision farming based on data collection, analysis and forecasting
Increase supply chain transparency	Little foresight on harvest volumes and timing Price volatility	Increase forecast accuracy, real-time data collection/analysis Integrate planning throughout the value chain, reducing risk
Improve downstream operations	Processing is high volume but low operational efficiency	'Big data' toolbox covering production optimisation

Source: Magnin, 2016

Precision farming has already advanced in land-based agriculture and is beginning to enter the aquaculture field (Fore *et al.*, 2017). Raising operational efficiency and exercising higher levels of control requires the use of new monitoring and analytical tools. Pilot projects for aquaculture, such as FindIT and Aquasmart (EC, 2017a), have developed cloud-based solutions for advanced data mining and analytics for hatchery and farm data. Predictive choices can be developed using machine learning protocols to enable and confirm improvements. Key performance indicators (KPIs), such as malformation rates in marine fish juveniles, can be identified and monitored on individual farms.

Biosensors that measure physiological responses could provide a key to assuring animal welfare standards, as well as monitoring behaviour. The integration of such diagnostic tools with husbandry procedures and the afore-mentioned analytics will improve the predictability of feeding and harvesting for integration into financial and economic forecasting.

The possibility exists for data sharing and comparative analysis to benchmark an individual hatchery or farm's performance, but confidentiality remains a barrier to generalisation.

The integrated automated monitoring that already exists could be used with environmental management generating a product environmental footprint (PEF) to give consumers a guarantee of credentials, confirming claims and overcoming scepticism to justify price premiums.

These data management projects noted that small enterprises generally lack the human capacity and skills for data analytics, an issue that will need to be addressed. Adoption of such tools by European micro-enterprises is thus a challenge but would facilitate refining both technical and financial management.

3.3.2 Training and skill development

Undergraduate and post-graduate qualifications exist in Europe, complemented by specialist training programmes. Official vocational education and training have been developed, including the consideration of lifelong learning. The issue of skill recognition through lifelong learning has been addressed but, to date, there is no European-level qualification in this area. The EATiP 2019 paper indicates a higher need for programme flexibility, using methodologies that link theory to on-site practice. The exchange of best practices foreseen by the EC Strategic Guidelines would need new collaborative mechanisms between industry and training organisations.

3.3.3 Potential developments

There are distinct differences within the components of European aquaculture, not only by species but also by financial capacity and ambition. The expansion and success of salmon farming attracted new investors and equity funding. While much of this attention targets salmon, the Mediterranean fish farming sector should also attract interest given the scale of the regional markets for seafood and the fish species concerned.

While offshore facilities have been highlighted as a target for aquaculture growth, the potential for RAS investments have provided an alternative. The adoption of new sensors and higher monitoring capacity for distant management may offset practical operational difficulties of offshore aquaculture, but licensing and insurance issues need to be resolved for continued investor confidence.

Efforts will continue in the use of selective breeding as a tool to support animal health and product competitiveness, as followed by the new AquaImpact and NewTechAqua projects, which look to develop genomic and nutritional innovations (AquaIMPACT, 2021). Actions in the same area for shellfish have been more limited but could provide answers to the biomineralization issues posed by environmental acidification.

Further developments in internet services should be anticipated, not only for farm management but also for product brokerage and logistics. User-friendly packages for small enterprises would allow access to existing or new markets for those whose production exceeds local sale possibilities.

4. Aquaculture and environmental integrity

4.1 STATUS AND TRENDS

4.1.1 Legislation

Within the European Union, environmental legislation affects all industrial and individual activities. This has been accompanied by questions regarding how aquaculture can be achieved inside the Natura 2000 network of protected natural areas, referring to the Birds Directive (OJ L, 2010) and the Habitats Directive (OJ, 1992) and how to apply the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) in relation to aquaculture. Indeed, the most important question is perhaps whether sustainable aquaculture is possible in Europe (Science for Environment Policy, 2015). The additional considerations on locally absent species and the prevention and management of the introduction and spread of invasive alien species are also to be noted. Common rules on this topic assist the resolution of transboundary risks.

Specific legislation for aquaculture is rare in European countries, often being integrated within agricultural and environmental topics. This situation has created a position where the producer faces a complex network of European, national and local legislation affecting the activity.

Planning for new aquaculture sites has to account of the directives concerning Environmental Impact Assessment (EP, 1985) and Strategic Environmental Assessment (EP, 2001). For marine aquaculture, the Directive on Maritime Spatial Planning (EP, 2014) covers the use of marine resources, including aquaculture, and the sustainable development of the maritime space. Each European Union member state has to provide national spatial plans in respect of this. The release of organic waste and nutrients is well documented, and much research has been done on their potential negative effects. It is important to identify the 'best' farm location for marine aquaculture, where the capacity of the surrounding environment to assimilate or disperse pollution can be estimated from advanced modelling programmes. In addition, specific national aquaculture monitoring programmes are often in place once aquaculture facilities are operational. The Scientific Advisory Committee on Aquaculture (CAQ) of the GFCM has developed specific guidelines on a harmonized environmental monitoring programme for marine finfish cage farming in its member countries (Massa *et al*, 2017).

4.1.2 Waste materials

Organic and dissolved nutrients are the most obvious wastes and improving the digestibility of feeds is the most evident means of reducing them. Concerns are often raised on the use of veterinary medicines and disinfectants, particularly antibiotics in open freshwater and marine farms. It should be noted that extensive fish aquaculture (for example, carps) and shellfish farming use no therapeutic agents. Overall, the use of antibiotics in fish farming has been much reduced through better management practices, reduced stocking densities and vaccination. The Norwegian salmon sector reported a 90 percent reduction in antibiotic use in the last 30 years, reflecting the widespread use of anti-microbial vaccines.

Sea lice treatment in marine salmon farms traditionally used pesticides (for example, emamectin benzoate) which, after several years of use, encouraged tolerance in the lice. In respect of such chemical use, a major concern is accumulation in sediments, where non-target species may suffer. The introduction of cleaner fish and alternative treatments have been instrumental in reducing this phenomenon.

The control of biofouling on cage nets and ropes is one of the highest maintenance costs for marine farms and copper-based antifoulants have been widely used to reduce biofouling. To date, no alternative solution has been found.

On the other hand, aquaculture requires clean water to be able to maintain the conditions where disease or infections are limited and that there is no risk of food poisoning. Managing the contamination risk has been addressed, notably by the Shellfish Waters Directive (OJ, 2006) and, following repeal of this, by the conditions required for clean water by the Water Framework Directive (WFD). Since the WFD looks to manage water quality in both river basins and coastal marine areas, cleaner water will benefit all European aquaculture.

4.1.3 Escapes

Escapes from fish farms are recognised as detrimental and such events must be reported publicly. Salmon escapes have received the most attention and all states with salmon aquaculture have detailed reporting rules. The Technical Working Group on Escapes of the Salmon Aquaculture Dialogue which preceded the creation of the Aquaculture Stewardship Council (ASC) prepared a detailed report on this in 2008 (Thorstad *et al.*, 2008). The conclusions were that potential solutions include the use of sterile fish, avoiding reproduction in areas where the species is exotic, accompanied by farm exclusion zones and improved technology for containment.

The Genimpact project (CORDIS, 2007) also highlighted that much work has been done on salmon escapes but very little on escapes of other marine species (for example, European seabass and gilthead seabream).

4.1.4 Invasive and introduced species

Invasive and introduced species are seen as a major threat to the integrity of both freshwater and marine ecosystems in Europe and introductions of alien species through aquaculture has been documented (Katsanevakis *et al*, 2013), although it is secondary to sources such as maritime ballast water and into the Mediterranean through the Suez Canal. The dangers of introduced species through shellfish transfers has been well documented and remains of high concern to the aquaculture sector (Mineur *et al.*, 2014).

In freshwater, the main issue encountered recently was the consideration by the Spanish Supreme Court in 2016 that rainbow trout is an exotic and invasive species which meant that no rainbow trout could be used for restocking and angling and that trout farms must be isolated and contained. In 2018, 21 species were catalogued on the Spanish list, including common and koi carp, rainbow trout, perch and pike-perch.

There has been long-standing concern that climate change, notably through ocean-warming, will lead to new introductions, diseases and infections affecting both fish and shellfish farming. Research and monitoring programmes are addressing these issues.

The use of alien species in aquaculture provides potential transboundary threats influencing biodiversity, natural habitats, ecosystems and related ecosystem services if not managed safely. In the Mediterranean and the Black Sea, bordering countries share a common aquatic ecosystem and, as a result, any local impact on the environment could have wider effects. More consideration needs to be given in this regard on the plans of non-EU states.

The absence of common rules on the use of alien species means that common guiding principles and minimum criteria should be applied to the use of alien species in aquaculture to reduce national and international-transboundary risks in this area.

4.1.5 Use of wild species for aquaculture

The success of aquaculture is due to the closure of the life cycle, establishing the capacity to reproduce and rear fish and shellfish to market size. At present, only the European eel *(A. Anguilla)* and blue-fin tuna *(Thunnus thynnus)* are still captured in the wild and stocked for on-growing to market size.

Eel farming depends on the natural supply of glass eels to the European coast, which are then grown on in farms. The drop in both fisheries and glass eel landings, combined with illegal trafficking, has led to a ban on exports and fishing closures, leading to pressure on the farming sector. After peaking at around 11 000 tonnes in the late 20th century, some 6 000 tonnes were produced in Europe in 2017, mostly in RAS systems. Measures to assure the restocking of eels in the wild have increased and have been supported by the industry. The Sustainable Eel Group and the EIFAAC / ICES / GFCM working group have been particularly active in this area (ICES, 2016; ICES, 2018, ICES, 2019).

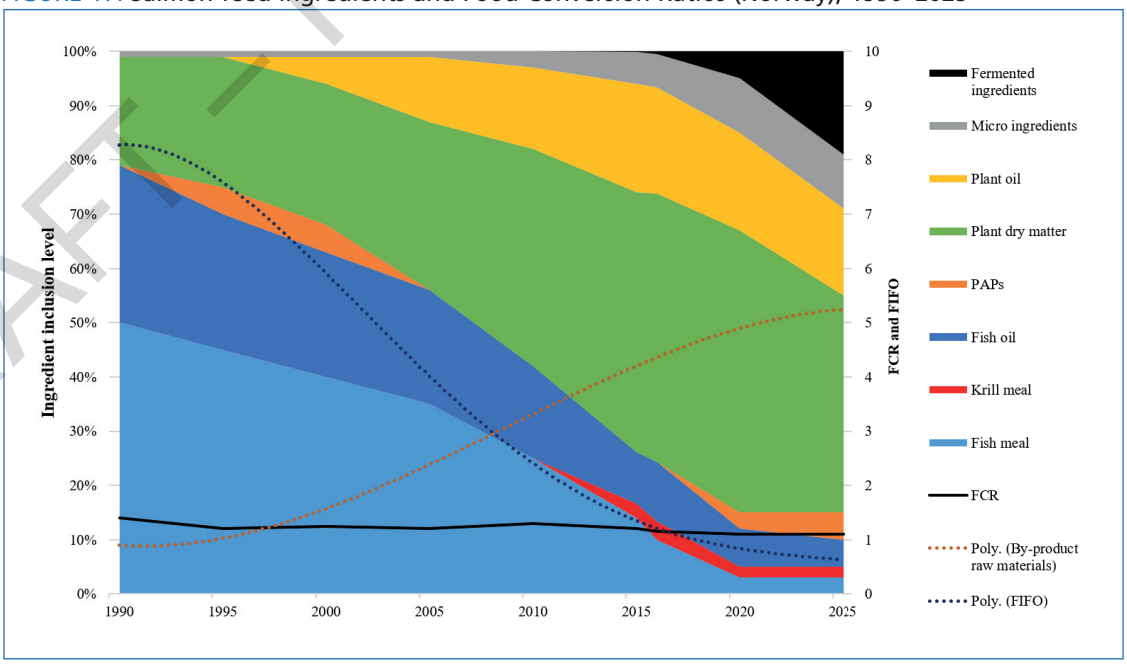
Tuna farming or ranching started in the Mediterranean where cage-based farms have been operated in Spain, Malta, Italy, Croatia and Turkey. With just over 7 000 tonnes of production, tuna farming is not an important component of European aquaculture, largely due to the controls on tuna fishing in the Mediterranean. Closed-cycle production appears to be an option after extensive R&D investments, but many technical and economic challenges remain before large scale production can be envisaged.

4.1.6 Use of wild fish species for feed

As indicated elsewhere, reducing the dependency of formulated feeds on fishmeal and fish oil has been to the fore of nutritional research for many years. The results of these efforts have lowered the food conversion ratio (FCR) of formulated feeds from around 2 kg of feed for 1 kg salmon produced in the 1980s to around 1.15 kg of feed in 2016.

Figure 17 based on Alsted (2017) demonstrates how ingredient use has changed while improving the FCR of farmed salmon in Norway.

FIGURE 17. Salmon feed ingredients and Food Conversion Ratios (Norway), 1990–2025



Source: Alsted, 2017.

Note the reduction of fishmeal inclusion from 50 percent and fish oil from 30 percent to under 10 percent for each. PAPs, krill and fermented ingredients are recent additions while the use of by-product raw materials from aquaculture and fisheries has increased significantly and now represents nearly 30 percent of world fishmeal production (IFFO, 2017).

Finding a substitute for fish oil appears to provide a greater challenge than does protein substitution. Algae or fermented organisms appear to have the highest potential in Europe due to the rejection of the use of genetically modified organisms.

In 2016, the International Union for the Conservation of Nature IUCN) developed a comprehensive review on the sustainability of feeding fish (IUCN, 2017), which details many of the challenges and solutions.

4.2 SALIENT ISSUES

A dominant concern for aquaculture producers in the European Region is how to enable operations alongside protected areas such as Natura 2000 zones while obtaining protection from predators that are protected species in Europe including cormorants and otters. While the EC has published guidelines on these topics, freshwater pond farming and valliculture remain particularly affected by predation. In some European Union countries, 80 percent of stocked fingerlings are taken by predators, reducing production. Governmental loss reimbursements are inadequate. The availability of space and access to water for new aquaculture projects has become problematic throughout the European Union, the result being few, new aquaculture licenses. In addition, competing urban and industrial use of freshwater can affect both the quality and availability of freshwater resources, as well as coastal waters suitable for aquaculture.

The reporting of escapes from salmon farms is a legal obligation and standards for cage structures and management are in place. These actions had a dramatic reduction on escapes even though the sector underwent growth, accompanied by larger installations and cage structures. As with offshore aquaculture, marine farms remain subject to potentially increased storm events due to climate change.

In the attention given to fish feeds, the concept of the forage fish dependency ratio (FFDR) has been developed to assess the quantity of wild fish used in feeds relative to the quantity of farmed fish produced (ASC, 2017). Debate continues as to the validity and accuracy of this approach (IFFO, 2017).

4.3 THE WAY FORWARD

The main challenge to growth of the sector in Europe is the allocation of licences to operate where there is intense competition for space. Extensive delays for farm licence approval are well known and without authoritative national aquaculture plans, application of the precautionary principle retards permit agreement at the local level. Novel integrated licensing processes are needed to support the development of IMTA.

The lack of space available for coastal aquaculture has been recognised as a constraint on development in many European Union states. Different approaches have been identified. Offshore aquaculture provides one answer but some states are looking at the reorganisation and optimisation of production areas.

The development of an evidence-based licensing system with pan-European application has been proposed by EATiP. Using high resolution satellite data for in-situ farms and their

surrounding environment, decision-support models can be used for accurate forecasting and monitoring of all types of aquaculture systems.

Within the European Union, much attention has been given to this issue. The most recent recommendations from the Aquaculture Advisory Council address the factors that would secure sustainable growth by adopting a harmonised licensing approach (AAC, 2019).

Actions recommended to European Union member states include:

- Put in place coordinated spatial planning for waters and land to secure an adequate allocation of space for sustainable aquaculture growth.
- Base aquaculture planning on an ecosystem-based approach.
- Identify licensing best practices and areas for improvement.
- Reduce the time and documents needed for obtaining an aquaculture operating licence and associated authorisations.
- Screen the main administrative burdens (time/costs) involved in the different types of aquaculture.
- Involve (regional and other) authorities with competencies in areas not directly related to aquaculture but in related fields, such as the environment, management of river basins, in the implementation of these guidelines.

The provision of ecosystem services by extensive pond aquaculture also requires better definition and recognition, accompanied by compensation mechanisms. Studies in France, Hungary and Poland have shown the high public appreciation of the environmental, social and cultural services of pond aquaculture (Mathé and Rey-Valette, 2015; Popp *et al.*, 2018; Turkowski, 2021). While production services were at the top, contributions to natural biodiversity and healthy ecosystems were also highly rated. Such multifunctional aquaculture activities need higher recognition.

Countries within the GFCM framework can count on specific guidelines for the streamlining of aquaculture authorisation and leasing processes that were adopted in 2017 and are intended as an instrument to address the main constraints connected to licensing and leasing and to facilitate the implementation of aquaculture activities (FAO, 2018).

5. Markets and trade

5.1 STATUS AND TRENDS

5.1.1 Data

Due to the relatively high proportion of seafood products that are traded internationally, trade statistics provide valuable insights into seafood market dynamics and trends in supply, demand and prices that may otherwise be obscured. When combined with production data, trade statistics, after the application of appropriate conversion factors, can also be used to estimate consumption of an identified species within a country's borders. However, there are some important caveats that must be kept in mind when engaging in any analysis based on trade statistics.

The first is that trade statistics generally do not allow for consistently reliable inferences regarding the markets for fishery products produced and consumed without crossing international borders. This information must be gathered using production surveys, price reporting at different points in the value chain, household consumption surveys and other forms of sample-based research conducted in the target market.

The second limitation of trade statistics is that they do not, with very few exceptions, distinguish between fishery products originating at aquaculture sites and fishery products sourced from capture fisheries. The challenge that this constraint presents from an analyst's perspective is primarily dependent on the species of interest. For certain species, nearly the entirety of production can be attributed to either aquaculture or capture fisheries, and thus one can safely assume the origin of any volumes identified in trade statistics. However, for others, for example, shrimp, there are significant quantities of product from both origins entering international trade.

For apparent consumption calculations within the European Union, the European Market Observatory for Fisheries and Aquaculture (EUMOFA, see EC. 2019f) estimates the traded quantity of aquaculture products by examining the share of aquaculture in production at the origin and applying the same proportion to the exported quantity. Product weights are then converted through the application of fixed conversion factors applied to traded quantities classified under the European Union's eight-digit combined nomenclature (CN) codes (EC, 2019a). While this provides useful insight into consumption of aquaculture products for a subset of the European market, the distinction between Europe and the European Union is an important one. In 2018, countries included under the FAO definition of Europe that are not members of the European Union accounted for 55 percent of European aquaculture production, 41.5 percent of Europe's fish export volume and 15.1 percent of imported volume. The FAO definition of Europe includes, *inter alia*, the Russian Federation and Norway, two of world's largest producers and exporters of fish and fishery products. It also includes Iceland, which, together with Norway, has one of the world's higher per capita levels of fish consumption.

For qualitative analysis of consumer purchasing behaviour, we rely primarily on the European Commission's recent surveys of consumer habits with respect to fishery and aquaculture products. In 2017 and 2018 the European Commission (DG MARE) published two reports (EC, 2017b & 2018b) on the results of these surveys, with the intention of informing various market-focused initiatives launched with support of the European Maritime and Fisheries Fund (EMFF). The findings, although restricted to the European Union and not specifically focused on aquaculture products, reveal some general features of purchasing behaviour in a large proportion of European fish consumers.

5.1.2 Consumers

The European Commission's surveys of fishery and aquaculture product consumer habits in the European Union identified various influences on purchasing decisions including taste, appearance, sustainability concerns such as "food miles", local vs non-local origin, health benefits, as well as perceptions relating to animal welfare and the environmental impact of fish farming. Positive perceptions of the health and wellness benefits were among the most popular reasons for consuming seafood, accompanied by the increased availability of prepacked products offering convenience. Price remains a strong influencing factor, with 68 percent of consumers saying their seafood consumption would increase if prices were lower. However, when seafood is consumed for special events, price is of less importance.

Survey responses indicated that 65 percent of Europeans buy fishery or aquaculture products at least once a month, with the majority of respondents (77 percent) making these purchases at grocery stores or supermarkets. There has been a significant shift towards large-scale retailers (LSR), including supermarket chains and discount retailers, as the point of final sale accompanied by a reduction in both the sales and number of small independent retail shops, including fishmongers. LSRs now account for 65 percent to 75 percent of sales in many European Union states. The increased availability of aquaculture products and added stability and control of production processes associated with aquaculture supply chains are among the factors driving this trend. The rising popularity of processed, pre-packaged convenience products is another contributor to the shift towards LSR sales. Since the European Commission surveys, the COVID-19 pandemic has also accelerated the move towards these types of products as a result of significantly higher interest in home cooking. The pandemic has also created ideal conditions for the development of home delivery services and online sales channels.

The European Commission survey results also provided information on differences between demographic groups. The studies identified a clear link between higher social classes and higher seafood consumption, compared with consumers with more limited economic resources including the unemployed, students and manual workers.

Consumption frequency was also found to be positively correlated with age. The EUMOFA study (EC, 2017b) showed the highest consumption was among those over 44 years old while the largest group of non-consumers was young people (15–24 years old). The older population also prefers fresh seafood and purchases fewer processed products while younger consumers tend to purchase relatively more frozen and processed products.

The low consumption levels of the youngest in populations (including kindergarten, primary and secondary schools) has led to several states creating awareness campaigns, typically emphasising the health benefits of seafood, targeting this population sector. The European Commission also developed school kits as part of its own awareness campaign, 'Farmed in the EU', with the objective of establishing an educational link between sector stakeholders and the school-age demographic (EC, 2016a).

Overall, wild fish was significantly preferred by European Union consumers over farmed (EC, 2018b). More than a third of the respondents who buy or eat fishery and aquaculture products preferred wild products (35 percent) while 9 percent said they preferred farmed products. Nearly a third (32 percent) said they had no preference. However, this varied by age, with younger people relatively more accepting of farmed fish.

The survey results also revealed that those concerned with the origin of the fish they eat are also more likely to attach importance to the distinction between farmed and wild, and those who value wellness and health as a product attribute are more likely to prefer wild fish.

Most LSRs reportedly purchase more farmed seafood than wild and this has been increasing. In the 2017 survey, the share of aquaculture products taken up by LSRs had increased for 56 percent of them, while the remaining 44 percent reported no increase or decrease.

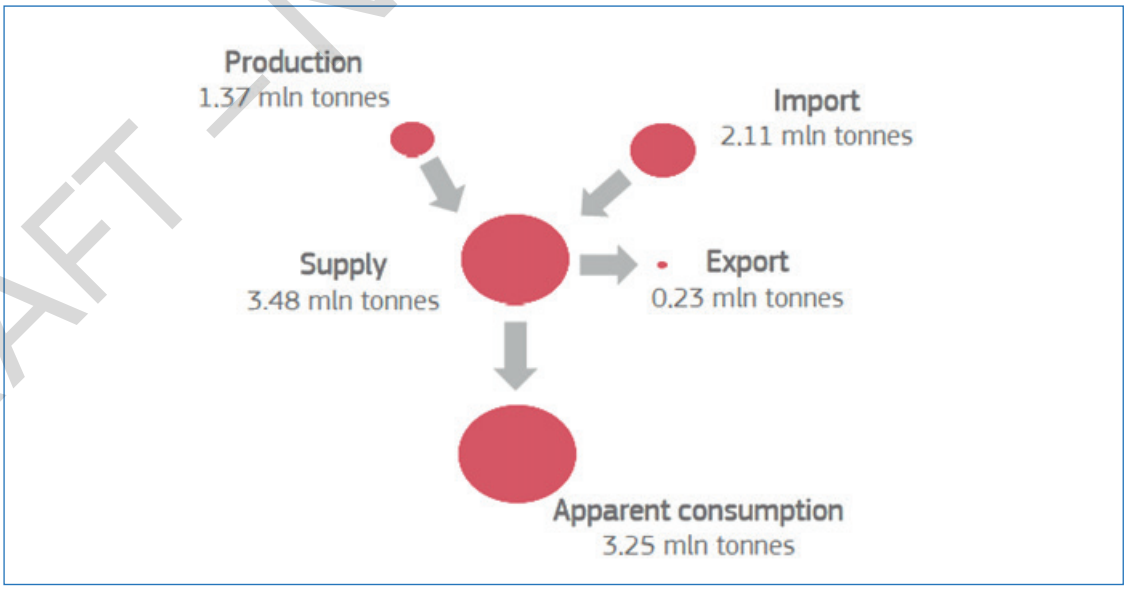
5.1.3 Consumption

The European Union market is the world's largest single market for fish and fishery products, and by far the most important destination for European aquaculture production. The European Union market is also a major market for a number of the most prominent cultured species entering international trade, including shrimp and pangasius.

EUMOFA data for 2017 puts European Union fish supply (production and imports) at 14.6 million tonnes, worth USD 36.6 billion. The fishery product trade deficit in the same year was USD 23.5 billion (EC, 2019f), reflecting the European Union's heavy dependence on imports to meet demand for seafood. The European Union self-sufficiency ratio (production as a percentage of consumption) in fish and seafood supply was calculated at 43 percent in 2017. For aquaculture products, the self-sufficiency ratio was marginally lower at 42 percent in the same year (Figure 18). The exclusion of major aquaculture producers such as Norway from the European Union production total means that this ratio would differ substantially for Europe as a whole, however.

EUMOFA's estimate (EC 2019b) of apparent fish consumption per capita in the European Union in 2017 was 24.35 kg per year, of which 6.35 kg (26 percent) was of aquaculture origin and 18 kg (74 percent) was from capture fisheries. On a geographic level, there are also many differences in consumption patterns within the European Union. Higher consumption in Portugal and Spain contrasts with much lower consumption in land-locked and Eastern European countries. A more detailed analysis of consumption patterns by country may be found in Table 9. For the complete European Union sample, 72 percent were regular consumers while 13 percent were non-consumers.

FIGURE 18. Aquaculture product supply for the European Union in 2017 (million tonnes, live weight equivalent)



Source: EC, 2019f.

TABLE 9. National fish consumption patterns within the European Union (percent of population consuming fish regularly = at least once/month and Non = no fish consumption)

Regular >80%	60%< Regular <80%	60%< Regular <80%	Regular <60%
Non <10%	Non <10%	Non >10%	Non >10%
Denmark	Belgium	Croatia	Austria
Estonia	Cyprus	Germany	Bulgaria
Finland	France	Ireland	Czechia
Netherlands	Greece	Italy	Hungary
Spain	Latvia	Malta	Slovakia
Sweden	Lithuania	Poland	
	Luxembourg	Portugal	
		Romania	
		Slovenia	
		United Kingdom	

Source: EC, 2017.

The data presented in Table 10 show how the contribution of aquaculture to consumption quantities has risen steadily over time, pointing to broader long-term trends in fish production that have seen wild catch volumes stagnate due to widespread resource pressure while the aquaculture sector continues to drive fish production growth at the global level.

TABLE 10. European Union seafood production and use estimates, 2013–2017 (tonnes and percent)

Use	Source	2013	2014	2015	2016	2017
Non-Food	Fisheries	791 944	959 567	1 056 098	857 663	1 227 070
Food	Fisheries	4 037 046	4 422 100	4 088 121	4 156 816	4 025 943
	Aquaculture	1 168 283	1 236 808	1 247 453	1 304 840	1 372 012
Total supply for food (tonnes)		5 205 329	5 658 908	5 335 574	5 461 656	5 397 955
Share (%) of aquaculture in seafood supply		22.4%	21.9%	23.4%	23.9%	25.4%

Source: EC, 2019f.

For Europe as a whole, apparent fish consumption per capita averaged 19.9 kg in 2017 (FAO, 2020b). Table 11 shows the different components of the calculation of total food supply, which is loosely analogous to what EUMOFA terms apparent consumption.

TABLE 11. Food balance sheet for fish and fishery products in the European region in 2017 (million tonnes, live weight equivalent and kg per capita)

Source/use	2017
Production	18.5 million tonnes
Non-food uses	3.4 million tonnes
Imports	18.5 million tonnes
Exports	17.1 million tonnes
Total food supply	16.7 million tonnes
Apparent consumption	19.9 kg/capita

Source: FAO, 2020b.

5.1.4 European trade in cultured species

Despite the issues with isolating aquaculture products in trade volumes described above, an informative analysis of European region trade in farmed species can be derived by restricting the focus to a specific set of species that are both commercially important in Europe and largely or entirely produced via aquaculture. For species whose European markets are primarily supplied by other European nations, these are Atlantic salmon (99.9 percent from aquaculture in 2017), rainbow trout (99.6 percent), gilthead seabream (95.7 percent), European seabass (93.9 percent), mussels (91.9 percent) and oysters (99 percent) (FAO, 2020c).

Salmonids

The cool waters and jagged coastlines of the European north-east Atlantic are one of a limited number of suitable environments for large-scale commercial salmonid farming. Capitalizing on these natural advantages and the worldwide popularity of Atlantic salmon, several European countries, led by Norway, have invested heavily in farming technology and export market development, developing highly efficient logistics and vertically integrated supply chains, supported by international marketing campaigns. The European Atlantic salmon aquaculture sector has risen to become one of the world's most lucrative aquaculture industries and a dominant force in international fish trade, accounting for six percent of the value of global exports of fishery and aquaculture products in 2018 (FAO, 2020c).

Norway is the world's largest producer and exporter of farmed salmonids, growing its export volume at a rate of 6.1 percent CAGR from 2000 to 2018 (FAO, 2020c). Over the same timeframe, value increased at 10.2 percent CAGR. The faster value growth rate points to an upward price trend that has been driven by the environmental and regulatory limitations on salmon aquaculture expansion in the context of strong global demand growth. In 2018, Norway exported a total of 1 084 593 tonnes of salmonids worth USD 8.67 billion, 29 percent of the global total quantity and the same proportion of value (FAO, 2020c).

The main exporters of salmonids to European countries are presented in Table 12. Norway exported Atlantic salmon products to 112 different trading partners in 2018 but Europe remains its core market, accounting for 77 percent of its export market in volume terms, and 74 percent in terms of value (Trade Data Monitor, 2020). Poland, France, Denmark and the United Kingdom of Great Britain and Northern Ireland are the top European destinations for Norwegian exporters. Of these, Poland and Denmark process and re-export the majority of their salmon imports to other European markets, while France and the United Kingdom of Great Britain and Northern Ireland import for consumption. Fresh, head-on, gutted Atlantic salmon accounts for 86 percent of Norway's salmon export revenue (Trade Data Monitor, 2020), although a significant proportion of this volume serves as raw material that undergoes further processing such as smoking.

European markets absorbed 47 percent of farmed Norwegian rainbow trout exports in quantity terms and 42 percent in value terms in 2018 (Trade Data Monitor, 2020). Eastern European countries are the leading importers of Norway's trout production, with Belarus, Poland and Ukraine the top European markets in 2018. However, a significant proportion

TABLE 12. Exports of salmonids* to European countries in 2018 (tonnes, USD thousands and percent)

Exporter	Quantity (tonnes)	Value (USD 1 000)	% share (quantity)	% share (value)
Norway	836 402	6 425 273	41.2	37.4
Sweden	431 399	3 410 097	21.3	19.8
Denmark	120 517	1 035 185	5.9	6.0
Poland	95 321	1 393 557	4.7	8.1
Chile	87 572	661 241	4.3	3.8
United Kingdom	62 659	551 966	3.1	3.2
Faroe Islands	53 002	484 272	2.6	2.8
Germany	47 052	611 322	2.3	3.6
China	36 169	245 790	1.8	1.4
Netherlands	33 694	363 407	1.7	2.1
Others	224 878	1 999 112	11.1	11.6
Total	2 028 665	17 181 222	100.0	100.0

* Primarily Atlantic salmon and smaller quantities of rainbow trout with minimal quantities of farmed and wild-caught Pacific species.

Source: Trade Data Monitor, 2020.

of this volume is re-exported to other European markets, primarily Germany in the case of Poland and Ukraine and primarily the Russian Federation in the case of Belarus. In 2014, the Russian Federation imposed an embargo on food imports from a number of Western European nations, including Norway, which remains in force.

Propelled by many of same factors that have driven Norwegian development, the Scottish Atlantic salmon aquaculture sector in the United Kingdom of Great Britain and Northern Ireland has seen its export revenues grow steadily. From 2000 to 2018, the value of the Scottish salmonid exports (almost entirely Atlantic salmon) increased at 7.5 percent CAGR, while quantity increased at 6.1 percent CAGR (FAO, 2020c), totalling 107 849 tonnes worth USD 920 million in 2018, or 3 percent of global total quantity and 3 percent of value.

The United Kingdom of Great Britain and Northern Ireland Atlantic salmon industry has sought to geographically diversify its export destinations, with the United States of America and China its second and third largest markets after France in 2018 (Trade Data Monitor, 2020) and is relatively less focused on supplying European markets than its Norwegian counterpart. In 2018, 58 percent of United Kingdom of Great Britain and Northern Ireland salmon exports were imported by European countries (Table 12), corresponding to 60 percent of the value.

Salmon market expansion has been driven by the unique qualities of the fish itself, as well as the enhanced control aquaculture producers are able to exercise over the colour, taste, texture and quality of the fish, and the relatively more predictable supply compared with capture fisheries. Salmon has proven a very versatile species with a significant presence at food service and retail and one of the most diverse product ranges in the seafood sector. The high value of the species has also facilitated the development of extensive air freight routes transporting fresh salmon from producer to final point of sale in a short time.

As shown in Table 13, the largest consumer markets for farmed salmonids in Europe include Germany, France, Italy, the United Kingdom of Great Britain and Northern Ireland and the Russian Federation (Trade Data Monitor, 2020). Sweden, Denmark and Poland are also large importers but a major proportion of these imports, which are primarily sourced from Norway, are redirected to other markets. Poland, in particular, has a large processing and smoking industry supplying a number of other European markets led by Germany. Germany and France, the two largest markets, source some 90 percent of imports from European producers. In Germany's case, 86 percent of import value was accounted for by Poland, Denmark, Sweden, Lithuania, Norway and the Netherlands in 2018, with the vast majority of this combined volume originating in Norway. France imports the majority of its Atlantic salmon from Norway via Sweden, Poland and Denmark, but also imported some 19 percent (both in terms of quantity and value) of its external supply from the United Kingdom of Great Britain and Northern Ireland in 2018. Scottish producers have successfully established themselves in the French premium segment, with Scottish farmed Atlantic salmon being one of the few non-French foods to receive Label Rouge certification.

In 2018, Germany was Europe's leading importer of trout with 37 106 tonnes, representing 24 percent of the European total and 15 percent of the global total. The value of these imports was USD 312 million, 30 percent of the European total and 16 percent of the global total (FAO, 2020c). The major share of this volume was of Norwegian origin, exported to the German market via Poland and Denmark. Germany was followed by the Russian Federation, Poland, Belarus, Finland and Sweden in terms of the quantity of trout imported in 2018 (Trade Data Monitor, 2020).

TABLE 13. Imports of salmonids by European countries in 2018 (tonnes, USD thousands and percent)

Importer	Quantity (tonnes)	Value (USD 1 000)	% share (quantity)	% share (value)
Sweden	543 650	4 277 699	26.5	24.6
Germany	201 376	2 190 268	9.8	12.6
Denmark	194 454	1 535 751	9.5	8.8
Poland	191 111	1 414 042	9.3	8.1
France	183 687	1 656 130	8.9	9.5
Russian Federation	104 146	765 225	5.1	4.4
United Kingdom	87 261	785 344	4.2	4.5
Italy	86 058	883 186	4.2	5.1
Spain	74 856	596 765	3.6	3.4
Finland	60 346	431 978	2.9	2.5
Others	327 228	2 872 676	15.9	16.5
Total	2 054 173	17 409 064	100.0	100.0

Source: FAO, 2020c.

Gilthead seabream and European seabass

Gilthead seabream and European seabass are farmed throughout the Mediterranean and the majority of consumption takes place in relative proximity to production, with most producers having large domestic markets of their own.

Greece has historically been the leading European producer and exporter of farmed bass and bream, followed by Spain, Italy, Croatia and France. However, in recent years, aquaculture producers in Turkey have risen to rival the Greek industry, buoyed by easy access to the large European market, favourable financial conditions and government support. From 2000 to 2018, the value and quantity of Greek exports of both species combined grew at a rate of 7.5 percent CAGR and 4.9 percent CAGR, respectively (FAO, 2020c). Over the same period, Turkish growth was significantly faster, with quantity and value starting at near zero in 2000 and increasing at 52.5 percent and 53.2 percent CAGR, respectively. From 2010 onwards, increasing scale saw this expansion slow somewhat with Turkish export growth rates averaging 21.4 percent CAGR for value and 22.2 percent CAGR for quantity. For European producers excluding Greece and Turkey, the same rates were 10.3 percent and 7.3 percent. These figures highlight the steady erosion of the Greek share of the international bass and bream market, a consequence of a series of business challenges, particularly those stemming from the economic fallout from the European debt crisis. In more recent years, Greece has found it difficult to compete with a fast-growing Turkish sector offering significantly cheaper product to European buyers, as well as suffering financial damage from sustained periods of low prices.

As of 2018, Greece accounted for 35 percent and 36 percent of global European seabass and gilthead seabream exports in terms of value and quantity, respectively, while for Turkey the equivalent shares were 35 percent and 30 percent, respectively (FAO, 2020c). Separated by species, Turkey accounted for 35 percent of the total export volume of European seabass in 2018 while Greece took a 33 percent share. For gilthead seabream, Turkish volumes made up a 27 percent share while Greece accounted for 34 percent. A more comprehensive breakdown of the key suppliers to European markets is presented in Table 14 and Table 15.

Generally speaking, both bass and bream are marketed through similar channels and both depend on the seasonal restaurant industry in warmer Mediterranean regions for a significant proportion of their sales. The most popular product form has traditionally been fresh whole fish sold through food service or at fish markets and supermarkets to retail consumers. The

TABLE 14. Exports of European seabass to European countries in 2018 (tonnes, USD thousand and percent)

Exporter	Quantity (tonnes)	Value (USD 1 000)	% share (quantity)	% share (value)
Greece	36 147	214 750	38.6	37.4
Turkey	30 930	153 029	33.0	26.7
Netherlands	8 247	55 198	8.8	9.6
Spain	6 236	55 186	6.7	9.6
Croatia	4 539	32 689	4.8	5.7
France	1 998	20 083	2.1	3.5
Italy	1 820	13 210	1.9	2.3
Germany	823	5 451	0.9	0.9
Denmark	644	5 083	0.7	0.9
United Kingdom	503	4 852	0.5	0.8
Others	1 803	14 371	1.9	2.5
Total	93 690	573 902	100.0	100.0

Source: Trade Data Monitor 2020.

TABLE 15. Exports of gilthead seabream to European countries in 2018 (tonnes, USD thousand and percent)

Exporter	Quantity (tonnes)	Value (USD 1 000)	% share (quantity)	% share (value)
Greece	45 849	248 797	40.4	39.4
Turkey	36 490	168 384	32.2	26.7
Spain	7 963	57 364	7.0	9.1
Netherlands	4 848	25 756	4.3	4.1
Croatia	4 162	26 078	3.7	4.1
Italy	2 677	16 523	2.4	2.6
Mauritania	1 910	12 471	1.7	2.0
Malta	1 769	8 832	1.6	1.4
France	1 437	13 554	1.3	2.1
Morocco	1 355	15 963	1.2	2.5
Others	5 033	37 571	4.4	6.0
Total	113 493	631 293	100.0	100.0

Source: Trade Data Monitor, 2020.

proportion of fillets and other value-added products has increased in recent times, however, in line with the increase in popularity of convenience-focused, "ready-to-cook" seafood items. However, it should be noted that there is no 'harmonised system' code (FAO and WCO, 2021) explicitly identifying bass and bream fillets and thus it is difficult to estimate the total amount of trade in these products.

Italy, France, Portugal and Spain together represented 54 percent of the global import market for exported European seabass and gilthead seabream in both quantity and value terms in 2018, led by Italy with a 27 percent share of both quantity and value (FAO, 2020c). A more detailed overview of the major importers in Europe may be found in Table 16 and Table 17.

In quantity terms, 56 percent of Italian bass and bream imports (38 108 tonnes) were of Greek origin in 2018, representing 56 percent of value (USD 215 million) (Trade Data Monitor, 2020). Turkey accounted for a 15 percent share of the Italian import value and 19 percent of quantity in 2018, with Croatia, Spain and France making up the remainder of the top 90 percent of Italian supply in the same year. These proportions did not differ significantly between the two species. Spanish supply is relatively more important in the case of France, making up 15 percent of value and 12 percent of imported quantity of both species in 2018, while the equivalent shares for Greece were 47 percent and 49 percent. Spain

TABLE 16. Imports of European seabass by European countries in 2018 (tonnes, USD thousand and percent)

Importer	Quantity (tonnes)	Value (USD 1 000)	% share (quantity)	% share (value)
Italy	32 147	198 561	34.4	34.7
Spain	11 257	59 614	12.0	10.4
Netherlands	8 728	52 342	9.3	9.1
France	7 523	50 409	8.0	8.8
Portugal	7 319	48 531	7.8	8.5
United Kingdom	7 261	41 060	7.8	7.2
Greece	4 162	18 583	4.5	3.2
Russian Federation	4 056	20 239	4.3	3.5
Germany	3 425	23 554	3.7	4.1
Bulgaria	1 338	8 099	1.4	1.4
Others	6 291	52 019	6.7	9.1
Total	93 507	573 011	100.0	100.0

Source: FAO, 2020c.

TABLE 17. Imports of Gilthead seabream by European countries in 2018 (tonnes, USD thousand and percent)

Importer	Quantity (tonnes)	Value (USD 1 000)	% share (quantity)	% share (value)
Italy	37 149	201 850	31.4	31.0
Spain	17 123	102 616	14.5	15.8
Portugal	14 600	83 787	12.4	12.9
France	12 468	68 729	10.6	10.6
Greece	6 940	29 672	5.9	4.6
Netherlands	6 775	33 827	5.7	5.2
Germany	6 749	37 596	5.7	5.8
Russian Federation	3 662	17 000	3.1	2.6
United Kingdom	3 423	15 672	2.9	2.4
Romania	1 709	8 949	1.4	1.4
Others	7 558	51 316	6.4	7.9
Total	118 156	651 014	100.0	100.0

Source: FAO, 2020c

and Greece make up some 80 percent of Portuguese imports, while the Spanish market has been more receptive to Turkish fish compared with the other large European markets, with fish of Turkish origin making up 35 percent of Spanish import quantity and 28 percent of value in 2018.

The importance of these core markets has reduced over time. In 2000, the share of these four large Mediterranean markets was 62 percent. This reflects the efforts made by Turkey in developing new markets throughout the middle east and north Africa region as well as the Russian Federation, and also the rising popularity of European seabass in the United States of America.

Mussels

Mussel farming has a long history in Europe, and most trade is still confined to long-established routes from European suppliers to European markets, with the notable exception of the significant role that Chile now plays as an external supplier. Compared to the more dynamic finfish sectors, farmed mussel markets are more mature and production growth has been significantly slower. From 2000 to 2018, the quantity of mussels exported by European countries increased at a rate of one percent CAGR while value increased at 4.4 percent

CAGR (FAO, 2020c).

In 2018, the Netherlands, a large producer and exporter, was the lead European mussel exporter by value with 43 percent of the European total (20 percent of the global total) and 27 percent of European export quantity (16 percent of the global total). Spain accounted for 20 percent of the European total value (10 percent of the global total) and 33 percent of the European quantity (20 percent of the global total). Germany, Denmark, Greece, Italy and Ireland accounted for most of remaining export volume. France, while a large producer, retains the majority of its production for its domestic market. Table 18 presents a breakdown of the major exporters of mussels to European markets in 2018.

The majority of mussel consumption in Europe is by a limited selection of countries with annual per capita consumption of up to 4 kg while other European countries reported per capita consumption levels as low as 200 g (FAO, 2014). Spain, France and Italy account for

TABLE 18. Exports of mussels to European countries in 2018 (tonnes, USD thousand and percent)

Exporter	Quantity (tonnes)	Value (USD 1 000)	% share (quantity)	% share (value)
Chile	58 215	166 013	25.6	31.9
Netherlands	48 402	154 449	21.3	29.7
Spain	45 567	53 222	20.0	10.2
Denmark	18 670	25 943	8.2	5.0
Germany	17 891	46 411	7.9	8.9
Italy	9 648	15 898	4.2	3.1
Ireland	8 902	15 433	3.9	3.0
Greece	5 808	4 247	2.6	0.8
Bulgaria	3 690	2 505	1.6	0.5
United Kingdom	2 851	6 320	1.3	1.2
Others	7 843	29 890	3.4	5.7
Total	227 487	520 331	100.0	100.0

Source: Trade Data Monitor, 2020.

some 78 percent of mussel consumption in Europe, and the same countries are responsible for the majority of production. In 2018, 82 percent of traded mussels were in live/fresh form, a proportion that has increased slightly compared to 2000. While the nutritional benefits and relatively low environmental impact of mussels aligns the species with current consumer trends, it has been a relatively slow-growing market with limited product innovation.

France was the largest European importer of mussels in terms of quantity in 2018, responsible for 25 percent of European imports (19 percent of the global total) and 18 percent of import value (12 percent of the global total) (FAO, 2020c). A more complete list of European imports of mussels may be found in Table 19.

Spain supplied 34 percent of French imports in the same year by quantity (22 percent by value), while the Netherlands supplied 27 percent of quantity and 34 percent of value (Trade Data Monitor, 2020). The vast majority of Spanish export volume originates from Spanish aquaculture producers, but the Netherlands is an important European trade intermediary with a significant but unknown proportion of re-exports, some imported from outside Europe (for example, from Chile), in its export volume. Belgian imports make up a 10 percent share of European imports in quantity (seven percent of the global total) and 18 percent of value (12 percent of the global total). The vast majority of Belgian mussel imports are traded from or through the Netherlands, which accounted for 94 percent of

TABLE 19. Imports of mussels by European countries in 2018 (tonnes, USD thousand and percent)

Importer	Quantity (tonnes)	Value (USD 1 000)	% share (quantity)	% share (value)
France	59 056	104 448	24.7	18.0
Italy	43 092	63 905	18.0	11.0
Netherlands	40 849	80 266	17.1	13.8
Belgium	23 368	104 552	9.8	18.0
Spain	19 439	63 491	8.1	10.9
Russian Federation	13 700	38 419	5.7	6.6
Germany	11 352	32 966	4.8	5.7
United Kingdom	5 604	18 236	2.3	3.1
Ukraine	4 664	12 504	2.0	2.1
Portugal	4 459	14 427	1.9	2.5
Others	13 263	48 438	5.6	8.3
Total	238 846	581 652	100.0	100.0

Source: FAO, 2020c.

value and 93 percent of quantity. The Netherlands itself reported mussel imports from 29 partners, led by Germany, Denmark and Ireland and mussel exports to 76 partners, led by Belgium, France and Germany in 2018.

Oysters

France produces some 76 percent of farmed oysters in Europe, with Ireland accounting for 12 percent (FAO, 2020c). France is also the world's leading exporter of oysters by value, accounting for 18 percent of global oyster export revenue in 2018 and 10 percent of exported quantity (FAO, 2020c). France exports significant volumes to high value markets in East and Southeast Asia as well as to a number of other European countries (Trade Data Monitor, 2020). The major international suppliers of oysters to European markets are presented in Table 20.

TABLE 20. Exports of oysters to European countries in 2018 (tonnes, USD thousand and percent)

Exporter	Quantity (tonnes)	Value (USD 1 000)	% share (quantity)	% share (value)
France	8 687	60 304	37.3	42.2
Ireland	6 464	38 585	27.8	27.0
Netherlands	3 420	16 137	14.7	11.3
United Kingdom	1 836	7 581	7.9	5.3
Denmark	1 023	4 556	4.4	3.2
Portugal	472	2 487	2.0	1.7
Spain	309	3 170	1.3	2.2
Italy	188	1 361	0.8	1.0
Greece	158	743	0.7	0.5
Germany	131	1 090	0.6	0.8
Others	597	6 953	2.6	4.9
Total	23 285	142 967	100.0	100.0

Source: Trade Data Monitor, 2020.

Most oysters produced in France are typically consumed live and domestically, following seasonal demand patterns. However, France also exports farmed oysters to some other European markets, led by Italy with a 30 percent share of French oyster export quantity in 2018 and a 21 percent share of value in the same year (Trade Data Monitor, 2020). Combined exports to European markets accounted for 67 percent of French oyster export value in 2018 and 61 percent of quantity. France also imports significant quantities from other producers, mainly Ireland, to supplement domestic supply. Table 21 shows a more detailed breakdown of European oyster imports.

TABLE 21. Imports of oysters by European countries in 2018 (tonnes, USD thousand and percent)

Importer	Quantity (tonnes)	Value (USD 1 000)	% share (quantity)	% share (value)
France	7 448	40 675	30.8	27.3
Italy	5 375	32 200	22.2	21.6
Spain	3 103	14 833	12.8	10.0
Belgium	1 682	12 149	7.0	8.2
Netherlands	1 380	12 576	5.7	8.4
Germany	961	6 477	4.0	4.3
Ireland	857	5 078	3.5	3.4
Sweden	612	2 199	2.5	1.5
Switzerland	482	4 481	2.0	3.0
Ukraine	439	2 682	1.8	1.8
Others	1 834	15 641	7.6	10.5
Total	24 173	148 991	100.0	100.0

Source: FAO, 2020c.

5.1.5 External supply of cultured species

The task of isolating aquaculture products in imports from external (non-European) suppliers by European countries may be approached in much the same manner as an analysis of internal trade. Specifically, based on the share of aquaculture in production, assumptions can be made that traded volumes of certain species exported by certain countries are primarily of cultured origin, even though this is not explicitly recorded in trade statistics. Tilapia and pangasius are two important examples of species imported into Europe in significant volumes which are produced almost entirely by aquaculture. The trade in shrimp, which accounted for 12 percent of the total value (7 percent of the quantity) of European fishery product imports in 2018 (FAO, 2020c), is more problematic in this regard, as suppliers to the European market source shrimp through aquaculture as well as through capture fisheries.

Pangasius

The most commercially important species of pangasius catfish, *Pangasius bocourti*, is not explicitly identified in trade statistics, but the dominance of this species in commercial trade and the extremely limited proportion originating from capture fisheries implies that the vast majority of reported traded identified only as "catfish" is farmed pangasius, sourced almost entirely from aquaculture sites in Viet Nam's Mekong Delta. Exports within Europe are mainly re-exports of Vietnamese product.

In 2018, European countries imported 111 945 tonnes of pangasius worth USD 338 million, representing 0.8 percent of Europe's fishery product imports by quantity and 0.5 percent of value in the same year (FAO, 2020c). Pangasius has become established as a cheaper alternative to wild whitefish species as raw material for processed retail products and several popular fast food dishes, including fish and chips, a staple fast food item in the United Kingdom of Great Britain and Northern Ireland. The Netherlands, the United Kingdom of Great Britain and

Northern Ireland and Germany were the top three European importers of pangasius in 2018 by value, accounting for 18 percent, 15 percent and 11 percent of total European import value respectively, and 17 percent, 12 percent and nine percent of quantity (FAO, 2020c). Netherlands re-exported the majority of this volume to other European markets, led by Germany.

Tilapia

European countries imported 43 968 tonnes of tilapia products in 2018, 0.3 percent of the total European fishery product import quantity (FAO, 2020c). The value of these imports was USD 136.5 million, or 0.2 percent of the European total. Trade in tilapia by European nations only began in earnest in 2010 and its penetration remains limited due to a lack of acceptance by European consumers. The Russian Federation, the Netherlands and Spain were the top importers in 2018. China, the world's largest tilapia producer, supplies the majority of the volume, almost entirely in the form of frozen whole fish or frozen fillets.

Shrimp

Shrimp is one of most heavily traded fishery products internationally and in Europe. Although there is some wild production of cold-water shrimp in Northern Europe, there is hardly any shrimp aquaculture and significant quantities are imported to meet demand. In 2018, total shrimp imports by European countries came to 933 562 tonnes worth USD 8 billion, representing 34 percent of European fishery product imports in terms of both quantity and value (FAO, 2020c). Spain and France were the leading importers with 18 percent and 12 percent of the total quantity respectively, and 16 percent and 12 percent, respectively, of value.

Ecuador was Europe's top supplier in terms of quantity in 2018, supplying 12 percent of imported quantity and ten percent of value, while Argentina was in second place, with nine percent of quantity and eight percent of value (Trade Data Monitor, 2020). Essentially all of Ecuador's shrimp production comes from aquaculture, while all of Argentina's production is wild-caught. India and Viet Nam are also significant suppliers of cultured shrimp to the European market, but volumes from these partners are comprised of a mix of wild-caught and farmed warmwater species. Table 22 presents the top exporters of shrimp to European markets, while also showing the proportional contribution of aquaculture to shrimp production in the exporting country.

TABLE 22. Exports of shrimp to European countries in 2018 (tonnes, USD thousand and percent)

Exporter	% Aquaculture production	Quantity (tonnes)	Value (USD 1 000)	% share (quantity)	% share (value)
Ecuador	100%	110 134	778 382	11.8	9.7
Argentina	0%	87 486	632 244	9.4	7.9
Viet Nam	77%	83 480	889 408	8.9	11.1
India	58%	81 387	633 277	8.7	7.9
Greenland	0%	73 717	373 017	7.9	4.7
Netherlands	0%	50 637	667 261	5.4	8.3
Denmark	0%	45 675	400 748	4.9	5.0
Spain	2%	35 317	327 268	3.8	4.1
Canada	0%	35 220	245 505	3.8	3.1
China	63%	29 259	211 019	3.1	2.6
Others	57%	300 588	2 848 052	32.2	35.6
Total		932 900	8 006 180	100.0	100.0

Source: Trade Data Monitor, 2020 (Trade), FAO, 2020c (Production)

5.2 SALIENT ISSUES

5.2.1 Public acceptance of aquaculture products

Public acceptance of the farming of animals for food, be they land or aquatic animals, is not a new challenge but is one that has become more prominent as dietary preferences have evolved, with more people adopting vegetarian and vegan diets. While food safety and environmental issues are firmly legislated, public confidence in farmed food products, including those produced in aquaculture operations, has been undermined by various events. News articles and recurring controversies have emerged, including the environmental impact of fish farms, chemical additives and contaminants such as microplastics in the production processes, as well as the implications of diseases and use of therapeutics at aquaculture sites. Climate change and the need to mitigate its effects are newer topics influencing consumer preferences and the public acceptance of food manufacturing processes, including aquaculture.

The salmon aquaculture industry, in particular, has repeatedly been the subject of negative attention relating to these issues from several media outlets and from civil society groups while shrimp farming practices, the Vietnamese pangasius industry and Chinese tilapia aquaculture have come under similar scrutiny. The concerns raised have varying degrees of objective validity, some providing a valuable social service in raising awareness of damaging practices while others may rely on incorrect, biased or outdated information and thereby mislead consumers. This points to a growing need for effective communication, education and transparency around aquaculture practices and their implications for both the consumer and for society as a whole, as well as for international fish value chains and the fish trade in general.

5.2.2 Changing consumer preferences

Casini *et al.* (2015) identify the rise of a new social preference for a healthy diet and lifestyle, creating an expanding group of consumers seeking healthy food products. At the same time, studies such as the European Union survey on fishery and aquaculture product consumption (EC, 2017b; EC, 2018c) indicate that the highest levels of fish consumption are found in the older age groups. Understanding the demand drivers of the younger consumer demographic, and how fish may be marketed effectively to this group, has consequently become an important objective for the aquaculture industry and the seafood sector as a whole.

The millennial generation, those born from the early 1980s to the mid-1990s, became adults in the new millennium and represent 50 percent of the workforce in 2020, increasing to 75 percent by 2028. Millennial consumers make up a significant proportion of food product purchases and their growing presence in the market accounts for increased demand for convenience and health-oriented products. Generation Z, those born from 1995–2010, are often termed 'digital natives' since they have grown up with the internet, social networks and mobile communication. Generation Z has been characterised by a search for truth and transparency and its consumption patterns are summarised as 'uniqueness', 'unlimited' and 'ethical' (Francis and Hoefel, 2018).

The International Food Information Council (IFIC, 2018) conducted a survey in 2018 of American consumers looking at perceptions, beliefs and behaviour behind food purchasing decisions. The 2018 ReThink Eat conference examined similar issues from a European perspective (Unigrains, 2018).

The main findings of these studies included:

- Sustainability is of increasing importance for consumers, where it is interpreted by the consumer as reducing the use of pesticides, an affordable food supply and conservation of natural habitats.
- Cost and access are key barriers to purchase and consumption.

- Interest in health benefits relates mainly to cardiovascular health and weight management.
- Understanding how food is produced is increasingly affecting food purchases.
- Millennials discuss food purchases and recipes but understand that food is fuel for the body and want the associated information on how it is made.
- Consumers mistrust most labels but 'organic' is viewed most favourably.
- Any food-related issue is strongly and quickly disseminated by the media, reflecting a general mistrust of big companies and mass food production.

For younger consumers, social media are increasingly influencing purchasing decisions, with nutrition, economics and the changing environment all playing a role in shaping preferences. Local brands are able to offer transparency and assurances as to how food is produced and are broadly increasing in popularity. New approaches to food production, marketing and product development need to account for these sensitivities.

5.2.3 Certification and labelling

The evolution of labelling in aquaculture started with quality schemes, where individual companies or associations sought to differentiate their product quality or origin from competing products. Private standards and related certification schemes have since become important tools of international fish trade and marketing, providing market-based complements to public regulatory frameworks seeking to achieve key social objectives such as sustainability and responsible fisheries management. In aquaculture, these schemes are also becoming more widespread as core components in efforts to assure consumers of food safety, organic standards, quality and environmental sustainability.

In Europe, external standards have largely replaced individual large scale retailer (LSR) schemes and producers may be obliged to be independently certified to supply European LSRs. The major aquaculture certification schemes include Global G.A.P., initiated by retailers, the ASC, initiated by the Worldwide Fund for Nature (WWF), Best Aquaculture Practices (BAP) of the Global Aquaculture Alliance (GAA) and the Sustainable Trade Initiative IDH (Potts *et al.*, 2016).

While these represent some of most well-known examples, there are numerous competing schemes and standards in the same space. This proliferation can create confusion amongst stakeholders, including producers, consumers and governments, which diminishes the value of each individual scheme (Washington and Ababouch, 2011). Consumers cannot clearly distinguish between the different labels and the standards they represent and this makes it more difficult for marketers to generate the trust and reputation necessary for consumers to accept the premiums that cover the costs of certification. At the same time, the risk is increased that the fallout from negative media coverage or other forms of damaging PR targeting one scheme may impact others.

The Global Sustainable Seafood Initiative (GSSI), a public-private partnership involving multiple stakeholders, offers a solution to this issue by offering a globally accepted tool to provide an objective and transparent assessment of different certification schemes (GSSI, 2019). GSSI also looks to publicly recognize credible and responsible schemes in order to build confidence and understanding amongst the public. The GSSI benchmark has had significant uptake by LSRs and fish supply companies in the major fish markets of Europe.

A detailed study on organic aquaculture in the European Union carried out in 2017 (EC, 2017c), estimated that organic production represented 4.7 percent of the aquaculture harvests of the top six species, most notably for salmon, trout, mussels, seabass and seabream. Ireland is the main producer, accounting for some 44 percent of total European Union organic

production in 2015, mainly comprised of Atlantic salmon and blue mussels, followed by Italy (17 percent), the United Kingdom of Great Britain and Northern Ireland (seven percent) and France (six percent).

Demand for organic products is growing and established, and trusted organic labels are key to continuing market development. At the same time, however, there are certain business challenges that need to be overcome to ensure the economic viability of organic aquaculture in Europe. Broadly speaking, the small scale of organic aquaculture in its current form does not allow for the supply chain efficiencies necessary to drive costs down to consistently profitable levels. On the market side, while limited price premiums are generally accepted by the consumer, organic labels compete to a significant degree with sustainability-focused ecolabels (EC, 2017c), and thus must contend with the same overcrowding issues outlined above.

The Product Environmental Footprint (PEF) is a multi-criteria measure of the environmental performance of a good or service throughout its life cycle. Methodologies for measuring PEF and Organisation Environmental Footprint (OEF) were proposed within the European Commission initiative of a single market for green products, with the objective of enabling easy-to-understand communication of the environmental footprint of food, drink and non-food products to the consumer (EC, 2012).

The preparation of category rules (PEFCR) for measurement of PEF was completed in 2018 for feeds for food animals, with the Federation of European Aquaculture Producers (FEAP) and the Norwegian Seafood Federation (NSF) participating in the Technical Secretariat of the aquaculture branch of this initiative (EC, 2018c).

Separately, investigation was made as to whether PEFCR could be developed for aquaculture; it was realised that this could not be achieved until those for feeds had been completed and tested. The European Commission has established a transition phase following the pilot initiatives and intends to provide a framework to monitor implementation and the development of new initiatives which include new PEFCR for marine fish (wild-caught marine fish and marine fish from marine open net pen aquaculture) that is being coordinated by the NSF (EC, 2019c). While the PEF and OEF approach is complex, its completeness is valuable and may lead to wider use in the future to benefit consumers.

Attaining the aspirations that prove sustainability is a worthy goal, if difficult and there are many different projects and articles devoted to this subject, whose aims and attributes develop regularly (see Boyd *et al.* (2020)).

5.3 THE WAY FORWARD

5.3.1 Background

European aquaculture's contribution within national and European markets is likely to increase if producers adapt to changing consumer preferences. The European Commission set out its vision for different stakeholders and sectors to align with the general framework of the Sustainable Development Goals in 'Reflection Paper: Towards a Sustainable Europe by 2030' (EC, 2019d). Recognizing challenges such as climate change and population growth, the paper identifies the aquaculture sector as a priority area within the broader objective of providing stable, sustainably produced, safe and high-quality food at affordable prices.

5.3.2 Adapting to the new consumer

The last decade has seen many issues raised in respect of European aquaculture by stakeholders, legislators and interest groups, which have covered all aspects of the

aquaculture value chain, ranging from feed components, production methodology, animal and worker welfare, transport and slaughter, processing and packaging. Many of these have been directly or indirectly linked to environmental and sustainability considerations that are increasingly linked to consumer sensitivities.

The increased sensitivity of consumers to issues relating to food production is notable and although organic aquaculture remains limited and more expensive than 'traditional' aquaculture, it fits firmly within the newly emerging set of consumer preferences. The environmental and climate impact of the production process, the welfare and health of the animals, and the sustainability of production processes are all issues that will increasingly affect consumer acceptance.

While such considerations are of growing importance, continued innovation in processing, packaging and distribution remains essential. Time-constrained modern consumers respond to products prepared and marketed for convenience, through both retail and food service. The emphasis on healthy living and a general interest in the origin of the food we eat also present some opportunities to marketers of aquaculture products, a sector which offers some advantages over capture fisheries in terms of control of production processes and supply chain traceability. The COVID-19 pandemic has also been something of a catalyst for new distribution channels that reduce perceived or real contagion risk, particularly e-commerce and home delivery. Finally, social media and other digital media will only continue to increase in importance as vehicles for sectoral communication and debate, targeted marketing and dissemination of news and market information.

5.3.3 Sectoral communication

The European Commission has developed the first pan- European Union communication campaign on aquaculture, "Farmed in the EU", accompanied by factsheets and a school education pack (EC, 2016a). This communication is targeted at the general public but more specifically at young future consumers. Aside from corporate advertisements, other communication efforts tend to be led at the national or local level using the representative associations. These efforts are typically generic, are rarely of long duration and do not promote company products. The impact and success of such generic campaigns remains open to debate. Improving the public perception of aquaculture will need new sectoral initiatives and approaches, as outlined by the European Aquaculture Technology and Innovation Platform (EATiP) position paper (EATip, 2019). Adapting to the new dynamics of social media is another challenge for aquaculture producers and is one that will need to be met quickly.

5.3.4 Marketing for sustainable development

The European Commission's vision for the future of the aquaculture sector in Europe (EC 2015a) identifies the most important areas of focus for stakeholders aiming to improve the sustainability of the sector:

- Measuring, improving and maintaining water quality at aquaculture sites and reducing contamination from organic waste and nutrients.
- Reducing use of pharmaceuticals such as vaccines, antiparasitic medications and antibiotics.
- Reducing the use of wild fish as ingredients in fish feed.
- Understanding and preventing harmful ecological interactions such as interbreeding between wild fish and escapees and the transmission of diseases from farmed fish to wild populations.

Each of these issues has, at some point in the relatively recent past, been the subject of negative media coverage or the motivator for civil society awareness-raising efforts directed against the aquaculture industry. At the same time, demonstrable progress has been achieved in recent years in several of these areas, particular in the salmonid aquaculture sector. To maximize the market return on these improvements, such progress must be independently verified and effectively communicated to consumers at every step, whether via certification and labelling or via marketing strategies and PR campaigns or both. As the industry evolves positively along key sustainability dimensions, to maintain this momentum, this should be mirrored by parallel gains in the public's perception of the sector.

Objective advantages that the sector has over competing market segments in terms of environmental impact should also be emphasised and incorporated into development strategies and policy direction. Recently, the European Commission "Farm to Fork" Strategy recognised that "farmed fish and seafood generate a lower carbon footprint than animal production on land", providing further incentives for growth and increased consumption (EC, 2020).

6. Contribution of aquaculture to food security, social and economic development

6.1 STATUS AND TRENDS

Following a decision in 2010 (OJ L, 2009), European Union member states are required to submit data on aquaculture under the provisions of the data collection framework (DCF) on the following enterprise variables; income (turnover, subsidies and other income), personnel costs (wages and salaries of staff and imputed value of unpaid labour), energy costs, raw material costs (livestock costs and feed costs), repair and maintenance costs, other operational costs, capital costs (depreciation of capital and financial costs), extraordinary costs, capital value, net investments and debt.

These figures are then consolidated into national values, including total volume of sales, employment (number of persons employed, gender and full-time equivalents (FTE)) and number of enterprises belonging to the European Union aquaculture sector. Turnover and sales volumes must be detailed by species.

The data collected are regularly analysed by the Joint Research Centre of the European Commission for the Scientific, Technical and Economic Committee for Fisheries (STECF). The most recent report covers data until 2016 and gives a comprehensive analysis of aquaculture in each member state for the period 2008–2016 (STECF, 2018). While not always complete, these studies provide the most detailed results of the progress of European Union aquaculture (Table 23).

For 2016, the report estimated that total European Union production was 1.42 million tonnes, worth USD 5.43 billion, where Spain, France, Italy, United Kingdom of Great Britain and Northern Ireland and Greece were the major producers, both in terms of volume and value, representing nearly 75 percent of European Union aquaculture. Compared to 2014, a six percent increase in sales volume and an eight percent increase in sales value was estimated, reflecting positive economic growth in the sectors of shellfish, freshwater and marine fish.

The STECF economic analysis indicates better performance since 2014, where the EBIT has improved to USD 456 million in 2015 and USD 844 million in 2016, having doubled since 2014. This progress is attributed to better sales values for all sectoral products, combined with improved labour productivity.

The report notes the dependence of the sector on part-time labour, specifically in the shellfish and extensive or semi-intensive freshwater fish (cyprinid) sectors, often due to seasonal harvesting and less intensive stock management. However, the social importance and contribution of micro-enterprises (less than ten employees), often engaging family members, is high in several European Union regions (including Spain, Portugal, Germany, Poland, Romania) and comprise 90 percent of the European Union aquaculture sector. Capital-intensive marine fish farming is usually represented by larger companies which have more permanent and large payrolls.

TABLE 23. Economic and employment indicators for the European Union aquaculture sector, 2014 and 2016

European Union	Number of enterprises	Total Sales Volume (tonnes × 1 000)	Turnover (USD million)	Employment	FTE	Average wage (USD)
2014	11 865	1 337	5 014	69 673	31 446	25 974
2016	12 496	1 422	5 578	75 466	43,680	28 500

Source: STECF, 2018.

Food 2030 is a European initiative targeting food and nutrition security (FNS), contributing to a European bioeconomy policy and investigating the role of research and innovation (EC, 2016b). Assuring the sustainable contribution of food value chains, such as aquaculture, to FNS was seen as a priority as was the need for a research base that underpins and promotes the sustainable and competitive development of European aquaculture.

6.2 SALIENT ISSUES

6.2.1 Contribution of the EU to aquaculture in the European Region

The share of European Union aquaculture in seafood supply from European Union sources has increased steadily, reaching over 25 percent in 2017. Following the latest STECF report, the number of aquaculture enterprises has also increased, with an accompanying rise in the number of employees and FTEs. It is to be noted, however, that some states have not reported data and analysis remains incomplete.

The report also indicates that the number of enterprises employing ten or more people has increased by three percent in recent times, indicating expansion or the diversification of activities. Shellfish production provides the largest number of workers, often part-time, and has a large social importance for several regions in the European Union (for example Galicia in Spain).

The leading European Union states, by volume and by value, were the United Kingdom of Great Britain and Northern Ireland, France, Spain, Greece and Italy. Following Brexit in 2020, European Union aquaculture production shrank by some 200 000 tonnes and by USD 1 billion, meaning that the major aquaculture producer countries of marine fish, including most of salmon farming, in the European region are non- European Union states and Spain, France, Italy and Greece becoming the leading European Union aquaculture producers.

Since the major markets for Norway, Turkey and the United Kingdom of Great Britain and Northern Ireland are those of the European Union, the self-sufficiency of the European Union's seafood supply will drop. Whether and how this situation will affect the development of European Union aquaculture remains to be seen.

6.2.2 Freshwater farming

Trout and carp are the dominant freshwater products of inland aquaculture, where trout farming has adopted more intensive technologies while carp production remains a traditional activity. With 260 000 tonnes representing 88 percent of freshwater fish yields, cyprinids overshadow other species. The historical traditions relating to carp farming are well recognised and large infrastructures of ponds and waterways dedicated to this activity exist throughout Eastern Europe. Increasingly, the role of these ponds in both water and landscape management is recognised, as well as their function in maintain valuable aquatic habitats and ecosystems. However, as economic fish production entities, their viability is becoming more difficult to maintain.

The main market for carp in Europe is for live fish prepared at home. Frozen or processed products are negligible although promising actions have been taken to encourage processing. Financial analysis (EC, 2016c) indicated production costs of USD 1/kg to USD 1.2/kg while ex-farm prices were USD 1.75/kg (average for 2012–2015). Nonetheless, these margins rarely allow for adequate pond maintenance and losses to predators, where some states provide financial assistance measures.

Diversification towards multifunctional use, including sport angling, ecotourism and cultural activities, provides further options for sustainability but recognition of the characteristics and potential of non-productive functions and non-product outputs has taken a long time. Transition to such activities is unlikely to be made by all pond farmers and the market limitations of the products can only be countered by maintained or increased local sales. The acknowledgment of the ecosystem services and habitats provided, notably wetlands, allowing biodiversity conservation at an important scale, would need to stimulate both public and private financial support to enable this sector to continue in the long term.

6.3 THE WAY FORWARD

6.3.1 Planning for development

The period examined (2000–2018) has shown the difficulties of accurate planning for development. In a sector that is made up of hugely different enterprises, ranging from the publicly quoted multinational organisations in salmon farming and feed manufacture to microenterprises and small service companies. Huge structural changes have occurred within the sector, leading to wide gaps in the approach of different components of the sector.

Of interest in the latest STECF (2019) report is the evaluation of the multiannual national strategic plans (MNSP) of European Union states (EC, 2016d), that were requested in the European Commission strategic guidelines of 2013. The STECF expert perception was that the measures and objectives of the MNSPs were being implemented but that the growth objectives could not be directly connected to the measure and actions that had taken place, although these were beneficial to the sector.

Difficulties were noted in assessing performance on growth objectives (up to 2023), principally in deciding whether growth was catching up on previous weak performance or due to the measures implemented. In noting that the projected values in the MNSPs were too optimistic, even unrealistic, the start of coordinated efforts towards common goals and strategy was identified as positive. Nonetheless, it remains unclear how many of the proposed actions will lead to an increase in aquaculture growth and development in the European Union.

Non-European Union, European states have also developed aquaculture plans and strategies, including Norway, Turkey, Iceland, Albania,, Montenegro, Russian Federation, Ukraine and the Faroe Islands, whilst others are in the process of developing one.

Norway's strategy (NMFCA, 2007) for a competitive Norwegian aquaculture industry was followed by a strategic plan (Hersoug, 2015) for growth based on economic and environmental sustainability, where three-fold growth was projected by 2030. The costs of sea lice control measures and licensing will no doubt affect this forecast. In addition, a new taxation system for Norwegian aquaculture is under debate, including proposals for an additional 40 percent tax on profits (Jengson, 2019). The argument for this action is based on returning financial benefits to communities whose natural resources are being used for aquaculture.

Balancing growth with sustainability is the basic challenge for all aquaculture operators within the European Region. Negative public reaction to unsustainable practices should not be underestimated.

6.3.2 Future investments in aquaculture

As a coastal and rural activity, aquaculture provides valuable year-round employment and significant economic contributions to local communities where farms and processing

activities exist. Nonetheless, urbanisation and a growing middle class are influencing how both rural agriculture and aquaculture are viewed, particularly concerning animal welfare, antibiotic and pesticide use. An analysis of Norwegian aquaculture noted the increased consciousness and awareness within the value chain, including consumers, about sustainability and preventive health (EYGM, 2019).

All European aquaculture faces production constraints which arise from health or management issues, biological questions on performance, legislation and controls. Technical development and innovations are expected from research support structures and the service sectors.

Freshwater aquaculture appears unlikely to expand significantly in the European Region, although the Russian Federation has increased both trout (CAGR, nine percent) and cyprinid (CAGR, three percent) aquaculture in the decade 2007–2017 (GAIN, 2017). Potential drought or high summer temperatures may stimulate investment in water treatment and recirculation, while increased productivity would be obtained primarily from high quality feeds and improved brood lines.

The Norwegian aquaculture analysis indicated that more than 30 mergers and acquisitions were reported in the sector of technical solutions for aquaculture between 2016 and 2019, indicating consolidation and reinforcement of service companies. The marine sector requires technical solutions for offshore and underwater rearing systems, accompanied by management systems, improved feeds and pharmaceutical responses. Given the scale and success of the salmon sector, increased interest is noted from new investors and financial institutions, particularly for land-based RAS systems that are free of the risks of sea pens, specifically, escapes and sea lice infestation. The current status of identified projects is reported in Table 24 (EYGM, 2019).

Two companies, Atlantic Sapphire and Pure Salmon, have announced production plans for more than 480 000 tonnes by 2030. While licensing and funding for the projects identified may not have been realised yet, the ambitions are clear. As capital-intensive projects, for both investment and working capital, they will require equity and external financing. While RAS systems are presented as more environmentally friendly, calculations of the carbon footprint of such installations indicate that the footprint of RAS systems would be 28 percent higher than that of cage farming (FHF, 2018).

The question of whether such an approach could be adopted by the Mediterranean marine fish sector is probably premature, given product market instability and restructuring in progress.

TABLE 24. Planned capacity for land-based salmon farming (thousand tonnes/year)

Area	2019	2020	2021	2022+
Norway-Denmark	50.7	76.6	117.4	208.0
US-Canada	33.5	46.5	46.5	357.6
Other	23.5	28.9	38.9	407.6
Total	107.8	152.1	202.9	973.2

Source: EYGM, 2019.

7. External pressures on the sector

7.1 STATUS AND TRENDS

European countries recognise that climate change is transforming the world, with the last two decades including eighteen of the warmest years on record. Increasingly frequent extreme weather events include heatwaves, floods, drought and forest fires. The impacts are multiple, including the loss of biodiversity within damaged ecosystems and are also recognised as having the potential to reduce food production capacity. European and European Union countries are signatories to the Paris Agreement to achieve climate neutrality by 2050 with actions to reduce greenhouse emissions, increase renewable energy sources and improve energy efficiency. Additional considerations, including the blue, green and circular economies, reflect the scope and reasoning of climate change concerns.

7.2 SALIENT ISSUES

External pressures, independent of legislative or consumer-related issues, differ by sub-sector but are of concern to all involved in European aquaculture. Climate change is of the greatest concern and could have a radical effect on European aquaculture (Barange *et al.*, 2018).

Observations include:

- Coastal erosion and flooding.
- Stressing of marine bio-systems.
- Higher winter storm risk.
- Inland waterlogging, eutrophication of lakes and wetlands.
- Increase in summer heatwaves.
- More droughts and reduced water availability.
- Higher salinity and eutrophication of coastal waters.

The preferred temperature for salmon is 16.5°C to 17.5°C and sea temperature increases could prolong the growth period while salmon aquaculture performance would be affected by a higher oxygen demand and disease susceptibility (FAO, 2017a). At high temperatures, feeding is normally reduced or abandoned due to higher oxygen needs and the resulting stress. In such conditions, easily digestible feeds of high quality are needed as an adaptive response. This situation is the same for trout and Mediterranean marine fish species (Rosa, Marques and Nunes, 2012).

In 2006, Turkish marine aquaculture was obliged to move its cages from inshore to sites of a minimum distance of 0.6 nautical miles (1.1 km) from the shore, a depth of greater than 30 metres and a current velocity of at least 0.1 metres/second. The reasons for this were multiple but included competition for space with tourism, biological and visual pollution. Despite initial resistance, there was recognition that these conditions provided better growth and health conditions as well as allowing spatial expansion and production growth (Ertor and Ortega-Cerda, 2018). Since similar conditions exist elsewhere in the Mediterranean, so it is probable that other states will follow this example.

For marine aquaculture, severe sea storms are a key risk encountered in farm operation and management, particularly when considering offshore investments. Freshwater aquaculture is increasingly affected by high summer temperatures and drought conditions, notably in inland Europe. Farms that use smaller sources for water supply have faced extreme difficulties in recent drought periods.

The 2018 STECF report indicated the severe events affecting aquaculture that occurred in Europe between 2015–2017, including drought and record high temperatures influencing trout yields in France, drought affecting carp harvests (-20 percent), including the drying of small watercourses, marine storms affecting net cage stocks (escapes) and infrastructure destruction, storms reducing yields of mussels (for example, rope culture), severe oyster juvenile mortality (France) and algal blooms.

Ocean warming and acidification, caused by the absorption of carbon dioxide, are of very high concern to shellfish farmers, since coastal acidification is increased by land run-offs and rising sea levels. Shells of all molluscs are affected, since these become thinner and mortalities increase, and two European projects have investigated causal effects and potential responses to increase resistance to environmental factors and shellfish diseases (CACHE ITN, 2021; VIVALDI, 2021).

7.3 THE WAY FORWARD

While operators have tended to be passive when discussing climate change, reflecting a 'what can we do about it?' position, there is a growing awareness of the potential, though unproven, effects on aquaculture. Issues include higher risks of epizootic infections, emergent diseases, temperature extremes, drought and ocean acidification; all are factors that can have severe effects but where the individual has little to no control.

The ClimeFish project analysed aquaculture case studies to provide a decision support framework for farmers. Selected conclusions are summarised in Table 25.

Overall, it is foreseen that production risks will be higher due to the increased occurrence of sub-optimal oxygen levels, harmful algal blooms and disease outbreaks. The proposed adaptation strategies vary with sector and include specific adaptive measures at the industry level, providing policy and monitoring recommendations, and identifying research and knowledge gaps.

TABLE 25. Impacts of climate change on European aquaculture

Mediterranean (European seabass)	North Atlantic (Atlantic salmon)	Inland Freshwater (Cyprinids)
Fish will grow faster in the future, requiring shorter periods to reach different commercial sizes. Depending on the region, production time may be shortened for up to three months by 2050.	Salmon are vulnerable to temperature increase due to thermal limitations. In some Norwegian regions, thermal optima for salmon aquaculture are already exceeded, causing vulnerability to extreme events, such as heat waves	Temperature, invasive species, eutrophication, and fishing are main threats to the cold-water species in central Europe, such as brown trout and whitefish. Temperature increases could stimulate growth of certain species (for example, carps, whitefish)
Extreme events such as storms and heatwaves will negatively affect production by a possible increase of mortality rates or disrupting feeding and increasing operational costs.	Reduced product quality, impaired welfare, increased occurrence of diseases and increased mortality.	Oligotrophication (decrease in nutrients) improves water quality but decreases production of commercial species.
Management options such as site (inshore/offshore), market size, and predominantly the stocking month, will have an overall higher effect on growth than the projected change in climate.	Knowledge gaps on environmental data, salmon biology and aquaculture production include the combined effects of climate drivers and stressors on biological performance, and climate projections with higher resolution that focus on the coastal areas and new technology	The emerging top predator, the wels catfish, thrives with increasing water temperatures, but is a threat to many species, especially percid fish, which also experience suboptimal temperature conditions as temperatures increase.

Source: Climefish, 2020.

Selected actions include:

- Knowledge building regarding the biological responses to high temperatures and other climate change drivers.
- Establishment of a flexible legal framework for farm operation and site identification and designation of new sites.
- Preparation of farmers for future changes at farm and sectoral levels.
- Increased surveillance of environmental factors combined with farm monitoring and reporting to establish best management practices.

Since many states have comprehensive environmental monitoring systems in place, combined with sophisticated satellite surveillance, the integration of the effects of climate change on aquaculture and the industry's requirements will be followed up more clearly in the future.

8. Governance and management of the sector

8.1 STATUS AND TRENDS

8.1.1 Background

Many of the countries represented by the European region are members of the European Union, whose trade and food safety legislation influences all states that export to the European market while environmental, labour and food safety considerations cover European Union producers. The Common Fisheries Policy (CFP) addresses not only the establishment of sustainable fisheries in European waters but also the market for fisheries products, hence the inclusion of aquaculture since its products are placed on the same market (OJ L, 2013b). The 2014 reform of the CFP recognised that aquaculture should be identified in its own right, alongside fisheries and the processing and marketing sectors. This reform provided increased clarity on the role and position of aquaculture, also within the pillars of the CFP, the Common Organisation of the Markets for Fisheries and Aquaculture Products and the support provided by the EMFF (OJ L, 2013a).

Most aquaculture producers have access to regional and national professional associations that link to institutions whose responsibilities influence aquaculture operations. At the European level, the FEAP is the umbrella for national fish farming associations, including non-European Union representation, while the European Mollusc Producers' Association is active for shellfish farmers (FEAP, 2017).

Within the European Union, the European Commission operated the Advisory Committee on Fisheries and Aquaculture (ACFA) from 1998 to 2013, providing advice on European issues relating to fisheries resources, aquaculture and markets, with a focus on consultations relating to European Union legislation. ACFA was replaced by Regional Advisory Councils (RACs) for fisheries and two European-level councils, for aquaculture and for markets. Aquaculture representation of the profession and other interest groups is assured primarily within the Aquaculture Advisory Council (AAC, 2019) and the Markets Advisory Council (MAC, 2018). Each advisory council is a separate legal entity, based on individual membership criteria, that must be recognised and approved by the European Commission to receive financial support for its operations while non- European Union organisations may apply for observer status. Membership should respect a 60:40 ratio between industry and 'other interest' organisations, which are predominantly NGOs.

Alongside these Councils, additional specialist European-level committees exist, notably the Animal Health Advisory Committee and the Strategic Working Group on Fisheries and Aquaculture Research of the Standing Committee on Agriculture Research (SCAR FISH, 2020).

Several countries in the European Region are also members of the GFCM, a regional fisheries management organisation under FAO with a specific mandate also for aquaculture in the Mediterranean and the Black Sea. The GFCM plays a crucial role in fisheries and aquaculture governance in the region to manage these activities in accordance with the FAO Code of Conduct for Responsible Fisheries (CCRF) and compatible with the proper functioning of Mediterranean and Black Sea sensitive ecosystems (Massa, Onofri and Fezzardi, 2017). The FAO also supports the European Inland Fisheries and Aquaculture Commission that focuses on freshwater issues, notably through specific initiatives and projects on aquaculture.

8.1.2 Strategic Planning for aquaculture

As reported in 2015 by the FAO Sub-Committee on Aquaculture, there were 94 relevant documents relating to strategic frameworks and plans for aquaculture in the European Region (FAO, 2015a). Many of these relate as responses to the Strategic Guidelines for the sustainable development of European aquaculture, coordinated by DG MARE (Maritime Affaires and Fisheries) published as a Communication by the European Commission to the other European Institutions (EEA, 2013). In the European Union, the European Commission has no delegated authority to manage European aquaculture, unlike fisheries, except through legislation that has direct or indirect effects on how operators can control their technical and marketing procedures. Such legislation includes food safety, environmental measures and controls, animal health and measures for consumer protection, whose responsibilities lie with different Directorate Generals of the European Commission (for example, environment, health and trade).

While stating that "Aquaculture can contribute to the overall objective of filling the gap between European Union consumption and production of seafood in a way that is environmentally, socially and economically sustainable", the European Commission requested multi-annual national plans (EC, 2021b) from member states to establish overviews on aquaculture development at national and European levels. Priorities to be addressed to assist development included simplification of administrative procedures, notably for licensing, securing sustainable development and growth of aquaculture through coordinated spatial planning, enhancing the competitiveness of European Union aquaculture and promoting a level playing field for European Union operators by exploiting their competitive advantages.

The document also highlighted actions to be taken by the European Commission, the member states and the AAC as follow-up measures to the four axes defined above. These included new governance support for European Union aquaculture, where national strategic plans were requested, whose operating plans would also identify where funding would use EMFF support. Actions such as the exchange of best practices were also emphasised.

The COFI-SCA report (FAO, 2015a) identified several priority areas that were common to regional planning efforts, including:

- aquatic animal health and welfare;
- regulation and environment;
- public perception of aquaculture;
- technology for innovation; and,
- improving knowledge transfer between research and industry.

These are issues that were recognised by the European Aquaculture Technology and Innovation Platform (EATiP), a European Technology Platform that is 'an industry-led stakeholder forum recognised by the European Commission as key actors in driving innovation, knowledge transfer and European competitiveness'. EATiP, through wide consultation, prepared a strategic research and innovation agenda in 2012, followed by a review in 2017 (EATiP, 2017), identifying topics requiring innovation and responses to the important issues identified.

The fish component of the Standing Committee on Agriculture Research (SCAR FISH, 2020) and the European Fisheries and Aquaculture Research Organisations (EFARO, 2017) both represent national research interests (European Union member states and research institutions) and have also prepared strategic research reviews. The common aim of each of these structures is to promote the sustainable development of national and European aquaculture.

For many aquaculture operators, regional or local administrators and researchers, such European actions are less relevant than local ones. This led EATiP to promote the concept of mirror platforms which follow the recommendations developed by EATiP at local, regional or national levels. Currently, EATiP has 15 mirror platforms active in 11 European states (EATiP, 2021).

This approach is complemented by FARNET, a network devoted to community-led local development which supports "fisheries local action Groups" (FLAGs), bringing together managing authorities, experts and citizens to work together on the sustainable development of fisheries, aquaculture and coastal areas (EC, 2016e). The FLAGs implement local actions and can access European funding for approved projects. While fisheries issues remain of the highest interest, an increasing number of FLAGs are addressing aquaculture development.

Marine spatial planning (MSP) is an approach that balances the uses of the marine environment with a view to providing a coordinated system that result in the development of a marine spatial plan for the regulation, zoning, management, protection and sustainability of the marine environment (Corner *et al.*, 2018).

The 2015 European region aquaculture review (FAO, 2017a) recognized the concept of allocated zones for aquaculture (AZA) as an effective management instrument to increase the available space for aquaculture development in the coastal area while reducing the possibility of conflicts with other coastal users and activities (Sanchez-Jerez *et al.*, 2016, Corner *et al.*, 2018). In the past few years, AZA has become even more an important tool recognized at European Union level, as well as being a prerequisite for releasing aquaculture licenses, for example, under a new law on aquaculture in Albania. Recently, the GFCM released both a guide for the establishment of AZA as well as an AZA toolkit (Macias *et al.*, 2019; FAO, 2019b).

8.1.3 Regulatory and Administrative Structures

As indicated, the European Union provides the basis for much of the legislation affecting and influencing European aquaculture operations within its member states. Several directorates general (DGs) of the European Commission have responsibilities affecting aquaculture, notably DG MARE, DG ENVIRONMENT and DG SANTE (Health); the European Parliament also has committees responsible for the areas covered, which function within the framework of the co-decision process of the European Union. Only DG MARE has personnel who work directly on aquaculture.

Much of the legislation on food safety also applies to third countries (non- European Union states) that wish to sell their aquaculture products to the European Union market. This position therefore influences countries such as Norway and Turkey, which export fresh products to European Union seafood markets.

While the CFP and its related instruments is the main policy that concerns aquaculture, there are many legislative factors of high importance with respect to aquaculture management and development. These include legislation, for example that concern food safety (including control and monitoring actions), animal health (OJ L, 2016) (including live transport and slaughtering (EC, 2017d)), water use and disposal (Water Framework Directive), integration with the Marine Strategy Framework Directive and rules on organic production, certification and labelling. Access to details on where aquaculture sits in European Union policies covering the environment, health and welfare, trade, consumer information and certification can be found on the European Commission website (EC, 2021c).

At national levels, responsibilities for aquaculture are normally within the same ministries as for fisheries and/or agriculture in land-locked countries. Monitoring of aquaculture operations is often seconded to environmental ministries.

8.1.4 Professional and stakeholder support structures

Professional production sectors are well represented through regional and national associations that are grouped in European Associations and Federations. These Associations look to develop common opinions on issues affecting the technical and economic performance of European aquaculture and to communicate these to the European authorities.

For fish farming, the FEAP provides the broadest coverage and represents the industry in 21 European states, covering the major European Union and non-European Union producers. COPA-COGECA includes the Committee of Professional Agricultural Organisations (COPA) and the General Committee for Agricultural Cooperation in the European Union (COGECA) and for states where aquaculture is included within the agricultural sphere, for example Germany and Italy, COPA-COGECA assures European representation. Shellfish representation is provided by the European Mollusc Producers' Association (EMPA). Fish feed manufacture is represented by a special committee within the Federation of Compound Feed Manufacturers (FEFAC).

All of these organisations are members of the Aquaculture Advisory Council, a self-managing organisation that includes NGOs and other stakeholder organisations. The member NGOs cover different interests, including environmental and welfare representation. While receiving financial assistance for its operations from the European Commission, the AAC is a subscription-based structure with a secretariat in Brussels. The AAC has a privileged line of dialogue with the European Commission, which participates in AAC meetings and which is bound to respond to both information requests and to positions agreed consensually by the AAC. For market issues concerning fisheries and aquaculture products, a similar organisation exists, the Markets Advisory Council, within which the aquaculture associations are also members.

Research support for the development of the European aquaculture sector was initially established by the European Fisheries and Aquaculture Research Organisations, which is composed of the Directors of the main European research institutes active in these sectors. Its goal is to achieve cohesion and improved coordination of European research and development actions. This is complemented by the Aquaculture Steering Group of the International Council for the Exploration of the Sea (ICES) that supports ICES expert groups working on aquaculture issues (ICES, 2021).

EATiP is the only multi-stakeholder organisation dedicated to European aquaculture, looking to establish consensual focus on research and innovation needs. While not doing research itself, EATiP, in applying its role of being an officially recognised European technology platform, was responsible for preparing a comprehensive strategic research and innovation agenda (SRIA) in 2012, complemented by a review in 2017.

8.2 SALIENT ISSUES

In 2016, Commissioner Vella of DG Mare asked the Scientific Advice Mechanism (SAM) of the European Commission "How can more food and biomass be obtained from the ocean in a way that does not deprive future generations of their benefits?", a question to which the High-Level Group of SAM responded in the report 'Food from the Oceans' (EC, 2017e).

A number of evidence-based policy recommendations were made on how to increase the amount of food harvested from the ocean while maintaining healthy marine and coastal ecosystems. Sustainable capture fisheries and aquaculture at lower trophic levels were highlighted, where marine aquaculture has the highest and most feasible potential. Shellfish and algae culture were emphasised, accompanied by the potential to develop feeds for marine fish and shrimp.

The main recommendations were as follows:

- Mainstream a "food from the ocean" paradigm of responsible culture and capture into broad European Union and global systems-level policy agendas.
- Take the development of mariculture in Europe to a higher and more strategic level via a comprehensive, concerted policy framework.
- Continue to improve implementation and enforcement of existing regulations and use of best practice for sustaining wild capture
- Facilitate policy change by optimal use of the open method of coordination and initiatives such as the Blue Bioeconomy Forum, to support identification and deployment of best practice, stakeholder dialogue and the acquiring of social license to operate.
- Future-proof policy and extend knowledge by further developing the Common Fisheries Policy's science advice system, addressing key knowledge gaps and uncertainties identified in the report and facilitating science-based pilot fishing of as-yet unexploited lower trophic-level species.

The report recognised the marginal treatment of marine aquaculture as a contributor to food security and nutrition and that ocean-derived protein should play a more important role globally. An important conclusion was that the value of seafood is not understood properly, and this aspect should be better incorporated within nutrition policies and integrated within global food security.

8.3 THE WAY FORWARD

While being aware that European agendas and issues are often broad and less well adapted to national or regional aquaculture interests, EATiP has promoted the creation of mirror platforms which are industry-driven multi-stakeholder clusters mirroring the objectives of EATiP at a local level (EATiP, n.d.). EATiP Mirror Platforms represent more than 850 aquaculture entities and are encouraged to promote interactions between themselves as well as engaging in European activities.

The present overview of representative structures indicates that there is comprehensive representation of the professional and research sectors at all European levels, ranging from small local associations to European-level structures, each having the common goal of communicating their opinions to the relevant authorities. These different levels of cooperation and communication have been extremely important in providing views on technical, political, administrative and scientific issues affecting aquaculture and its development.

9. Contribution of aquaculture to the FAO strategic objectives, the Sustainable Development Goals, and the Blue Growth Initiative

9.1 STATUS AND TRENDS

The FAO Strategic Objectives, when applied to aquaculture, aim to:

- help eliminate hunger, food insecurity and malnutrition;
- make aquaculture more productive and sustainable;
- reduce rural poverty;
- enable inclusive and efficient aquaculture systems; and,
- increase the resilience of livelihoods to disaster.

FAO has refined its strategic objectives recently to align with the SDGs (FAO, 2021; UN, 2021b) and is now developing a new priority programme area, called Blue Transformation (FAO, 2021a; FAO, 2021b), based on the experiences of the Blue Growth Initiative (BGI; FAO, 2015b).

Food production within the European Region, has targeted increasing productivity, efficiency and sustainability, but there is increasing public concern regarding malnutrition induced by poor diets leading to obesity and obesity-related diseases. The nutritional benefits of seafood products, including those from aquaculture, have been placed to the fore in many media and continue to receive attention.

The Blue Growth Initiative focuses on unlocking the potential of seas and oceans, aiming to integrate essential ecosystem services and biodiversity with the provision of food and livelihoods for the world's growing population. Providing safe and nutritious food from fisheries and aquaculture is seen as being among the best opportunities of this initiative, while improving resource use and increasing efficiencies in the fisheries and aquaculture value chains.

In 2012, the European Commission prepared a communication on blue growth opportunities for marine and maritime sustainable growth (EEA, 2012) where fisheries and aquaculture were eighth in importance (in terms of employment and added value) after tourism, shipping activities, offshore oil and gas. The focus areas identified for action were blue energy, aquaculture, maritime, coastal and cruise tourism, marine mineral resources and blue biotechnology. Further aquaculture considerations were reported for the Mediterranean and the Black Sea in a FAO Regional Conference (FAO, 2017b)

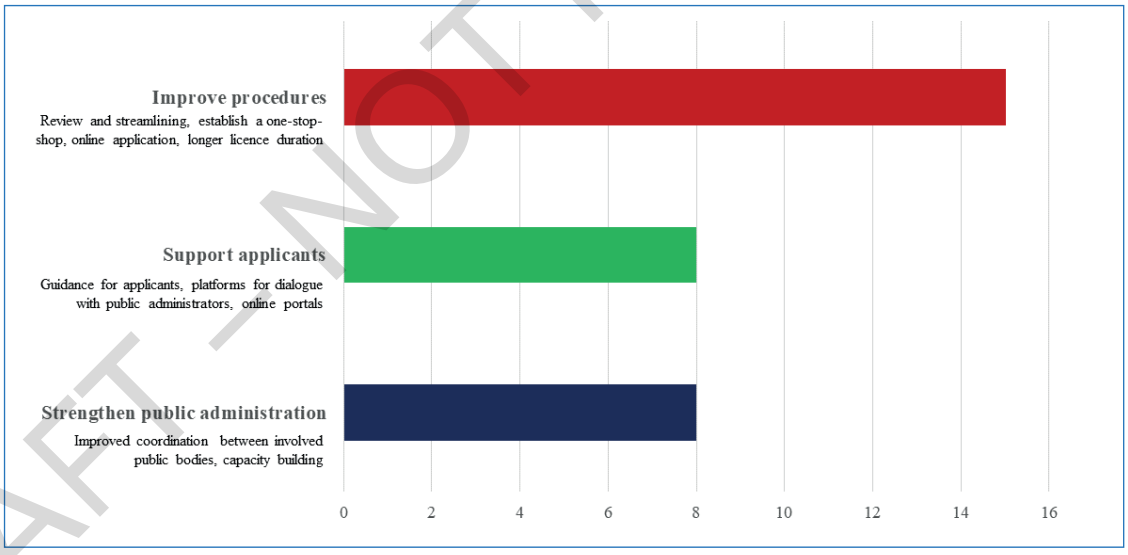
The European Commission indicated that additional effort should be made in these five areas to stimulate long-term growth and jobs in the blue economy, using consultations with member states and stakeholders. The European Commission reported on the Blue Growth Strategy in 2017, noting that while European Union aquaculture production had remained relatively constant, its value had increased by 40 percent and that virtually all European Union aquaculture produce is consumed internally (EC, 2017f). The report indicated that European Union aquaculture gave added value to consumers concerned about fresh, healthy and sustainable choices and that blue growth exerted a leverage effect for niche markets with a focus on local products, traditional methods and high value species and products.

Because the procedures for granting aquaculture licences are governed by national, regional and local authorities, the European Commission recognised that European Union standards and legislation need to be understood and implemented efficiently but without hindering development. Guidance documents on how the Water Framework Directive and the Marine Strategy Framework Directive link to aquaculture were published in 2016. In line with the multiannual national plans for the sustainable development of aquaculture, an analysis of progress was also presented. Figure 19 indicates the actions planned by member states (in number), reflecting identified priorities and shows that while there is a general move towards improving procedures, other actions are lagging behind.

Twenty percent of the budget of the EMFF, equal to USD 1.35 billion, was set aside for the development of European Union aquaculture, principally for investments in modernisation, providing environmental services, reducing the environmental footprint and productivity. Additional measures foreseen were for training and undertaking insurance on live stocks of fish.

A special strategy was developed by the European Commission in 2017 for the blue economy in the western Mediterranean (EC, 2017g). This included actions for marine aquaculture within the goal of sustainable consumption and production where diversification, capacity building and the development of common standards were highlighted. This was complemented in 2019 by the European Commission publication of "the green deal", an ambitious strategy to provide a consistent response to the effects of climate change (EC, 2019e).

FIGURE 19. Planned actions by European Union member states to reduce administrative burdens in aquaculture licensing



Source: EC, 2017b.

Aquaculture in the European Region contributes specifically to several of the United Nations SDGs:

	Poverty may be alleviated in some areas through aquaculture practices and operations and associated post-harvest processing and distribution of aquaculture products with seasonal or full-time employment and income opportunities benefiting rural poor including women, youth and men.
	Production and distribution of aquatic foods from aquaculture in some areas can help contribute to efforts of enhancing diversified and nutritious food supply and availability as well as key nutritional benefits to poor, vulnerable and malnourished people, which may include children, adolescent girls, pregnant and lactating women and older persons.
	Aquaculture products contribute significantly to a good diet, providing micronutrients, omega-3 polyunsaturated fatty acids, vitamin D and easily digestible proteins. Increasing seafood and aquaculture product consumption is widely seen as a response to a poor diet and obesity. Weight problems and obesity cause several non-communicable diseases, including diabetes and cardiovascular disease.
	To improve aquaculture practices and promote innovation, new skills are needed within the workforce, obtained through training or by the employment of new personnel. New biological technologies, engineering advances, automatization and digitalisation are all seen as contributing to the aquaculture of the future, where education of the highest quality is needed.
	Gender equality in aquaculture is encouraged throughout Europe and is addressed through different fora. The most recent European aquaculture conference organised a seminar on 'Women in Aquaculture', identifying gender-related obstacles and advising on careers in the aquaculture sector. The EURASTIP (Eurastip, 2020) project also included this topic within its scope of developing international cooperation on aquaculture.
	The numerous strategies and achievements concerning the economic growth of European aquaculture have been presented. Numerous measures have been taken for assuring the safety of workers, particularly in marine aquaculture, and providing employment opportunities and an interesting and decent workplace. In the support sector, a wide range of service companies have developed to accompany and support the growth of European and global aquaculture.
	Innovation is at the forefront of the considerations surrounding European aquaculture's sustainable development and growth. Obtaining successful incorporation of innovation (i.e. moving from research results to in-house operation) has been identified as a problem in Europe. This problem has been addressed at different levels, including an Enhanced European Innovation Council pilot (EC, 2021d) and the promotion of open science and innovation.
	The term 'responsible' mixes with 'sustainable' in many respects and food products are promoted to European consumers in terms of local production, animal welfare, food miles, fair trade etc. For producers, the legislative background on aquaculture is such that it can be assessed as being responsible. Nonetheless, the challenge of achieving broader public acceptance remains.
	While aquaculture itself may not achieve much direct climate action, with the notable exceptions of carbon sequestration by shellfish production and the integrated multi-trophic approach, the industry is aware of the issues and will adapt. The European projects ClimeFish and CERES are both investigating appropriate responses and mitigation tools; results will be published in 2020-2021.
	Aquaculture produces aquatic food and evidently contributes to life below water but in different ways, dependent on the culture system, not only in coastal and marine waters but also in freshwater bodies. The extensive freshwater ponds provide separate aquatic ecosystems; similarly, the Mediterranean vallliculture installations that produce marine fish provide a similar service. Integrated Multi-Trophic aquaculture also encourages life below water. Although it is less well advanced than other aquaculture systems, pilot work has started in several European states. Impacts of aquatic pollution and habitat degradation that may result from aquaculture are being addressed at local and eco-regional levels through improved farming practices, environmental impact assessment and management, spatial planning and area- and ecosystem-based management approaches.
	The creation of partnerships to support and contribute to the UN Sustainable Development Goals was achieved within the European Union. A high-level multi-stakeholder platform was created for this purpose and to support and advise the European Commission and all stakeholders on the implementation of the SDGs at all levels. Although its mandate finished at the end of 2019, this platform's reflections and recommendations contributed to 'Towards a sustainable Europe by 2030' (Ertor and Ortega-Cerda, 2018).

In May 2021 the European Commission adopted new Strategic Guidelines for more sustainable and competitive European Union aquaculture for the period 2021 to 2030 (EC, 2021e). The guidelines offer a common vision for the European Commission, European Union Member States and stakeholders to develop the sector in a way that contributes directly to the European Green Deal and in particular the Farm to Fork Strategy. The guidelines are to help building a European Union aquaculture sector that is competitive and resilient, ensures the supply of nutritious and healthy food, reduces the European Union's dependency on seafood imports, creates economic opportunities and jobs, and becomes a global reference for sustainability.

The guidelines should also help European Union consumers make informed choices of sustainable aquaculture products and to ensure a level playing field for aquaculture products marketed in the European Union. These guidelines should also help guide the use of the many instruments and funds available to support European Union aquaculture, as well as to support the implementation of applicable European Union legislation.

Achieving this vision will, as stated, require addressing different challenges and opportunities of the European Union aquaculture sector in order to reach the following inter-related objectives (EC, 2021f; EC, 2021g) of:

- building resilience and competitiveness;
- participating in the green transition;
- ensuring social acceptance and consumer information; and
- increasing knowledge and innovation.

The Aquaculture Advisory Council (AAC) in 2019 contributed recommendations for the development of the above Strategic Guidelines and then highlighted three priority areas (AAC, 2019): securing sustainable growth through optimizing licensing procedures, enhancing the competitiveness of European Union aquaculture and promoting a level playing field.

In 2021 the AAC also issued recommendations on both the Farm to Fork Strategy (AAC, 2021a) and the climate footprint in the European Union food system (AAC, 2021b). These recommendations are wide-ranging, reflecting consultation of and dialogue among stakeholders interested in sustainable aquaculture development in Europe. They illustrate opportunities stakeholders are using to contributing inputs into multi-stakeholder processes and policy-making at regional levels. Examples of recommendations by the AAC are that the council:

- Recognizes the strategic intent that the transition to a sustainable food system will deliver affordable foods, improve the incomes of primary producers, improve environmental and animal welfare outcomes and reinforce the European Union's competitiveness.
- Stresses that sustainable growth must be based on business investment predictability and legal certainty.
- Stresses the need to also support and promote greater sustainability in aquaculture, which is essential to improving the European Union's aquatic food self-sufficiency.
- Notes that overall emissions of greenhouse gases (GHGs) per kg of edible fish flesh at farm gate from finfish aquaculture is similar to pig meat and broiler meat and that bivalves, algae and seaweed have the lowest emissions, as they rely on natural food from their environment and encourages further development of aquaculture systems with low GHG emissions.
- Emphasizes that sustainable aquaculture can contribute to ensuring long-term food and nutrition security as well as growth and employment for EU citizens and highlights that aquaculture production could offer dynamic opportunities to young farmers and fishers, enabling synergies between terrestrial and aquatic food production systems.

- Supports developing a contingency plan for ensuring food supply and food security to be put in place in times of crisis and emphasizes that the plan must include aquaculture.
- Emphasizes the importance of exploring new forms of energy efficiency and energy production, such as the application of solar panels and the coupling of micro-hydroelectric or wind power plants on aquaculture farms

The European Commission's new Vision and the Strategic Guidelines for the European Union's aquaculture sector and the interactions and inputs by the AAC in many ways mirror the aspirations of the 2030 Agenda and the SDGs. Within the European aquaculture sector, and as active member of the AAC, the Federation of European Aquaculture Producers (FEAP) has established links with the European bodies and international organisations, including IUCN and FAO, to enable information exchange and communication on aquaculture. At the national level, most aquaculture associations have strong links to national and regional administrations, institutes and universities that work with aquaculture. Although these interactions may not be related directly to follow-up on the UN SDGs, the relevance of the work is.

9.2 SALIENT ISSUES

The European Commission Food 2030 initiative identified different areas where research in aquaculture is active, noting the importance of international collaboration in responding to the UN SDGs. Within Europe, an important initiative is Bluemed that covers issues relating to marine and maritime interests in policy and research (Bluemed, 2021). In respect of wider international cooperation, the European Union has signed the All Atlantic Ocean Research Alliance (AORA, 2021) which includes Canada and the USA (Galway Statement) and Brazil and South Africa (Belem Statement), an action that covers aquaculture interests and associated research activities.

A challenge raised in 1995 was how to transform scientific advances into marketable innovations. Research on aquaculture is done at national and European levels, where different mechanisms exist for basic and applied research, as well as industry-led actions. Fast-tracking programmes that target projects of high sectoral or industrial relevance also exist. Establishing the means for assuring successful knowledge transfer to the profession and for rapid implementation of promising results remain priorities.

Nutrition and welfare remain key focal points for development, but tools that enhance processes and control will also improve productivity and financial performance.

9.3 THE WAY FORWARD

This review has highlighted that to achieve safe and healthy diets, productive and sustainable agriculture, food supplies and nutrition, fisheries and aquaculture must be prioritised, views that are complemented by the 2020 State of World Fisheries and Aquaculture (FAO. 2020d). However, the factors that influence the growth and development of aquaculture in the European Region are multiple and, in some cases, conflicting, A simple observation is that, with few exceptions, aquaculture has grown and developed in those non-European Union states that encourage aquaculture at the national level and have the European Union single European market for seafood as its main consumer target.

The examples of salmon farming in Norway and the Faroe Islands, and mariculture and trout farming in Turkey could imply that European Union rules and regulations are hindering aquaculture development within the European Union itself. However, this position would ignore the geographic and climatic advantages of these non- European Union countries for

aquaculture. A simple example is that the coastline of Norway, including fjords and islands, measures 25 000 km while France has only 3 500 km. Turkey benefits from warmer sea waters compared to Italy, Greece and Spain and thus has a longer growing season for the species reared.

The European Commission and the European Parliament have both provided supportive policies and positions for the growth and development of aquaculture in the European Union, most specifically the Strategic Guidelines of 2013 that requested national multi-annual plans of development. Non-European Union states in the European Region, for example, Norway, Turkey and Faroe Islands also have specific regulations and policies that provide frameworks and controls on operations that have stimulated growth.

Within the European Union states, multi-annual plans for aquaculture have been published, where new aquaculture laws were foreseen in several countries. Collated in 2016 (EC, 2021b), the combined plans foresaw a production increase in the European Union of 300 000 tonnes to 1.5 million tonnes by 2020, principally for marine fish (+60 percent) and shellfish (+25 percent) respectively whereas significant rises in freshwater production were not forecast. The micro-enterprises that constitute a large part of this sector have difficulty accessing financial credit for investment in installations and stock development.

For the marine sector, member states have indicated that they will simplify administrative procedures and, in some cases, implement a one-stop-shop for the individual licences required. In moving towards better and coordinated spatial planning, several states are achieving studies to identify the best areas for aquaculture, responding to the competition for space.

Throughout Europe, research programmes are in place to overcome technical, nutritional and health issues and raise performance levels. These need to be accompanied by improved communication on the sector's operations and better marketing of fresh and processed products. For shellfish, improving the resilience of the sector to climate change and environmental hazards is a top priority.

The consolidation of companies in the marine fish sector has led to the creation of publicly quoted organisations, primed for growth and modernisation of salmon farming and the widespread availability of its products, accompanied by significant price reductions. The Mediterranean sector saw a similar move, notably in Greece, whose impact was complicated by the financial crisis. For freshwater and mollusc aquaculture, there are few similar examples, and the dominance of micro-enterprises means that these sectors have difficulty in providing the volumes and conditions required by the retail chains.

While cooperatives and grouped processing and marketing facilities are active in shellfish aquaculture, these are less visible in the freshwater fish sector. Freshwater farmers will have to diversify and focus on local and speciality markets to obtain satisfactory profit margins on the smaller volumes produced. The consumer trends towards this food product area, namely, local, fresh and organic are therefore encouraging.

The leading European salmon companies and feed suppliers are prominent in global aquaculture and have subsidiaries throughout the world. European equipment suppliers are also active at the world level, while consultancy operations are also evident. The possibility of achieving aquaculture SME growth or diversification by investing outside of Europe has been investigated, notably through the AORA (European Union-North America) and EURASTIP (European Union-South East Asia) projects. While there is little interest in

this from SME aquaculture producers, service suppliers and consultancy organisations are following such opportunities, supporting aquaculture development outside Europe.

The price and profit recovery reported by EUMOFA in recent years also provides optimism across the European aquaculture sector in the immediate future. Nonetheless, awareness of the immediacy of price collapses due to market competition and difficulties in accessing investment and working capital financing are negative influences on the short-term growth of the micro-enterprise component of European aquaculture.

In the last decade, European aquaculture's visibility has improved within the legislative environment, most notably the Common Fisheries Policy and its accompanying instruments, and has access to new networks and communication lines that encourage recognition and development. Market competition and changing consumer preferences must be recognised, requiring constant monitoring and adaptive strategies within the profession. There is clear recognition of aquaculture's contribution to local employment and development or maintenance of coastal and rural communities. Nonetheless, the issues relating to competition for space, licensing and public acceptance remain as potential blocks to predictable growth and development.

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Annex 1. FAO statistical data

Data used in this regional aquaculture review, derive mainly from the different FAO fisheries and aquaculture statistics (FishStat), accessible through different tools, including the FAO Yearbook Fishery and Aquaculture Statistics, online query panels and FishStatJ (FAO, 2020a; FAO, 2020b; FAO, 2020c). These tools provide free access to fisheries and aquaculture data, including production, trade, consumption and employment for over 245 countries and territories from 1950 to the most recent year available. FAO represents the only global source of fisheries and aquaculture statistics, which are mainly compiled from data submitted by member countries. Statistics received are validated by FAO through adequate quality controls and, in the absence of official reporting, FAO estimates the missing data based on information obtained from alternative sources or standard estimation methods. Estimates also involve disaggregating some of the data received by FAO in aggregated form by species and, in the case of production, also by culture environment.

FAO highlights that data received from countries show different levels of quality in terms of coverage of species, environment and overall national reporting. Inconsistencies may occur in data reported or data are not reported at all. For example, in the case of aquaculture production, FAO has noted that not all the countries have adequate and effective data collection systems set in place. Many countries still do not have a systematically established framework aligned with internationally and regionally accepted standards for data collection from fish farms. In addition, in several countries, the staff responsible for reporting aquaculture production lack the relevant knowledge, support or relevant mechanisms such as specifically designed databases to develop accurate production estimates and improve monitoring and control of the industry. Production data are often estimated through extrapolation by multiplying the area under fish culture by an estimate of average productivity, with adjustments according to advice from key contacts in the industry. Improvements to this problem could, for example, be found by resolving issues related to the fish farm licensing process and devising a system for direct reporting of production, coupled with validation through sample survey by trained enumerators.

Problems occur as well for other typologies of aquaculture statistics. Only a very limited number of countries have a breakdown for farmed vs wild species in their trade statistics and, in addition, many farmed species are often reported in an aggregated form under miscellaneous entries as other fish. The lack of accurate trade data on farmed fish and fish products implies the impossibility to calculate separate consumption statistics on farmed species, with no clear assessment of the nutritional role of farmed species in the countries. In addition, not all the countries have a good collection of employment data in the primary and secondary aquaculture sectors, including insufficient detail on the role of women in the sector, which is captured mainly by ensuring employment data is sex-disaggregated and that all types (part time, full time, occasional time use) are all collected and reported . These data are essential to better assess dependency on the sector and other relevant indicators.

Due to the key role that accurate and timely data play in the management and policy formulation for sustainable aquaculture development, FAO remarks the urgent need for national capacity development in aquaculture statistics systems at several levels, including:

- the legal status, institutionalization and resource allocation;
- development of national statistical standards in line with international standards;
- adequate and stable staffing plus an effective mechanism for data collection, compilation, storage, dissemination and reporting; (FAO, 2020d);
- improvement in the coverage of farmed species in trade statistics, with the clear separation of farmed vs wild species; and,
- improvement in the coverage and accuracy of employment data, disaggregated by sex, occupational status and age.

In continuing the global efforts to achieve aquaculture sustainability through dissemination of up-to-date information on the status and trends of the sector, FAO publishes Aquaculture Regional Reviews and a Global Synthesis about every 5 years, starting in 1997. This review paper summarizes the status and trends of aquaculture development in Europe.

Relevant aspects of the social and economic background of each region are followed by a description of current and evolving aquaculture practices and the needs of the industry in terms of resources, services and technologies. Impacts of aquaculture practices on the environment are discussed, followed by a consideration of the response by the industry to market demands and opportunities, and its contribution to social and economic development at regional, national and international levels. External pressures on the sector are described, including climate change and economic events, along with associated changes in governance.

The review concludes with an analysis of the contributions of aquaculture to the Sustainable Development Goals, the FAO Strategic Objectives, and the FAO Blue Growth Initiative. Throughout the review, outstanding issues and success stories are identified, and a way forward is suggested for each main topic.