

# An assessment of the economic contribution of EU aquaculture production and the influence of policies for its sustainable development

John Bostock<sup>1</sup>  · Alistair Lane<sup>2</sup> · Courtney Hough<sup>3</sup> · Koji Yamamoto<sup>1</sup>

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**Abstract** This review paper examines the structure of the EU aquaculture sector, the contribution it makes to the EU economy and the policy environment for past and future development. The primary analysis uses statistical data from the Food and Agriculture Organization of the United Nations which has been re-categorized according to species groups established by the European Aquaculture Technology and Innovation Platform (EATiP) and by culture system type using expert knowledge. Additional data sources for the analysis include the European Market Observatory for Fisheries and Aquaculture Products (EUMOFA) and the European Commission Scientific, Technical and Economic Committee for Fisheries. EU aquaculture production was 1.34 million tonnes in 2012 with a first sale value of €4.76 billion. Shellfish comprised 45 % by volume and 28 % by value; marine fish 30 % by volume and 53 % by value; and freshwater fish 25 % by volume and 19 % by value. The total production volume has actually fallen slightly from 1.4 million tonnes in 2000, whilst the value has increased significantly from 2.79 billion in 2000, mainly due to a growth in Atlantic salmon production. Five countries accounted for around 78 % of the direct output value of EU aquaculture in 2012, the UK, France, Greece, Italy

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✉ John Bostock  
j.c.bostock@stir.ac.uk  
Alistair Lane  
a.lane@aquaculture.cc  
Courtney Hough  
courtney@feap.info  
Koji Yamamoto  
koji.yamamoto@stir.ac.uk

<sup>1</sup> Institute of Aquaculture, University of Stirling, Stirling FK9 4LA, UK

<sup>2</sup> European Aquaculture Society, Slijkensesteenweg 4, 8400 Ostend, Belgium

<sup>3</sup> Federation of European Aquaculture Producers, rue de Paris 9, 4020 Liege, Belgium

and Spain. Around 50 % of the direct output value was generated using marine cage systems (28 % by volume), whilst less than 3 % of value was generated in recirculated aquaculture systems (<1.5 % by volume). Around 5 % of value was contributed by extensive to semi-intensive inland and coastal pond systems. STECF (2014) estimates there are between 14,000 and 15,000 aquaculture enterprises in the EU employing around 80,000 people, approximately 40,000 full-time equivalent (FTE). The greatest number of jobs (FTE) is provided by the freshwater pond and suspended shellfish sectors due to much lower productivity figures. This could be seen as a social benefit in rural and coastal regions, but corresponding low wages could also discourage young entrants to the industry and lead to dependency on migrant workers. Where efficiencies can be improved through capital investment there is likely to be significant scope for consolidation of ownership as can be observed in the marine fish sector. The output from aquaculture has to find a place within the wider fish and seafood market where volumes are generally inversely related to price. The potential growth of the sector is therefore constrained both in relation to the overall market and with respect to competition from substitute products. These include product from EU capture fisheries as well as imports from third countries (sourced from aquaculture and capture fisheries). Whilst interactions between individual products can be hard to demonstrate, any increase in production costs is likely to lead to lower output volumes, whilst improvements in production efficiency can lead to increased output volumes. With around 60 % of EU fish and seafood supply obtained through imports, and little prospect of increasing outputs from capture fisheries, EU policy is generally supportive of sustainable aquaculture development for reasons of food security and economic development. The underlying basis for this is maximizing the quality and health benefits of farmed products, whilst improving resource efficiency and minimizing impacts. This is expressed through funding support for research and technological development and structural funds to the fisheries and aquaculture industries. However, constraints to growth also exist in the form of regulatory barriers and costs that reduce industry competitiveness. Changing market requirements are also a factor. Prospects for growth have been assessed using the results of EATiP stakeholder workshops combined with the analysis of the sector by system type. These suggest an overall increase in production by 55 % is possible by 2030 based mainly on expansion of marine cage-based farming using larger systems in more exposed sites and similarly shellfish farming using larger-scale suspended systems. Expansion of recirculated aquaculture systems appears likely based on entrepreneurial and European policy for research and technological development activity, although constrained by currently low competitiveness.

**Keywords** Aquaculture · EU · Europe · Economics · Policy · Systems · Competitiveness

## Introduction

Fish and shellfish have been produced using aquaculture techniques for hundreds of years. However, a new phase of growth commenced in the 1970s–1980s as production from capture fisheries reached a plateau, whilst demand for aquatic food products continued to rise. Total EU output increased throughout the 1990s but stabilized in the early 2000s although consumption and imports maintained an upward trend. This review paper examines the structure of the EU aquaculture sector, the contribution it makes to the EU

economy and the policy environment for past and future development. The paper is based on work carried out by the authors for the European Parliament in 2014 (Lane et al. 2014) which in particular featured a preliminary (i.e. based on expert knowledge rather than survey-based farm data) disaggregation of production and value data by system type. Whilst this cannot be taken as definitive, it provides another view on the industry which should help inform future analysis and policy development.

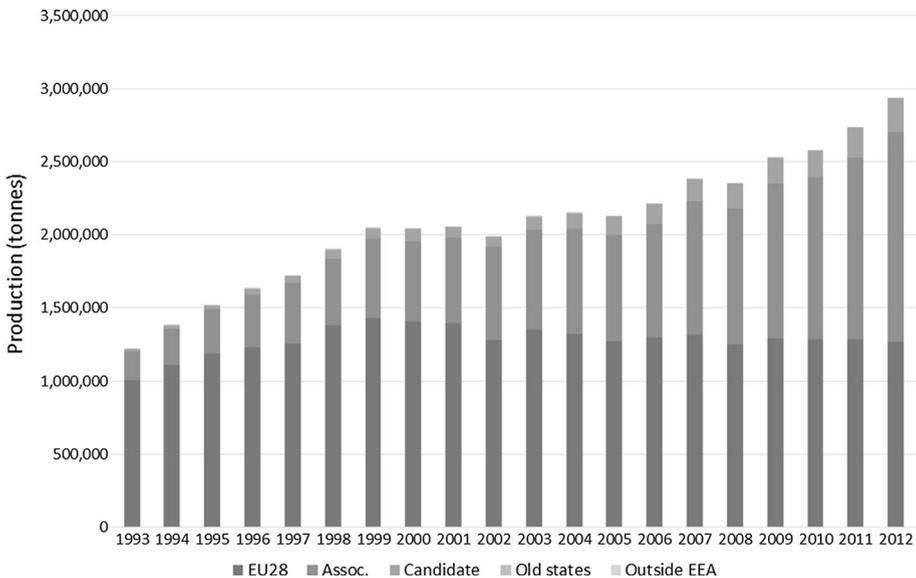
## The scale and structure of the European aquaculture industry

This section provides a short overview of production of the key European species. The authors have identified the main technologies used and have developed a new classification of ‘production by technology’ based on expert knowledge of the sector.

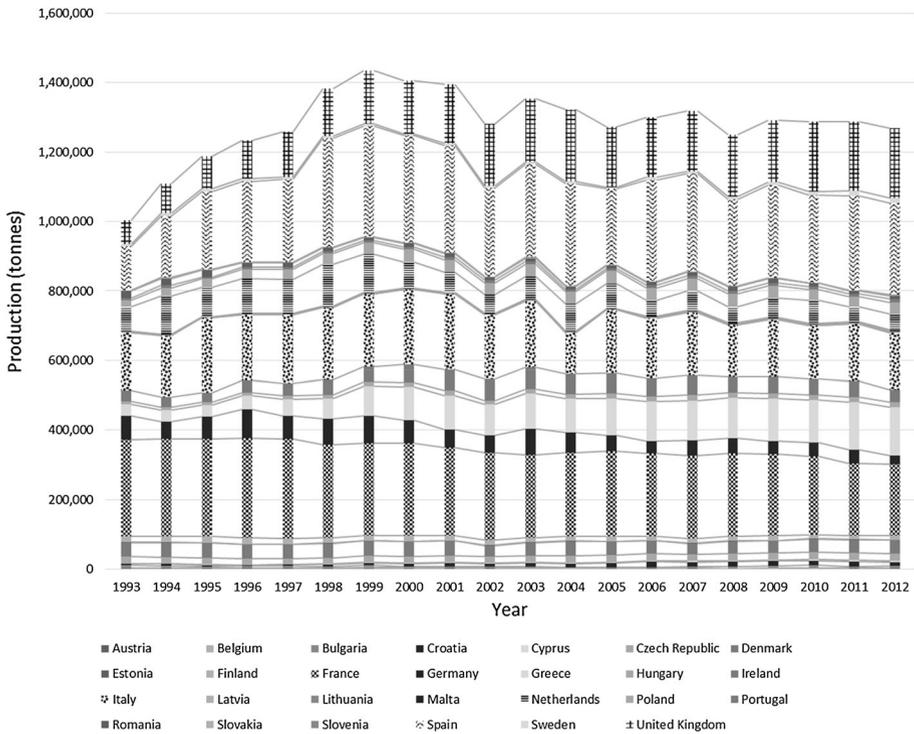
### Aquaculture development in European countries

Whilst global aquaculture production expanded at an average annual rate of 6.2 % in the period 2000–2012 (9.5 % in 1990–2000) (FAO 2014a) to reach 90.4 million tonnes (live weight equivalent), growth in Europe was well below this at an average of 2.9 % and total production is only 4.3 % of the global total at 2.88 million tonnes. Most of the positive growth was due to Norway, whilst production in the EU actually declined after 1999 (See Fig. 1).

Aquaculture is practised in almost every European country with the largest producers being Spain, France, UK, Greece and Italy (Fig. 2).



**Fig. 1** Development of European aquaculture production in relation to EU membership (Source: developed from FAO FishStat database)



**Fig. 2** Geographic distribution of EU production (*Source:* developed from FAO FishStat database)

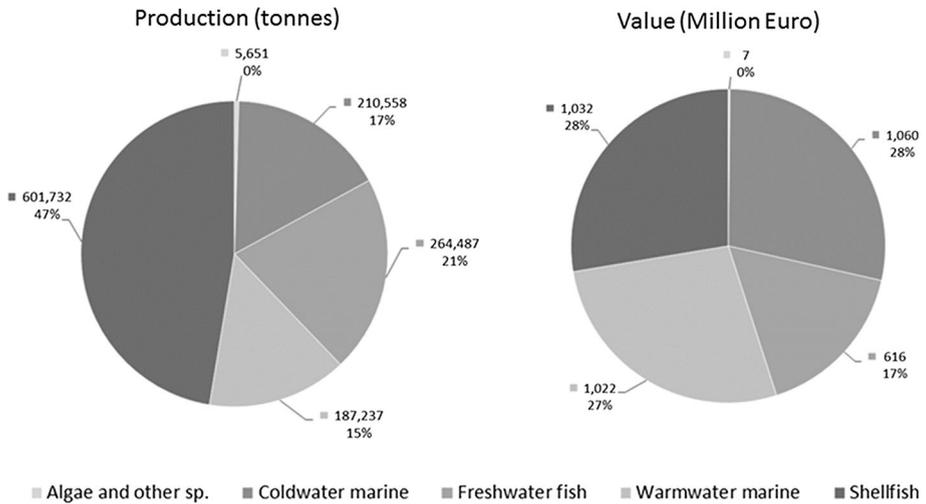
## Production by species of the principal sub-sectors of European aquaculture

In volume terms, the largest segment of EU aquaculture is shellfish—mainly of mussels and oysters. In value terms, however, fish production is more significant. More than 70 different fish species are cited for aquaculture in the EU (FAO 2014b), but production (in 2012) was dominated by rainbow trout, Atlantic salmon, gilthead sea bream, European sea bass and common carp. These five species make up 90 % of all fish production in the region.

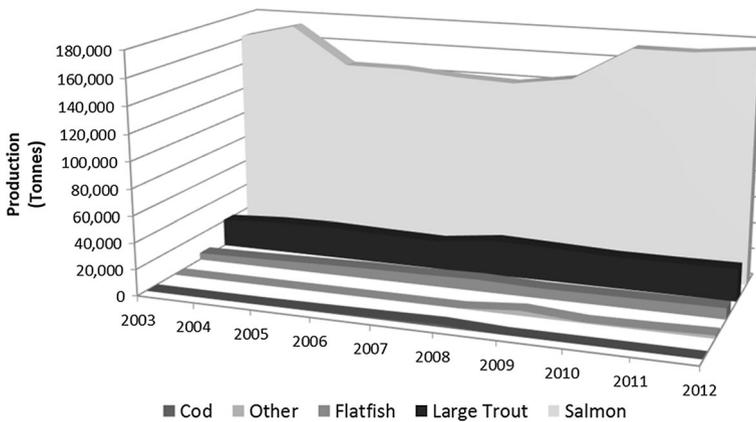
For the purpose of this study, we consider the EU aquaculture industry as comprising five separate segments, namely: coldwater marine fish, warmwater marine fish, freshwater fish, shellfish and algae and other aquatic products (Fig. 3).

### *Coldwater marine fish*

The cultivation of Atlantic salmon dominates this segment and is seen as the major success story in this sector. Production rose from only 900 tonnes in 1980 (FAO 2014b) to 168,000 in 2013 (FEAP 2014), reared mainly in Scotland (UK) with 11,500 coming from Ireland. The EU production is, however, significantly overshadowed by Norway (1.2 million tonnes) in 2013 (FEAP 2014). This is supplemented by the rearing of large rainbow trout in marine/brackish water conditions (Scotland, Denmark, Finland and Sweden) of 24,000 tonnes (FEAP 2014) (Fig. 4).



**Fig. 3** EU aquaculture production by major group (tonnes and €million in 2012) (Source: FAO FishStat data)

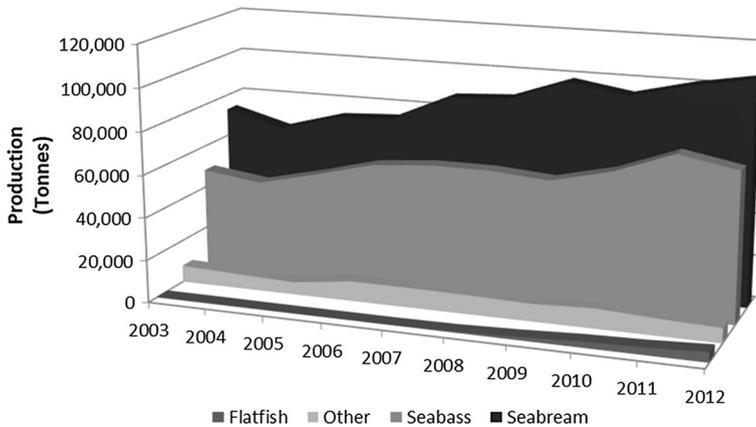


**Fig. 4** EU production of marine coldwater fish (Source: FAO FishStat data)

Efforts on diversification have focused on cod, sole and halibut—but so far with a small number of operations servicing mostly niche markets. Norway invested heavily in cod production, resolving technical challenges and reaching annual production levels exceeding 20,000 tonnes. However, resurgent wild stocks and market/price competition led to a crash and suspension of this activity (Jensen et al. 2014; Norwegian Directorate of Fisheries 2015).

*Warmwater marine fish*

This sector covers fish farming in warmer marine conditions, notably in the Mediterranean and Southern Europe (France, Portugal, Spain). The dominant species are gilthead sea



**Fig. 5** EU production of warmwater marine fish (Source: FAO FishStat data)

breem and European sea bass, with turbot and meagre leading the remainder. EU production totalled 218,000 tonnes in 2013 (FAO 2014b). As with salmon farming, the total production of these 3 species in 1980 was less than 500 tonnes. Growth started in the 1990s, when hatcheries were able to produce juveniles more readily for stocking in cages (Fig. 5).

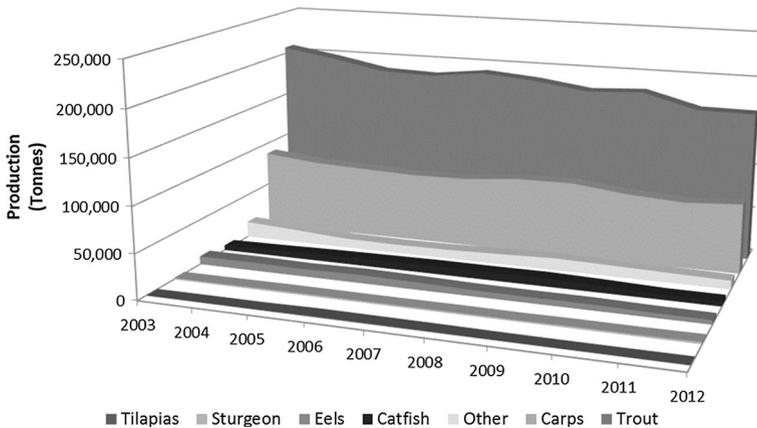
The growth in Turkish aquaculture (of sea bass and sea bream) has also been significant, especially as it exports mainly to the EU. From 25,000 tonnes of sea bass/sea bream in the late 1990s, Turkey produced 78,000 tonnes in 2010 and is estimated to be over 85,000 tonnes in 2013 (FEAP 2014).

### *Freshwater fish*

Whilst the freshwater sector is by far the oldest in European fish farming, it is divided into 2 main components, those of rainbow trout and common carp. This distinction principally reflects climatic conditions where rainbow trout is more suitable for temperate environments with carp being better in the more extreme continental conditions seen in Central Europe (hot summers, cold winters) (Fig. 6).

*Rainbow trout* production expanded from the 1980s, moving from 100,000 tonnes to a peak of approximately 250,000 tonnes in 2000–2001. This has since fallen to around 165,000 tonnes in 2012, although combined with the large trout reported under coldwater marine fish, production still exceeded that of salmon in 2012. It is produced not only for consumption (principally as a portion-size fish ( $\pm 250$ – $350$  g.) that is produced in one growing season) but also for stocking lakes and rivers for sport fishing. The decline in production is attributed to operational and licensing difficulties, in relation to environmental legislation, and the difficulties faced by smaller companies to deal with evolving market conditions and competition, notably with salmon. Significant reductions have been seen in Italy, Germany, Denmark, France and Spain (FEAP 2014).

*Common carp* attained 90,000 tonnes of production in the 1970s; major producers were Poland, Romania, Hungary, Germany, Czech Republic and Poland (each >10,000 tonnes). Smaller production levels were reported for France, Croatia and Lithuania. Carp is seen as a ‘traditional’ species, being a cultural fish dish for many inland countries that did not have



**Fig. 6** EU production of freshwater fish (Source: FAO FishStat data)

access to marine seafood. EU carp production is now around 60,000 tonnes (FEAP 2014). This reduction is attributed to different causes; predation from wild birds (cormorants, herons) is a major factor and disease (koi herpes virus) is an additional issue. In addition, with adhesion of Central European States to the EU, supermarkets have replaced traditional markets and access to other seafood and fish products has ensued (e.g. marine fish, salmon, pangasius catfish). Carp markets have remained traditional, and added-value products are relatively few (STECF 2013a, b).

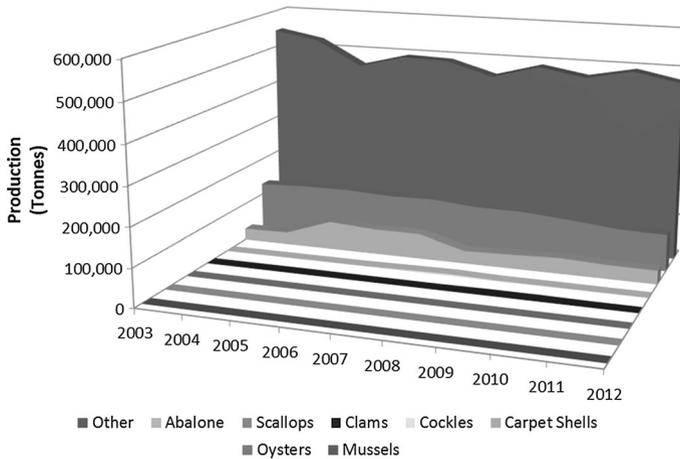
Eel farming reached a maximum of 11,000 tonnes in 2000 but is entirely dependent on the wild catch of young eels (glass eels) for its initial stock; the reductions in wild catch availability and high price competition for the stock with Asia have led to a fall in production, which was around 6000 tonnes in 2012 (FAO 2014b).

Many other freshwater species have been cultured at smaller scale in the EU, including Arctic char and other trout species, sturgeon—mainly for caviar, perch, pike-perch, roach and tench, African catfish—reared in warmwater, recirculation systems (mainly in the Netherlands) and tilapia and barramundi—tropical species reared in warmwater and recirculation systems. With the exception of African catfish and sturgeon, these all remain very minor components of EU aquaculture due to technical and/or marketing issues. Sturgeon rearing for caviar has expanded significantly in recent years, assisted by restrictions on the exploitation of wild sturgeon and trade in wild caviar under CITES advice and agreements (Bronzi et al. 2011; Doukakis et al. 2012).

### Shellfish

European shellfish production is mainly of oysters (the Pacific cupped oyster, *Crassostrea gigas*, and the European flat oyster, *Ostrea edulis*) and mussels (the blue mussel, *Mytilus edulis*, and the Mediterranean mussel, *Mytilus galloprovincialis*). Together, oyster and mussel culture represent 93 % of the total European cultivated mollusc production (Eurostat 2011). The third element of shellfish production is of clams, cockles and ark-shells (Fig. 7).

France is by far the leading producer of oysters ( $\pm$  85,000 tonnes in 2011), Spain of mussels ( $\pm$ 209,000 tonnes in the same year) and Italy of clams ( $\pm$  32,000 tonnes in the same year).



**Fig. 7** EU production of shellfish (Source: FAO FishStat data)

Over recent years, the production of oysters has declined with abnormal mortality events of *Crassostrea gigas* adults reported in most French oyster production areas, generally linked with oyster herpes virus (Martenot et al. 2011). It is now thought that the bacterial pathogens *Vibrio splendidus* and *V. aestuarianus* may play a more significant role in the mortality events, with interactions between pathogens and the development of some resistance by previously infected stocks playing a role in the severity of losses (Vezzulli et al. 2015; Petton et al. 2015). The UK, Jersey, Ireland and the Netherlands have all suffered recent similar mortalities (Renault 2011).

### *Algae and other aquatic products*

European production of algae and other species has only really started to evolve since 2007. Of these, aquatic plants (including brown seaweeds of the genus *Phaeophyceae*) have seen the most growth and this has been reported for Denmark (FAO 2014b).

Other species groups include crustaceans (mostly freshwater crayfish species in Central and Eastern European countries, but also several prawn species including the kuruma prawn, *Penaeus japonicus* in Southern Europe).

Mollusc species include mainly octopus and the miscellaneous aquatic animal group such as sea urchins and non-specified aquatic animals from inland waters.

## **European aquaculture technologies and estimation of production by technology**

### **Classification of systems and overview of production**

European aquaculture is a very diverse activity. Not just in terms of species produced, but also in the technologies that are used for rearing them. Aquaculture can be classified according to various primary characteristics such as scale (Lazard et al. 1991), intensity of production and feeds used (e.g. Edwards 1993), and finally by a matrix of environment and/or species (or species group).

**Table 1** Key to system types used in analysis

EP code	System type
EP01	Freshwater pond aquaculture (extensive to semi-intensive)
EP02	Coastal pond aquaculture (mostly semi-intensive)
EP03	Intensive freshwater flow-through and partial recirculation systems (mostly tanks, raceways and small ponds)
EP04	Intensive marine flow-through and partial recirculation systems (mostly large tanks)
EP05	Indoor land-based recirculated aquaculture systems (freshwater)
EP06	Indoor land-based recirculated aquaculture systems (marine)
EP07	Small cage systems—freshwater
EP08	Small cage systems—sheltered marine
EP09	Large cage systems—marine in exposed sites, using mechanized systems
EP10	Marine bottom culture (non-fed sedentary and attached animals and plants)
EP11	Marine supported and suspended culture (non-fed sedentary and attached animals and plants)

A technology-based classification primarily considers the nature of the containment system, and a primary distinction is made between land-based and water-based systems. For the former, there are potential benefits both to the farm and to the environment if water is recycled and treated on the farm. ‘Recirculated aquaculture systems’ (RAS) are normally defined by replenishing less than 5 % of the system volume per day. This approach allows systems to be effectively isolated from the environment and water quality conditions fully controlled. Water-based containment systems are either floating structures that are moored in position or static constructions usually placed in the intertidal zone or shallow water and fixed into the substrate.

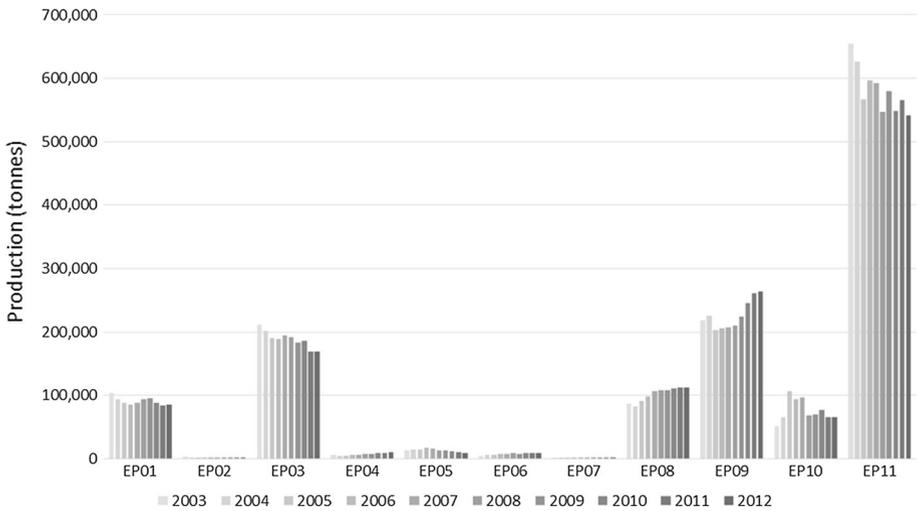
A recent study (Lane et al. 2014) performed for the Committee on Fisheries of the European Parliament selected 11 production technologies (see Table 1) as being the most dominant technologies for EU production and, using data from FAO, characterized by country and by species by assigning the 2012 production to the most dominant technology used for (ongrowing) production (Fig. 8). Hatchery and nursery technologies were therefore not included as their impacts are small and included in overall production calculations.

## Analysis of main segments by production system

### *Coldwater marine fish*

Cage/net production is the primary ongrowing technology (Table 2), and there has been a gradual expansion of unit size accompanied by automatically controlled feed distribution, remote-monitoring and mechanized movement/harvesting of fish. This has significantly reduced labour costs as well as providing safer working conditions in the marine environment (Bostock et al. 2010).

The vast majority of cage-based marine fish farming is conducted in relatively sheltered coastal areas that provide protection from storms and ease of access by personnel (for maintenance work, stocking, feeding and harvesting, etc.). However, the number of such sites that have been licenced for development over the past 15 years has been limited due to planning authorities responding to expressed concerns over the potential and perceived impacts of the waste produced by farms, influence of escapees (e.g. from storm damage) on



**Fig. 8** EU aquaculture production by system type (Source: Lane et al. 2014)

wild stocks, visual impact (e.g. to coastal residences and hotel businesses) or interactions with wildlife and conservation interests. For these reasons both ‘offshore’ farming (further away from the coastal zone) and closed containment system (e.g. onshore RAS) have been promoted as being a panacea for the future (Olsen et al. 2008; Klinger and Naylor 2012).

### *Warmwater marine fish*

As for the coldwater marine segment, ongrowing is usually done in cages, although generally smaller than used for salmon (Table 3). It is anticipated, however, that production in larger cage sizes will be prevalent in the future and that production will develop more in exposed or high energy sites.

There are a few specialized pump-ashore marine tank systems mostly for flatfish, and some use of coastal ponds, particularly in Italy and Portugal, but the contribution to total marine fish production is low.

### *Freshwater fish*

Freshwater aquaculture—compared to marine aquaculture—is fixed to the site where the installations are made and is largely dependent on adequate access to water for its production potential (Table 4). Traditionally, incoming water provides the environment for growing the fish and site selection is usually based on a combination of clean water and temperatures appropriate for the species.

Both trout and carp were originally reared in earthen ponds that require considerable maintenance (banks, floor, inlets/drains, etc.). Trout farming expanded as a result of increased productivity, due to the development of compound feeds adapted to nutritional requirements and the use of concrete tanks/raceways and latterly oxygenation allowing higher stocking levels and greater mechanization and automation for feeding, grading and harvesting fish.

Carp and coarse fish are generally reared in large freshwater ponds with minimal extra feeding (extensive production); the use of specific compound feeds is much rarer. This

means that the aquaculture process to provide fish of market size is longer (2–3 years) and less direct stock management (e.g. grading and vaccination) is practised. Nonetheless, the infrastructure of extensive pond farming is recognized as providing environmental services—providing flood protection, habitats for wild birds and animals, and water treatment (outlet water is often cleaner than inlet) (Szücs et al. 2008).

Sturgeon production for caviar often uses water recirculation systems—particularly for younger fish—and uses advanced monitoring procedures of individual fish, so as to follow ovary development for caviar harvesting.

Recirculated aquaculture systems (RAS) have been in use since the 1980s as a means of reducing water usage (and thereby increasing potential production for any given site/water supply), maintaining stable and more biosecure environments, and in some cases to assist the conservation of heat energy. Installations and monitoring equipment have evolved considerably, and large-scale units have been installed for different freshwater species (notably for salmon juvenile production, eels, African catfish, barramundi and tilapia). State-of-the-art systems use approximately 500 litres of water per kg production, but with increased capital and energy costs (Verdegem et al. 2006; Martins et al. 2010).

### *Shellfish production*

European oyster production is usually a three-year process that starts with the collection of small oysters on a support from which they can be easily removed (spat collector, e.g. white-painted roofing tiles, as practised in the Bassin d’Arcachon) or on a substrate such as mussel shells. The newly settled oyster juveniles are then transferred to intertidal or subtidal bottom culture plots, or in intertidal bags on trestles, or suspended from frames.

There are three different culture techniques for mussel culture—using poles (‘bouchot’), suspended ropes or bottom culture. A ‘bouchot’ is a wooden pole, placed upright into the sand. Mussel seed, collected (usually around March) either on poles (placed further out to sea) or on ropes, is transplanted onto the growing poles and harvested after 12–15 months. Suspended rope culture: Ropes covered with mussel seed are suspended from either frames, floating structures (rafts), or longlines with surface buoys. Frames are built from metallic poles, placed upright into the ground, at water depths ranging between three and nine metres. Bottom culture: Based on the harvesting of naturally producing mussel beds—a technique that is widely practised in the Netherlands and Germany and to some extent in UK and Ireland. Since the 2000s mussel seed is also derived from suspended seed collectors and then relayed on bottom culture plots, particularly in the Netherlands and Germany.

Scallop, clam and cockle species are generally produced using bottom culture techniques, with juveniles from the wild or in some cases, hatcheries (Table 5).

### *Algae and other aquatic products*

The majority of reported production volume is of brown seaweeds using suspended culture techniques. Other species groups, such as crayfish and shrimps, are generally produced in ponds, whether freshwater or brackish water (Table 6).

Small cage marine systems are used for the culture of cephalopods, mainly octopus species.

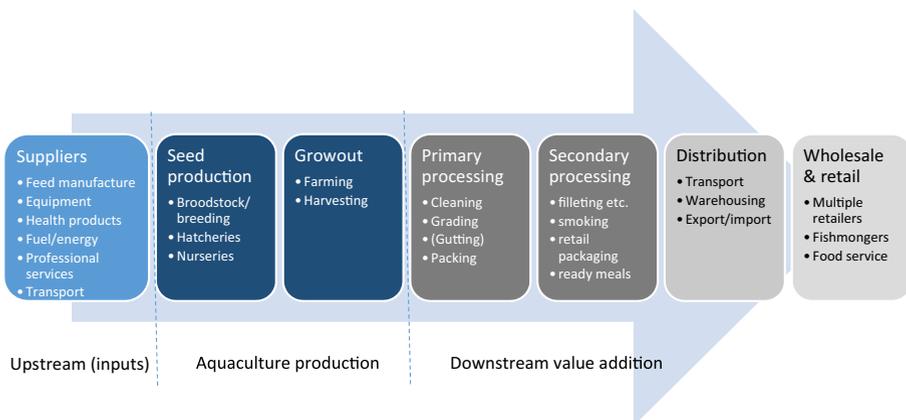
## The economic value of EU aquaculture

### Overview of value chain structures

The EU Fish Processors and Traders Association estimated the total turnover of the seafood sector in the EU to be around €27 billion (AIPEC-CEP 2015). The contribution of EU aquaculture producers and capture fisheries to this was, respectively, €4 billion and €7 billion (STECF 2013a, b). The remainder of the €16 billion mostly comprises the value of imports. This value is doubled, however, once retailing and food service are taken into account. The European Market Observatory for Fisheries and Aquaculture Products estimated total expenditure on fish and seafood products in the EU in 2011 to be €52.2 billion (EUMOFA 2014). Their figures also suggest the value of imports to be €19.2 billion in 2012. These figures can best be understood through value chain analysis.

The value of any product at the point of consumption can be considered to be the sum of the value added through many intermediate activities needed to produce it and deliver it to the consumer. Such value chains can be quite complex, but with respect to aquaculture production can be considered to consist of farming itself and associated upstream (suppliers) and downstream (processing and distribution) activities. The price of a product at any point is a combination of the cost of all the inputs required to reach that point in the value chain plus a contribution to company profits. Where each step is carried out by separate companies, there will be an element of profit taken at each step. If all the activities are carried out by a single company (vertical integration), the profit margin may only be applied at the final stage (Fig. 9).

The value chain for aquaculture products varies regionally depending on the nature of the production process and the degree of processing prior to market. The simplest will be for shellfish that are marketed without substantive processing and packaging, whilst the more complex will be for salmon or other species that have substantial upstream inputs and downstream processing and distribution. Based on limited studies of seafood value chains (e.g. Gudmundsson et al. 2006; EUMOFA 2013) raw material (e.g. output from fishing or farming) accounts for between 15 and 40 % of the final retail price. Processing and distribution adds between 10 and 30 % to the final price, whilst retail costs and margins



**Fig. 9** Generic value chain (simplified)

adds between 25 and 40 % to the final price. A specific example for farmed fish is a study by EUMOFA (2014) on fresh sea bream in Italy (i.e. no secondary processing) which found ex farm values to be around 40 % of the final retail price. Care needs to be taken in such an analysis to take account of wastage (e.g. in gutting and filleting) although where value is obtained from by-product that should also be considered. In the case of food service (e.g. institutional catering and restaurants), the ingredient cost will only represent 30–35 % of the price charged per meal,<sup>1</sup> so the cost of primary production (e.g. a farmed fish) may only represent 10–15 % of the final value of the product as sold to a consumer. For this reason, it is important to consider the whole value chain as changes in output from the production sector, for instance, can have a larger economic impact in the downstream activities than in the production sector itself. For instance, an analysis of the Scottish salmon farming industry (IMANI/SRSL 2014) estimated the turnover from primary production to be £537 (€660) million in 2012 with downstream processing, distribution, retail and catering adding a further £270 (€332) million within Scotland and over £860 million (€1.06 billion) across the whole UK value chain (total £1.4 (€1.72) billion). On the upstream side, feed is generally the most significant input for aquaculture. In the case of the Scottish salmon industry, this was estimated to account for between 50 and 60 % of production costs (IMANI/SRSL 2014). Other activities supplying aquaculture producers include engineering, transport and equipment supply companies, fuel supply and professional services.

### Economic assessment at the EU level

Since many companies involved in both the upstream and downstream activities are also servicing other sectors, they are generally not fully reliant on aquaculture production for their turnover. In some cases, they could (and often do in the case of secondary processor, retailers and food service) substitute local aquaculture products with fisheries products or imported products. For this reason, a formal analysis of economic impact of an activity (e.g. aquaculture production) is considered in terms of direct impact (e.g. hatcheries, farms, primary processing and sales operations), indirect impact (suppliers and wider business transactions) and induced (expenditure of company employees in the broader economy, etc.). Economic input–output models are used to quantify these effects, usually within defined geographic boundaries. Few examples of this approach are available, but a study by Fisheries and Oceans Canada (2010) quotes a direct output value of the Canadian aquaculture industry in 2007 to be C\$1.026 billion, whilst the gross output (including calculated indirect and induced impacts) was C\$2.1 billion (i.e. over double). This multiplier effect is industry and region dependent and can be applied to other measures of economic value including employment and value added (discussed below). In the case of the aquaculture sector in Scotland for instance, the output multiplier for indirect effects is 1.7, whilst the multiplier for both indirect and induced effects is 1.9 (Scottish Government 2015—data for 2012).

Whilst a full value chain approach or the use of input–output models provides an important overall perspective on the value of aquaculture activities, obtaining the appropriate economic data can be difficult or expensive. Many studies (e.g. STECF 2014) focus only on direct impacts for which data are more readily available. The main economic indicator used so far is output which is the total value of the products from aquaculture—essentially the same as turnover. However, it is more meaningful in economic terms to

<sup>1</sup> <http://restaurants.about.com/od/menu/a/foodcost.htm>.

consider the value that is added by a particular activity (e.g. the farming process) as gross value added (GVA). This is the value of the output minus the cost of purchased inputs (e.g. feed, medicines, fuel, services, etc.). The value that is added is therefore comprises employee costs, the cost of capital employed and the profit that is made. GVA values are therefore substantially lower than output values. Hence, the total GVA for the EU aquaculture sector in 2012 was reported to be €1.294 billion, whilst total turnover (output) was €4.365 billion (i.e. the multiplier from turnover to GVA is around 0.3) (STECF 2014). However, this varies by sector with shellfish averaging 0.54 and sea bass and sea bream less than 0.1. Shellfish provides a greater GVA in relation to output because there are no costs for feed. The GVA for sea bass and sea bream is low due to negative profitability in the sector at this time (2012).

A further economic indicator is profitability (measured as earnings before interest and taxes (EBIT) albeit with some variation in definition) and ratios of EBIT to turnover and capital employed. These are particularly useful for assessing the economic health of the sector and potential for reinvestment or tax revenues. STECF (2014) using data from 18 countries (excluding Greece and Poland) found the overall ratio of EBIT to turnover was around 8 % in 2012 and return on investment (EBIT divided by total assets) was 7 % (down from 9 % in 2011). Further analysis and perspectives on EU aquaculture sector profitability are provided by Guillen et al. (2015) using data from submitted company accounts and somewhat different means of calculation. This analysis by country and segment illustrates significant variability over time suggesting the need for relatively long-term financial planning on the part of companies.

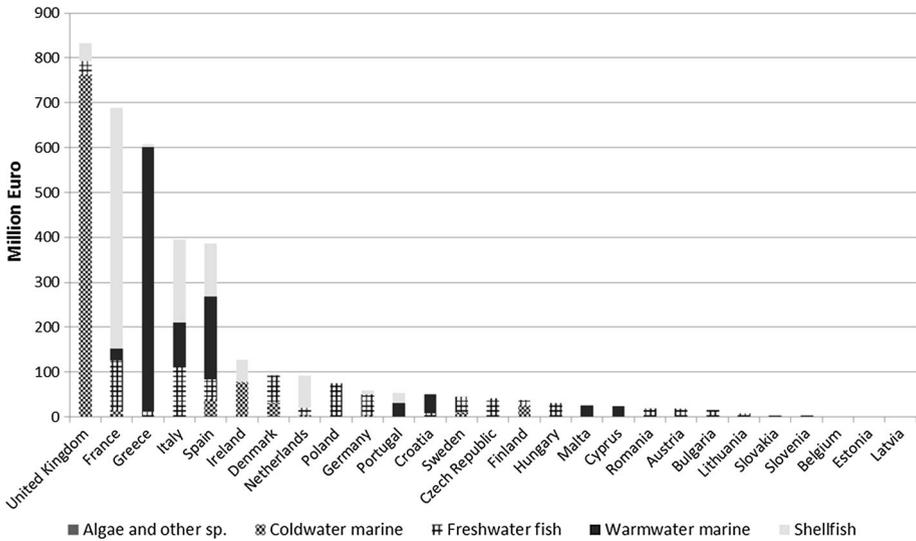
The social economic value of the sector is generally measured in terms of the number of people employed and the normalized measure of FTE (full-time equivalent). The employment generated by aquaculture is mostly in rural and coastal regions with fewer economic opportunities and, hence, may have a greater social impact than an equivalent number of jobs in cities. A more precise measure of economic value is labour income, which is a measure of earnings by the people employed in the industry. STECF (2014) estimates total employment in EU aquaculture to be around 80,000 people and around 40,000 FTE (indicating a fairly high degree of part-time and seasonal work). Average wages per FTE (based on data from 19 countries) were €22,100 per annum in 2012, but this varied from €3100 in Bulgaria to €70,000 in Denmark. Total labour earnings in EU aquaculture were therefore around €884 million.

### **Economic value by sub-sector**

A detailed analysis of the economic performance of the EU aquaculture sector by species/system and country has been carried out by the EU Scientific, Technical and Economic Committee for Fisheries (STECF 2014) as far as data are available. Data from that report have been combined with the analysis of FAO FishStat data in order to provide a perspective using the species groupings and system types defined earlier.

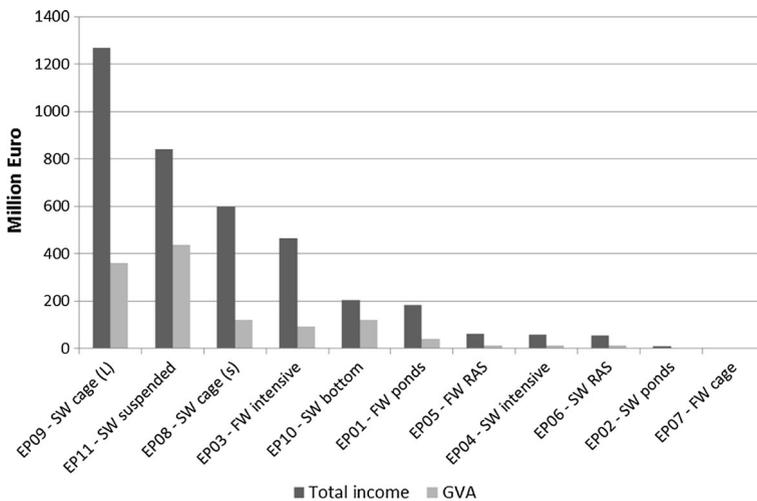
Five countries accounted for around 78 % of the direct output value of EU aquaculture in 2012, the UK, France, Greece, Italy and Spain. For the UK, the main component is Atlantic salmon culture, whilst for France the output is dominated by shellfish production. Greece is predominantly sea bass and sea bream, whilst both Italy and Spain have more diverse aquaculture sectors involving shellfish and both marine and freshwater finfish (Fig. 10).

The importance of the UK (Scottish) salmon production by output value carries through to an analysis by system type with large marine cage systems (supplemented by some

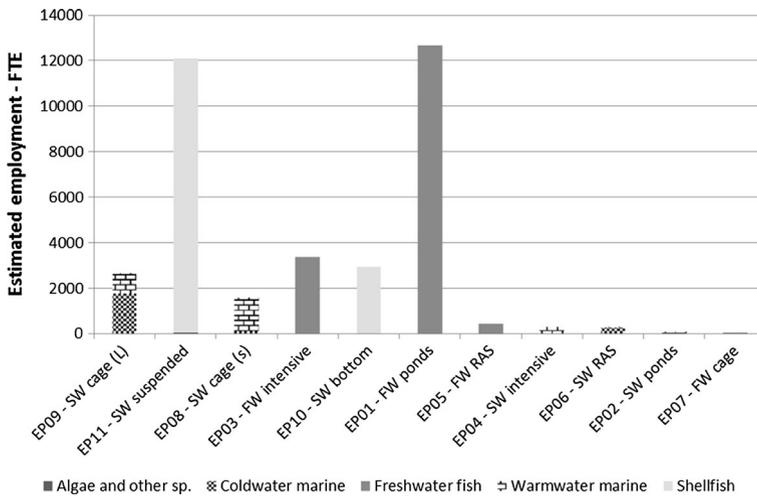


**Fig. 10** Direct output value of EU aquaculture production (2012) [Source: analysis of FishStat (FAO 2014b) data]

production of sea bass and sea bream in several Mediterranean countries) providing the greatest direct output value (€1.26 billion). This is followed by the marine shellfish sector and in particular suspended systems (e.g. mussel culture in Spain) (€0.84 billion). Interestingly, this achieves a higher GVA (€436 million) than large cage culture (€360 million) due to the lower purchased inputs for shellfish farming. Conversely, smaller marine cage systems for sea bass and bream and intensive systems for trout had lower GVAs (around 20 %) in relation to output value due to poor profitability in 2012 (Fig. 11).



**Fig. 11** Output value and estimated GVA of EU aquaculture production by production system type (2012) [Source: based on FishStat (FAO 2014b) and STECF (2014) data]



**Fig. 12** Estimated employment (FTE) in EU aquaculture by system type (2012) [Source: calculated using FishStat (FAO 2014b) value data and STECF data on employment. Note that limited data mean that the same employment ratios are applied to all shellfish systems and to minor fish systems]

Some analysis of employment patterns is possible using data from STECF, although data are not available for all countries or species/system combinations. Dividing output value by FTE employment provides an indication of labour productivity and can also be used to estimate the FTE employment by sub-sector. The highest productivities are seen in the Scottish salmon industry at around €490,000 output per FTE employee. On the basis of available data, the lowest productivity can be found in the freshwater pond sector with an output of only €14,000 per FTE employee. The shellfish sector is second lowest at around €70,000 per FTE. This means that these sectors provide more employment in relation to output and hence will have greater social impact. However, in practice it can mean low wages which can prompt the local population to seek higher returns from alternative occupations and increased dependency on immigrant labour from economically weaker countries (Fig. 12).

The labour productivity figures are best in the sectors which are most invested in technology and larger-scale farming operations. Low productivity is associated with smaller-scale enterprises with relatively low mechanization and use of capital. Analysis carried out by STECF (2014) confirmed the EU production sector in general to be highly fragmented with 12,466 companies recorded (14–15,000 estimated) with aquaculture as their main activity in 2012. These have an average of 5.5 employees with only 9 % of companies having more than ten. In contrast, the salmon industry is increasingly consolidated. The number of active companies in Scotland has fallen from 132 in 1993 to 15 in 2013. These employ an average of 72 people (Marine Scotland Science 2014). The sea bass and bream sector in Southern Europe are following a similar trend.

### Competitiveness of aquaculture

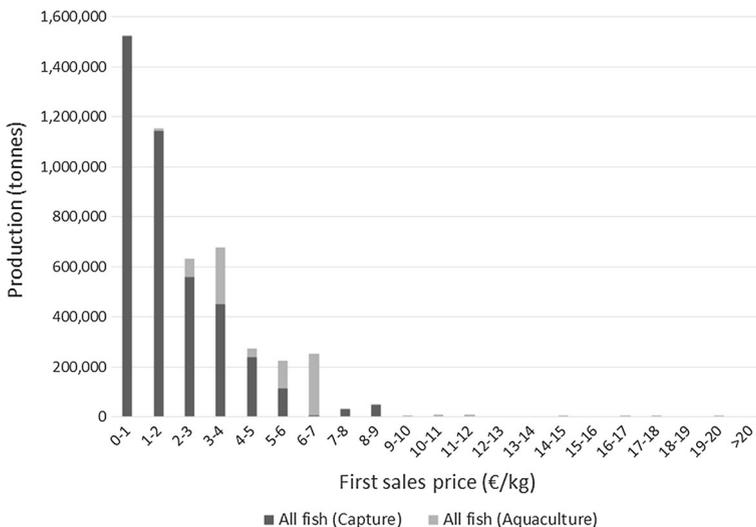
The outputs from European aquaculture enterprises find a place on the market alongside products from capture fisheries and imported seafood (both captured and farmed) from

around the world. This implies competition on price, quality and other attributes determined by consumer perceptions. Price is the dominant factor as conventional supply and demand economics predicts that demand falls as prices rise, whilst the incentive and then ability of producers to supply the market fall as prices fall. Price is the mechanism that balances supply and demand. As consumers have choice over their expenditure, and particularly in a commodity market such as unprocessed fish and seafood, potential market volumes for aquaculture producers are increasingly limited as production costs rise. This is illustrated in Fig. 13 which shows sales volumes of EU capture fish and aquaculture production in relation to wholesale price band (2012). It must be noted that the capture fisheries data include industrial fisheries for reduction to fishmeal (approximately 50 % of the €0–€1/kg price band) and that sales values recorded for aquaculture products will be higher than capture fisheries products due to most aquaculture prices including primary processing and distribution, whilst capture fisheries prices are generally based on landed auction prices. Note that higher price categories are included in the following charts as there are species falling into most of these categories, although production is sometimes too small to register on the chart.

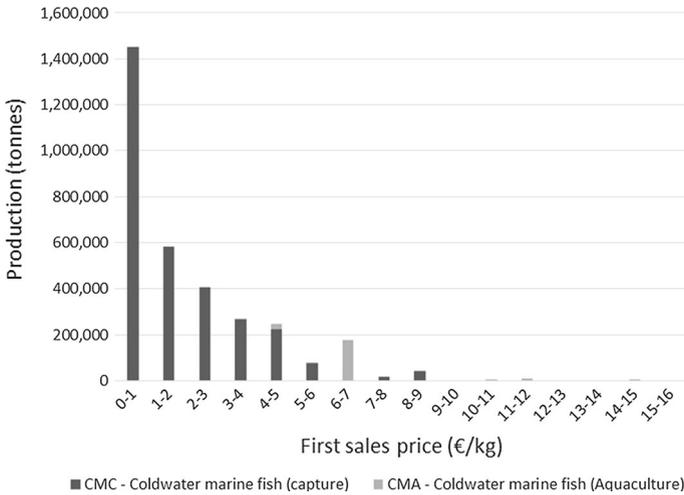
Although the prices are not strictly comparable, it is interesting to note that over 50 % of EU finfish production has a first sale price below €2/kg, which is below the cost of production for most European fish species using existing aquaculture systems. Aquaculture starts to make a contribution to supplies as prices rise above €2/kg and particularly over €3/kg. It is dominant in the €6–7/kg category. This picture represents around 40 % of total EU supplies (due to imports), but gives some indication of overall market structure.

Breaking this down by sub-sector shows that freshwater aquaculture and shellfish farming are more competitive with capture fisheries products than finfish (Figs. 14, 15, 16, 17).

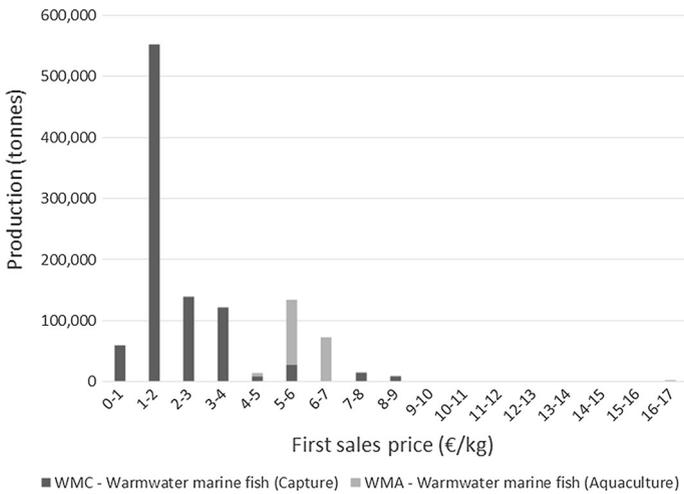
If products from aquaculture and capture fisheries readily substitute for each other, the volume of aquaculture production within the EU can be expected to be strongly influenced by



**Fig. 13** EU capture finfish landings and EU aquaculture fish production (2012) by price band [Source: calculated using FishStat production data and value data for aquaculture (FAO 2014b) and capture fisheries prices from EUMOFA (<http://www.eumofa.eu>)]

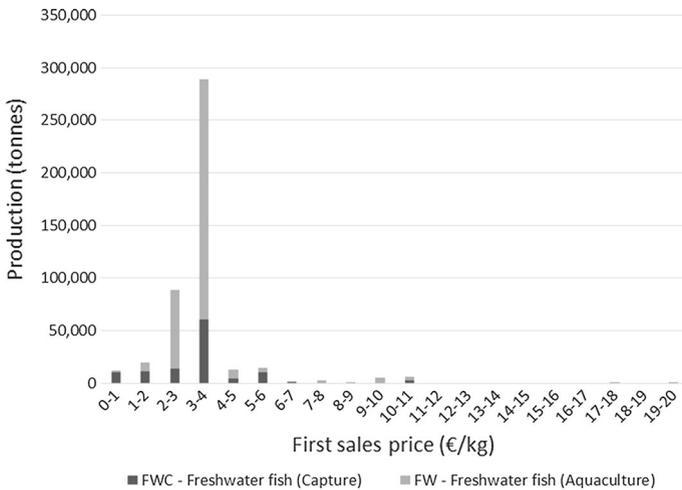


**Fig. 14** Price structure of EU capture fisheries and aquaculture production of coldwater marine fish species (2012). [Source: calculated using FishStat production data and calculated prices for aquaculture (FAO 2014b) and capture fisheries prices from EUMOFA (<http://www.eumofa.eu>)]

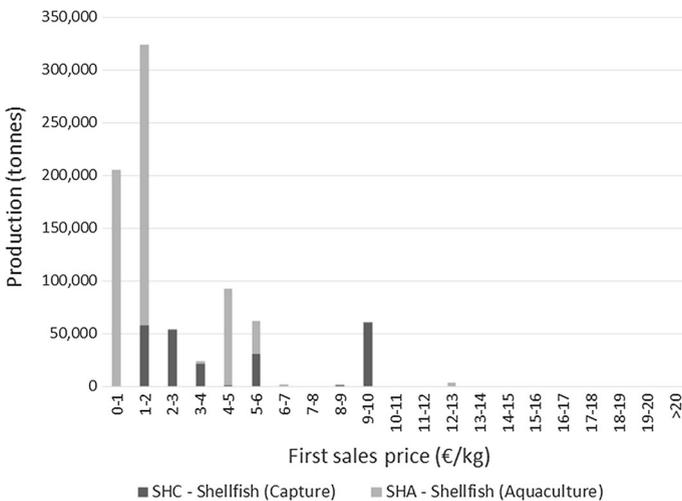


**Fig. 15** Price structure of EU capture fisheries and aquaculture production of warmwater marine fish species at first sale (2012) [Source: calculated using FishStat production data and calculated prices for aquaculture (FAO 2014b) and capture fisheries prices from EUMOFA (<http://www.eumofa.eu>)]

its competitiveness on price in relation to other sources (capture fisheries and imports). Technical and management innovations that reduce the cost of production would be expected to increase competitiveness and increase the potential for EU production, whilst higher input and regulatory compliance costs should reduce the scope for EU production (Bostock et al. 2009). On this basis, there is the potential for aquaculture to be more competitive and eventually replace some of the capture fisheries supplies. This hypothesis was examined by Asche et al. (2001) which found little evidence of market interactions between species other



**Fig. 16** Price structure of EU capture fisheries and aquaculture production of freshwater fish species at first sale (2012) [Source: calculated using FishStat production data and calculated prices for aquaculture (FAO 2014b) and capture fisheries prices from EUMOFA (<http://www.eumofa.eu>)]



**Fig. 17** Price structure of EU capture fisheries and aquaculture production of shellfish species at first sale (2012) [Source: calculated using FishStat production data and calculated prices for aquaculture (FAO 2014b) and capture fisheries prices from EUMOFA (<http://www.eumofa.eu>)]

than where both farmed and wild species were available together. Overall, it was considered that aquaculture production expanded the market for seafood. This conclusion was further strengthened in a later study (Asche et al. 2009) on the European whitefish market. However, stronger market interactions have been found in some cases. For instance, whilst Norman-Lopez (2009) found no interactions between farmed catfish and tilapia in North America, fresh farmed tilapia fillets were found to compete with wild whole red snapper wild fresh fillets of sea dab, and blackback flounder. Regnier and Bayramoglu (2014) found greater

evidence of differentiation in the French fresh fish market between farmed and wild sea bass than between farmed and wild sea bream. They attributed this to sea bass being a higher value product with consumers being more willing to pay higher prices (in this case for wild caught fish) to make ethical choices with higher priced products. As aquaculture production overtakes capture fisheries for human consumption, a greater diversity of market segments and interactions can be anticipated particularly with respect to ethical issues relating to production methods (Natale et al. 2013).

## Policy support measures and mechanisms for European aquaculture and their influence

### Studies and policy development

Identifying challenges for sustainable development of aquaculture, and hence growth, has to refer to an extensive combination of economic, social and technical issues. Whilst some of these apply specifically to aquaculture, many are more general in nature, covering livestock rearing conditions, water use, environmental considerations and food supply in general. The complex interweaving of legislative and societal approaches that cover these issues tends to show that, until recently, aquaculture has been an ‘add-on’ that remained outside core policy considerations.

This is most clearly demonstrated by the history of the Common Fisheries Policy (CFP) where aquaculture was included primarily because its products are in the same market(s) as those of fisheries. This is reflected in the requirements of the oldest component of the CFP, the Common Organisation of the Markets for Fisheries and Aquaculture Products, which has existed since 1970. As aquaculture grew in the 1980s–1990s, both in Europe and globally, its higher level of visibility meant that both markets and legislation had to adapt to this new developing activity.

After different reforms, the CFP<sup>2</sup> in 2014 recognized aquaculture to be a key component of its scope, alongside traditional fisheries and seafood processing.

Nonetheless, whilst the CFP is the legislative instrument used for the management of European fish stocks that are a common resource/good, **aquaculture is predominantly an economic activity of the private sector, where the stock belongs to the operator**. This gives different responsibilities to both the operator and suppliers, which include:

1. Environmental respect and, in many cases, management, covering:
  - a. Water use and waste management
  - b. Adaptation to: for freshwater environments the Water Framework Directive, River Basin Management principles and for marine environments the Marine Strategy Framework Directive (2008), the Directive for Maritime Spatial Planning (2014) and, more generally, Natura2000 and the Habitats Directive.
2. Health and welfare of livestock (mainly covered by EFSA advice)
  - a. Standards for the protection of animals bred or kept for farming purposes (including fish)<sup>3</sup>

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<sup>2</sup> Regulation (EU) No 1380/2013.

<sup>3</sup> Directive 98/58/EC.

- b. Aquatic Animal Health Directive<sup>4</sup>
  - c. Live Animal Transport Directive<sup>5</sup> (for stock movements [e.g. from hatcheries])
  - d. Stunning and killing
3. Feed composition
    - a. Awareness of the finite nature of fishmeal and fish oil sources
    - b. Ban on ruminant protein sources (following TSE and dioxin crises) although non-ruminant PAPs were reintroduced in 2013
    - c. Promotion of plant-based and alternative protein/oil sources
  4. Processing standards
    - a. European food processing standards
    - b. Adherence to market-oriented quality and/or certification labels

Complementary policies (non-exhaustive) that influence aquaculture include the Integrated Maritime Policy, Blue Growth, the Circular Economy and the Bioeconomy.

Challenges to European aquaculture development are numerous, and the most important ones identified by Lane et al. (2014) are:

- Strong market competition within the EU seafood market, particularly with imported seafood (fisheries and aquaculture), which has kept market prices down for several years.
- Administrative burdens, particularly slow times to licensing (and the very number of licences/permits needed to operate), that restrict investments and expansion potential.
- High labour and employment costs and working conditions (e.g. 35 h week).
- Adequate access to bridging finance for working capital (investment in stocks).

These challenges are at the core of the European Commission's strategic guidelines for the sustainable development of European aquaculture,<sup>6</sup> where they were described in detail and specific targets for each of these were set for compliance by Member States and also for the Commission.

The European aquaculture industry agreed that the main challenges to progress are (EATIP 2012):

- Competition in the marketplace, principally from imports
- Access to and competition for space for coastal and inland aquaculture
- Maintaining health and welfare of livestock
- Improving resource use (husbandry, feeds, farm technology)
- Governance within the Common Fisheries Policy

### Support for research and technological development

The EU aquaculture sector has been supported through both national and EU-level research funding. EU funding is mainly through the RTD framework programmes, usually through primary research themes but also included in various cross-cutting programmes which have

<sup>4</sup> Directive 2006/88/EC.

<sup>5</sup> Directive 95/29/EC.

<sup>6</sup> COM(2013) 229.

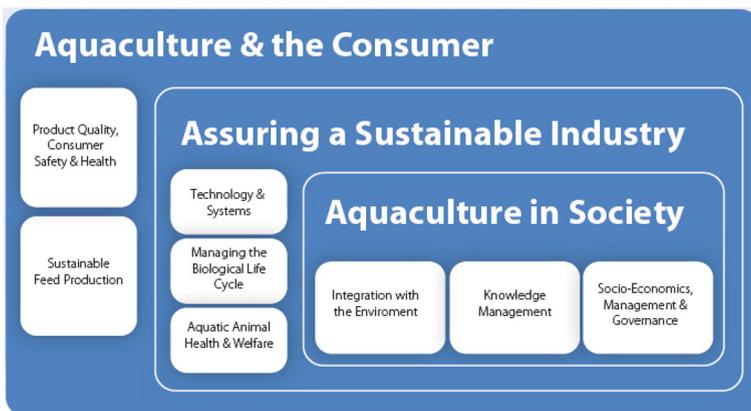
supported networking, mobility, access to research infrastructures and SME participation, etc. (Table 7).

Research funding under the main RTD programmes has been increasingly directed by the European Commission to ensure it properly supports strategic and policy objectives. In responding to the needs for consultation on research needs in aquaculture, a multistakeholder technology platform was created in 2008, the European Aquaculture Technology and Innovation Platform (EATiP). Recognized as an official European Technology Platform (ETP)s, EATiP has to have a strategy, mobilization and dissemination function, encompassing.

- The preparation of an industry-focused **strategic research and innovation agendas** including technology roadmaps and implementation plans;
- encouraging **industry participation in Horizon 2020**, the EU's framework programme for research and innovation, and cooperating with networks in Member States;
- fostering **networking opportunities** with other ETPs and other partners along the value chain to address cross-sectoral challenges and promote the move towards more open models of innovation;
- identifying **opportunities for international cooperation**;
- acting as one of the channels of external **advice** for the programming and implementation of Horizon 2020; notably, ETPs have been a key driving force behind the launch of high profile public–private partnerships under the programme.

EATiP provided a detailed Vision document, and a strategic research and innovation agenda (SRIA) was made in 2012, which identified specific sectoral needs—in terms of both legislation and research requirements. Its value for policy was recognized within the EC strategic guidelines for the sustainable development of European aquaculture, and several of the topics identified in its SRIA have become topics for the subject of calls in recent work programmes (Fig. 18).

Further inputs on strategic research priorities are provided by the European Fisheries and Aquaculture Research Organisation (EFARO—<http://www.efaro.eu>) and the COFASP project (Cooperation in Fisheries, Aquaculture & Seafood Processing—<http://www.cofasp.eu>).



**Fig. 18** Thematic priorities identified by EATiP

## Support for aquaculture industry development

Direct support for aquaculture industry investment is provided through EU structural funds. The first of these was the Financial Instrument for Fisheries Guidance (FIFG) which ran over the period 1994–1999 and 2000–2006. These provided grants that were part-funded by national governments within a framework of multiannual support programmes with differing levels of contribution depending on country region. The total programmed expenditure under FIFG 1994–1999 was ECU 2.676 billion and for FIFG 2000–2006 €3.746 billion.<sup>7</sup> In the latter programme, €0.317 billion was provided to support a total investment of €1.199 billion in the aquaculture sector (EC 2010).

FIFG was followed by the European Fisheries Fund (EFF), which ran from 2007 to 2013. With a budget of €4.3 billion, its aim was to improve the competitiveness of the sector and help it become environmentally, economically and socially sustainable. Aquaculture, processing, marketing and inland fisheries made up Axis 2 of the fund, with aid being available for diversification into new aquaculture species with good market prospects, environmentally friendly aquaculture, public and animal health measures, processing and marketing and lifelong learning. Special provision existed for inland fishing, reflecting its importance in Central and Eastern Europe.

In its interim evaluation report of the EFF (Ernst and Young 2011), Ernst and Young reported that of a total of €1.24 billion programmed under Axis 2, €518 million (43 %) had been committed to 3556 projects across all Member States. Delays in implementation were (in general) stated to have been due to limited co-financing in an unfavourable economic environment, and the late launch of the programme, mostly due to delays in validation of the operating programmes.

Specifically under Axis 2, measure 2.1 (aquaculture) represented 27 % of the EFF spend, measure 2.2 (inland fishing) less than 1 % and measure 2.3 (fish processing and marketing) the vast majority with 72 %. Projects under measure 2.1 were principally focussed on productive investments, although many were reported as being constrained by environmental impact assessment, requirements. Investments in ‘environment measures’ were observed to be well implemented, but animal and public health measures were considered by many Member States to be unsuitable and not adapted to the reality in both the fish and shellfish sectors. Under measure 2.3, the majority of investments were in increasing production capacity, improving systems and improving hygiene and working conditions in processing. These reportedly produced positive impacts on employments, but the national evaluations did not enable an assessment on their effects on competitiveness and sustainability.

In its 6th annual report on EFF (COM (2013) 921 final), the European Commission reported that the expenditure in aquaculture measures had leveraged additional national public contribution of €183 million and a further €538 million of private funding. Hence €1 of EFF funding had a leveraging effect of €1.68.

The EFF has been superseded by the European Maritime and Fisheries Fund (EMFF) which will run from 2014 to 2020. This has a total EC budget of €6.4 billion (Table 8).<sup>8</sup> Each country is required to draw up an operational programme<sup>9</sup> which takes account of both the EU fisheries and aquaculture policies and national policies and priorities (in the case of aquaculture expressed through a National Aquaculture Plan). Applicants are

<sup>7</sup> <http://www.eurocbc.org/page355.html>.

<sup>8</sup> [http://ec.europa.eu/fisheries/documentation/publications/2015-cfp-funding\\_en.pdf](http://ec.europa.eu/fisheries/documentation/publications/2015-cfp-funding_en.pdf).

<sup>9</sup> See [http://ec.europa.eu/fisheries/cfp/emff/country-files/index\\_en.htm](http://ec.europa.eu/fisheries/cfp/emff/country-files/index_en.htm).

required to show compliance with the relevant national operational programme, and as with previous programmes, there will be an element of national co-funding. A new element is Fisheries and Aquaculture Monitoring and Evaluation (FAME) which will be carried out by an expert support unit based in Brussels. This has the remit to (i) assist in monitoring and evaluating the implementation of the EMFF and provide the Commission with regular updates and analysis of the state of play of the implementation of the EMFF, and (ii) build capacity across the Member States and in the Commission on evaluation and monitoring methodologies, indicators and good practices.<sup>10</sup>

## Future directions

At the present, the principle EU policy for aquaculture development remains the Common Fisheries Policy, supported by the Common Organisation of the Markets for Fisheries and Aquaculture Products and the financial instrument, the EMFF.

The submission of the National Aquaculture Plans foreseen in the strategic guidelines for the sustainable development of European aquaculture has been delayed, principally due to late finalization of the EMFF and the need to combine these multiannual plans with the operational programmes of each Member State. It is anticipated that these will be published in 2016.

From the consultation within EATiP, during the preparation of its Vision document, the following forward production projections were prepared from expert inputs and assessments for individual species and sectors (Table 9).

Based on our categorization of the sector by production technology (Tables 2, 3, 4, 5, 6) and by the outcomes of the consultations within EATiP and directly with the professional sector, an estimation on the trends (for 2030) of the use of technologies for each of the production sub-sectors was prepared. This is shown in Table 10. The arrow indicates the trends (upwards, stagnant and downward).

The main conclusions of this foresight exercise were as follows:

- **Productivity/competitiveness drive towards larger cages**, particularly in offshore locations, seen as increasing location trend for both Mediterranean and coldwater farming.
- **Coastal pond aquaculture will decline or stagnate**, principally because of lower yields and competition for space (availability and licences)
- **Indoor marine recirculation systems will increase for hatcheries**, but less likely for on-growing (costs of investment, energy costs) due to cost comparison with cage production (Mediterranean and coldwater production) although may play a role in the development of some higher value species such as sole and shrimp
- **Freshwater pond production, stable or increasing**, dependent on a combination of market demand, diversification activities and recognition of environmental services
- **Intensive flow-through systems for freshwater will probably decline**, dependent on a combination of market demand, water availability and diversification towards specialized/niche markets (e.g. organic label) where lower intensity demanded
- **Freshwater recirculation systems will increase**, notably for high-value production (sturgeon, pike-perch) and potentially for warmwater species that can be produced at high density (e.g. African catfish, eel, tilapia)

<sup>10</sup> [http://ec.europa.eu/fisheries/cfp/emff/fame/index\\_en.htm](http://ec.europa.eu/fisheries/cfp/emff/fame/index_en.htm).

**Table 2** Coldwater marine fish—estimated production quantity by system type

Technology	Estimated 2012	
	Production (tonnes)	Value (million euro)
Large cage systems—marine in exposed sites, using mechanized (automated) systems	190,090	870.21
Small cage systems—sheltered marine	11,000	37.46
Indoor land-based recirculated aquaculture systems (marine)	9180	51.85
Coastal pond aquaculture	180	0.75
Intensive marine flow-through and partial recirculation systems (mostly large tanks)	100	0.87
Total	210,550	961.14

Source: Lane et al. (2014) and present study

**Table 3** Warmwater marine fish—estimated production quantity by system type

Technology	Estimated 2012	
	Production (tonnes)	Value (million euro)
Small cage systems—sheltered marine	102,420	558.69
Large cage systems—marine in exposed sites, using mechanized (automated) systems	74,330	369.88
Intensive marine flow-through and partial recirculation systems (mostly large tanks)	9910	58.47
Coastal pond aquaculture and valliculture	900	4.18
Indoor land-based recirculated aquaculture systems (marine)	340	3.57
Total	187,900	1021.80

Source: Lane et al. (2014) and present study

- **Shellfish production will continue to be dominated by supported/suspended cultivation systems**

It is anticipated by many stakeholders that an increasingly proportion of the expected increase in large cage culture for fish species and supported and suspended culture for shellfish species will be done in integrated multitrophic aquaculture (IMTA) systems, where species are combined (e.g. salmon, seaweeds, mussels) within a complementary area so as to best use space and to mitigate environmental impact. At this time, it is not possible to estimate the percentage production from such systems, since practicality, legal frameworks, licensing conditions and economic viability need to be elaborated by region or coastal area.

## Conclusions

EU aquaculture production contributes the equivalent of 2.66 kg (live weight) of fish and seafood per EU citizen with a first sale value of €4.76 billion contributing a GVA of €1.29 billion and employing around 80,000 people (40,000 FTE) (STECF 2014). Whilst the

**Table 4** Freshwater fish—estimated production quantity by system type (tonnes)

Species	Freshwater pond	Intensive freshwater flow-through	Indoor land-based recirculated	Small cage	Total production
Trout	310	164,390	0	250	164,950
Carp	77,860	0	0	0	77,860
FW other	6640	2580	290	0	9510
Catfish	1140	400	3790	0	5330
Eels	0	0	4960	0	4690
Sturgeon	400	1910	0	0	2310
Tilapia	0	0	450	0	450
Salmon	0	5	0	0	5
Total (t)	86,350	169,285	9220	250	265,105
Total (€M)	184.22	464.63	60.66	2.07	711.58

Source: Lane et al. (2014) and present study

**Table 5** Shellfish—estimated production quantity by system type

Technology	Estimated 2012	
	Production (tonnes)	Value (million euro)
Marine supported and suspended culture (non-fed sedentary and attached animals and plants)	537,050	837.21
Marine bottom culture (non-fed sedentary and attached animals and plants)	65,440	204.01
Total	602,490	1041.23

Source: Lane et al. (2014) and present study

value of EU aquaculture industry increased by 70 % between 2000 and 2012, actual volumes declined slightly. As the overall market for fish and seafood products in the EU is in the region of €27 billion (AIPEC-CEP 2015), the lack of output growth has been widely attributed to competitiveness issues including access to suitable sites (EC 2013). Recognizing this, and based on widespread recognition of the potential contributions that the sector could provide to European seafood supplies, the 2014 reform of the CFP provided a new impetus for the sustainable development of European aquaculture.<sup>11</sup> This was accompanied by a number of different studies and position papers on issues and challenges that affect directly or indirectly the potential for development. Consultations with industry stakeholders presented above indicate potential to responsibly increase output volume by 55 %, value by 77 % and employment by 40 % by 2030 if suitable social and economic conditions prevail. The overall strategy to achieve this sustainable development of (European) aquaculture is by maximizing the quality and health benefits of farmed products, whilst improving resource efficiency and minimizing impacts. Based on this strategy, and within the framework of the CFP, EU Member States are preparing national multi-annual plans for aquaculture development. These will, for the first time, provide an overview of Member State intentions to grow aquaculture and the approaches that are prioritized to achieve this.

<sup>11</sup> [http://ec.europa.eu/fisheries/cfp/index\\_en.htm](http://ec.europa.eu/fisheries/cfp/index_en.htm).

**Table 6** Algae and other aquatic products—estimated production quantity by system type

Technology	Estimated 2012	
	Production (tonnes)	Value (million euro)
Marine supported and suspended culture (non-fed sedentary and attached animals and plants)	5352	0.01
Coastal pond aquaculture	247	2.39
Freshwater pond aquaculture	38	0.31
Marine bottom culture (non-fed sedentary and attached animals and plants)	9	2.95
Small cage systems—sheltered marine	5	0.02
Intensive freshwater flow-through and partial recirculation systems	1	0.007
Indoor land-based recirculated aquaculture systems (marine)	1	0.01
Total	5653	5.70

Source: Lane et al. (2014) and present study

Monitoring progress is another challenge, and the STECF (2013a, b) study underlined the difficulties of obtaining accurate and up-to-date statistics on the performance of the EU Aquaculture Sector. However, the Data Collection Framework (DCF) continues to be implemented and should be adapted to include all forms of aquaculture, be it marine or freshwater. This was also a clear recommendation to the Commission from the European Court of Auditors (2014) when considering the effectiveness of the EFF support for aquaculture. With improved data it will be easier to understand developments within the sector and develop appropriate policies to support social and economic development.

There is increasing recognition that aquaculture can contribute to additional EU policies and strategies, including Blue and Green Growth and the Bioeconomy, the use of sustainable resources, food security and public health—by providing sustainably produced, high quality and healthy food. Clarification of the position of aquaculture within the existing environmental legislation has been initiated with recommendations existing for Natura2000 and is under development for the EU Water Framework Directive and for the Marine Strategy Framework Directive. This is essential so as to boost the potential integration of the activity and the expansion of site availability. Assessment and agreed quantification of environmental services provided by aquaculture requires to be integrated, alongside potential incentives.

Finally there is a need to better understand market interactions and competitiveness for EU aquaculture products to guide future investment and support policies. The establishment of EUMOFA<sup>12</sup> is an important step in this direction together with the PrimeFish Horizon 2020 project<sup>13</sup> which is studying several key species and developing models that will help understand boom and bust cycles, the success factors for new product development and the interactions between key aquaculture, capture and imported whitefish species.

Taken together, these policy positions, strategies and project initiatives, particularly the requirement for National Aquaculture Plans, will form the basis of the planning required to move towards the next stage of EU aquaculture policy realization and implementation.

<sup>12</sup> <http://www.eumofa.eu>.

<sup>13</sup> [www.primefish.eu](http://www.primefish.eu).

**Table 7** Major EC funding for aquaculture research and technological development

Framework programme	Main theme including aquaculture	Aquaculture priorities	Funding allocation
FP4 (1994–1998)	FAIR	The impact of environmental factors; ecological impact of aquaculture; biology of species and optimization of aquaculture; improved methodology for data collection and analysis	103 M ECU for fisheries and aquaculture
FP5 (1998–2002)	Quality of live (QoL)—key action 5, sustainable agriculture, fisheries and forestry and integrated development in rural areas including mountain areas	Sustainable production systems with the reduction of the impact on ecosystems and diversification of cultivated species (both plant and animals); improvement of production techniques, genetic improvement; disease resistance and control	520 M EUR for action 5 (sustainable agriculture and fisheries and forestry....)
FP6 (2002–2006)	Scientific support to policy (SSP—linked with the Common Fisheries Policy); Priority 5—‘Food Quality and Safety’ and Priority 6—‘Sustainable Development’	Integration of environmental requirements into the CFP; sustainable aquaculture production; synthesis and dissemination of results to end-users; to support a better seafood production, improving the knowledge about diseases, health conditions, processing, etc	159 fisheries and/or aquaculture-related projects were funded with a total budget of 292.9 million euro. Of these, 75 projects (98 million euro) were aquaculture specific
FP7 (2007–2013)	Food, agriculture and biotechnology	Sustainable production and management of biological aquatic resources; fork to farm—seafood, health and well-being	1760 M euro on food, agriculture, fisheries and biotechnology
Horizon 2020 (2014–2020)	Food security, sustainable agriculture and forestry, marine, maritime and inland water research and the bioeconomy (under societal challenges pillar)	Domestication of new species; interactions with the environment; health and nutrition of farmed aquatic organisms; reproduction and breeding; social aspects of the seafood sector for the cohesion of the social fabric in the European coastal areas	4152 M euro for all food security including funding of the European Institute of Innovation and Technology

Sources: Impact Fish (2005), EC (2008), [http://ec.europa.eu/research/horizon2020/pdf/press/horizon\\_2020\\_budget\\_constant\\_2011.pdf](http://ec.europa.eu/research/horizon2020/pdf/press/horizon_2020_budget_constant_2011.pdf) and Cordis (<http://cordis.europa.eu/>)

**Table 8** Total EU allocations of European Maritime and Fisheries Fund 2014–2020 (unit €, current prices)

MS	2014	2015	2016	2017	2018	2019	2020	Total	%
BE	5,722,130	5,795,229	5,848,204	5,942,991	6,081,279	6,122,861	6,233,357	41,746,051	0.7
BG	12,071,289	12,225,498	12,337,253	12,537,214	12,828,942	12,916,663	13,149,763	88,066,622	1.5
CZ	4,263,975	4,318,446	4,357,922	4,428,555	4,531,602	4,562,588	4,644,927	31,108,015	0.5
DK	28,559,270	28,924,111	29,188,510	29,661,596	30,351,790	30,559,328	31,110,815	208,355,420	3.6
DE	30,100,054	30,484,577	30,763,242	31,261,850	31,989,281	32,208,016	32,789,256	219,596,276	3.8
EE	13,840,012	14,016,816	14,144,946	14,374,205	14,708,679	14,809,253	15,076,507	100,970,418	1.8
IE	20,231,798	20,490,256	20,677,561	21,012,701	21,501,645	21,648,669	22,039,349	147,601,979	2.6
EL	53,289,776	53,970,543	54,463,896	55,346,644	56,634,503	57,021,756	58,050,796	388,777,914	6.8
ES	159,223,336	161,257,387	162,731,468	165,369,007	169,216,972	170,374,037	173,448,682	1,161,620,889	20.2
FR	80,594,423	81,624,003	82,370,140	83,705,190	85,652,923	86,238,597	87,794,897	587,980,173	10.2
HR	34,629,786	35,072,176	35,392,777	35,966,420	36,803,321	37,054,974	37,723,684	252,643,138	4.4
IT	73,642,561	74,583,332	75,265,111	76,485,002	78,264,728	78,799,884	80,221,941	537,262,559	9.3
CY	5,443,762	5,513,306	5,563,703	5,653,880	5,785,440	5,824,999	5,930,119	39,715,209	0.7
LV	19,167,006	19,411,862	19,589,309	19,906,810	20,370,021	20,509,307	20,879,427	139,833,742	2.4
LT	8,694,653	8,805,725	8,886,220	9,030,247	9,240,371	9,303,555	9,471,451	63,432,222	1.1
HU	5,358,928	5,427,387	5,477,000	5,565,770	5,695,280	5,734,223	5,837,705	39,096,293	0.7
MT	3,101,540	3,141,162	3,169,876	3,221,253	3,296,208	3,318,746	3,378,637	22,627,422	0.4
NL	13,915,788	14,093,559	14,222,391	14,452,906	14,789,211	14,890,336	15,159,053	101,523,244	1.8
AT	954,693	966,888	975,727	991,541	1,014,613	1,021,551	1,039,987	6,965,000	0.1
PL	72,814,233	73,744,422	74,418,532	75,624,702	77,384,410	77,913,547	79,319,610	531,219,456	9.2
PT	53,797,969	54,485,229	54,983,288	55,874,453	57,174,593	57,565,539	58,604,393	392,485,464	6.8
RO	23,085,512	23,380,425	23,594,150	23,976,562	24,534,471	24,702,232	25,148,019	168,421,371	2.9
SI	3,400,584	3,444,026	3,475,509	3,531,839	3,614,022	3,638,734	3,704,400	24,809,114	0.4
SK	2,163,649	2,191,290	2,211,321	2,247,162	2,299,451	2,315,174	2,356,953	15,785,000	0.3
FI	10,197,069	10,327,335	10,421,739	10,590,653	10,837,087	10,911,188	11,108,097	74,393,168	1.3

Table 8 continued

MS	2014	2015	2016	2017	2018	2019	2020	Total	%
SE	16,469,779	16,680,178	16,832,654	17,105,477	17,503,503	17,623,188	17,941,225	120,156,004	2.1
UK	33,327,114	33,752,863	34,061,403	34,613,468	35,418,887	35,661,073	36,304,629	243,139,437	4.2
EU 27 <sup>a</sup>	788,060,689	798,128,031	805,423,852	818,478,098	837,523,233	843,250,018	858,467,679	5,749,331,600	100

Source: DG MARE

<sup>a</sup> LU is excluded, because it is not a recipient of EMFF

**Table 9** EATiP exercise and forward production projections (a) coldwater marine assumptions, (b) warmwater marine assumptions, (c) fresh water marine assumptions, (d) shellfish assumptions, (e) summarized assumptions

		Forecast growth (tonnes)					Value 2010		Value 2030		Jobs	
		APR (%)	2010	2020	2030	2030	ME	ME	ME	ME		
<b>(a) Coldwater marine assumptions</b>												
Cod	4.0	1	1	2		€ 0.00	€ 0.01	Upstream	143	191		
Flatfish	9.6	189	473	1,079		€ 1.21	€ 5.39	On-farm	951	1273		
Large trout	2.0	30,220	36,838	44,025		€ 75.55	€ 110.06	Added-value (processing)	951	1273		
Salmon	4.0	159,912	236,709	336,910		€ 495.73	€ 1044.42	Downstream	95	127		
Subtotal		190,322	274,021	382,016		€ 572.49	€ 1159.88	Total jobs	2139	2865		
Total increase	101.0			191,694			587.40	Feeds (tonnes)	285,561	458,419		
<b>(b) Warmwater marine assumptions</b>												
Flatfish	5.0	10,102	16,455	25,527		€ 89.30	€ 225.66	Upstream	912	1358		
Other	4.0	16,453	24,355	34,664		€ 151.70	€ 319.60	On-farm	6080	9051		
Sea bass	4.0	74,907	110,881	157,818		€ 346.07	€ 729.12	Added-value (processing)	6080	9051		
Sea bream	4.0	111,322	164,784	234,539		€ 445.29	€ 938.15	Downstream	608	905		
Subtotal		212,784	316,474	452,548		€ 1,032.36	€ 2,212.54	Total jobs	13,679	20,365		
Total increase	112.0			239,764			€ 1,180.18	Feeds (tonnes)	383,011	543,057		
<b>(c) Fresh water marine assumptions</b>												
Carp	1.5	67,484	78,318	89,548		€ 131.59	€ 174.62	Upstream	1175	2259		
Catfish	6.0	7,279	13,036	22,023		€ 10.41	€ 31.49	On-farm	12,653	15,060		
Eels	5.0	6,561	10,687	16,579		€ 99.73	€ 252.01	Added-value (processing)	7,592	10,583		
Other	3.0	1,988	2,672	3,486		€ 10.73	€ 18.82	Downstream	1265	1506		
Sturgeon	8.0	1,928	4,162	8,320		€ 15.19	€ 65.56	Total jobs	22,686	29,409		
Tilapia	25.0	130	1,211	9,021		€ 0.22	€ 15.33					
Trout	1.5	246,498	286,071	327,090		€ 601.45	€ 798.10					
Subtotal		331,868	396,156	476,068		€ 869.33	€ 1355.94	Total jobs	17,473	25,925		
Total increase	43.0			144,200			€ 486.61	Feeds (tonnes)	305,658	367,977		

Table 9 continued

		Forecast growth (tonnes)				Value 2010		Value 2030		Jobs	
		2010	2020	2030	2030	ME	ME	ME	ME	2010	2030
<b>(d) Shellfish assumptions</b>											
Abalone	25.0	2	19	139		€ 0.10		€ 6.83			Upstream
Carpet shells	4.0	37,800	55,953	79,639		€ 138.60		€ 292.02			€ On-farm
Clams	10.0	1700	4,409	10,397		€ 3.92		€ 23.97			€ Added-value (processing)
Cockles	5.0	2000	3,258	5,054		€ 5.47		€ 13.82			€ Downstream
Mussels	1.0	490,000	541,265	591,973		€ 434.70		€ 525.17			Total jobs
Oysters	1.5	121,800	141,354	161,623		€ 434.49		€ 576.54			
Scallops	25.0	16	149	1,110		€ 0.09		€ 6.42			
Subtotal		653,318	746,407	849,935		€ 1017.37		€ 1444.77			Total jobs
Total increase	30.0			196,617				€ 427.39			
<b>(e) Summarized assumptions</b>											
	Growth %	Forecast growth (tonnes)			Value 2010		Value 2030		Jobs		
		2010	2020	2030	ME	ME	ME	ME	2010	2030	
Coldwater marine	101.0	190,322	274,021	382,016	€ 572.49	€ 1159.88	€ 1159.88	€ 1159.88	2139	2865	Coldwater marine
Freshwater	43.0	331,868	396,156	476,068	€ 869.33	€ 1355.94	€ 1355.94	€ 1355.94	22,686	29,409	Freshwater
Mediterranean	112.0	212,784	316,474	452,548	€ 1032.36	€ 2212.54	€ 2212.54	€ 2212.54	13,679	20,365	Mediterranean
Shellfish	30.0	653,318	746,407	849,935	€ 1017.37	€ 1444.77	€ 1444.77	€ 1444.77	–	–	Shellfish
Subtotal		1,388,292	1,733,058	2,160,566	3491.55	€ 6173.13	€ 6173.13	€ 6173.13	38,504	52,638	Total jobs
Total increase	55.6			772,275				€ 2681.58	974,230	1,369,453	Feeds (tonnes)

The total increase in volume and value (constant prices) of for 2030 compared to 2010 data

The job data are based on estimates taking into account technology developments and automation

The feeds required take into account expected advances in food conversion ratio (FCR)

The Aqualnova forecasts used here did not have complete data for job developments in the shellfish sector

Source: Aqualnova (<http://www.eatip.eu/default.asp?SHORTCUT=405/EATIP>) forecasts for scenarios in each sub-sector, re-formatted by the study authors

**Table 10** Trends in prevalence of production technologies

Technology	Estimated 2012 production (tonnes)	Trend in use of technology 2030
<i>Coldwater marine finfish</i>		
Coastal pond aquaculture	180	↘
Indoor land-based recirculated aquaculture systems (marine)	100	↗
Intensive marine flow-through and partial recirculation systems (mostly large tanks)	9800	↗
Small cage systems—sheltered marine	11,000	↘
Large cage systems—marine in exposed sites, using mechanized (automated) systems	190,090	↗
<i>Warmwater marine finfish</i>		
Coastal pond aquaculture and valliculture	900	→
Indoor land-based recirculated aquaculture systems (marine)	9910	↗
Intensive marine flow-through and partial recirculation systems (mostly large tanks)	340	↗
Small cage systems—sheltered marine	102,420	↘
Large cage systems—marine in exposed sites, using mechanized (automated) systems	74,330	↗
<i>Freshwater fish</i>		
Freshwater pond aquaculture (extensive to semi-intensive)	86,350	↗
Intensive freshwater flow-through and partial recirculation systems (mostly tanks, raceways and small ponds)	169,285	↘
Indoor land-based recirculated aquaculture systems (freshwater)	9220	↗
Small cage systems—freshwater	250	→
<i>Shellfish</i>		
Marine bottom culture (non-fed sedentary and attached animals and plants)	65,440	→
Marine supported and suspended culture (non-fed sedentary and attached animals and plants)	537,050	↗

*Source:* estimated by the authors of this study

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