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THE LONG-TERM ECONOMIC AND ECOLOGIC IMPACT OF LARGER SUSTAINABLE AQUACULTURE

STUDY

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DIRECTORATE-GENERAL FOR INTERNAL POLICIES

POLICY DEPARTMENT B: STRUCTURAL AND COHESION POLICIES

FISHERIES

THE LONG-TERM ECONOMIC AND ECOLOGIC IMPACT OF LARGER SUSTAINABLE AQUACULTURE

STUDY

This document was requested by the European Parliament's Committee on Fisheries.

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The Long-Term Economic and Ecologic Impact of Larger Sustainable Aquaculture

STUDY

Abstract

The EU recognises aquaculture as an important contributor to the EU food basket and this study provides insights into the economic and ecological implications of increased EU aquaculture. Current production, classified by technology and by sector, is transposed into forecasts up to 2030 that identify the main future technologies, trends and sectoral challenges. An ecological impact assessment matrix is used to compare production systems. Feed requirements are presented, with observations on how these might impact EU fisheries. Public support and policy considerations are discussed.

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LIST OF ABBREVIATIONS

ANF	Anti-Nutritional Factor
APR	Annual Percentage Rate
ASC	Aquaculture Stewardship Council
B2B	Business to Business
CCRF	(FAO) Code of Conduct for Responsible Fisheries
CITES	Convention on International Trade in Endangered Species
CFP	Common Fisheries Policy
CWP	Coordinating Working Party on Fishery Statistics
DHA	Docosahexaenoic acid
DCF	Data Collection Framework
EATiP	European Aquaculture Technology and Innovation Platform
EcIA	Ecological Impact Assessment
EFF	European Fisheries Fund
EIA	Enviromental Impact Assessment
EMAS	Eco-Management and Audit Scheme
EPA	Eicosapentaenoic acid
FAO	Food and Agriculture Organisation of the United Nations
FEAP	Federation of European Aquaculture Producers
FIFO	Fish-in Fish-Out ratio
FLAGS	Fisheries Local Action Groups
GMO	Genetically Modified Organism
ICZM	Integrated Coastal Zone Management
IFFO	International Fish Meal and Fish Oil Organisation - now called the Marine Ingredients Organisation
IFFO RS	IFFO Global Standard for Responsible Supply
KBBE	(European) Knowledge Based Bio-Economy
LC-n3-PUFA	Long Chain omega 3 polyunsaturated fatty acid
PAP	Processed Animal Protein
RAS	Recirculating Aquaculture System
RTD	Research and Technological Development
SME	Small and Medium sized Enterprise
UoS	University of Stirling (Institute of Aquaculture)

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EXECUTIVE SUMMARY

European aquaculture is a diverse activity that covers the production of finfish, shellfish and other aquatic species, including algae, in both freshwater and marine conditions.

Over the last decade, EU aquaculture has seen little or no volume growth (estimated at 0.5% APR), compared to estimated global aquaculture growth of 7% APR over the same period. Bottlenecks and factors inhibiting growth have been identified in the EC Communication on the "Strategic Guidelines for the Sustainable Development of EU Aquaculture" that sets out actions to overcome the challenges to sustainable growth.

This study addresses the long-term economic and ecologic impact of an increased EU aquaculture sector.

Section 1 of the study provides an overview of the current status of aquaculture for 4 sub-sectors – coldwater marine, warmwater marine, freshwater and shellfish. Apart from reviewing production data, the study presents the principal technologies and estimates the proportion of 2012 aquaculture production volume of 1.266.045 tonnes, by sub-sector and by technology, in the following table.

Recent reports and consultation with producers have identified the main issues for growth in economic, environmental social and market challenges, assigning the importance of each challenge to the sub-sectors.

2012 EU aquaculture production by production technology

Technology	Estimated 2012 production (tonnes)
COLDWATER MARINE FINFISH	
Coastal pond aquaculture	180
Intensive marine flow-through and partial recirculation systems (mostly large tanks)	100
Indoor land-based recirculated aquaculture systems (marine)	9.180
Small cage systems – sheltered marine	11.000
Large cage systems – marine in exposed sites, using mechanised (automated) systems	190.090
WARMWATER MARINE FINFISH	
Coastal pond aquaculture and 'valliculture'	900
Intensive marine flow-through and partial recirculation systems (mostly large tanks)	9.910
Indoor land-based recirculated aquaculture systems (marine)	340
Small cage systems – sheltered marine	102.420
Large cage systems – marine in exposed sites, using mechanised (automated) systems	74.330

FRESHWATER FISH	
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)	9.220
Small cage systems – freshwater	250
SHELLFISH	
Marine bottom culture (non-fed sedentary and attached animals & plants)	65.440
Marine supported and suspended culture (non-fed sedentary and attached animals & plants)	537.050
TOTAL PRODUCTION (2012 in tonnes)	1.266.045

Principal challenges for the development of EU aquaculture sectors

As identified by the study authors

Challenge for development	Coldwater marine	Warmwater marine	Freshwater	Shellfish
ECONOMIC				
Productivity gains	+	+ + +	+ + +	+
Access to capital	+	+ + +	+ +	+
Diversification of the offer	+	+ + +	+ + +	+ +
ENVIRONMENTAL				
Access to high quality water	+	+ +	+	+ + +
Spatial planning	+ + +	+ + +	+ + +	+ + +
Use of outputs	+	+	+ +	
SOCIAL				
Communication	+ +	+ + +	+ + +	+
Recruiting skilled workforce	+	+ +	+ +	+
Generation change	+	+	+ + +	+ +
MARKET				
Changing consumer preferences	+	+ + +	+ + +	+
Labelling and certification	+ +	+ +	+	+
Multiple Retail Store domination	+ + +	+ + +	+ +	+
Import competition of fish products	+ +	+ + +	+	+ +
Competition with other foods	+ + +	+ + +	+ +	+

Climate change is also seen as a potential hazard, as are new diseases. The European Aquaculture Technology and Innovation Platform (EATiP) identified additional strategic risks, including; structuring to avoid boom-bust conditions and unfair competition; adapting policies to understand and incorporate aquaculture; addressing public perceptions and responding to consumer concerns and inadequate financial capacity of SMEs and family firms.

Section 2 provides growth forecasts up to 2030 for EU aquaculture including developments in production technologies, feeds and jobs, which are based on the EATiP 2012 Vision document due to late delivery of national aquaculture strategies.

For coldwater marine species, growth is foreseen to be 100% by 2030, meaning 4% per year over the period, based on solid markets and achievement of potential, representing an additional 192.000 tonnes and a value increase of 587 M€; an increased feed demand of 173.000 tonnes is seen. Similar growth trends are predicted for warmwater marine species, where a production forecast of 240.000 tonnes is made for these species, providing increases in value of 1.200 M€ and feed demand of 160.000 tonnes. Production growth in the freshwater sub-sector is lower at 40%, which is 1.5% per year. Volume growth is 144.000 tonnes providing a value increase of 487 M€ and with an additional feed requirement of 62.000 tonnes. Finally, shellfish production growth is projected at 30% by 2030, an annual growth rate of 1.3%/year, and an additional volume of 197.000 tonnes valued at 427 M€.

Within these forecasts, productivity improvements due to technology, management and feed quality are anticipated for each sector.

The total increase in volume from 2010 to 2030 is therefore 772.000 tonnes in volume (+56%), with a corresponding value increase of 2.7 billion euros and requiring an additional 395.000 tonnes of feeds. For some sectors, new sites will be required for this increase. In others, better use of existing sites with acceptable footprint principle will be evident.

The use of fish protein and fish oils and their partial substitution by terrestrial plants is reviewed. The EU consumption of fishmeal and fish oil for aquaculture feed is estimated to be 3.3% and 8.1% respectively of global use for aquaculture. For both commodities, EU production exceeds the amount used by the EU aquafeed industry at present.

If aquaculture feeds are increasingly sourced from terrestrial materials, this will have implications for land and freshwater requirements, raising issues on biodiversity and other environmental concerns, including the environmental footprint of (EU) aquaculture. Comparative resource use by aquaculture is considered briefly, concluding salmon to be highly competitive with beef and pork and more efficient than chicken.

An ecological impact assessment matrix has been developed, based upon various methodologies reviewed in the literature. The technologies and productions systems have been ranked according to expected growth and associated impact issues. Highest growth is expected in large cage systems in exposed sites and coastal, suspended culture (molluscs). While Recirculating Aquaculture Systems (RAS) is expected to increase, economic sustainability will need to be reinforced.

Additional feed requirements for EU aquaculture in 2030 would only exceed EU fish meal fish and fish oil supply if all of the FMFO were sourced in the EU but this is not the case. The potential use of PAPs, GM oil seeds and other marine sources would further reduce any impact on EU fish stocks. If EU aquaculture did not grow, then EU FMFO would be diverted to produce fish and shrimp in 3rd countries, returning to EU consumers in these forms.

Placement of substitutable products on the market (e.g. cod, turbot, sole and potentially tuna) probably has more impact on EU aquaculture than it does on EU fisheries.

Section 3 looks at economic considerations and public support to the sector. Of the €1.24 billion programmed under the European Fisheries Fund (EFF) Axis 2 (2007-2013), only €518 million (43%) had been committed across all Member States in 2011. Delays in EFF implementation included limited co-financing and a late launch, mainly due to delays in validating the Operating Programmes. Under Axis 2, aquaculture represented 27%, inland fishing less than 1% while fish processing and marketing had the vast majority with 72%.

Based on the categorisation of the sector, expert interviews, reports and dedicated workshops on future scenarios for European aquaculture, an estimation of the trends in technology use by 2030 is summarised as:

- A productivity/competitiveness drive toward larger cages, particularly offshore, as an increasing trend for both Mediterranean and Coldwater farming.
- A stagnation or decline in coastal pond aquaculture, principally because of lower yields and space availability.
- An increase in indoor recirculation systems for marine hatcheries and nurseries but less likely for final ongrowing due to cost comparison with cage production.
- Stable or increasing freshwater pond production, dependent on market demand, diversification and recognition of environmental services.
- Probable decline in intensive freshwater flow-through systems, due to market demand, water availability and diversification towards specialised markets.
- An increase in freshwater recirculation systems, notably for high-value species and for those that can be produced at high density.
- A continued domination of supported/suspended cultivation systems for shellfish production, with further decreases in bottom culture techniques.

Increased activity is foreseen for multi-trophic aquaculture 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.

The last section addresses policy issues. Few individual Member States have policies on aquaculture development, so the CFP remains central. The major effects of public policies are related to the environment, water use, disease treatment and control and food safety. Furthermore, aquaculture is an evident component of many recent and new European strategies, including Blue Growth and the Bioeconomy. The reformed CFP will contribute to the Europe 2020 strategy for smart, sustainable and inclusive growth.

The key issues relating to the sustainable development of European aquaculture are addressed in the new CFP but, in many cases, implementation is dependent on national and local motivation and decision, particularly for licensing. Assuring the coherence of multi-annual national strategic plans should provide the basis of these positions, although local authorities, where licencing issues are generally decided, will be involved in implementation.

Challenges for SMEs include the cost and time of obtaining licences, investments in working capital and modernisation, access to skilled employees in remote areas, and having sufficient information to support market strategies and pricing over long production cycles.

Policy recommendations include the need to quantify multi-annual strategies, providing a clearer growth forecast with adaptations to the Data Collection Framework, assessment and quantification of the environmental services provided by aquaculture, uniform availability of vaccines, therapeutic agents and other products required for fish welfare and a clear allocation for aquaculture within the European Maritime and Fisheries Fund (EMFF) independent of the importance of fisheries in Member States.

Aims and approach

This study provides an assessment of the impact of increased growth of the European aquaculture sector, by identifying the challenges to growth and how these may be overcome. It comprises 4 main chapters – the current status of EU aquaculture and the challenges to achieve robust growth; the consequences of a larger EU aquaculture sector; economic considerations and public support to the sector and sustainable development criteria and public policy measures.

The general approach was to provide an assessment of the current production of finfish and shellfish (in the sub-sectors of coldwater marine fish culture, warmwater marine fish culture, freshwater culture and shellfish cultivation), accounting for diversity in terms of geographical location, cultivated species, technologies for production and emerging species with strong potential. Based upon FAO national and species production statistics, the authors selected 11 technologies for marine and freshwater production of the most important finfish and shellfish species. Production data for 2012 by country and by species was then categorised into each of these technologies, so as to provide new data on the most used production technologies. Consultation with the sector, supported by the Vision document of the European Aquaculture Technology and Innovation Platform (EATiP), was used to identify the core challenges – economic, environmental, social and market – and to rank each in terms of their importance to each of the above sub-sectors.

In the absence of specific data for aquaculture development for Member States, resulting from a delay in the adoption of the European Maritime and Fisheries Fund (and with the unlikeliness that all plans will be received before October), the future growth of the aquaculture sector is based upon the growth scenarios developed by EATiP. These growth scenarios are based upon expected developments (increase, stagnation or decline) in production volumes for each of the major species in each sub-sector, and linked to expected developments in production efficiency, and feed use. The growth forecasts are complemented by linking them to the identified challenges.

The use of marine proteins and oils in aquaculture feeds is summarised by the authors and based on current literature. A detailed description explains the partial replacement of marine proteins and oils over recent years by terrestrial plants and the potential use of other feed ingredients such as non-ruminant processed animal protein, GM plants, algae, bacteria and krill. The EU fish meal and fish oil (FMFO) market is described with predictions on how an increased demand for FMFO would impact this.

Various methodologies and examples of environmental impact indictor identification and assessment have been brought together and presented by the authors. On this basis, an impact ranking system has been developed for each of the production technologies. Predicted growth in the use of these technologies up to 2030 has enabled the identification of environmental issues that will accompany this growth. Available information on the uptake of public subsidies in the sector (mainly the European Fisheries Fund – EFF) has looked to identify technologies that have benefited from this support.

The final chapter reviews the major public policy measures to support sustainable growth and provides recommendations for policy makers.

1. EU AQUACULTURE TODAY AND THE CHALLENGES TO ACHIEVE ROBUST GROWTH

KEY FINDINGS

- In volume terms, the main component of EU aquaculture is shellfish – mainly of mussels and oysters. In value terms, however, it is the fish production that leads.
- More than 70 different fish species are cited for aquaculture in the EU, but production (in 2013) 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.
- The study authors have identified 11 production technologies and have classified the 2012 production data by species and country within these 11 categories.
- Large cage systems are the dominant production technology for coldwater marine fish; smaller cage systems for warm water marine fish; intensive flow-through systems for freshwater fish and supported or suspended culture for shellfish.
- The MAJOR challenges to growth selected by the study authors are adapting and structuring to market changes (including changing consumer preferences, import competition of fish products and competition with other food products (chicken and pork), technical improvements (including feed quality, disease prevention and treatment, selective breeding and integration of activity with the environment) and improving spatial planning (including licensing issues).

1.1. Current status of EU aquaculture production

The FAO and the Coordinating Working Party on Fishery Statistics (CWP) define aquaculture as “the farming of aquatic organisms: fish, molluscs, crustaceans, aquatic plants, crocodiles, alligators, turtles, and amphibians. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated”.

For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licences, are the harvest of capture fisheries.

European aquaculture is a diverse activity that is divided into several sectors, including marine and freshwater conditions. Firstly, European aquaculture covers principally: Fish, Shellfish (Molluscs) and Algae.

Of these, fish and shellfish are the 2 main products – reared mainly for food purposes. It is to be noted that there are globally more than 30.000 individual fish species but that only a few have been successfully adapted to rearing in captivity.

Within the fish production sector, there are further sub-divisions, separating marine and freshwater species (sp.), which are developed further in the following section.

Source: Drawn by authors

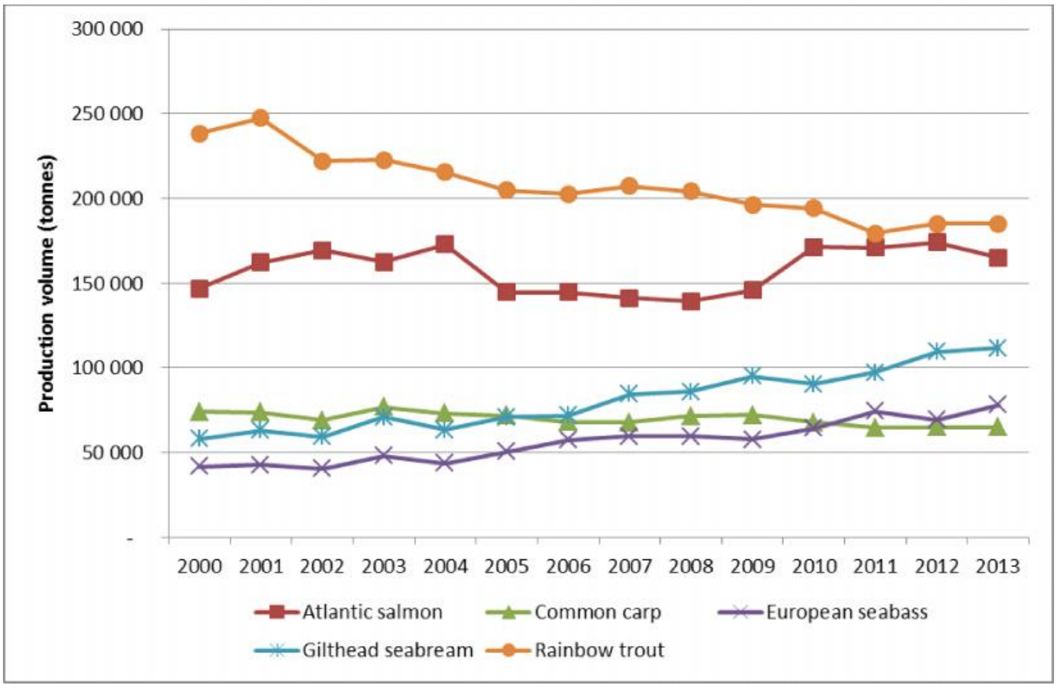
This general classification allows an overview of the European sector and the potential scenarios for development that are the pillar of this report.

From the FAO statistical database (FISHSTAT), over 70 different fish species are cited for aquaculture in the European Union but production (in 2012) was dominated by

- Rainbow trout -185.000 tonnes
- Atlantic salmon – 175.000 tonnes
- Gilthead sea bream – 112.000 tonnes
- European sea bass – 78.000 tonnes
- Common carp – 65.000 tonnes

These 5 species make up 90% of all fish production in the European Union.

Figure 1. Production of the top 5 EU farmed fish for the period 2000 to 2013



Source: FEAP (2014)

The most important species of the remaining 10% are turbot, the European eel, catfish and tuna. The lifecycle for eel and tuna remain to be closed and managed successfully and require access to live stock material from fisheries. Over recent years, EU-financed projects (ReproDOTT, ProEel) have, however, made significant grounds in closing the biological life cycle for these species.

1.1.1. Finfish production

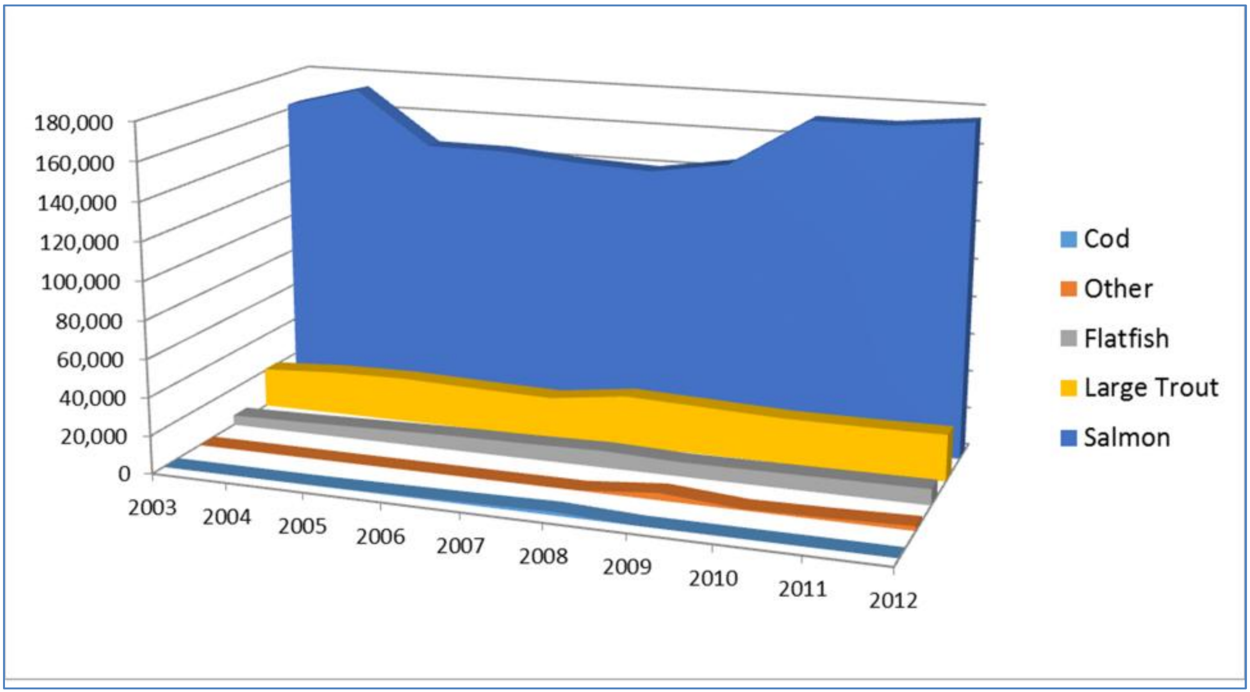
1.1.1.1. Coldwater marine species

The cultivation of Atlantic salmon dominates this component and is seen as THE success story in this sector. Production rose from only 900 tonnes in 1980 (FAO) to 168,000 in 2013 (FEAP), reared mainly in Scotland (UK) with 11.500 coming from Ireland. Evidently, this production is overshadowed by Norway (1,2 million tonnes) in 2013 (FEAP). This is supplemented by the rearing of large rainbow trout in marine/brackish water conditions (Scotland, Denmark, Finland, and Sweden) of 24,000 tonnes.

Efforts on diversification focused on cod, sole and halibut – but without reaching commercial levels of production. 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. Nearly all of the Norwegian hatcheries closed or have converted to other species.

Market issues for salmon – rising production, dropping prices – led to corporate consolidation and major efforts to find new products and new markets. Processed (large) salmon has become commonplace and is commonly used in a wide range of convenience products. One has to note that salmon was once a luxury product – valued at a wholesale price of £6/kg in 1982, equal to £16.60 in 2013 (allowing for inflation), or €20.90. 2013 wholesale prices were +/- €4.40 for whole fresh fish.

Figure 2. EU production of coldwater marine fish 2003-2012



Source: FAO (2014)

1.1.1.2. Warmwater marine species

This sector covers fish farming in warmer marine conditions, notably in the Mediterranean and southern parts of Europe (France, Portugal, Spain). The dominant species are gilthead sea bream and European sea bass, with turbot and meagre leading the remainder. EU production totalled 218.000 tonnes in 2013. 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.

Sea bream moved to over 50.000 tonnes by 2000, while sea bass followed with 40.000; turbot (produced on-land, usually with heated water or recirculation) was around 5.000 tonnes. EU support for Objective 2 areas stimulated investment, particularly in Greece, which rapidly became the EU leader in this sector (followed by Spain and Italy). By 2014, Greece was producing >120,000 tonnes of sea bass and sea bream while Spain followed with 36.000 tonnes.

This sector has been beset with financial problems since its expansion in the 1990s. Finance for working capital in several Mediterranean countries was difficult (higher lending rates than in other EU countries) and several of the larger Greek companies went to the Stock Exchange to raise finance. The financial crisis of 2008-9 led to bankruptcies/mergers with the result that – like salmon in the north – consolidation of the production sector ensued.

In 1990, the price for sea bass was +/-$17/kg while sea bream was +/-$14 (source FAO); by 2000, these had dropped to $6 and $5 respectively (€3.5-4/kg). Although price recovery occurred in mid-2000s, the financial crisis and lack of lending capacity (Greece, Spain) meant that many companies sold under-sized fish to bring in cash to meet payments, again causing market strains. This situation was compounded by growth in Turkish aquaculture, which also focused on export to EU. From 25.000 tonnes of sea bass/sea bream in the late nineties, Turkey produced 78.000 tonnes in 2010 and is estimated to be over 85,000 tonnes in 2013 (FEAP).

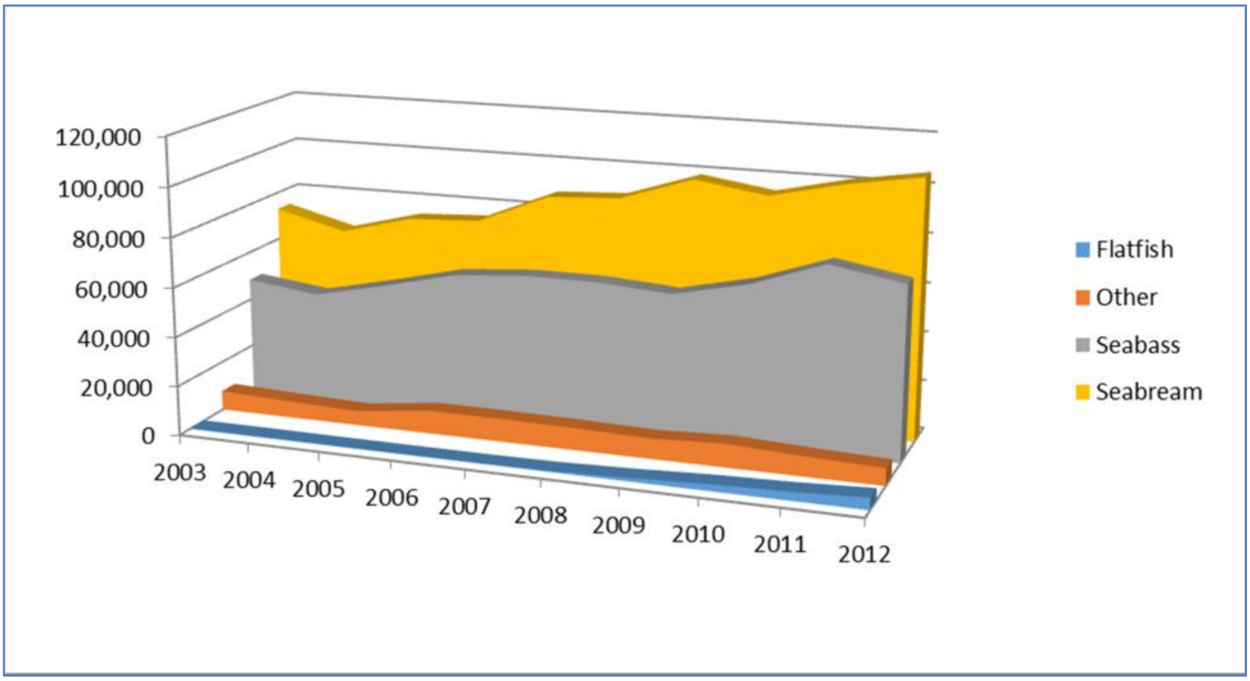
This sector is characterised by having a smaller (portion) product (vs. salmon) and by targeting the fresh fish market (not processed). It has thus not made significant efforts to market its products in the processed/added-value portion, making it very susceptible to market fluctuations.

Emergent species include turbot (produced mainly in Spain (8.000 t) and Portugal (3.000 t)), which has managed to maintain price stability since production has been slow to expand (high investment costs).

Meagre has also become an alternative, with production interest but a slow market. Otherwise, while many species are mentioned in statistics, no immediate ‘challenger’ to the dominant species has emerged.

Tuna rearing, ranching Atlantic Bluefin tuna was initiated with some early success, exporting fish that were ongrown from fished wild specimens. Strongly influenced by the availability of catch that is increasingly regulated, production appears to have stabilised around 3-4.000 tonnes.

Figure 3. EU Production of warmwater marine fish species 2003-2012



Source: FAO (2014)

1.1.1.3. Freshwater species

While 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 (coastal) with carp being better in the more extreme continental conditions seen in central Europe (hot summers, cold winters).

Rainbow trout production peaked at +/-250.000 tonnes in 2000-2001, being the top species produced in EU aquaculture; it is produced not only for consumption (principally as a portion-size fish (+/-250-350 g.) that is produced in one growing season) but also for stocking lakes and rivers for sport fishing. Some trout are also used for growing onto 'large' trout, which is a substitute/support product for salmon. Finland, Sweden and Denmark are the principal producers of this product, grown on in cages in marine/brackish water. This production sector expanded from the 1980s, moving from 100.000 tonnes to 250.000 tonnes in 20 years.

In the last decade, production has decreased to around 160.000 tonnes. This 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.

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 access to marine seafood.

EU carp production is now around 60.000 tonnes. 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 few.

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 has led to a crash in production, which is now around 6.000 tonnes.

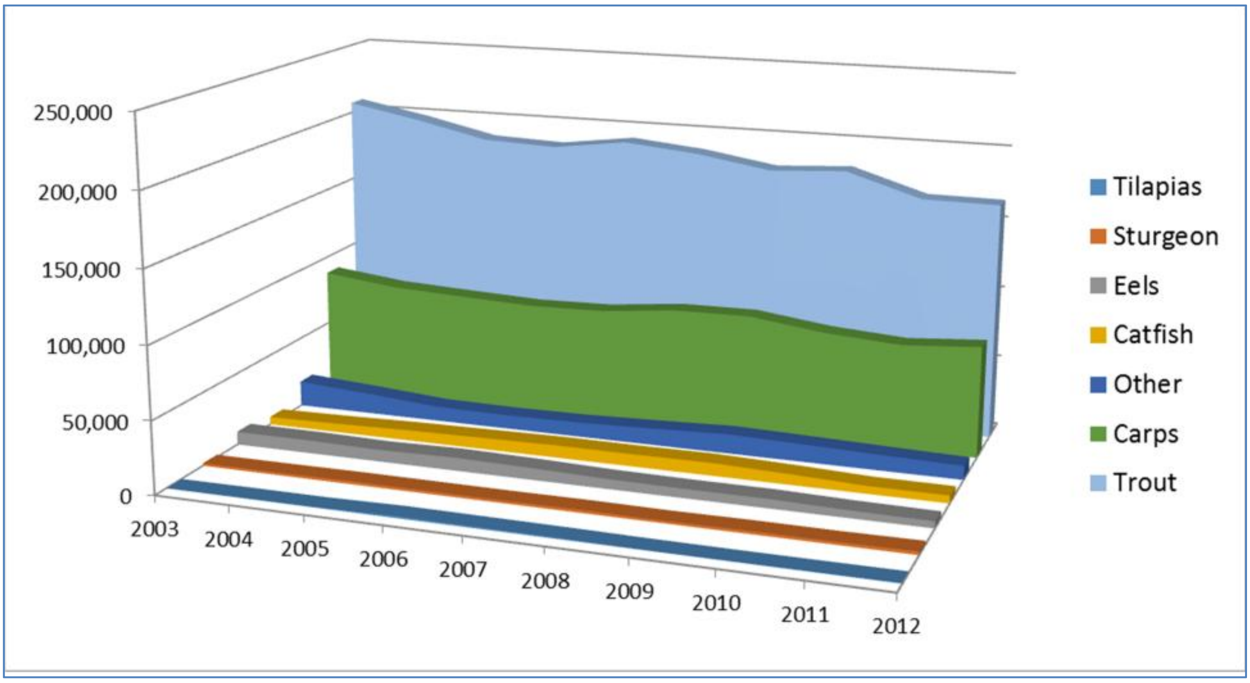
Many alternative species have been investigated, including:

- Arctic char and other trout species
- Sturgeon – mainly for caviar
- Perch
- Pike-perch
- Roach and tench
- African catfish – reared in warm-water, recirculation systems (mainly in the Netherlands)
- Tilapia and barramundi – tropical species reared in warm-water 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 the CITES ban on wild caviar.

Compared to marine aquaculture, the freshwater aquaculture profession is dominated by smaller SMEs or family firms, which inevitably has restricted investment and rationalisation of the profession. A major challenge is addressing generational change for the smaller family companies.

Figure 4. EU Production of freshwater fish species 2003-2012



Source: FAO (2014)

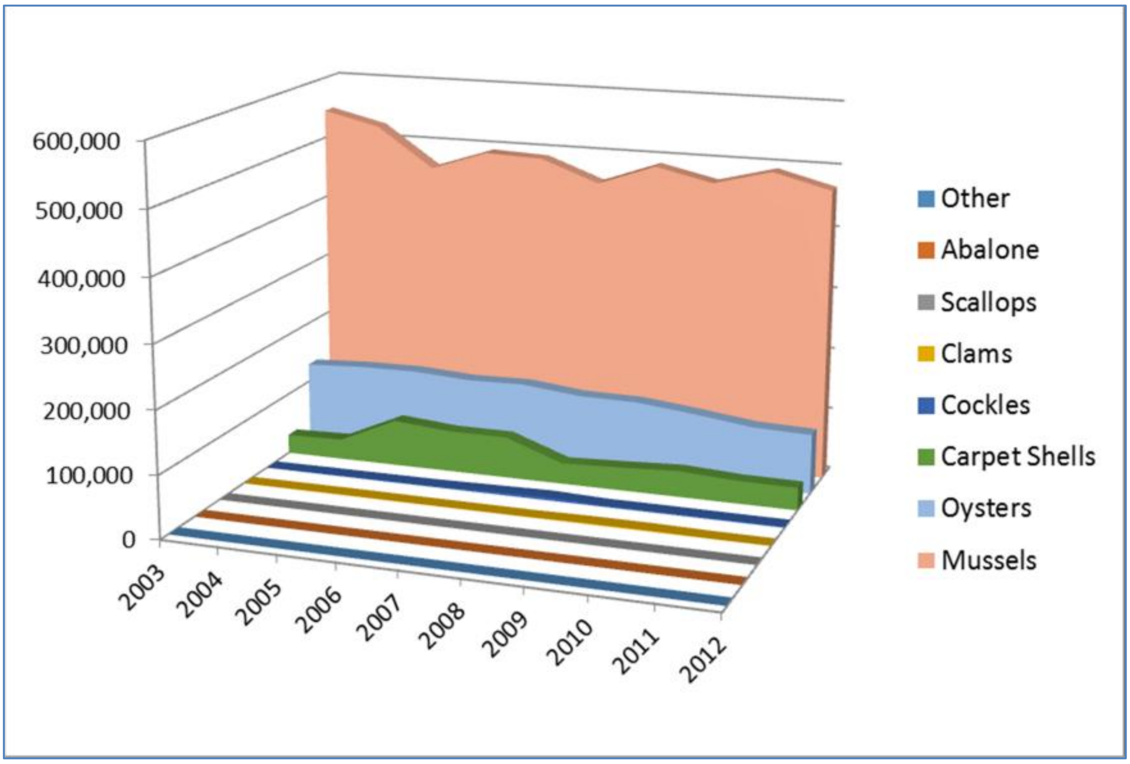
1.1.2. Shellfish production

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 represents 93% of the total European cultivated mollusc production (Eurostat 2011). The third element of shellfish production is of clams, cockles and arkshells.

France is by far the leading producer of oysters (+/-85.000 tonnes in 2011), Spain of mussels (+/-209.000 tonnes in the same year) and Italy of clams (+/-32.000 tonnes in the same year).

Over recent years, the production of oysters has declined with abnormal mortality events of Crassostrea gigas adults reported in most French oyster production areas. In 2012, mortality events of adult C.gigas occurred in several oyster producing areas in France and were associated with the detection of Vibrio aestuarianus. In the summer of 2013, similar events were observed in adults, but also in juveniles (#18months old) in all the main French production areas. The UK, Jersey, Ireland and the Netherlands have all suffered recent mortalities.

Figure 5. EU shellfish production 2003-2012



Source: FAO (2014)

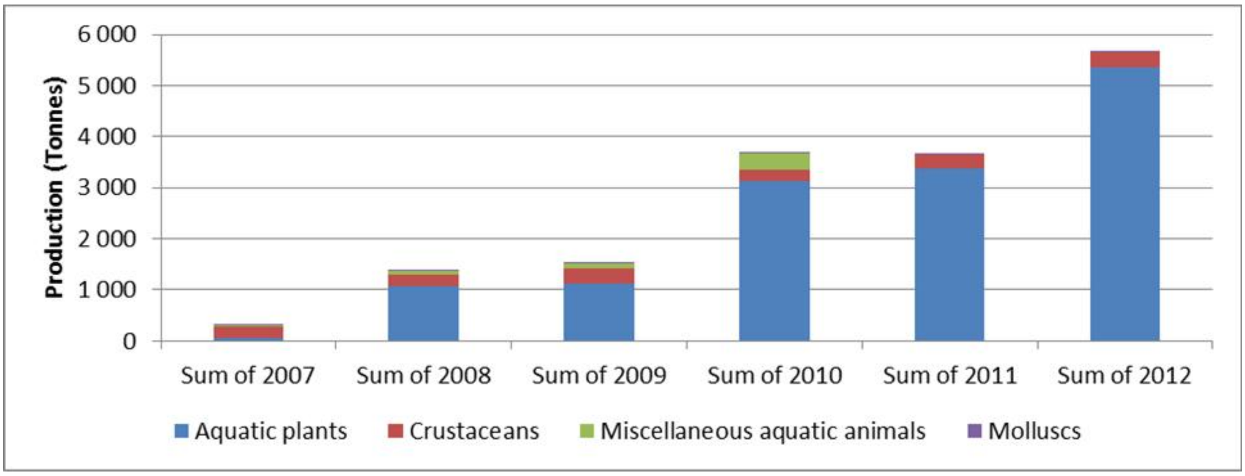
1.1.3. Production of algae and other species

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) has seen the most growth and this has been reported for Denmark.

Other species groups included here are crustaceans (mostly freshwater crayfish species in central and eastern European countries, but also several prawn species including the kuruma prawn, Penaeus japonicas in southern Europe).

Mollusc species included here are mainly octopus and the miscellaneous aquatic animal group includes sea urchins and non-specified aquatic animals from inland waters.

Figure 6. EU production of other aquaculture species.



Source: EUROSTAT

1.2. Production technologies and their attributes

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, intensity of production and feeds used, and finally by a matrix of environment and/or species (or species group).

Classification by scale (Lazard et. al. 1991):

- Aquaculture for subsistence (family level)
- Artisanal aquaculture, producing for the market on a small scale
- Specialised aquaculture in which various stages of the production cycle are carried out by different farmers
- Industrial-scale aquaculture.

Classification by intensity of production and type of feed used (based on Edwards 1993):

- Extensive (not fed, low stocking density, low water exchange)
- Semi-intensive (fed partial diets, medium stocking density, medium water exchange)
- Intensive (fed complete diets, moderate to high stocking densities, high water exchange)
- Hyper-intensive (fed complete diets, very high stocking densities, very high water exchange & oxygen supplementation).

Classification by matrix of environment and/or species (or species group):

- Freshwater/brackishwater/seawater
- Tropical/temperate/cold water
- Fish, crustacean, mollusc, aquatic plants
- Monoculture or polyculture
- Integrated (if waste nutrients from one species or system is used as a feed source for another)

A technology-based classification primarily considers the nature of the containment system as shown in the figure overleaf. A primary distinction is made between land-based systems which are on-land with water taken from a distinct source and passed through the containment system; and water-based systems where the system itself is located within a natural water body, enabling free environmental exchange.

Land-based containment systems are based around two principle types of holding system:

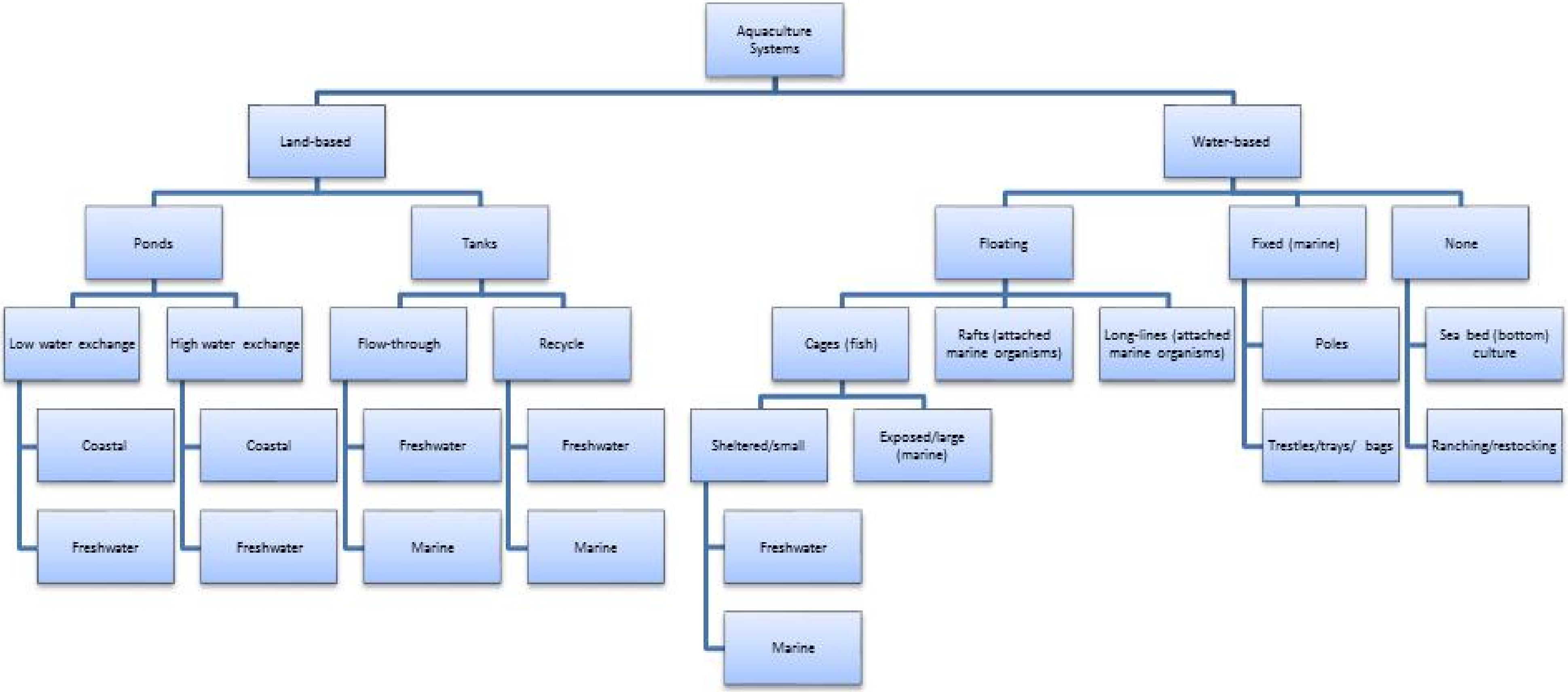
- Ponds - generally earthen construction from a few hundred to several tens of thousands of cubic meters in volume. Usually 0.5 – 1.5 m operational depth. May be lined with waterproof membrane, or more commonly soil contains sufficient clay to limit water seepage. Water exchange generally 5-30% per day, although can go much higher in some circumstances.
- Tanks – constructed from GRP, polythene, polypropylene, concrete and other materials. From less than $1m^3$ to several hundred m^3 in volume. Usually circular or long rectangles (raceways). Water exchange can be from 0.5 to 4 volume change per hour.

Inland, water can be supplied from freshwater sources (such as streams, rivers, lakes or reservoirs) by gravity flow or pumped supply. Coastal ponds can sometimes make use of changes in the tidal level to fill and empty ponds, although this is usually augmented or replaced by pumping in more intensive systems.

The water flow is required in semi and fully intensive systems to replenish dissolved oxygen used by the stock and to flush away solid and dissolved wastes. The higher the stocking density (e.g. kg/m^3), the higher the flushing rate required.

There are potential benefits both to the farm and the environment if water is recycled and treated on the farm, rather than entering and then being discharging with minimal treatment. Any level of water recirculation or reuse is possible, but “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. Such systems may also be termed “closed containment” as there is a much reduced chance of stock escaping or interacting with wild fish. At the present time, this approach is limited to hatcheries and some specialised production due to limited economic competitiveness.

Figure 7. A technology-based classification (based on the nature of the containment system).



Water based containment systems are either floating structures that are moored in position, or are static constructions usually placed in the intertidal zone or shallow water and fixed into the substrate. Key examples of floating structures include:

- Cages – usually for fish, generally based on a moored floating collar with net bag suspended below to contain fish. The mesh size depends on the size of fish being grown. Circular cages constructed with high density polythene pipe have become the industry standard in Europe with diameters ranging from below 10 to over 40 m. Volumes can range from 100 to over 20.000 m^3. Whilst there is a continuum in scale, a distinction can be made between smaller-scale systems designed for sheltered locations and mainly manual labour (e.g. net changing and feeding); and robust larger scale systems that can be used in more exposed conditions and requiring specialised ancillary equipment such as workboats with hydraulic cranes, specialised feed barges for feed supply and well boats for fish transfer, grading and some disease treatments.
- Rafts – These are floating platforms, usually of wooden construction to support ropes that hang down in the water upon which mussels or sometimes other bivalves can be attached for cultivation. Special lantern nets can also be suspended from rafts to contain shellfish that do not naturally attach to ropes.
- Longlines – Usually cheaper than rafts, they are long horizontal ropes fixed to the shore or other mooring points and each end and supported in the water with floats. These again have vertical rope “droppers” to support shellfish stocks.

Fixed structures include fish pens (rectangular nets supported from uprights at each corner that are fixed into the substrate). These are generally only suitable for calm and shallow waters and are rarely used in Europe. The main commercial fixed systems are for shellfish and seaweeds which rely on natural productivity (non-fed):

- Bottom culture – used for mussels, scallops, clams etc. in some areas – no containment structures, just management practices.
- ‘Bouchot’ – wooden poles placed in intertidal areas with rope twisted around for mussel attachment.
- Trestles – usually steel fixed into intertidal sands to support plastic mesh bags or trays containing oysters or other shellfish.
- Lines – suspended between fixed poles and used for seaweed cultivation, or to suspend baskets for shellfish etc.

As these different aquaculture systems have quite different profiles with respect to potential environmental interactions and sustainability issues, analysis of the current aquaculture sector in relation to system technology would be desirable. Unfortunately in most countries little information about system design and scale has been routinely collected. This is changing with the implementation of Commission Regulation (EC) No. 665/2008 (14 July 2008) which established a Data Collection Framework (DCF) for aquaculture and fisheries.

The current specific requirements are contained in Decision 2010/93/EU (18 December 2009) and requires production data to be related to the aquaculture production system. For finfish production this is land based farms, hatcheries and nurseries, on growing, combined and cages and for shellfish production, rafts, long line, bottom and other. In addition, data should be categorised by species – salmon, trout, sea bass & sea bream, carp, other freshwater fish, other marine fish, mussel, oyster, clam and other shellfish.

Combining the production techniques and species classifications therefore provides a total of 41 categories or “segments” for analysis! While this should give a clearer analysis than has previously been available through FAO or Eurostat statistics, it misses the opportunity to measure progress made with recirculated aquaculture systems or capture trends in the development of cage based systems. It also implies a significant lag in recording the introduction of any new species as these will not be noted until they exceed some threshold and the regulations are refreshed. Nevertheless the structure was presumably selected with reference to pragmatic considerations and the essential needs of policy organisations.

Table 1. Selected technologies used for the classification of European aquaculture

EUROPEAN AQUACULTURE TECHNOLOGIES

Selected for this study

For this study we consider the following technology categories to help with our analysis:

- Freshwater pond aquaculture (extensive to semi-intensive)
- Coastal pond aquaculture (mostly semi-intensive)
- Intensive freshwater flow-through and partial recirculation systems (mostly tanks, raceways and small ponds)
- Intensive marine flow-through and partial recirculation systems (mostly large tanks)
- Indoor land-based recirculated aquaculture systems (freshwater)
- Indoor land-based recirculated aquaculture systems (marine)
- Small cage systems – freshwater
- Small cage systems – sheltered marine
- Large cage systems – marine in exposed sites, using mechanised (automated) systems
- Marine bottom culture (non-fed sedentary and attached animals & plants)
- Marine supported and suspended culture (non-fed sedentary and attached animals & plants).

Hatcheries and nurseries are excluded as their impacts are small and included in overall production calculations.

1.3. EU production by technology

1.3.1. Finfish production

1.3.1.1. Coldwater marine species

For both salmon and trout, freshwater hatcheries are used to provide live juvenile stock from 'eyed' (fertilised) eggs. Considerable efforts have been given to selective breeding for desirable traits, with specialized companies developing for this purpose (e.g. Landcatch (UK), AquaGen & Salmobreed (Norway), Stofnfiskur (Iceland)) and making worldwide deliveries of 'eyed' eggs.

Hatcheries are increasingly sophisticated operations – where broodstock selection, control of development (temperature, lighting etc.), vaccination, hygiene and automation are integral to modern operations. Increased and efficient control measures are integral to development – due to planning needs, disease/infection risks and juvenile quality.

Juvenile salmon are moved from the hatchery/nursery environment once they have changed physiologically to adapt to marine conditions (as smolts); normally, live fish are moved by well-boat – usually without manual handling – to the ongrowing infrastructure. Cage/net production is the primary ongrowing technology, where cage construction moved from the use of small floating wood/steel units to large plastic entities has significantly increased productivity potential. All cages have to be moored so as not to move with wave action, tides and storms. Accompanied by automatically-controlled feed distribution, distance-monitoring and automated movement/harvesting of fish, technology has significantly reduced labour costs – as well as providing safer working conditions in the marine environment.

A range of conditions have contributed to looking at 'offshore' farming as being a panacea for the future. The vast majority of marine fish farming is coastal, since protection from storms and ease of access (for maintenance work, stocking, feeding, harvesting…) by personnel. Concerns on the destiny of the waste produced by farms, the perceived impact of escapes (e.g. from storm damage) on wild stocks, visual impact (e.g. to coastal residences, hotels…) are contributory factors to this consideration. As fish farming has grown, access to space for farming is dependent on licence attribution (permission to farm).

Moving offshore provides a range of different challenges, to which technology has to respond. Submersible cages (that can avoid storm damage) are one option while integration with other activities (such as wind farms) are another. To date, there is no simple answer since logistics have to be married to how such activities can be integrated (legally) within use of maritime space. Most offshore fish farming activities remain experimental, although some specific examples exist in Europe.

The following table gives the authors estimates of the EU production of coldwater marine species, by our selected technologies and based on data from the FAO.

Table 2. Total EU production of coldwater marine finfish by production technology

Technology	Estimated 2012 production (tonnes)
Coastal pond aquaculture	180
Intensive marine flow-through and partial recirculation systems (mostly large tanks)	100
Indoor land-based recirculated aquaculture systems (marine)	9.180
Small cage systems – sheltered marine	11.000
Large cage systems – marine in exposed sites, using mechanised (automated) systems	190.090
Total	210.550

Source: Estimated by the authors of this study

1.3.1.2. Warmwater marine species

As for salmon, the sector requires specialised hatcheries and ongrowing units.

The hatchery operations are considerably more complex than for salmon since the adult fish have to be induced to breed (photoperiod, temperature…) and fertilised eggs are removed from spawning facilities to be grown on as larvae. Hatcheries also have to have facilities for the production of microalgae, rotifers and brine shrimp nauplii (Artemia spp.) in large quantities, to be used as live feed for fish larvae. Not only are these feeds essential, but also the larvae require considerable monitoring efforts. This is a relatively complex procedure, requiring skilled staff and technicians for the different components.

Although some companies have selective breeding programmes, advances in growth or feed conversion ratio or disease resistance of such programmes – for example as obtained for Atlantic salmon, are less evident in this sector.

Larval rearing is followed by weaning of fry (1-2.5 cm) to the fingerling stage (8-10 cm). However, due to the need to transport young fish in warm conditions to ongrowing sites, in many cases stocking is made of fry rather than fingerlings. Live transport is usually done in trucks carrying oxygenated, cooled tanks.

Ongrowing is usually done in cages, generally smaller than used for salmon. Initially, a preference for smaller, wood/steel floating cages was evident (local manufacture, lower cost...) but recently more modern infrastructures are being used (round plastic cages, automatic feeding/monitoring systems). It is anticipated that production in larger cage sizes will be prevalent in the future.

As increasing corporate consolidation has occurred, most of the large companies have integrated operations, including self-owned hatcheries, ongrowing and product preparation units.

As for salmon, offshore production has been put forward, primarily due to competition with tourism interests for coastal space; in Turkey, several farms near Bodrum were obliged to move further out (in a bay) but, as for salmon, logistic and legal issues remain problematic.

As consumer trends advance, notably in respect of conveniences dishes and processed products, this sector find itself at a disadvantage. Filleting remains largely manual (high cost) and the northern European consumer is less aware of sea bass and sea bream, compared to salmon.

Table 3. Total EU production of warmwater marine finfish by production technology

Technology	Estimated 2012 production (tonnes)
Coastal pond aquaculture and valliculture	900
Intensive marine flow-through and partial recirculation systems (mostly large tanks)	9.910
Indoor land-based recirculated aquaculture systems (marine)	340
Small cage systems – sheltered marine	102.420
Large cage systems – marine in exposed sites, using mechanised (automated) systems	74.330
Total	187.900

Source: Estimated by the authors of this study

1.3.1.3. Freshwater species

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.

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 oxygenation allowing higher stocking levels 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, vaccination…) is practised. Nonetheless, the infrastructure of extensive pond farming is recognised for providing environmental services – providing flood protection, habitats for wild birds and animals, cleaning water (outlet water is often cleaner than inlet).

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.

Since the 1980s, attention has been given to the potential for water treatment and recirculation, reducing water usage. This involves removal of solids (faeces, uneaten feed) by filtration and treatment of the water by a biological 'filter) that converts dissolved waste (ammonia) to nitrates; this is usually accompanied by degassing (to remove CO_2 and nitrogen) and ozonation (additional impurities). 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, tilapia).
State-of-the-art systems use approximately 500 litres of water per kg production

The main drawback is the combination of investment (made before any production) and energy costs, for pumping. It can be said, for the same species, that recirculation vs. 'normal' systems has no economic advantage; consequently, the value of the product and other production and marketing advantages (e.g. disease-free, proximity to market, reduced environmental impacts) have to be significant for economic success.

Table 4. Total EU production of freshwater finfish by production technology (2012)

Species	Freshwater pond	Intensive freshwater flow-through	Indoor land-based recirculated	Small cage	Total
Carps	77.860	0	0	0	77.860
Catfish	1.140	400	3.790	0	5.330
Eels	0	0	4.690	0	4.690
FW Other	6.640	2.580	290	0	9.510
Salmon	0	5	0	0	5
Sturgeon	400	1.910	0	0	2.310
Tilapias	0	0	450	0	450
Trout	310	164.390	0	250	164.950
Total	86.350	169.285	9.220	250	265.105

Source: Estimated by the authors of this study

1.3.2. 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, for example white-painted roofing tiles, as practiced in the Bassin d'Arcachon. The newly-settled oyster juveniles are then transferred to the intertidal range, either directly on the ground (bottom culture), or in bags on trestles, or suspended from frames.

Traditionally in France, pre-market oysters are transferred to special ponds ("clair") or holding tanks for "affinage", where the algae (Navicula sp.) gives a green tinge to outside part of the oyster, and becoming a "fine de clair" or a "special".

Epizootic disease episodes over recent years, have fuelled a trend to develop hatcheries for oysters, so that sterile or disease-resistant juveniles can be bred and supplied to producers.

Two mussel species, Mytilus edulis (Atlantic, North and Baltic Sea coasts) and Mytilus galloprovincialis (Atlantic and Mediterranean coasts), make up the vast majority of European production. There are three different culture techniques - using poles ("bouchot"), suspended ropes or bottom culture.

Pole 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, are transplanted onto the growing poles and harvested after 12-15 months.

Suspended rope culture: Ropes covered with mussel seed are suspended either from frames, floating structures (rafts), or long-lines with surface buoys. Frames are built from metallic poles, placed upright into the ground, at water depths ranging between three to nine metres.

Bottom culture: Based on the harvesting of naturally-producing mussel beds - a technique that is widely practised in the Netherlands and to some extent in UK. Clam and cockle species are generally produced using bottom culture techniques, with juveniles are certain species coming from hatcheries.

Table 5. Total EU production of shellfish by production technology

Technology	Estimated 2012 production (tonnes)
Marine bottom culture (non-fed sedentary and attached animals & plants)	65.440
Marine supported and suspended culture (non-fed sedentary and attached animals & plants)	537.050
Total	602.490

Source: Estimated by the authors of this study

1.3.3. Production of algae and other species

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.

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

Table 6. Total EU production of other species by production technology

Technology	Estimated 2012 production (tonnes)
Freshwater pond aquaculture	38
Coastal pond aquaculture	247
Intensive freshwater flow-through and partial recirculation systems	1
Intensive marine flow-through and partial recirculation systems (mostly large tanks)	1
Small cage systems – sheltered marine	5
Marine bottom culture (non-fed sedentary and attached animals & plants)	9
Marine supported and suspended culture (non-fed sedentary and attached animals & plants)	5.352
Total	5.653

Source: Estimated by the authors of this study

1.4. Challenges for growth

Identifying challenges for growth has to refer to a range of economic, social and technical issues that cover not only aquaculture but also food supply in general, livestock rearing, water use and environmental considerations. A complex interweaving of legislative and societal approaches that cover these issues tends to show that aquaculture has been an 'add-on' that remained outside core policy considerations until recently.

This is most clearly demonstrated by the Common Fisheries Policy where aquaculture was included primarily because its products are in the same market(s) as those of fisheries. As aquaculture grew in the 1980s-1990s, both in Europe and globally, its higher level of visibility meant that markets and legislation had to adapt to this new activity.

After different reforms, the CFP[1] in 2014 recognises aquaculture to be a key component of its scope, alongside fisheries and processing.

Nonetheless, while the CFP is the legislative instrument that is 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 the operator and suppliers that include:

1. Environmental respect and, in many cases, management
    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.
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)[2]
    b. Aquatic Animal Health Directive[3]
    c. Live animal transport Directive[4] (for stock movements [e.g. from hatcheries]
    d. Stunning and killing
3. Feed composition
    a. Awareness of finite nature of fishmeal and fish oil sources (see separate section)
    b. Ban on ruminant protein sources (following TSE and dioxin crises) although non-ruminant PAPs 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-based 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 and these are developed further in section 4.

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[1] REGULATION (EU) No 1380/2013
[2] Directive 98/58/EC
[3] Directive 2006/88/EC
[4] Directive 95/29/EC

Challenges are numerous and the most important ones identified in this study 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 number of licenses/permits needed), that restrict investments and expansion potential.
- High labour and employment costs and working conditions (e.g. 35 hour 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 [COM(2013) 229], where they were described in detail and specific targets for each were set for Member States and also for the Commission.

The European aquaculture industry agreed that the main challenges to progress[5] are:

- 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

Further consultation within the main production sectors – through their representative organisations, notably the Federation of European Aquaculture Producers (FEAP) and the European Mollusc Producers Association (EMPA) provides the background for the following table that lists and prioritises the challenges and their level of importance for each sector.

[5] 'The Future of European Aquaculture' (EATiP) 2012.

Table 7. Principal challenges for the development of EU aquaculture sectors
As identified by the Study authors

Challenge for development	Coldwater marine	Warmwater marine	Freshwater	Shellfish
ECONOMIC				
Productivity gains	+	+ + +	+ + +	+
Access to capital	+	+ + +	+ +	+
Diversification of the offer	+	+ + +	+ + +	+ +
ENVIRONMENTAL				
Access to high quality water	+	+ +	+	+ + +
Spatial planning	+ + +	+ + +	+ + +	+ + +
Use of outputs	+	+	+ +	
SOCIAL				
Communicating the attributes and benefits of the sector	+ +	+ + +	+ + +	+
Recruiting high level workforce	+	+ +	+ +	+
Generation change	+	+	+ + +	+ +
MARKET				
Changing consumer preferences	+	+ + +	+ + +	+
Labelling and certification conditions	+ +	+ +	+	+
Multiple Retail Store domination	+ + +	+ + +	+ +	+
Import competition of fish products	+ +	+ + +	+	+ +
Competition with other food products (chicken and pork)	+ + +	+ + +	+ +	+

Source: Study Authors

Climate change is also seen as a potential hazard, as are new diseases.

The EATiP identified specific strategic risks that accompany these challenges:

1. Structuring to avoid boom-bust conditions and unfair competition
2. Adaptation of policies to include and understand aquaculture conditions
3. Addressing public perception of aquaculture and responding to consumer concerns
4. Inadequate financial capacity of SMEs and family firms.

A 2013 STECF report[6] on the fish processing industry highlighted economic difficulties within a weakened sector, where it was noted that low margins and increasing raw material and energy costs "cannot be translated into price rises due to the retail sector's high negotiation power. This leaves companies very vulnerable to developments in the world markets." This is an identical position to many aquaculture companies.

The report also notes that "As the list of countries with an increasing demand for certified products [which are more expensive] shows, this is basically a development in the northern part of the EU. In the countries around the Mediterranean, a different development is taking place. Consumers have lower purchasing power than before and move from high-valued products to low-valued products."
There also is in many countries a shift towards processed products compared to fresh fish in the past. "However, this is not only the case for fish products but for food products in general."

The decisions for producers to go further down the line – moving higher up the value chain – appear to depend on the size of the individual company (access to adequate volumes, investment in quality/certification, processing) or on the willingness to use tools such as cooperatives/producer organisations that give access to the scale required.

In conclusion, there are different opinions and priorities within different sub-sectors of European aquaculture, the main challenges resulting from these different analyses are provided here in the table below. Details of proposals for how many of these challenges can be addressed are included within the Strategic Research and Innovation Agenda of the EATiP. It is also interesting to note that most of the profession underlines the need for improved communication – not simply product promotion, but more on the attributes and benefits of the sector's development.

Table 8. Principal challenges for growth in EU aquaculture

EUROPEAN AQUACULTURE CHALLENGES FOR GROWTH
Selected for this study
Adapting and structuring to market changes:
Changing consumer preferences
Labelling and certification conditions
Multiple Retail Store domination
Import competition of fish products
Competition with other food products (chicken and pork)
Technical improvements
Feed quality
Disease prevention (vaccines) and treatment (therapeutic)
Livestock quality (selective breeding)
Integration of activity with the environment
Improving spatial planning
Access to adequate sites
Reduced time to licensing approval and duration/cost of license.

Source: Study authors

[6] EUR 26444 EN

2. The consequences of a larger aquaculture sector

KEY FINDINGS

- The projections for EU aquaculture growth presented here are taken from the 2012 Vision of the European Aquaculture Technology and Innovation Platform and not from Member State multi-annual strategies and operating plans. With delays in the adoption of the EMFF, these strategies and plans have not all been submitted to the Commission at this time and have not been available to the study authors.
- For coldwater marine species, the major trend is a production growth of more than 100% by 2030, meaning 4% per year over the period, based on solid markets and achievement of production potential more towards offshore locations. Similar growth trends are predicted for warmwater marine species, with production growth again at an average of 4% per year. Production growth in the freshwater sub-sector to 2030 is estimated to reach 40%, which is 1.5% per year, although considerably less than for the other sub-sectors. This growth will be based on diversification (not necessarily in new species) and the recognition of environmental services will be important for extensive operations. Shellfish production growth is projected to be 30% by 2030, meaning an annual growth rate of 1.3%/year. This growth relies on overcoming ongoing mortalities (especially in oysters) and the development of breeding programmes and hatcheries for the key species.
- In all sub-sectors, new production sites will be needed.
- Growth requires additional feeds, but anticipates improvements in quality and new resource components. It is important that the continued reduction in dependence on fishmeal and fish oil does not compromise the quality and health attributes of EU aquaculture products.
- An ecological impact assessment matrix has been developed, and technologies and productions systems are ranked according to expected growth and associated impact issues. There is no clear division of 'intensive/extensive' systems and, for example, stocking densities in large cage systems are more easily reduced /controlled than in small cage systems.
- Additional feed requirements for EU aquaculture in 2030 would only exceed EU fish meal fish and fish oil production if all of the FMFO were sourced in the EU and this is not the case. On the other hand, if EU aquaculture were not to expand, then EU FMFO would be increasingly used to produce farmed fish and shrimp in third countries and then come back to EU consumers in this form.
- The potential use of PAPs, GM oil seeds and other sources such as krill would reduce even further any impact on EU fish stocks.
- Placement of similar products on the market from aquaculture or fisheries sources probably has more impact on EU aquaculture than it does on EU fisheries.

This section looks at growth scenarios for EU aquaculture. From January 2010 to July 2012, the European Aquaculture Technology and Innovation Platform (EATiP) coordinated an EU initiative entitled 'Aquainnova'[7] that is described in the following section. The first sub-section presents growth scenarios for the main species groups that resulted from the Aquainnova initiative. The second sub-section looked to bring together information from the

[7] Aquainnova, supporting governance and multi-stakeholder participation in aquaculture research and innovation. FP7 KBBE Coordination and Support Action. EC contribution: €988,954. Duration: February 2010-July 2012. http://www.eatip.eu/default.asp?SHORTCUT=100

Member States on their national aquaculture strategies. The third sub-section addresses the potential increases in needs for protein and oil for aquaculture feeds, and the sources of these major nutrients for fed species.

The projected increases in production are linked to expected trends in the development of technologies used to farm these products and their potential ecological/environmental interactions. Finally the section addresses some elements of the impacts of increased aquaculture production on the EU fisheries sector.

2.1. Growth scenarios for species groups

Aquainnova – "Supporting governance and multi-stakeholder participation in aquaculture research and innovation" – was an FP7 project focusing on the creation of an international framework to facilitate the development of vision documents and strategic research agendas on the sectoral components of European aquaculture. As part of its work, Aquainnova facilitated workshops for the species categories featuring in this report, where a combined total of more than 350 experts, including aquaculture producers, researchers and other key stakeholders, who came together to work on development issues relating to their sector. A part of this exercise was for individuals to indicate their personal opinion of growth forecasts for individual species in their sector for 2010, 2020 and 2030 and give their opinion of future production technologies. All of this data was then compiled to provide a series of scenarios and these were subsequently included in the EATiP Vision of the Future of European Aquaculture (EATiP 2012). The following subsections provide the main conclusions of this exercise for the species groups that were part of the Aquainnova process.

2.1.1. Finfish production

This has been split into the three main species groups as in previous sections of this report. The actual forecasts are shown in the figures overleaf.

2.1.1.1. Coldwater marine

The major trend projected for the sub-sector is a production growth of more than 100% by 2030, meaning 4% per year over the period, based on solid markets and achievement of production potential. Atlantic salmon will remain the main species, due to market attractiveness and resolution of many technical issues, but alternative species (cod, flatfish and large trout) will all increase, with more attention being given to technological improvements. For example, individual cage size is forecast to be 20,000 m^3, having a depth of 20 m. Productivity improvements will move from 200 tonnes/person employed to 300 (technology-management). Feed conversion will improve from 1.5 kg/kg fish produced to 1.2 (quality improvement).

In terms of technology, it appears likely that more and more farms will be integrated (i.e. producing more than one species on the same site) and multi-functional (so not just producing food). It is also likely that more farms will be located in areas that have higher water energy (waves and currents).

Overall, while minor species will develop, salmon will continue to dominate. Consequently, there is a substantial need for feeds (+173.000 tonnes) and hatchery/smolt supplies (+0.2 billion). On the current production basis (40 m^3/ton), 390 hectares of marine space would be needed for new cages (39 hectares).

The main challenges identified in achieving growth in this sub-sector are to develop robust, perhaps sterile, juvenile fish for exposed sites; maintaining PUFA quality while feed components (plants) change; minimise impact of escapes; create new partnerships for integrated culture practices (Integrated Multi-trophic Aquaculture [IMTA]) and mastering the management of offshore production.

Table 9. Estimation of future production and performance data for EU aquaculture.

Coldwater Marine Assumptions		Forecast growth (tonnes)			Value 2010	Value 2030	Jobs		
	APR	2010	2020	2030	M€	M€		2010	2030
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	1,273
Large Trout	2.0%	30,220	36,838	44,025	€ 75.55	€ 110.06	Added-value (processing)	951	1,273
Salmon	4.0%	159,912	236,709	336,910	€ 495.73	€ 1,044.42	Downstream	95	127
Subtotal		190,322	274,021	382,016	€ 572.49	€ 1,159.88	Total Jobs	2,139	2,865
TOTAL INCREASE	101.0%			191,694		€ 587.40	Feeds (tonnes)	285,561	458,419

Warmwater marine Assumptions		Forecast growth (tonnes)			Value 2010	Value 2030	Jobs		
	APR	2010	2020	2030	M€	M€		2010	2030
Flatfish	5.0%	10,102	16,455	25,527	€ 89.30	€ 225.66	Upstream	912	1,358
Other	4.0%	16,453	24,355	34,664	€ 151.70	€ 319.60	On-farm	6,080	9,051
Seabass	4.0%	74,907	110,881	157,818	€ 346.07	€ 729.12	Added-value (processing)	6,080	9,051
Seabream	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

Freshwater Assumptions		Forecast growth (tonnes)			Value 2010	Value 2030	Jobs		
	APR	2010	2020	2030	M€	M€		2010	2030
Carps	1.5%	67,484	78,318	89,548	€ 131.59	€ 174.62	Upstream	1,175	2,259
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	1,265	1,506
Sturgeon	8.0%	1,928	4,162	8,320	€ 15.19	€ 65.56	Total Jobs	22,686	29,409
Tilapias	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	€ 1,355.94	Total Jobs	17,473	25,925
TOTAL INCREASE	43.0%			144,200		€ 486.61	Feeds (tonnes)	305,658	367,977

Shellfish Assumptions		Forecast growth (tonnes)			Value 2010	Value 2030	Jobs		
	APR	2010	2020	2030	M€	M€		2010	2030
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%	1,700	4,409	10,397	€ 3.92	€ 23.97	Added-value (processing)		
Cockles	5.0%	2,000	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	€ 1,017.37	€ 1,444.77	Total Jobs		
TOTAL INCREASE	30.0%			196,617		€ 427.39			

Summarised Assumptions	Growth	Forecast growth (tonnes)			Value 2010	Value 2030	Jobs		
	%	2010	2020	2030	M€	M€		2010	2030
Coldwater Marine	101.0%	190,322	274,021	382,016	€ 572.49	€ 1,159.88	Coldwater Marine	2,139	2,865
Freshwater	43.0%	331,868	396,156	476,068	€ 869.33	€ 1,355.94	Freshwater	22,686	29,409
Mediterranean	112.0%	212,784	316,474	452,548	€ 1,032.36	€ 2,212.54	Mediterranean	13,679	20,365
Shellfish	30.0%	653,318	746,407	849,935	€ 1,017.37	€ 1,444.77	Shellfish	-	-
Subtotal		1,388,292	1,733,058	2,160,566	€ 3,491.55	€ 6,173.13	Total Jobs	38,504	52,638
TOTAL INCREASE	55.6%			772,275		€ 2,681.58	Feeds (tonnes)	974,230	1,369,453

Notes:

1. The total increase in volume and value (constant prices) of for 2030 compared to 2010 data.
2. The job data is based on estimates taking into account technology developments and automation
3. The feeds required take into account expected advances in Food Conversion Ratio (FCR)
4. The AquaInnova forecasts used here did not have complete data for job developments in the shellfish sector.

Source: AquaInnova / EATIP forecasts for scenarios in each sub-sector, re-formatted by the study authors

2.1.1.2. Warmwater marine

Similar growth trends are predicted for this sub-sector, production volume growth again at an average of 4% per year. The main species are seen to be sea bass, sea bream, but sole, meagre and turbot all projected for higher production rates.

The production technology will remain based in sea cages, but flatfish species will be produced in land-based systems. It is foreseen that this sector will diversify to produce functional food additives and potentially bio-energy from algae.

Principle conclusions are that juvenile survival (in hatcheries) is predicted to increase by 20% compared to 2012 while food conversion should reduce significantly to 1.2. Cage size is forecast to be 300 m^2 but 20 m deep.

Feed requirements increase by 200,000 tonnes) and juvenile supplies by 1.5 billion).
On this production basis (75 m^3/ton), 1090 hectares of marine space would be needed for new cages (109 hectares). Employment in both production and service sectors should increase by around 8,500 FTE.

The main challenges are effective marine & coastal spatial planning; improving livestock through breeding programmes for the species concerned; disease control & prevention; overcoming climatic challenges and severe weather and ensure that innovation and best knowledge management are applied.

2.1.1.3. Freshwater

The production growth to 2030 is estimated at more than 40%, which is 1.5% per year, and considerably less than for the other sectors.

Trout and carp will remain the core products but diversification towards tilapia, sturgeon, catfish, eels and other species (including perch and pike-perch) will encourage growth for these species above the average for the sub-sector. Technology should contribute to higher survival levels and better food conversion rates.

Trout farming
A separation of trout farming into ‘industrial’ and ‘artisanal’ production is foreseen, with different levels of productivity and target markets but increasingly artisanal (low productivity levels) in nature. While productivity will increase in the industrial sector, higher price values should compensate the artisanal component.

It is the artisanal sector that is forecast to grow most, supplying local markets and sport fisheries, to reach a 45:55 split with ‘industrial’ production that will remain at similar production levels to now. Consequently, an increase of 80,000 tonnes of feeds is forecast alongside a need for 0.15 billion more juveniles. An extra 2,700 jobs should be created in the artisanal sector but 1,200 would be lost in the industrial trout component.

Carp – Extensive pond aquaculture
For carp – or the extensive freshwater sector – it is foreseen that a slight productivity increase would be obtained (improved management, feeds…) but that diversification would give added production and revenue. If environmental services are recognised, this aspect would encourage expansion of pond surface, allowing increased production – where a target of an increase of 22,000 tonnes = additional 27,000 hectares of farm space.

It is anticipated that the European eel management plan will relieve pressure on the use of glass eels for eel farming (mainly in water recirculation systems) allowing a return to previous production levels.

Sturgeon production for caviar will undergo controlled growth – so as to avoid market disturbances – also in water recirculation systems. It is anticipated that technology improvements will contribute to the production of pike-perch and perch, also in controlled systems.

Production will diversify to meet mass and target niche markets, with extensive freshwater farms diversifying their activities to establish new activities. Recognition and expansion of ecosystem services across the sector is also predicted. Employment in both production and service sectors should increase by around 5,200 FTE for this freshwater sector.

<u>The challenges for freshwater pond aquaculture development are to identify and communicate the advantages of this type of aquaculture and its contributions to society; raise productivity of traditional farms and integrate recirculation systems and improved use of farm outputs (effluents); define targets for lesser-known species and overcome complex environmental legislation that is currently hindering development.</u>

2.1.2. Shellfish production

The general synopsis is for production growth of 30% by 2030, meaning an annual growth rate of 1.3%/year. This growth will initially come from and mussels and minor species, while disease-resistant oysters are bred for production purposes.

It is envisaged that demand for EU shellfish products will increase, with the sector being perceived by consumers as being natural, safe and sustainable.

In terms of technology, farms will become integrated and multifunctional and more production will be offshore.

<u>Challenges foreseen in the sector are assuring production in deeper waters, developing disease-resistant stock, having access to clean waters, increasing competitiveness and improving knowledge on pathogens – detection & quantification.</u>

2.1.3. Production of Algae and other species

The production of algae and other species was not the subject of a regional workshop within Aquainnova, and hence no specific growth scenarios were developed for these species.

2.2. National multiannual strategic plans for aquaculture development

A core governance task arising from the European Commission’s Strategic Guidelines for the sustainable development of EU aquaculture, was for Member States to prepare a multiannual strategic plan for aquaculture developments in their countries. The plan should cover the period 2014-2020 with a mid-term assessment produced by 2017. Member States were also encouraged to submit three proposals of good practice (policies, programmes or institutional arrangements, including with respect to the assessment and mitigation of environmental impacts) in their multiannual national plan.

The Commission had hoped to produce a summary report of all national plans by April 2014 but, due to delays in the adoption of the EMFF, this did not happen.

At the time of the finalisation of this study report, and after consultation with the administrations within Member States and with the Commission by the study authors, several Member States have completed their plans, but many have not. Furthermore, those plans that have been completed are not available in English and do not generally contain quantified production estimates or scenarios by species.

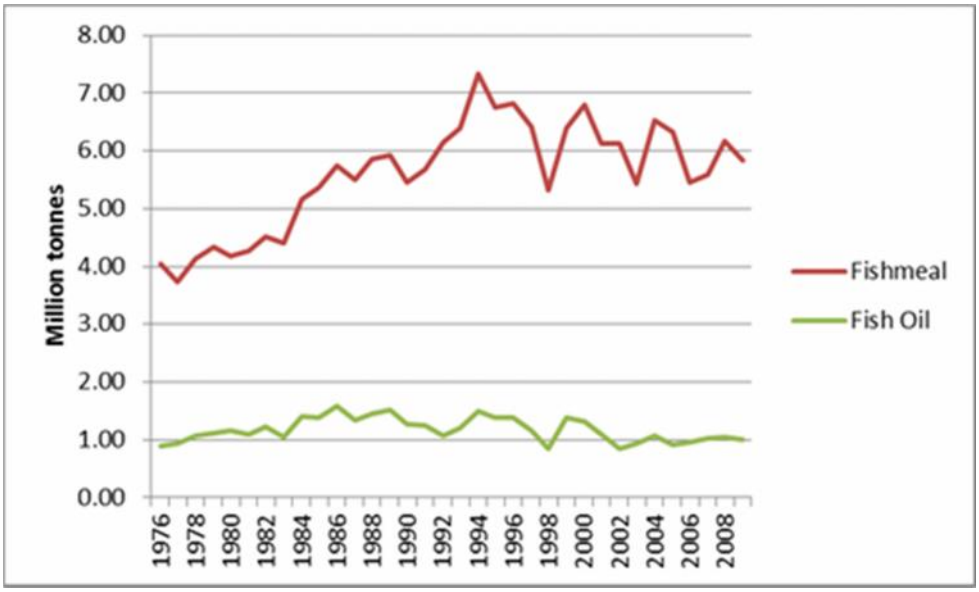
It is unlikely that all plans will be received before October, so this report is based upon the growth scenarios developed by EATiP and described above.

2.3. Protein and oil sources for aquaculture feeds

2.3.1. The use of marine ingredients in aquaculture feeds

Over half of global aquaculture production uses no feed at all. This includes plants and algae, filter feeding bivalves and extensively cultured carp (Tacon et. al., 2011). However, continued growth in aquaculture production and a trend towards intensification and the farming of species that are higher up the trophic ladder has led to an increased use of formulated feed. An estimated 29.2 million tonnes of industrial aquafeed was manufactured in 2008 with a growth rate of 11% per annum (Tacon et. al, 2011). This represented just 4% of global animal feed production, which was 708 million tonnes in 2009. For some countries and species there is also a significant production of farm-made feed which is generally of lower quality. Within Europe, industrial formulated feed is used for most fin-fish aquaculture with the exception of some extensive production of carp and other freshwater species in Central and East Europe and tuna ranching in the Mediterranean, which uses frozen feed fish directly.

Figure 8: Global production of fishmeal and fish oil



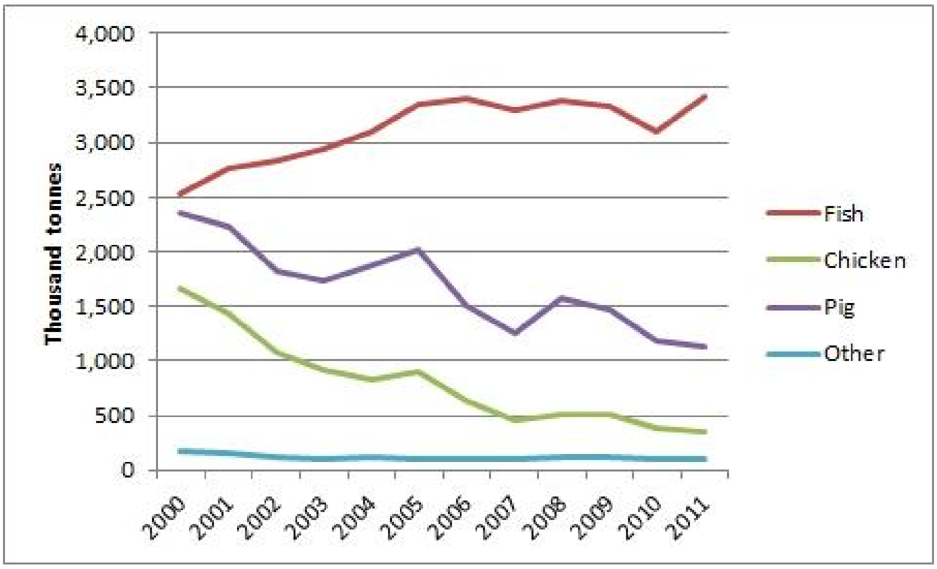
Source: FAO

Figure 9: Fishmeal and soybean commodity prices over past 30 years

Source: http://www.indexmundi.com

When industrial manufacture of fish diets commenced, fishmeal was an obvious key ingredient. It has a very good nutritional profile with all essential amino acids, good digestibility and few problems with anti-nutritional factors (ANFs). By contrast, most plant proteins lack essential amino acids, can have poor digestibility and may contain anti-nutritional factors. It is a biological fact that many fish eat fish in nature. Other animal proteins are intermediate in suitability. Fishmeal was also competitively priced and widely used in terrestrial animal diets. As aquaculture production increased so it took an increasing share of global fishmeal supplies which have not increased substantially over the past 20 years. The rising demand against limited supplies led to prices steadily increasing from 2000 onwards, causing the aquaculture industry to seek at least partial substitution with alternative ingredients such as soybean meal (Rana et. al. 2009).

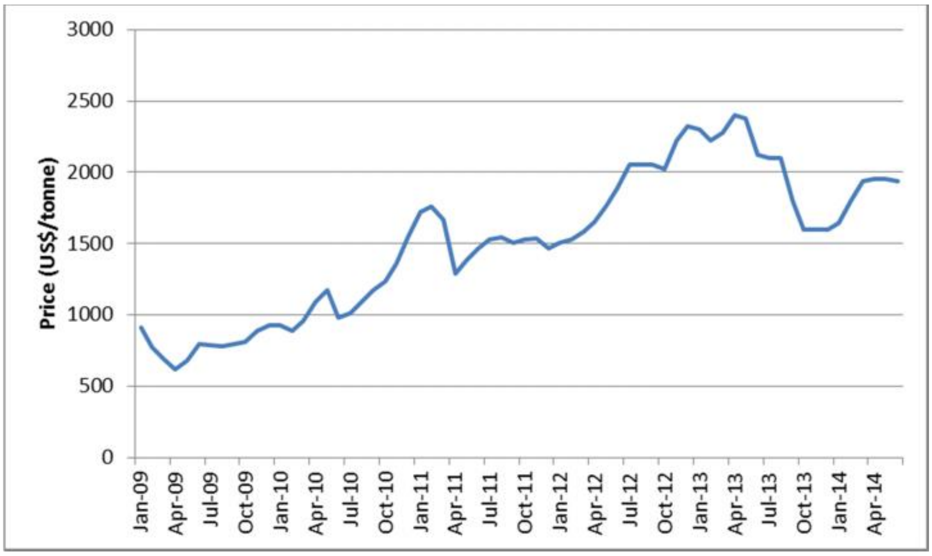
Figure 10: World fishmeal consumption by production sector (2000-11)



Source: IFFO

The consumption of fishmeal by aquaculture appears to have peaked in 2005 when it reached 4.23 million tonnes. This reduced to 3.49 million tonnes in 2008 (Tacon et. al. 2011) and has since fallen to 3.2 million tonnes (Jackson 2012). In 2008 fishmeal accounted for 12.8% of aquafeed by weight, but this is expected to reduce to 4.9% by 2020 (Tacon et. al., 2011).

Figure 11. Fish oil commodity prices since 2009



Source: FAO / Oil World, www.oilworld.de

The situation with fish oil is somewhat similar. For marine fish in particular, there is an essential nutritional requirement for long-chain (Ω-3) polyunsaturated fatty acids which are mainly derived from marine sources (e.g. phytoplankton) and are concentrated up the marine food chain. In the case of salmon, fish oil inclusion rates increased in the 1990s as a means of increasing the energy levels in the diet to allow more of the protein to be utilised for growth. A benefit of this to consumers was very high levels of omega 3 oils in farmed Atlantic salmon. However, fish oil supplies have remained relatively stable at around 1 million tonnes (Figure 8) with up to 81.3% in 2008 (Tacon, et. al. 2011) being utilised for aquaculture and especially salmonids. Increasing demand naturally led to increasing prices (Figure 11) with feed manufacturers looking to use alternative oils particularly as the market for fish oil health supplements for direct human consumption has grown. Partial substitution of fish oil with vegetable oil has proven to be relatively straightforward, but with the loss of some potential health benefits for consumers. Complete substitution is more problematic due to the essential needs of the fish.

Figure 12. Mass balance of marine ingredient production 2010

Source: IFFO http://www.iffo.net/node/464

The sustainability of aquaculture has frequently been questioned on the basis of its utilisation of fishmeal and fish oil, even though the industry has had very little impact on the overall quantity of capture fisheries utilised for fishmeal and oil. Any increase in availability has come through greater use of fish processing co-products.

The efficiency with which this is used in aquaculture has been an issue of controversy. For instance a widely cited indicator is the "Fish-in Fish-Out" (FIFO) ratio. Naylor et. al. (2009) cites a value of up to 5 kg of forage fish per kg of salmon produced. On the other hand, the International Fishmeal and Fish oil Organisation (IFFO) - now called the Marine Ingredients Organisation present data to show a FIFO ratio of 1.7 for salmon (Jackson, 2009), or 1.4 for all salmonids and just 0.3 for all fed aquaculture.

Table 10. FIFO for farmed seafood, 2000 and 2010

Farmed Feed Category	2000	2010
Eels	3	1.8
Salmonids (including trout)	2.6	1.4
Marine fish	1.5	0.9
Crustacea including shrimps & crabs	0.9	0.4
Tilapia	0.3	0.2
Other fed freshwater fish (e.g. catfish & pangasius)	0.6	0.2
Fed Cyprinids	0.1	0.1
Total for fed Aquaculture	0.6	0.3

Source: IFFO (http://www.iffo.net/node/463)

The main reason for the difference in figures is that IFFO allow for the fact that fishmeal and fish oil are utilised separately across a range of species, so calculating the quantity of fish required to supply the fish oil in salmon diets results in a surplus of fishmeal which can be used elsewhere. Furthermore, no account is often taken of the use of processing by-product. Additional adjustments could be made by considering the ratio with respect to edible flesh rather than whole fish. This would also make salmon even more efficient converters as they have a higher flesh yield than most other species. Further accounting refinement should also consider the use of 'processing-wastes' in other aquatic or animal protein production systems.

It is often argued that FIFO ratios above 1 are intrinsically inefficient and a conversion of larger quantities of cheap fish that could be consumed by poorer populations into a smaller quantity of luxury fish for wealthier consumers. This issue was examined by Wijkström (2009) and data summarised into a table by IFFO:

Table 11: IFFO groups of whole fish used for fishmeal and fishoil

Category	Species	Marketability as food	Annual catch for food and feed
Industrial grade forage fish	Gulf Menhaden, sandeel, Atlantic menhaden, Norway pout	No market as food. Fishery would cease if no fishmeal plants	1.2 million tonnes
Food grade forage fish	Peruvian, Japanese, South African, European and other anchovy, capelin, blue whiting and European sprat	Demand often small, localised or niche. Fishmeal plants take what food fish markets cannot absorb	13.2 million tonnes
Food fish rejected by the market	Chilean jack mackerel, chub mackerel & other species of sardine, mackerel & herring	Well established food markets. Landings not in demand for food to for fishmeal and fish oil	6.25 million tonnes

Source: http://www.iffo.net/system/files/FMFOF2011_0.pdf

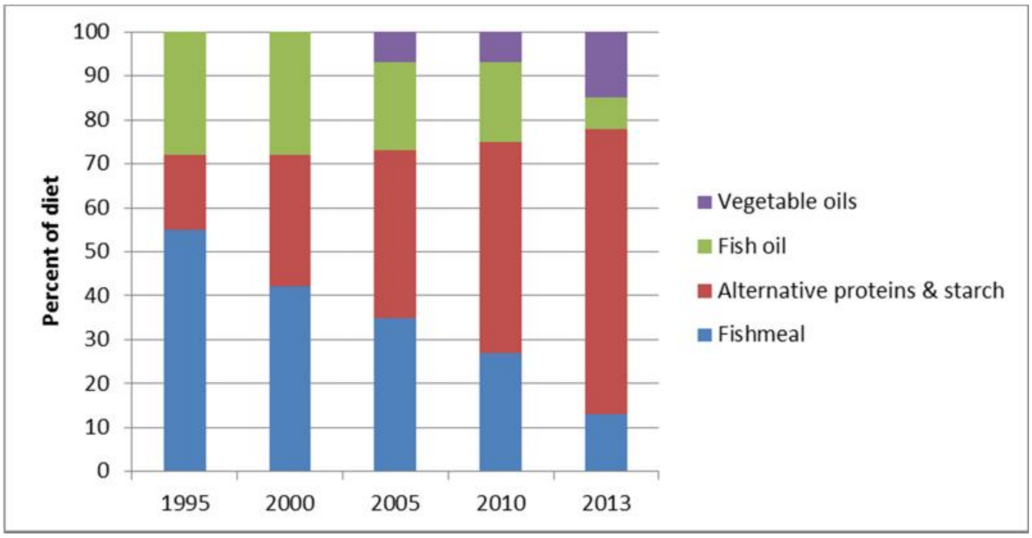
The analysis is complex as it is unrealistic to expect markets will not operate for forage fish as with any other product. There is also the direct economic benefit that is transferred to local communities through engaging in fishing, processing and in some areas also aquaculture. IFFO report that on the basis of the above calculations, there is a net benefit of 7-8 million tonnes of food fish supplied for human consumption through the use of forage fish for fishmeal and oil. A particular issue for Europe is how fishing bycatch that under forthcoming EU regulations must be landed will be utilised as not all will be economically marketable as human food.

A secondary concern that follows from analysis of this market is that rising prices (due to increased demand) encourages unsustainable levels of fishing activity. This has been more of a problem in poorly managed smaller-scale fisheries in Asia than better managed industrial fisheries in Europe and South America, but is clearly an area requiring more work. The IFFO have introduced a Global Standard for Responsible Supply (IFFO RS) and other voluntary certification bodies have standards in place to ensure that fishmeal and oil used in aquaculture come from sustainable sources.

Further perspectives on the use of fishmeal and oil in aquaculture have been provided by Welch et. al. (2010). Firstly they consider the FIFO in the context of natural ecosystems where transfer between trophic levels often involves a simple ratio of around 10 kg consumed for every 1 kg produced. This is actually highly variable, but a FIFO ratio as high as 5 might still be a significant ecological improvement on capturing carnivorous fish from the wild. This assessment can be taken further using the "Primary Productivity Required" (PPR) metric Talberth et. al. (2006). This considers the amount of oceanic primary productivity (photosynthesis and upwelled nutrients) needed to support the food web that ultimately produces fish. Carnivorous fish require an order of magnitude more primary productivity than smaller forage fish. Welch et. al. (2010) show that using this analysis, aquaculture is more ecologically efficient than commercial fishing for species such as tuna, salmon and cobia. Related factors include the use of bait fish in longline and other fisheries, the issue of bycatch and problems with habitat destruction linked with the use of certain fishing gears.

A detailed review of the European fishmeal and fish oil sector was carried out in 2003 for the European Parliament (European Parliament, 2004).

Figure 13. Changing composition of salmon feeds over time with substitution of fishmeal and fish oil



Source: Redrawn from http://www.iffo.net/node/464

The use of fishmeal and fish oil in aquaculture raises a number of complex issues. Whilst on some evidence it appears to be an ecologically efficient means of high quality aquatic food production there is full agreement that this is a finite resource and that expansion of aquaculture will require adaptation of diets and related systems. This is indeed the case, with salmon diets in particular having undergone substantial change since 2000 (Figure 13).

2.3.2. Fishmeal substitution

The practicality of substituting fishmeal in aquaculture diets varies considerably with species and developmental stage. There are usually multiple objectives such as ensuring a correct protein to energy ratio, consideration of the physical characteristics of the resulting extruded pellet and ensuring all the essential nutrients are present and balanced. Fishmeal has many advantages being high in protein with the correct balance of essential amino acids, good digestibility and no anti-nutritional factors. Potential ingredients for fishmeal substitution include:

Table 12. Alternative protein and oil sources

Animal	Plant
Animal by-product meals:	Oilseed meals:
Meat meals	Soybean
Meat & bone meals	Rapeseed
Blood meals	Cottonseed
Hydrolysed feathermeals	Cereals:
Poultry by-product meal	Maize
Cultured organisms:	Wheat
Insect meal	
Worm meal	

Animal proteins are generally high in protein although may have a sub-optimal balance of amino acids for fish nutrition. However, by mixing different protein sources, a more suitable diet can be formulated. Animal by-products were commonly used in early aquaculture diets, however, the BSE crisis, matched by the subsequent dioxin contamination scandal, brought close attention to the livestock feed industry resulting in the banning of certain raw materials (processed ruminant proteins) as permitted feeds within the EU. Strict legislation was applied to all feed manufacturers with a gradual adaptation as scientific research provided much-needed answers. The basic rule is that processed animal proteins (PAPs) from one species cannot be fed to the same species and ruminant proteins are excluded. Fishmeal is excluded from this ban, being considered safe. Non-ruminant PAPs are permitted for use in fish feeds, such as poultry and porcine PAPs, since 2012 (European Commission, 2013).

There are many advantages to using PAPs in fish feeds, having strong environmental and nutritional credentials, complemented by high availability. It is estimated that there is 10 times more PAPs than fishmeal. Nonetheless, suspicion and reticence mean that certain retail chains and consumer organisations do not condone the use of PAPs and opinions differ between different EU States. Recent work by Hatlen et. al. (2013) found porcine blood meal to be an effective partial substitute for fishmeal in diets for Atlantic salmon and cited other work indicating potential health benefits in terms of preventative effect of cataracts through higher levels of histidine. However, in addition to potential health concerns, the use of porcine blood meal could compromise the market for Atlantic salmon to Halal, Kosher and other consumers avoiding porcine or other mammal meat ingredients. The use of insect or worm meals in aquaculture has received some attention, particularly where these animals can be used to process waste materials from other industries or food processes. An EU FP7 project "PROteINSECT" is investigating two species of fly larvae cultured on organic waste for instance, and a linked UK DFID (Agri-TT) project 'Ento-Prise' is exploring commercialisation options with tilapia producers. Both the technical and economic viability of this approach remain to be confirmed, but represent an interesting avenue for future development.

The primary approach to substituting fish protein is currently the use of vegetable proteins. Depending on the plant these pose a range of challenges. In general they have lower protein concentrations and can lack, or have very low levels of some essential amino acids. Poor digestibility (e.g. linked with high fibre content) can also reduce nutrient availability. Plant ingredients can also contain a variety of anti-nutritional factors which can reduce the availability of other nutrients in the diet.

Table 13. Anti-nutritional factors in some vegetable feedstuffs

Feedstuff	Anti-nutritional factor
Wheat	Pentosans
Barley	β-glucans
Soybean meal	Trypsin inhibitors (glycinin, β-conglycinin) lectins, saponins, oligosaccharides (raffinose, stachyose), phytin
Rapeseed meal	Glucosinolinates, tannins, phenolic acids, fiber
Sunflower meal	Fiber, tannins
Peas	Lectins, tannins, oligosaccharides, fiber
Lupin	Alkaloids, fiber, NSP

Source: Charlton 1996

However, increasing sophistication of processing methods can improve the nutritional profile. This has most notably been the case for soybean which can only be used for partial substitution of fishmeal in its standard format, but which can almost fully substitute for fishmeal once processed to a protein concentrate. Dietary inclusion of enzymatic supplements targeting ANFs can also increase utilisation of otherwise unavailable nutrients.

Table 14. Composition of soybean products (as fed basis)

Soybean	Dehulled Meal	Heated full-fat Soybean meal	Soy Protein Soybeans	Soy Protein Concentrate	Soy Protein Isolate
Metab. Energy, Mcal/kg	3.382	3.294	3.938	3.5	3.56
Crude protein, %	43.9	47.7	37.6	64	85.8
Fat, %	1.24	1.52	20.18	3	0.6
Fiber-NDF, %	9.52	5.28	10	-	-
Fiber-ADF, %	6.66	1.1	6.17	-	-

Source: Cromwell, 2012

Substantive research on alternatives to fishmeal use in European Aquaculture is ongoing through the EU FP7 RTD project "ARRAINA" (Advanced Research Initiatives for Nutrition & Aquaculture), which follows on from RAFOA (Research on Alternatives to Fish Oil in Aquaculture) and PEPPA (Perspectives on Plant Protein use in Aquaculture) (Both FP5 projects). Avenues of investigation include the identification and development of new crops for aquafeeds, diet supplementation with synthetic amino acids, and the use of enzymes, pro- and pre-biotics and feed attractants. Attention must also be given to health and welfare aspects of diet formulations particularly when using feeds that are substantially different to those the species would normally encounter in nature. For instance, full fat soybean meal has been associated with intestinal damage in salmon and trout due to allergic response to soy allergens (Dersjant-Li, 2002). This has been partially overcome through the use of soy protein concentrates in which levels of these anti-nutritional factors are much reduced.

There may also be some health benefits to greater use of vegetable proteins, as reported by Brinker & Reiter (2011). Research is also examining the role of different bacteria within the digestive tract as it has been found that this changes with the use of different feed ingredients and may play a role in the inflammatory response noted to soy and other plant-based ingredients (Heikkinen et. al. 2006). The inclusion of a pre-biotic (mannan-oligosaccharide) has been found to ameliorate this effect (Green et. al. 2013). The selective breeding of plants for lower concentrations of antinutritional factors and greater protein digistibility is also possible (Davis, 2012), or supplementation of plant protein with purified amino acids (e.g. Salze et. al. 2010). There are also environmental implications as changes in both diet formulation and process methods can affect the balance and amount of carbon or nutrient discharges (Lund et. al. 2011).

2.3.3. Fish oil substitution

Vegetable oils are readily available for inclusion in fish diets and are lower cost than fish oil. There has also been some interest in using poultry oil which is also cheaper and readily available (Hatlen et. al., 2013). Some substitution in salmon diets is now routine, except for specialist (e.g. Label Rouge) products. <u>It is also possible to use higher levels of vegetable oils during the early rearing phase and increase the proportion of fish oils towards the end so that the final product has higher concentrations of long chain omega 3 polyunsaturated fatty acids</u> (LC-n3-PUFA) such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (e.g. Thanuthong, 2011).

Research is focusing on identifying alternative sources of LC-n3-PUFA. As these originate in marine microalgae, consideration has been given to the commercial culture of such algae and subsequent extraction of lipids (Adarme-Vega et. al. 2012; Martins et. al. 2013). The potential for this is now also of great interest for biofuel production and significant commercial investment. However, there are considerable technical and economic challenges to large-scale culture and harvesting systems, so production is so far limited to high-value, low-volume food supplements and nutriceuticals (Darzins et. al, 2010; Griffiths et. al. 2011). This does include one U.S. company (Martek Co.) which produces biomass through heterotrophic fermentation (using sugar based nutrients in the dark) rather than autotrophic photosynthesis. A potentially more efficient process would be the use of genetically modified bacteria in similar fermentation systems as tested by Amiri-Jami & Griffiths (2010).

In the marine ecosystem, microalgae is often consumed by zooplankton, so these would represent an intermediate target source for LC-n3-PUFA. Most feasible to harvest are krill (order Euphausiacea) which can often be found in large concentrations, most notably the Antarctic krill (Euphausia superba). The total biomass of this species is estimated to be 379 million tonnes which can be compared with an estimated 128-470 million tonnes of consumption by predators (Atkinson et. al., 2009). There is an allowable fishery of up to 5 million tonnes of this species which is currently underexploited, with some product currently processed for use in aquaculture hatcheries. The main technical constraint with respect to krill is a high concentration of natural fluoride in the shells which limits direct inclusion in diets and contaminates extracted oils. More sophisticated processing technologies would be needed to be overcome this. More generally, the importance of krill in the food chain for key Antarctic species such as whales, seals and penguins as well as fish and squid raises ethical concerns over industrial exploitation (e.g. Vermeulen, 2013). Taking one step further up the food chain, there is increasing evidence of large stocks of mesopelagic fish which live at depths of between 200 and 1000 m. There could be between

1 and 10 billion tonnes (Kaartvedt et. al., 2012), although efficient technologies for exploitation are currently poorly developed. The ecological significance of these fish, particularly with respect to oceanic carbon and nutrient cycles needs further research before the implications of industrial exploitation can be predicted (Irigoien, et. al., 2014).

Researchers are exploring the potential for different oil seed crops to provide the necessary lipids for aquaculture species (e.g. Miller et. al., 2008). Most promising appears to be the potential for genetically modified crops. Rapeseed for instance contains some omega 3 lipids (alpha-linolenic acid), but does not naturally produce the more elongated and desaturated omega 3 EPA and DHA. Monsanto has a GM soy oil containing stearidonic acid, which is a step closer to EPA and DHA (EWOS, 2013). More recently Camelina sativa (false flax) has been modified to include genes from microalgae to produce EPA and DHA levels comparable with fish oil (Ruiz-Lopez et. al., 2014). The modified Camelina oil is now being tested in Atlantic salmon diets (BBSRC, 2012). A genetically modified yeast which produces EPA is also being commercialised in Chile (Xue et. al., 2013; Gunther, 2013). Whilst the use of such products in Europe may face regulatory and consumer acceptance obstacles, the potential benefits deserve greater consideration.

2.3.4. Ecological implications of aquaculture feeds

Analysis of the sector by Tacon et. al. (2011) using data up to 2008 found that whilst aquafeed is a minor segment of the global animal feed market, it is a major consumer of fishmeal and fish oil (63% and 83% respectively). Although as discussed earlier, the use of fishmeal and fish oil sourced from industrial capture fisheries in aquaculture feeds is declining, both in relative and absolute terms due to economic factors and technical advances. Significant progress is also being made to ensure the sustainability of such fisheries (e.g. IFFO RS).

Table 15: Comparative summary of feed inputs

	All Aquaculture	EU aquaculture
Industrial aquafeed production (tonnes per annum)	29,200,000	771,050
Aquaculture feed as a percentage of all animal feed	4.12%	0.11%
Annual quantity of fishmeal used (tonnes)	3,720,000	192,760
Percentage of global fishmeal utilized	63%	3.26%
Annual quantity of fish oil used (tonnes)	782,000	78,200
Percentage of global fish oil used	83.1%	8.13%
EU fishmeal production (tonnes)	(203,000)	
EU fishmeal production as percentage of aquaculture fishmeal utilisation	5.5%	105.3%
EU fish oil production (tonnes)	(85,000)	
EU fish oil production as percentage of aquaculture fish oil utilisation	10.9	108.6
Estimated total soy bean meal utilised (15% inc.)	4,380,000	115,658
Percentage of global soy production utilised for aquafeed	2.6%	0.07%
EU soybean meal production (tonnes)	(10,000,000)	
EU soybean meal production as percentage of aquaculture soybean meal utilisation	228%	8646%
Land area used for soya production for aquafeed (ha)[8]	2,168,746	57,268
Water footprint (total) for soya production for aquafeed (m^3)[9]	10.95 billion	289 million

Source: Developed from Tacon et. al. (2011); Thoenes (2006); Ercin et. al. (2011)

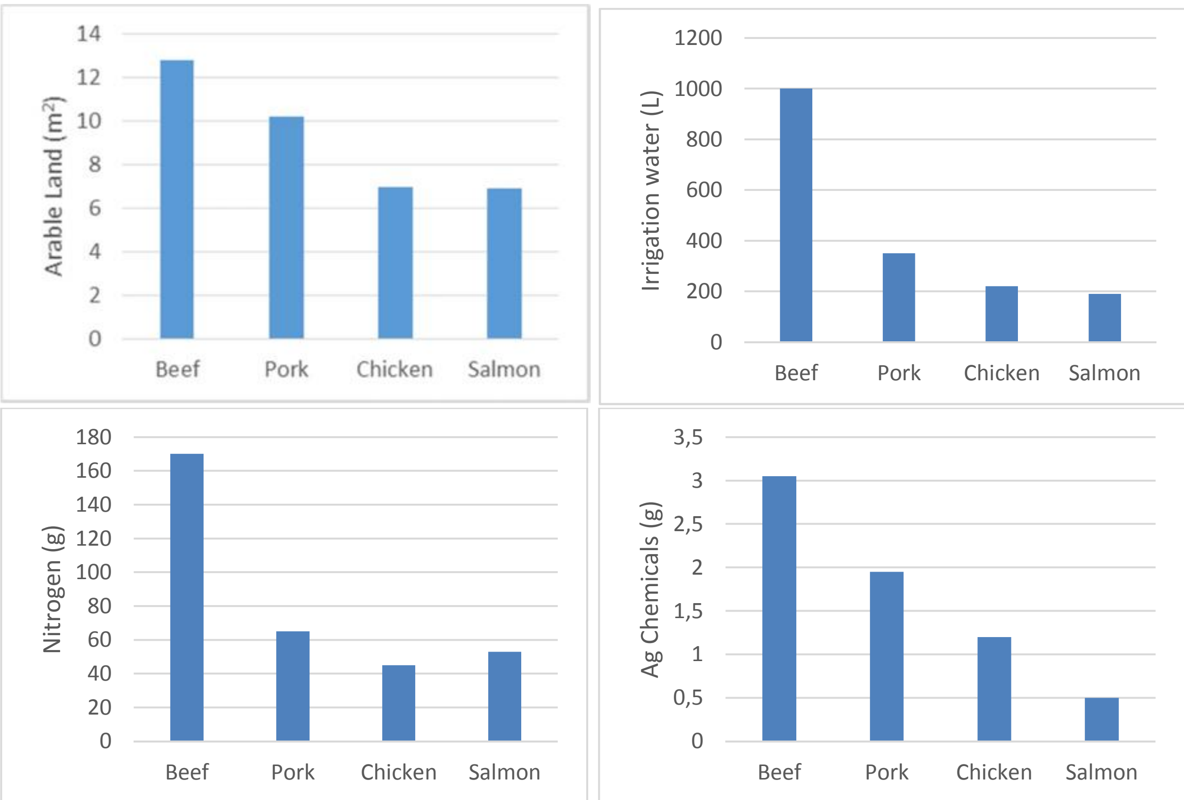
[8] Assumes soybean meal yield of whole soyabean is 79.2% (http://ussec.org/resources/conversion-table/)
[9] Based on definition by Hoekstra et. al. (2011)

The EU consumption of fishmeal and fish oil for aquafeed is estimated to be around 3.3% and 8.1% of global use for aquaculture respectively. For both commodities, EU production exceeds the amount used by the EU aquafeed industry. Since the EU imports 2.6 times as much aquaculture produced fish and crustaceans than it produces (EUMOFA, 2014), it is the EU fish consumption patterns and production practices outside the EU which will most affect the aquaculture related demand for fishmeal and oil. In particular, 47% of the fed imported aquaculture produce is due to salmonids, for which Norway would be the leading exporter.

If aquaculture feeds are increasingly sourced from terrestrial rather than marine materials, this will have implications for land and freshwater requirements, with consequential issues for biodiversity and other environmental impacts. Considering soybean as the second most utilised source of protein and oil, European aquaculture currently uses only around 1.1% of European production, or 0.07% of global soybean meal supplies. However, based on global averages, this requires a cultivated land area of around 57,000 ha and has a water footprint of around 290 million cubic metres.

The resource use of aquaculture in comparison with livestock was considered briefly by Welch et. al. (2010), with the conclusion that salmon is highly competitive for instance with beef and pork, and on balance more efficient than chicken.

Figure 14. Comparable resource use per kg of edible beef, pork, chicken and salmon



Source: Welch et. al., 2010

There has been a recent increase in the number Life Cycle Analysis (LCA) studies investigating global environmental impacts of alternative allocation decisions linked to aquaculture with industry collaboration. A broader examination of the environmental impacts of plant vs fishmeal based salmon diets was carried out by Boissy et. al. (2011) using Life Cycle Analysis (LCA). They found the geographic sourcing of feed ingredients to be more important than the balance between fish-based meal and oil and vegetable-based ingredients for indicators such as water use, eutrophication, climate change and cumulative energy demand.

2.4. Ecological impact of current and future production technologies

2.4.1. Definitions and approach

Ecological assessments are by their nature very complex, so it is important to state here that the approach used here is a substantial simplification, but one that aims to make more readily accessible the key issues for the purposes of high level policy debate.

A formal process of Ecological Impact Assessment (EcIA) is often incorporated into Environmental Impact Assessments as required by Directive 2011/92/EU of the European Parliament and the Council (13/12/2011). The basis for this was set out by Treweek (1999) and is placed in the context of marine and coastal development by IEEM (2010). The assessment of ecological impact is considered to be a process that includes the following stages (IEEM, 2010):

- scoping, involving consultation to ensure the most effective input to the definition of the scope of an EcIA (in practice, scoping is iterative throughout the EcIA process);
- identification of the likely zone of influence, which may vary during the whole lifespan of the project;
- identification and evaluation of ecological features, resources and functions likely to be affected by the project;
- identification of the drivers of biophysical changes attributable to the project;
- identification of the biophysical changes attributable to the project that are likely to affect valued ecological features and resources;
- assessment of whether these biophysical changes are likely to give rise to a significant ecological impact, defined as an impact on the integrity of a defined site or ecosystem and/or the conservation status of habitats or species within a given geographical area, including cumulative and in-combination impacts;
- refinement of the project to avoid or reduce identified negative impacts and incorporate mitigation measures and/or compensation measures for any residual significant negative impacts and ecological enhancement measures to improve the wider environment;
- assessment of the ecological impacts of the refined project and definition of the significance of these impacts, including cumulative and in-combination impacts;
- provision of advice on the consequences for decision making of the significant ecological impacts, based on the value of the resource, feature or function; and
- provision for monitoring and following up the implementation and success of mitigation and compensation measures and ecological outcomes, including feedback in relation to predicted outcomes.

From this, it can be seen that ecological impacts can only be assessed within specific contexts that include consideration of geographic location and scale, as well as temporal factors. The aim here therefore is to identify potential drivers of biophysical change and suggest indicators that could be used to help determine their potential significance in relation to the range of aquaculture species and technologies that are used or likely to be used.

The process of ecological impact assessment tends to imply that the technology is designed to meet other objectives (e.g. economic) and consideration is then given to either whether or not its deployment is justified in an ecological context, or how it might be modified to accommodate ecological concerns. Whilst this may normally be the case, a good deal of work has been done in the area of aquaculture to turn this around and consider the ecology and ecosphere first and design aquaculture systems that best utilise or complement ecological systems and processes. This is particularly set out by the UN FAO “Ecosystem approach to aquaculture” (FAO, 2010): “An ecosystem approach to aquaculture (EAA) is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological systems.” Important points here are that ecosystems include humans and again that this is a process that must have stakeholder participation as the base of the strategy.

The core ideas underlying the ecosystem approach are (FAO, 2010):

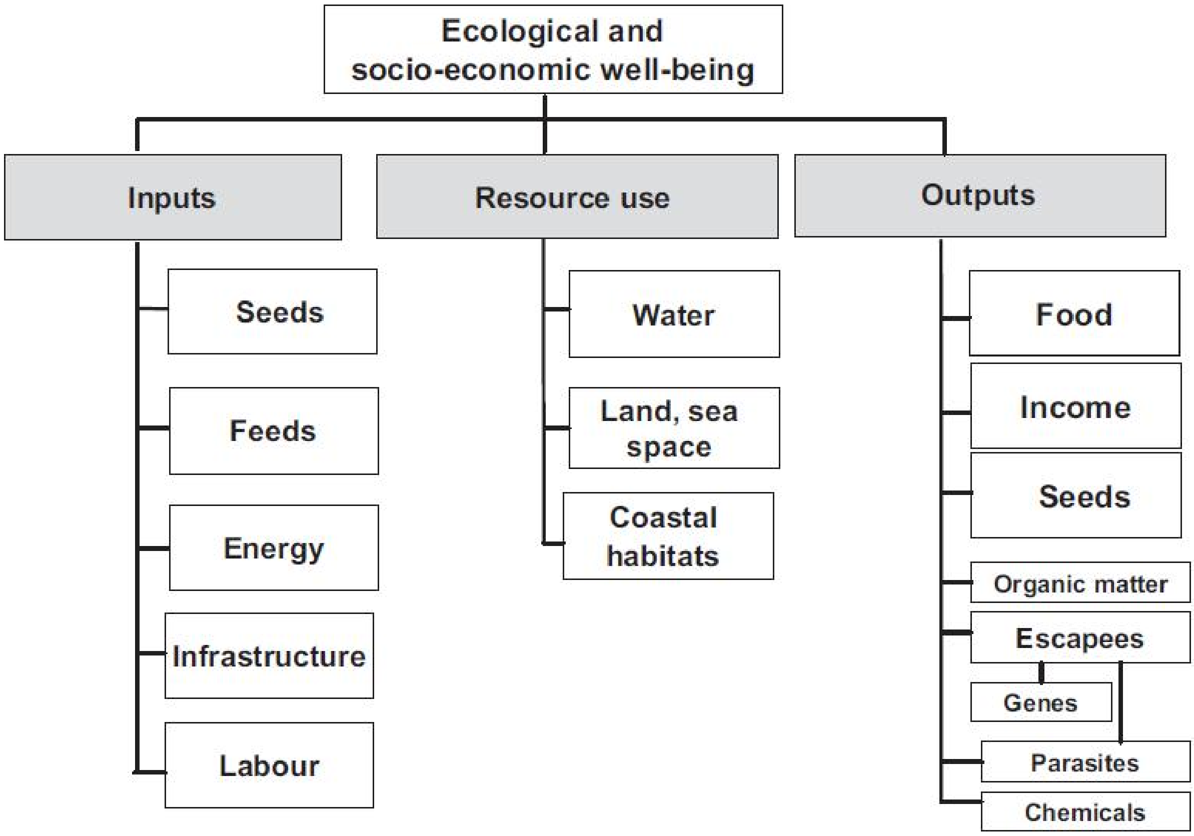
- Humans are an integral part of important ecosystems and people should be at the centre of biodiversity management. This implies the need for integrated, participatory approaches in the identification of issues and further in to “ecosystem” management
- ecosystems provide services that underpin most human activity, and that we need to ensure that we do not threaten the sustained delivery of these services through damage to ecosystem functions
- given our ignorance of the functioning of these highly complex systems, there is a need for a precautionary and adaptive approach
- some activities threaten or reduce the quality of the ecosystem services available to society at large and therefore represent a cost that should be accounted for or internalized
- waste products from one activity or sector may serve as inputs to another, thus enhancing productivity and reducing pressure on ecosystem functions and services
- ecosystems function at a range of scales from highly local to global, and we therefore need a “nested” approach with different approaches to management according to scale
- there is a need for analysis and understanding of the broader social, economic and environmental implications of meeting targets and for transparency of decision-making in relation to trade-offs between social, economic and environmental objectives.

Another important perspective at this stage is that aquaculture increasingly sits within complex global value chains and that ecological impacts at the production site are only part of the total ecological interaction which includes everything from the farming and processing of aquaculture feed ingredients to human consumption of final products and the disposal or recycling of wastes that causes. This raises the theoretical possibility that greater impacts from aquaculture farms might be justified on the basis of reducing more significant impacts elsewhere in the value chain. Although focused mainly on energy use and carbon production, Life Cycle Analysis (LCA) is providing useful insights into potential whole value chain impacts (e.g. Henriksson et. al., 2014). Potential frameworks for evaluating ecological impacts of different aquaculture systems are considered in Annex 1.

2.4.2. Identification of appraisal criteria

The aim in this study was to identify appraisal criteria for drivers of biophysical change relevant to different types of European aquaculture species and systems and how they may be used to better inform policy decisions relating to support for aquaculture development. The first step is consideration of the main sources of impact/ecological interaction within aquaculture production systems. An initial analysis was offered by FAO (2010) as shown in the figure below.

Figure 15: Schematic tree to identify issues of the ecological and socio-economic nature related to different parts of the aquaculture production process



Source: (FAO, 2010)

This basic framework is used, although with greater focus on ecological interactions. The purpose of the analysis is to help distinguish between different types of aquaculture system and practice and also to better understand the ecological impacts within the wider reference frame of food production. Indicators are therefore suggested within each category with the aim of maximum utility in different contexts. As with the EAFI described in Annex 1, two or more levels of analysis can be carried out depending on the data available or the geographic context.

Table 16. Ecological impact - key issue identification

Type	Category	Issues
Inputs	Seed	The main ecological issue is whether seed is sourced from full-cycle hatcheries with captive broodstock or if production is reliant on wild seed, wild juveniles or wild broodstock. The use of imported non-native species could also be a concern.
	Feed	The major concern to date has been the use of fishmeal and fish oil from industrial fisheries in aquaculture diets. The use of terrestrial ingredients is increasing, but this also has implications for greater land use (possible loss of biodiversity) and freshwater consumption.
	Energy	Primary concern is use of non-renewable 'fossil' fuels and secondary impact implications

	Infrastructure	More sophisticated culture systems require greater infrastructure (power supplies, roads, communications, buildings and facilities) which have localised impacts or indirect impact through material sourcing etc.
	Labour	Generally considered a positive – labour is required for aquaculture production. Usually this is helping to sustain coastal and rural populations, but could be a driver for localised growth and hence housing and associated infrastructure.
Resource Use	Water	The major concern is freshwater consumption where this supply for alternative uses is limiting. Care is needed in defining and measuring this as consumption by aquaculture itself is minimal, but in some systems (e.g. ponds) there can be losses due to seepage and evaporation. A more significant issue can be the degradation of water quality, linked with the nutrient outputs discussed below.
	Land, sea, space	Aquaculture installations require space on land and/or in other aquatic environments. The area requirements are linked to the intensity of production and overall production quantities. This will have implications for the local ecosystem and habitats and other resource users.
	Habitats	Habitats that may be directly affected by aquaculture developments may already be considered degraded and of little conservation value, or may be of high conservation interest. The zone of effect of any aquaculture development also needs to be taken into account.
Outputs	Food	Aquaculture products are generally high quality food with good protein content and potentially high levels of beneficial omega 3 fatty acids, although increased use of terrestrial oils in intensive fish diets is likely to reduce this benefit. There will be population level health benefits from increase aquatic food consumption.
	Income	Income from aquaculture activities will provide economic benefits at individual, community and national levels.
	Seeds	Some aquaculture operations may output seed to other producers, or for use in culture based fisheries or wild stock enhancement.
	Nutrients	Unless captured within the system, most aquaculture operations discharge suspended organic solids, dissolved organic matter and dissolved inorganic nutrients into natural waters, promoting eutrophication
	Escapees	Failures in containment systems can result in escapees that may interact with wild populations in various ways; competing for food and habitat resources or interbreeding and altering the genetic profile of natural populations
	Disease and parasites	Farmed aquatic animals that become infected with a disease or infested with a parasite (usually originally from wild species) can become a reservoir for the disease agent, promoting further infection of wild populations
	Chemicals	Chemicals used for hygiene purposes or as therapeutic agents against parasites and disease can be released into natural waters with potential ecological impacts.

From this initial assessment of issues, a more detailed list of potential indicators was drawn up to combine discrete category type assessments (i.e. whether seed comes from a full-cycle hatchery or not) and full variables calculated from available data, such as the quantity of nutrients discharged per unit of production. Applying these indicators to individual aquaculture species and system combinations allows a clearer identification of which systems are most associated with which types of ecological impact, and the types of impact that will be most affected by projected growth in the aquaculture sector. The full list of potential indicators is shown in Annex 2.

From this a simplified matrix was prepared using a five point ranking scale on key issues (Table 17 below) where one star = none or negligible impact and five stars = most significant impact. This helps to identify the key ecological issues associated with particular systems and species. The systems were then ranked by expected growth in production and associated ranked ecological issues (Table 18). This shows over 60% of the expected increase in production to come from three marine system types and 90% to come from six systems including two freshwater.

On this basis the most significant issue is the use of feed and issues relating to sourcing raw materials. Other ecological impacts are more significant in freshwater and inshore marine locations.

Table 17: Ecological impact assessment matrix (ranked by overall impact rating)

System	Major Species	2012 production	1) Reliance on wild seed	2) Reliance on feed	3) Use of fishmeal and oil	4) use of power	5) Infrastructure requirements	6) Freshwater footprint	7) Area/t production	8) Habitat impact	9) Nutrient discharge	10) Escapee impact risk	11) Disease spread risk	12) Chemical discharge	13) Protein input/output
Marine small cage systems – sheltered	Sea bass, sea bream, trout	113,420	+	+++++	++++	++++	+++	++	++	+++++	+++++	+++++	+++++	+++++	++++
Intensive FW flow-through	Trout	169,285	+	+++++	+++++	++++	++++	+++++	++	++++	+++++	+++	++++	+++	++++
FW small cage	Trout	250	+	+++++	+++++	+++	++	+++	++	++++	++++	++++	++++	++++	++++
Marine large cage in exposed sites	Salmon, sea bream, sea bass	264,420	+	+++++	+++++	++++	++++	++	++	++++	++++	++++	++++	+++	+++
Intensive marine flow-through	Turbot & other flatfish	9,520	+	+++++	++++	+++++	+++++	+	++	+++	++++	+++	++++	+++	++++
Coastal pond	Sea bream, sea bass, shrimp,	1,080	+++	+++	+++	+++	+++	++	++++	+++	+++	++++	++++	++	++
FW pond	Carps	86,350	++	++	++	++	++	+++	+++++	+++	+++	++++	++++	++	++
Indoor marine RAS	Sea bass, turbot, sole, shrimp	10,010	+	+++++	++++	+++++	+++++	++	+	+	++	+	+	+	+++
Indoor FW RAS	Tilapia, catfish	9,220	+	++++	++++	++++	+++++	+++	+	+	++	+	+	+	+++
Marine bottom culture	Mussels, cockles	65,440	+++++	+	+	+	+	+	+++++	+++	+	+	++	+	+
Marine supported and suspended	Mussels, oysters	537,050	++++	+	+	+	++	+	++++	++	+	+	+++	+	+

Key to ranking: + = Best (negligible or no impact); +++++ = Worst

Table 18: Systems ranked according to expected growth and associated ecological impact issues

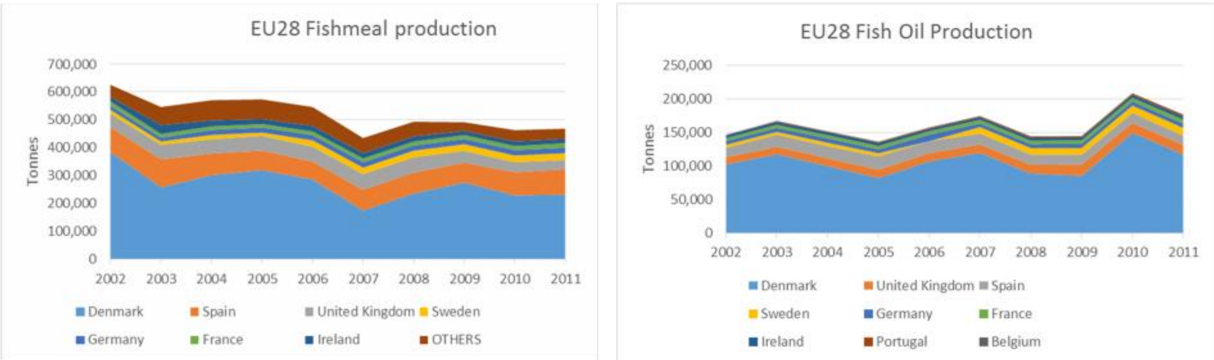
System	Major Species	2012 production	Projected 2030 production	Projected production increment (t)	Cumulative production increase	5 star ecological impact issues
Large cage systems – marine in exposed sites	Salmon, sea bream (sea bass)	264,418	527,940	263,522	31.3%	Reliance on feed Use of fish meal/oil
Marine supported and suspended culture	Mussels, oysters	536,287	679,816	143,529	48.3%	
Small cage systems – sheltered marine	Sea bass, sea bream, trout	112,760	219,370	106,610	61.0%	Reliance on feed Habitat impact Nutrient discharge Escapee impact Disease spread risk Chemical discharge
Intensive freshwater flow-through and partial recirculation systems	Trout	169,078	256,494	87,416	71.3%	Reliance on feed Use of fish meal/oil Freshwater footprint Nutrient discharge
Marine bottom culture	Mussels, slipper shells, cockles	65,444	149,322	83,877	81.3%	Reliance on wild seed Area/t production
Freshwater pond aquaculture	Carps	85,938	153,187	67,249	89.3%	Area/t production
Indoor land-based recirculated aquaculture systems (marine)	Sea bass, turbot, sole, shrimp	9,525	49,236	39,711	94.0%	Reliance on feed Use of power Infrastructure requirements
Indoor land-based recirculated aquaculture systems (freshwater)	Tilapia, catfish	9,221	48,374	39,153	98.6%	Infrastructure requirements
Intensive marine flow-through and partial recirculation systems	Turbot & other flatfish	10,012	20,597	10,585	99.9%	Reliance on feed Use of power Infrastructure requirements
Coastal pond aquaculture	Sea bream, sea bass, shrimp,	1,079	2,247	1,168	100%	
Small cage systems – freshwater	Trout	250	114	-136	100%	Reliance on feed Use of fish meal/oil

2.5. Impacts of an enlarged aquaculture sector on fisheries

2.5.1. EU28 fisheries for fishmeal and oil production

An earlier European Parliament study (European Parliament, 2004) found that 1,524 million tonnes of EU capture fisheries plus 277.000 tonnes landed by foreign vessels and 912.500 tonnes of processing trimmings gave 549.500 tonnes of fishmeal and 140.264 tonnes of fish oil. FAO statistics[10] indicate that EU production of fishmeal has declined over the past decade whilst production of fish oil (all types) has increased slightly. This may indicate improved economics in the recovery of fish oils from processing waste, including that of farmed species.

Figure 16. EU Fishmeal and fish oil production



Source: FAO

Industrial fisheries for feed fish are not recorded separately in fisheries landings statistics as some species are often also sold for direct human consumption. This is particularly the case with herring and to varying extents with other species such as sprats and blue whiting. The proportion utilised for food probably varies significantly from year to year depending on market forces (FAO, 2009). The total EU28 catch of fish potentially used in feed was 1,23 million tonnes in 2012, representing around 28% of the EU catch. Of this, 170.000 tonnes were solely feed fish species and approximately 553.000 tonnes came from mixed utilisation species.

The species used for feed, especially sand eel, sprat, Norway pout and South American anchoveta have relatively short lifecycles so population numbers can rise and fall substantially depending on fishing pressure and other environmental variables. Stocks of anchoveta for instance are well known to be influenced by the periodic El Niño climatic events[11] and stocks of most feed fish species are thought likely to be affected by climate change. This complicates assessment and certification of sustainable fishing pressures. Another factor that has become important for fisheries policy e.g. with respect to European sandeel, is the wider ecological role of feed fish species. Concern that overfishing of sandeel was causing a decline in seabird populations led to the closure of several UK fisheries for this species in 2000 and this has been a continuing priority in the setting of sand eel TACs.

[10] The authors have noted important differences in production data for fishmeal from FAO and data from IFFO. For instance, for 2009, IFFO data for EU countries is 261,800 tonnes whilst FAO data gives 522,997 tonnes (almost double). This is partly due to more countries being included in the FAO data, but there are also differences within countries - Denmark = 181,000 tonnes in IFFO data and 275,804 tonnes in FAO.

[11] E.g see http://www.pfeg.noaa.gov/research/climatemarine/cmffish/cmffishery4.html

Later research has shown more complex environmental interactions, with decline in sand eel stocks potentially linked with climate change and alterations in zooplankton species and abundance (Frederiksen et. al. 2013). Further progress on sustainable management of feed fish stocks can be anticipated as knowledge improves and appropriate management is implemented through regulatory measures and voluntary certification schemes.

Table 19. European feed fish species status

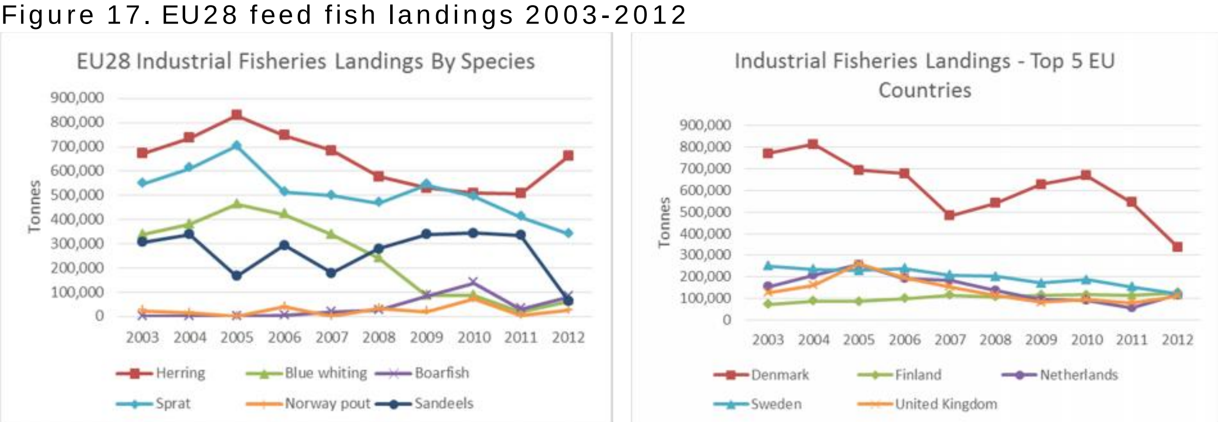
	Species	Catch area(s)	Landings (tonnes, 2012)	TAC/EU quota 2014 and stock status	~ % red-uced*
Feed fish only	Sand eel (Hyperoplus spp., Gymnammodytes spp. And Ammodytes spp.)	North Sea	65.038	207.219/ 207.219 (d)	100
	Norway pout (Trisopterus esmarkii)	North Sea, Kattegat/Skagerrak	25.567	NA/106.250 (d)	100
	Boar fish (Capros aper)	East Atlantic	80.716	127.509/ 127.509 (d)	100
Human consumption and feed fish	Sprat (Sprattus spp.)	Baltic, North Sea and Kattegat/Skagerrak	340.154	182.430/ 422.388 (a) (d)	40
	Herring (Clupea spp.)	Baltic, North Sea, Kattegat/Skagerrak and East Atlantic	660.964	1.203.576/ 782.778 (a) (b) (c) (d)	10
	Blue whiting (Micromesistius poutassou)	North Sea, East Atlantic	62.096	1.200.000/ 218.348 (a)	30

Sources: FAO Fishstat database and European Commission http://ec.europa.eu/fisheries/documentation/publications/poster_tac2014_en.pdf

Key to stock status: (a) fished within sustainable limits; (b) overfished but within safe biological limits or is being managed under a long term plan approved by scientific advice; (c) overfished and outside safe biological limits with either no long-term management plan or scientific advice that there should be no fishing; (d) status of the stock is unknown. Multiple categories indicate that stocks in different fishing areas have different status. *Estimates of percentage of catch reduced to fishmeal and oil from Mallison (2013).

Denmark is the leading EU producer of fishmeal and fish oil (producing over 50%), and also accounts for between 30 to 40% of feed fish species landings by EU vessels.

Figure 17. EU28 feed fish landings 2003-2012

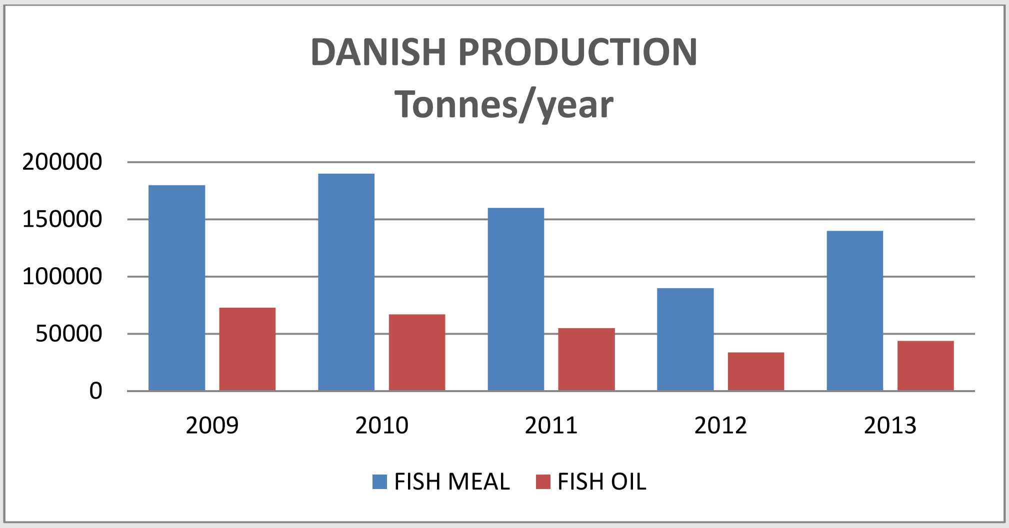


Source: FAO

The decline in EU catch of feed fish species has been balanced to some extent through greater use of processing trimmings. Mallison (2013) from IFFO suggests the proportion has risen from around 16% in 2002 to 65% in 2012. Fishmeal producers in countries such as Spain, France, Germany and Italy are entirely dependent on trimmings (European Parliament, 2004) whilst for Denmark it is around 12-15% (pers. comm. Marine Ingredients Denmark). In the future it is possible that the EU ban on fisheries discards will provide further material for meal and oil production, although the economic viability of this given the geographically dispersed nature of catches remains to be established.

CASE STUDY – DANISH FISH MEAL FISH OIL (FMFO)

Denmark is the seventh biggest fishmeal producing country in the world and the fourth biggest producer of fish oil.



The average Danish production of fishmeal over the 5-year period (2009-2013) is 152.000 t/year. The average production of fish oil from 2009-2013 is 54.600 t/year. Denmark has a very large part of the EU quotas for the principal pelagic species fished for fishmeal and fish oil. The fall in production (2010-2012) was directly related to a fall in quotas, mainly for sandeel. Other EU producing countries include UK, IE, DE, ES and FR.

A major proportion of Danish fishmeal and fish oil is sold to the aqua feeds sector – export goes to more than 60 countries, with Norway the biggest importer. An increasing global trend is noted for fish oil sales for direct human consumption.

The use of co-products for Danish production is at 12-15% of the total production volumes and this has been relatively stable over recent years. FMFO production thus contributes positively to the EU fisheries sector by making full use of the resources and adding economic value to co-products. Some facilities in UK, and Germany produce mainly from co-products (trimmings and off-cuts), but they also take in direct landings.

An important issue for the European FMFO sector is the modalities and logistics of the use of discards or by-catch for production of FMFO. While producers are the potential interested buyers for this potentially important resource, there are as yet no clear modalities and enactment incentives for fishermen and for FMFO producers and this is requested from the European Institutions.

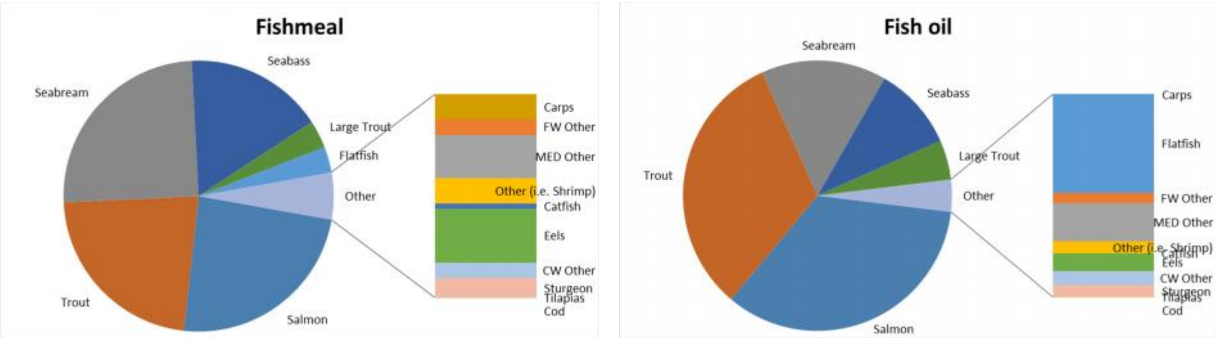
The International Marine Ingredients Association (formally IFFO) Responsible Supply standard is seen by the profession as being the industry B2B 'norm' going forward, but questions are raised as to how this standard will be positioned in the sector against the Aquaculture Stewardship Council (ASC) Feed Standard that seeks to introduce consistency into the way in which the aquaculture feed industry has been asked to address sustainability and social responsibility issues concerning feed.

EU fishmeal, the European Fish Meal and Fish Oil Association, brings together the major production companies within and outside of the EU to share non-quota common-interest issues, including production, quality, energy use, environmental issues and others.

2.5.2. The utilisation of fishmeal and fish oil by the European aquaculture industry

Data presented earlier in this report shows that aquaculture has taken an increasing share of global fishmeal and oil production (68% and 74% respectively in 2012 according to IFFO) although this trend is now reversing as more fish oil is processed for direct human consumption (22% in 2012). Around 70% of fishmeal consumption is accounted for by the four main fed species, salmon, trout, sea bass and sea bream. These species also account for around 80% of fish oil use with salmon and trout using the greater share as shown in the figure below.

Figure 18. Utilisation of fishmeal and fish oil by EU28 aquaculture, 2012



Source: Author estimates based on FAO and IFFO data

Fishmeal and fish oil are globally traded commodities with European producers selling to Asia as well as Europe and European fish feed producers purchasing ingredients from Latin America in addition to European sources. An example of maximum use of marine ingredients is a Scottish salmon diet from 2007 shown in the table below. This comprised 40.5% fish meal, 26.5% fish oils and 33% plant ingredients. A wide range of ingredients were involved, with over 40% of the fishmeal and 35% of the fish oil sourced from Latin America. Whilst the inclusion rates of these ingredients are now much reduced, it is likely that manufacturers will continue to source product widely depending on prevailing availability, prices and quality factors.

Table 20. Scottish salmon diet formulation from 2007

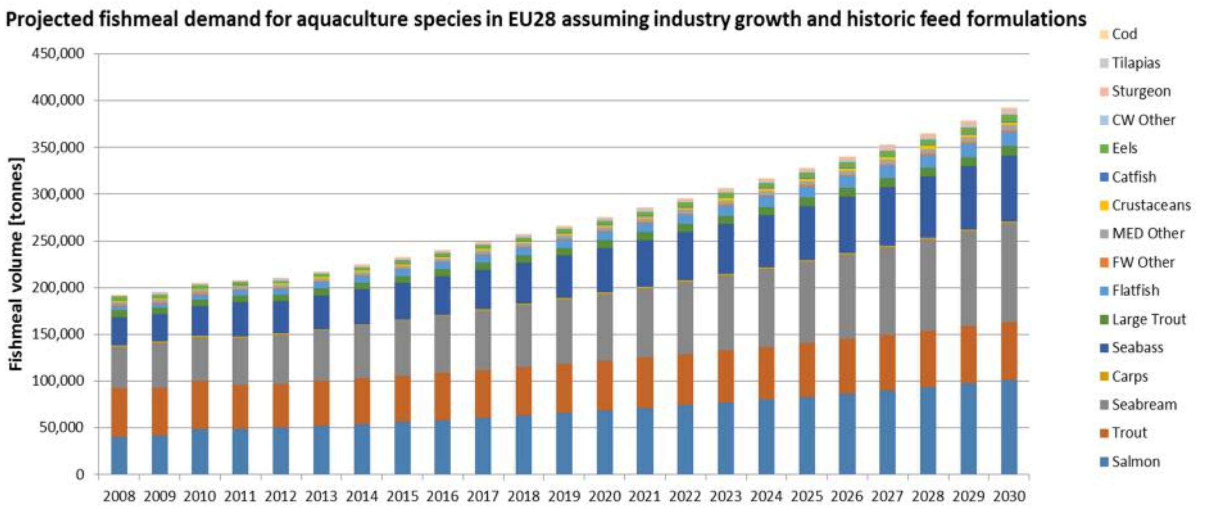
Plant proteins & binders		Fish meals		Oils	
Ingredient	Inclusion (%)	Ingredient	Inclusion (%)	Ingredient	Inclusion (%)
Fava bean	5.1	Anchoveta meal	16.6	Rape seed oil	1.1
Maize gluten meal	5.5	Blue whiting meal	3.8	Anchoveta oil	9.3
Pea protein concentrate	2.8	Capelin meal	0.1	Blue whiting oil	0.6
Soy meal	9.2	Atlantic herring meal	0.4	Capelin oil	0.7
Sunflower meal	2.4	Atlantic herring by product meal	5.1	Atlantic herring oil	4.2
Wheat	5.7	Mixed whitefish meal	9.2	Atlantic herring by-product oil	5
Wheat flour	0.2	Sand eel meal	0.8	Mixed whitefish oil	2.5
Wheat gluten meal	1.4	Sprat meal	4.5	Sand eel oil	0.1
				Sprat oil	4.3

Source: Pelletier et. al. (2009)

2.5.3. Effect of future growth in European aquaculture on demand for raw materials from fisheries

The Authors estimate of fishmeal and fish oil demand by EU28 aquaculture in 2012 is 209.000 and 80.000 tonnes respectively. This is well below the EU28 production of 505.000 and 177.000 tonnes respectively in 2011 (FAO data). However, if there are no future changes in diet formulation and feed efficiency, and aquaculture production increases according to projections in Section 1, there would be a corresponding rise in raw material demand to 392.00 tonnes of fishmeal and 142.000 tonnes of fish oil in 2030. This is still within current EU production.

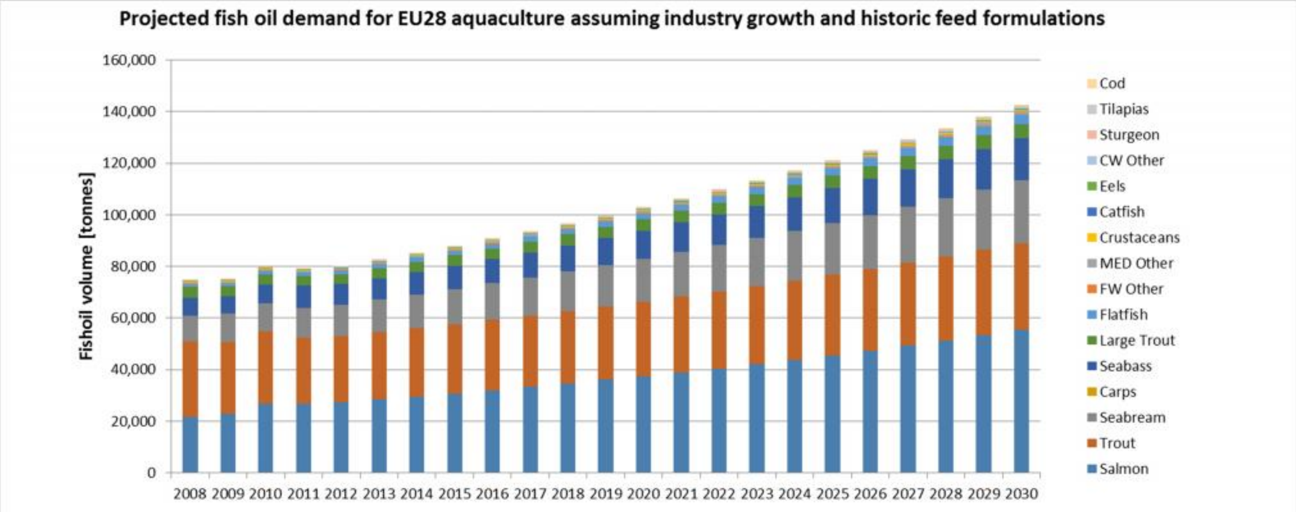
Figure 19. Projected fishmeal demand for EU28 aquaculture assuming industry growth and historic feed formulations



However, based on a conversion rate from whole fish to fishmeal of 20%, <u>and</u> assuming supply only from capture fisheries (i.e. without offcuts or trimmings), this scenario would represent a demand for 1,96 million tonnes of feed fish, which would exceed the 2014 quota (1,86 million tonnes) by 100.000 tonnes.

The same calculation with fish oil leads to a theoretical higher demand for capture fisheries; requiring approximately 2,37 million tonnes in 2030 without allowance for extraction from trimmings and other co-products.

Figure 20. Projected fish oil demand for EU28 aquaculture assuming industry growth and historic feed formulations



In order not to exceed current demand for fishmeal and fish oil whilst continuing to expand the EU aquaculture sector, it will be necessary to reduce fishmeal and fish oil inclusion rates to levels at or below those shown in the table below and, at the same time, increase the use of offcuts or trimmings. This assumes no significant change in feed conversion ratio (FCR), although the scenarios presented in this report do take improvements into account. It should be noted that any need to use sub-optimal ingredients could compromise this.

Table 21. Target fishmeal and fish oil inclusion rates to maintain current raw material demand

	Fishmeal inclusion rates			Fish oil inclusion rates			
Species	2010 (estimated)	2020 (target)	2030 (target)	2010 (estimated)	2020 (target)	2030 (target)	Assumed FCR
Salmon	22%	16%	11%	12%	9%	6%	1.3
Trout	22%	21%	18%	12%	12%	10%	1.3
Seabream	26%	17%	11%	6%	4%	3%	1.9
Carps	2%	2%	2%	0%	0%	0%	1.8
Seabass	26%	18%	12%	6%	4%	3%	1.9
Large Trout	22%	19%	16%	12%	10%	8%	1.3
Flatfish	26%	14%	9%	6%	3%	2%	1.9
FW Other	24%	24%	18%	4%	4%	3%	2
MED Other	26%	26%	17%	6%	6%	4%	1.9
Crustaceans	16%	8%	5%	2%	1%	1%	1.6
Catfish	5%	4%	2%	0%	0%	0%	1.5
Eels	46%	42%	26%	4%	4%	2%	1.5
CW Other	26%	5%	4%	6%	1%	1%	1.9
Sturgeon	24%	11%	5%	4%	2%	1%	2
Tilapias	3%	0%	0%	0%	0%	0%	1.6
Cod	26%	14%	9%	6%	3%	2%	1.9

As discussed in Section 2.3 research and development is leading to these targets being achievable, probably well before the target dates, especially if the use of GM oilseeds and PAPs are more widely accepted, or progress is made with alternative marine ingredients.

The use of discards to produce FMFO is of key importance. A SEAFISH report (Mangi and Catchpole, 2012) concluded that based on the price potential, discards should ideally be used for human consumption and where this is not practicable then bulk uses such as fishmeal or animal feed is the next preferred option. Outlets that may be considered ‘waste’ operations, such as composting and anaerobic digestion, are least desirable.

FARNET report a recently funded EFF Axis 4 FLAG project[12] in Huelva, Spain, where the sea bass/bream aquaculture company Salinas del Astur is producing its own fishmeal from local fish auction waste that was previously incinerated. They now estimate that half of their fishmeal use is now provided by this source, with annual savings of 20k€.

In summary, the projected increase in EU aquaculture has the potential to increase demand for capture fisheries product, although still within the limits of current EU production. However, a combination of economic factors, technology development, better regulation and voluntary industry standards are most likely to lead to changes in diet formulation that at least avoid additional demands on industrial capture fisheries.

2.5.4. Effect of fisheries on aquaculture

The EU market for seafood has shifted from a dominance of self-supply, primarily from fisheries yields, to >65% imports (source: White Fish Study (2013) of AIPCE). EU aquaculture’s share has increased, in spite of stable production.

The main effects of fisheries on aquaculture come from competing species, consumers’ buying preferences being a mix of species choice vs. price, where additional quality criteria (freshness, flesh quality, visual aspect…) are also important factors. For salmon, as an example, salmon from fisheries is marketed as ‘wild’, with promotion of ‘wild’ being better than ‘farmed’; given that wild salmon supplies are now very low volumes, compared to farmed salmon, such influences are now negligible. On the other hand, the major Norwegian investments in cod farming pushed annual farmed levels to over 20.000 tonnes, encouraged by high prices and lower fisheries yields. The recovery of wild stocks led to abundant fisheries supplies and low prices, resulting in virtual total closure of this new farming sector.

Fundamentally, where fisheries can provide significant landings of a particular species, that ‘competes’ with aquaculture produce, the effects will be negative for aquaculture – primarily on a price basis. Where volumes are low, such influences are less evident.
Seabass and seabream farming evolution supported this trend, although fished seabass and seabream have a slightly separate market, due primarily to larger sizes available from fisheries. However, with the aquaculture sector providing larger volumes, the point of sale to the customer can be different (e.g. supermarket vs. fish market). Nonetheless, aquaculture’s products are sold alongside those of fisheries in most outlets.

Turbot represents a success story for EU fish farming, developing slowly but surely, principally in Spain and Portugal. High investment costs restrict entry to this production. Annual production has reached 10.000 tonnes and this sub-sector has avoided the boom

[12] FARNET Project Summary #018-ES08-EN – Fishmeal from fish waste

and bust scenario. As for salmon and other species, the main distinction comes in the sale to the consumer – 'wild' vs. farmed.

In the short-medium term, 3 species are receiving a lot of attention. Tuna, where a range of technical issues remain to be fully resolved; sole is also the subject of investment in aquaculture but has yet to provide significant production levels, although Mediterranean production is increasingly looking as Solea senegalensis as a valid candidate. Since this is visibly different to Atlantic/Dover/Lemon sole, competition with fisheries is less evident.
Finally, pike-perch or Zander is a popular fish in inland EU States, provided principally from freshwater fisheries. Supplies are not large and the species is appreciated, with good high prices. Culture of pike-perch is in its infancy but is unlikely to be affected by high competition with fisheries.

The principle effect on EU aquaculture from fisheries comes from the fisheries dedicated to providing fishmeal and oil, which is described elsewhere. Limitations on these would inevitably push prices up, increasing compound feed prices and hence final production costs.

As a final comment on the interaction between fisheries and aquaculture, the ubiquitous aggregation of wild fish around fish farms as a consequence of the introduction of new habitat and the easy availability of food — fish farms act as enhanced fish aggregation devices (FADs) and this has been widely reported in the scientific literature.

3. PRINCIPAL ECONOMIC CONSIDERATIONS AND PUBLIC SUPPORT TO THE SECTOR

KEY FINDINGS

- France, Greece, Italy, Spain and the UK provide nearly 80% of all aquaculture production.
- While (in number) EU aquaculture is dominated by microenterprises and family firms, certain sub-sectors contain large multi-national companies (marine cold and warm water sub-sectors).
- Of EUR 1.24 billion programmed under EFF Axis 2, only EUR 518 million (43%) had been committed across all Member States in 2011. Delays in implementation included limited co-financing in an unfavourable economic environment, and late launch of the programme, mostly due to delays in validation of the Operating Programmes.
- Specifically under Axis 2, aquaculture represented 27%, inland fishing less than 1% and fish processing and marketing the vast majority with 72%.
- Continued growth in the sector is likely to be linked to proving added value products, developing niche markets and be price-competitive in EU markets.
- Based on our categorisation of the sector by production technology, the predicted increase in the use of these technologies is well balanced, despite the fact that the largest growth is foreseen in the marine sector, with a trend towards the use of large cage systems.
- While the aquaculture profession is looking to improved support services, the EMFF has identified environmental compatibility and improved market orientations as key areas.

This section of the report addresses issues relating to public sector support to the sector, notably though the EFF and adopted EMFF.

Several key indicators and observations on the economic performance of the sector are followed by a summary of EFF spend.

The projected use of aquaculture technologies in 2030 is presented as a table with 2012 data showing the trends in utilisation.

Finally some observations are made concerning where funds should be directed.

3.1. Economic performance of strategic components of the aquaculture sector

The most comprehensive recent review of EU aquaculture is the JRC/STECF 2013 report on ‘the Economic Performance of the EU Aquaculture Sector’ which highlighted specific socio-economic issues concerning the sector. It was based on data of 2011 and used a combination of data obtained through the DCF and the FAO. However, this covered aquaculture more by medium (saltwater fish, freshwater fish and shellfish) than the sector-oriented division of this report.

The following selected observations of the report are supplemented by authors' comments;

- Within the EU (28), the value (sales) of aquaculture was €4 billion for 1.35 million tonnes (fish and shellfish), employing more than 80,000 people; the number of micro-enterprises/family firms, as well as employees in processing/distribution in vertically-integrated companies makes such calculations very difficult.
- France, Greece, Italy, Spain and the UK provide nearly 80% of all aquaculture production, which is increasingly marine and coastal.
- While the sector is dominated in number by microenterprises (family firms) [estimated at 90% by number], consolidation and vertical integration is visible (within marine fish farming).
- Competitive advantage is seen in the presence of a well-educated workforce; as technology and knowledge improves, maintenance/improvement of this position is essential.
- Market expansion for both fish and shellfish is foreseen – both in Europe and elsewhere – but new products should be foreseen from the 'traditional' species so as to adapt to consumer preferences and trends.
- Increasing attention is given to adding-value (for example, through processing or promoting direct retail sales), while prices have recovered since 2010. Profitability appears to have returned, with better returns on investment and EBIT ratios.

3.2. Public support to technologies and/or species

The European Fisheries Fund (EFF) ran over the period 2007 to 2013. With a budget of EUR 4.3 billion (in today's value) 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 EUR 1.24 billion programmed under Axis 2, EUR 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 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 paid 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 MS to be unsuitable and not adapted to the reality in both fin 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 EUR 183 million and a further EUR 538 million of private funding. Hence EUR 1 of EFF funding had a leveraging effect of EUR 1.68.

Based on our categorisation of the sector by production technology (Tables 2-6), and by the outcomes of the consultations within EATiP and directly with the professional sector, the study authors have prepared an estimation on the trends (for 2030) of the use of technologies for each of our production sub-sectors. This is shown in the following table. The arrow indicate the trends (upwards, stagnant and downward).

These estimations are based on expert interviews, reports and the Aquainnova workshop on future scenarios for European aquaculture.

- Productivity/competitiveness drive toward 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 licenses)
- Indoor recirculation systems will increase for hatcheries but less likely for ongrowing (costs of investment, energy costs) due to cost comparison with cage production (Mediterranean and Coldwater production)
- 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 specialised/niche markets (e.g. organic label) where lower intensity demanded
- Freshwater recirculation systems will increase, notably for high-value production (sturgeon, pike-perch) and also for warmwater species that can be produced at high density (e.g. African catfish, eel, tilapia)
- Shellfish production will continue to be dominated by supported/suspended cultivation systems

It should also be noted that an increasingly rising 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 Multi-trophic 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 legal frameworks and licensing conditions need to be elaborated.

Table 22. Trends in prevalence of production technologies

Technology	Estimated 2012 production (tonnes)	TREND in use of technology 2030
COLDWATER MARINE FINFISH		
Coastal pond aquaculture	180	↘
Indoor land-based recirculated aquaculture systems (marine)	100	↗
Intensive marine flow-through and partial recirculation systems (mostly large tanks)	9.180	↗
Small cage systems – sheltered marine	11.000	↘
Large cage systems – marine in exposed sites, using mechanised (automated) systems	190.090	↗
WARMWATER MARINE FINFISH		
Coastal pond aquaculture and valliculture	900	→
Indoor land-based recirculated aquaculture systems (marine)	9.910	↗
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 mechanised (automated) systems	74.330	↗
FRESHWATER FISH		
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)	9.220	↗
Small cage systems – freshwater	250	→
SHELLFISH		
Marine bottom culture (non-fed sedentary and attached animals & plants)	65.440	↘
Marine supported and suspended culture (non-fed sedentary and attached animals & plants)	537.050	↗

Source: Estimated by the authors of this study

3.3. Where should public funding be directed?

The destination of public funding depends primarily on the national strategic plans. The general policy indicator that public funding should be used for the fostering of sustainable, innovative, competitive and knowledge-based EU aquaculture that is socially responsible – following the conditions set out for smart, sustainable and inclusive growth. In respect of this, adequate funding should be set out to achieve the spatial planning so as to allow growth through new site allocations.

The overall EMFF funding is presented here, and it is clear that MS with substantial fisheries sector dominate. No clear estimates are made specifically for aquaculture spend.

Table 23. 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%
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%**
EU27 (*)	**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**	100.0%

** LU is excluded, because it is not a recipient of EMFF.*

Source; DG MARE

The EU profession has proposed that improving support services (e.g. veterinarian and health services) and networks (knowledge/best practice transfer) would be valuable to this purpose. Nonetheless, support to new (young) farmers in productive systems and innovatory investments (e.g. for modern water/waste treatment installations) would also be welcomed.

Overall, the plans put forward in the new EMFF respond to the needs of both producers and society, particularly in terms of environmental compatibility (e.g. conversion to eco-friendly and certifiable operations) and market orientations (e.g. processing and added-value).
Attention should also be given to the updating of skills and knowledge in the aquaculture workforce. New technologies and marketing tools are evident in many sectors and the promotion of life-long learning needs support.

The profession has noted the success of the FLAG initiative (Fisheries Local Action Groups) and would like to see more of this approach embedded in aquaculture development, giving direct promotion to local actions.

The main lines of these positions have been adopted within the new EMFF, which has received formal approval.

4. CRITERIA FOR SUSTAINABLE DEVELOPMENT AND PUBLIC POLICY MEASURES

KEY FINDINGS

- To date, very few Member States have clear policies on aquaculture development, meaning that the CFP remains the overriding central guide.
- Aquaculture is an evident component of many recent and new European strategies, including Blue Growth and the Bioeconomy. Within the reformed CFP, aquaculture should contribute to the Europe 2020 strategy for smart, sustainable and inclusive growth.
- The key issues of the EC Strategic Guidelines for the sustainable development of European aquaculture are addressed in the CFP reform but, in many cases, their implementation is dependent upon national and local motivation and decision, particularly in the case of licensing and spatial planning.
- Assuring the coherence of the multi-annual national strategic plans should provide the basis of these positions, although local authorities, where licencing issues are generally decided, have to be involved in the implementation process.
- The major effects of public policies on aquaculture are related to the environment, alternative water uses, approaches to disease treatment and control and food safety.
- Fundamental challenges for SMEs include the cost and time of obtaining licences, investments in working capital and modernisation, access to skilled employees in remote areas, and having sufficient information to support market strategies and pricing over long production cycles.
- Several policy recommendations have been made, including the need to quantify multi-annual strategies and provide a clearer forecast for the growth of EU aquaculture.

This section looks at public policies and their effects on aquaculture and its development. The core assumption is that policies are defined as serving to provide the rules while strategies identify the means of achieving the policy goals or plans.

Prepared in 1995 by the FAO, Article 9 of the Code of Conduct for Responsible Fisheries[13] covers aquaculture development but is limited to broad principles of responsible development and resource use.

It is important to recognise that very few States in Europe have actually developed specific national policies for aquaculture. A web-search brings up national policies in Africa, India, Canada and Australia but very little information on individual EU Member States. On the other hand, several EU States have developed different national strategies on aquaculture in the last 20 years.

[13] http://www.fao.org/3/a-v9878e.pdf

The core European policy affecting aquaculture is the Common Fisheries Policy which aims to ensure that fishing and aquaculture are environmentally, economically and socially sustainable and that they provide a source of healthy food for EU citizens. The scope of the CFP includes the conservation of marine biological resources and the management of fisheries targeting them. In addition, it includes, in relation to market measures and financial measures in support of its objectives, fresh water biological resources and aquaculture activities, as well as the processing and marketing of fishery and aquaculture products. Therefore, as an overriding European policy, it covers sustainable development – in all aspects – alongside conservation and management measures.

The role of aquaculture in Europe is seen as being a contributor to the preservation of the food production potential, on a sustainable basis, throughout the EU so as to guarantee long-term food security, including food supplies, as well as growth and employment for Union citizens, and to contribute to meeting the growing world demand for aquatic food. An important basis for this is the provision (creation and promotion) of a level playing field for EU aquaculture so as to assure its sustainable development.

By contributing to long-term environmental, economic, and social sustainability in Europe, the CFP includes provisions that aim to ensure the traceability, security and quality of products marketed in the EU.

The latest CFP also encourages a contribution to increased productivity, to a fair standard of living for the fisheries [and aquaculture] sector, to stable markets, to ensure the availability of food supplies and that these reach consumers at reasonable prices. The provision of highly nutritious food to the EU market is an evident priority and higher supplies will reduce the EU market's [increasing] dependence on food imports.

It is therefore anticipated that the new CFP should therefore contribute to the Europe 2020 Strategy for smart, sustainable and inclusive growth, and should help to achieve the objectives set out within this.

4.1. Specific and important measures of the CFP

4.1.1. Sustainability

The references to aquaculture in the CFP are generally accompanied by the terms 'sustainable' and 'sustainable development' but with the accompanying goals of contributing to food security, economic growth and employment. It is recognised that there are EU-wide differences and these are largely addressed in the Strategic Guidelines.

Inevitably, different stakeholders have different views on the conditions of sustainability and there have been several calls to develop a 'universally' adopted definition of what this means. International bodies remain rather vague on an exact definition and this is understandable, given the complexities and the fact that 'sustainability' is constantly in flux.

The major challenge to operators is how to assure competitiveness (and economic sustainability) within the conditions of a global market and in the absence of a level playing field in respect of, as examples, environmental legislation, feed ingredients, availability of vaccines and therapeutic agents and access to markets. It appears, from the JRC study, that high labour costs also contribute to difficulties in competitiveness – although the sector contains a lot of part-time labour. Consequently, national employment policies impact.

Environmental sustainability is covered largely by protective legislation on water use and waste emissions, which can vary between States, although the costs of water treatment can be prohibitive in specific cases. Limitations on feed use (affecting waste emissions) can affect production capacity and economic performance – while wider issues (such as eutrophic measures in the Baltic) can also influence the authorisation procedure. Nonetheless, the identification, measurement and reporting of appropriate indicators on environmental performance remains 'work in progress'. European efforts have given encouragement to this, through different projects and initiatives, and which should provide a more solid basis for assessment in the future (e.g. Product Environmental Footprint work in the Single Market for Green Products Initiative where both feeds and fish are current subjects).

Social sustainability in aquaculture is largely influenced by the acceptability of a relatively new food production activity not only by the consumer but also by the processing and retail sectors. Often seen as a competitor to fisheries, modern aquaculture originally focused on high value products that were in short supply (e.g. salmon, sea bass, sea bream, turbot, trout, eel) while carp rearing has long been characterised by cultural influences and traditions in central and eastern Europe. Aquaculture has evidently contributed to providing more of these species to the market, with accompanying price decreases – rendering easier consumer access to these products. Nonetheless, even though European aquaculture respects legislation and quality standards, an underlying bias exists against aquaculture in certain markets accompanied by a lack of knowledge on what aquaculture does and contributes. In addition, competition for space use (vs. tourism or coastal residence, as examples) also impacts on acceptance. Nonetheless, Article 34 of the new CFP is entitled 'Promoting Sustainable Aquaculture' which looks to create non-binding cooperative efforts across disciplines and throughout Europe so as to have well-planned, sustainable development of the activity.

4.1.2. Governance

The management of the CFP is to be guided by principles of good governance, including decision-making based on best available scientific advice, broad stakeholder involvement and a long-term perspective. The successful management of the CFP also depends on a clear definition of responsibilities at Union, regional, national and local levels and on the mutual compatibility of the measures taken and their consistency with other Union policies. Included in this aspect is the creation of a stakeholder-led Aquaculture Advisory Council and a special Committee composed of representatives of Member States, following the conditions of Regulation 182/2011. The existence of similar comitology and structures at National and local levels is rare, particularly in States where aquaculture is not well developed.

As needs have been identified for research and innovation – for improved resource use, diversification and technological improvements – European, National and Regional actions have evolved (generally on a multi-stakeholder basis) so as to move forward and kick-start efforts on a range of fronts. Examples include the work of the European Aquaculture Technology and Innovation Platform (EATiP), covering fish and shellfish culture, and mirrored to efforts in Spain, Greece, Italy and Hungary, and the recent Science and Research Strategies for sustainable aquaculture in Scotland and Germany.

4.1.3. Protective Measures

Application of the precautionary principle, following the Lisbon Treaty (Article 191.2) is referred to for marine biological resources, denoted more specifically for fisheries stocks but applicable to aquaculture.

Assuring animal health, animal welfare, food and feed safety are priorities for aquaculture – and recognised within the CFP.

4.1.4. Issues to resolve

The Strategic Guidelines for the sustainable development of European aquaculture highlighted:

- Improvement of competitiveness
- Authorisations (operational) and simplification of licensing procedures
- Encouragement of innovation, diversification and economic activity
- Open coordination of information and best practices

Each of these issues is addressed in the CFP but in most cases their implementation is dependent on national and local motivation and decision, particularly in the case of licensing. Assuring the coherence of the multi-annual national strategic plans should provide the basis of these positions, although local authorities, where licencing issues are generally decided, have to be involved in the process of implementation.

4.2. How public policies affect the development of sectoral components of aquaculture

The most direct effects on European aquaculture as a whole are related to European and National policies concerning the environment and water use, which influence license attribution that allows aquaculture farms to operate. The responsibility for aquaculture enterprises, throughout Europe, is generally in the hands of the Ministry of Fisheries at national level for marine aquaculture while Ministries for Environment/Agriculture are responsible in inland States.

At the national level, coastal and rural development policies are the most influential in terms of site allocation, while local authorities are usually responsible for operating licences. The application of Environmental Impact Assessments (before implementation and as follow-up measures) is also important for the continuity of development.

Adoption, for marine fish farming, of Integrated Coastal Zone Management (ICZM) measures is highly variable. One of the best examples, however, is the CLAMS[14] initiative – promoted in Ireland and also Area Management Agreements in UK – looks to improve local aquaculture management and consultation, improving acceptance of the professional activity.

National interpretation of EU Directives is also referred to in terms of application differences, with ‘gold-plating’ being reported in certain countries.

- <u>Water management</u> (Water Framework Directive, extending though River Basin Management) is also a major issue for the more intensive fish farms, particularly when limits are placed on outputs (e.g. Nitrogen and Phosphorous) – notably through

[14] CLAMS = Coordinated Local Aquaculture Management Systems - http://www.bim.ie/media/bim/content/BIM_CLAMS_Explanatory_Handbook.pdf

the attribution of feed quotas (limiting productivity of a particular site. Similar restrictions apply in the Baltic region.

- Predation, particularly by cormorants and herons in Natura2000 zones, is often cited as being one of the prime reasons for extensive inland aquaculture experiencing difficulties. Despite different efforts, no European management plan for cormorant control exists. Appreciation of different control measures differs between Member States.
- The availability of therapeutic agents is a longstanding issue for fish farmers; the limiting of market authorisations at national levels means that States with low production may not have adequate markets to justify health companies investing in such authorisations. Unequal availability throughout the EU for therapeutants, vaccines and anaesthetics is notable. This position is in relative contradiction to requirements for the best fish welfare.
- The TRACES system of the EU covers animal health and welfare alongside public veterinary health, specifically where live animals are moved. This applies to movements of juveniles from specialised hatcheries and mature specimens for stocking. This affects a large part of the sector and the profession believes it could be improved.
- Despite requests for a full European management plan for eels, this has been translated into national management plans in 19 States. Stock management plans and a ban on international trade (through CITES) have influenced eel ongrowing activities.
- For salmon farming, sealice infestation is a major issue; the potential of infected farmed salmon transferring lice to wild salmon and trout is a recurrent issue for this sector. Regulatory enforcement measures are different, depending on the State in question.
- Escapes from fish farms are an additional topic, where escaping salmon is the most visible issue[15]; Scotland has an 'Aquaculture and Fisheries Act' that makes relevant legal powers and provisions in relation to fish farms for containment and fish farm escapes due to concerns on effects on biodiversity and/or infection transfer. Containment actions generally relate to monitoring installations (particularly for cages), while land-based farms can install appropriate physical installations. While salmon is well-documented, the knowledge of the effects of other species/sectors escapes is less well known.
- Feed components are of prime concern to all sectors, although much less for extensive, freshwater culture. The concerns of the availability of fishmeal and fish oil are valid. Access to novel ingredients is relatively equivalent throughout the different production sectors, although the inclusion of non-ruminant PAPs in fish feeds raises some national sensitivities (e.g. France), potentially affecting access to markets, while access to GM plants producing Ω-3 fatty acids also remains a long-term question.

For the aquaculture profession, faced with local limitations on water access and waste, access to space (e.g. for increased production facilities, water treatment or for fallowing) is a prime concern. This is evidently related to national, regional and local public policies.

Although the EU has its own organic legislation, this is often seen as being a minimum standard and has not displaced existing 3rd party standards. The EU legislation is currently under review and is also being addressed by a FP7 project, ORAQUA.

[15] See Prevent Escape project (FP7) - http://preventescape.eu/

In summary, national policies and strategies specifically for aquaculture are few, generally limited to important production States (Scotland, Germany, Greece…) and often linked to research and innovation needs for growth. Evidently, the request for national multi-annual plans, foreseen in the Strategic Guidelines, will change this position.

4.3. How key European policies affect aquaculture

As indicated in the previous section, alongside the aquaculture components of the Common Fisheries Policy, EU policies on the environment, water and river basin management, food and feed safety, aquatic animal health and consumer interests are the principle ones that affect aquaculture directly.

In addition, there are several overriding policies that influence European aquaculture, included broadly under the EU 2020 Strategy for smart, sustainable and inclusive growth:

- SUSTAINABLE AND BEST USE OF RESOURCES: the sound use of resources and promotion of less resource intensive processes/products
  - Perception that intensive aquaculture is not as ‘good’ as extensive
  - Aquaculture, both fish and mollusc, use fewer resources (including water) and have lower footprints than other livestock rearing sectors (e.g. beef, pig, poultry…)
  - Currently, Product Environmental Footprint (PEF) pilots (under Single Market for Green products initiative of DG ENVI) for FEEDS, FISH and MEAT are underway.
- SUSTAINABLE ECONOMIC GROWTH: where competitiveness and profitability are the key issues, notably given the increasingly weak position of producers vs. retail.
- BLUE GROWTH: This is the long term strategy of the EU, mirrored by many other States, to support sustainable growth in the marine and maritime sectors as a whole. Aquaculture is seen as having high potential to provide sustainable jobs and growth, alongside tourism, energy, biotechnology and mining.
- CIRCULAR ECONOMY: boosting recycling and loss of materials, specifically where waste materials can re-enter the economy with value.

The consideration of the European bioeconomy must also be noted. The EU imports energy, feed and food and is increasingly looking to the components of the bioeconomy to respond to improving EU supplies of these, through sustainable bioeconomy activities. The Bioeconomy Strategy and its Action Plan[16] aim to pave the way to a more innovative, resource efficient and competitive society that reconciles food security with the sustainable use of renewable resources for industrial purposes, while ensuring environmental protection. Aquaculture is integral to the achievement of this Strategy

Improved knowledge of the different aquaculture processes and their impacts and footprints will provide answers as to how aquaculture can contribute to these.
As examples:

- Lower PEF of aquaculture, fish and mollusc production, vs. other food products
  - Potential integration of Integrated Multi-trophic aquaculture (e.g. fish, seaweed, molluscs) as an integrated economic activity
  - Potential integration of off-shore activities (e.g. wind energy) with marine aquaculture
- Recycling of fish/mollusc wastes after processing – which is already practised in many instances

[16] COM(2012) 60 final

- Recognition and compensation for positive environmental contributions (carbon-fixing by molluscs, contributions of extensive pond aquaculture…)
- Use of constructed wetlands to fix waste from on-land fish farms

The aquaculture profession has requested the establishment of a level playing field for its activities when compared to the conditions of imported products. Much of the reasoning for this rests with existing EU legislation affecting EU producers compared to practises in 3rd countries. So as to measure and confirm this, consideration was promoted for a specific EU label, for consumer recognition purposes, but this has yet to progress (c.f. EMAS recognition). Nonetheless, additional considerations (Single internal market, WTO regulations) evidently influence this aspect.

In summary, all EU legislation on the safety of food products, on the environment – particularly water - and on animal health affect aquaculture directly. Adaptation is possible, but most of these require significant investment in materials and skills (personnel), which may lead to a loss of short-term competitiveness when market prices are not influenced by these.

4.4. SME operations and needs

The most complete recent assessment for economic performance of the EU aquaculture sector is the STECF report of 2013[17]. The key findings are summarised as:

- 14-15,000 companies have aquaculture as their main activity, where 13% have more than 10 employees.
- 90% of the companies are classified as micro-enterprises – with significant part-time labour (notably for the mollusc and extensive production systems)
- Major costs items are feeds (31%), stock materials (from hatcheries) at 18%, labour (15%) with other operational costs at 15% - but the report noted important variations by sector.
- Operating profit margins (EBIT) were some 13% in 2011 while the Return on Investment was 10%.
- Improvements in both labour and capital productivity had improved to €44,000/FTE and 29.1% respectively in 2011.
- There are significant performance differences within the different sub-sectors and between States
- Extensive fish farming and mollusc production is much less capital intensive and require less active on-farm monitoring, supervision and manipulation than the intensive fish farming systems (e.g. cage-produced salmon, sea bass and sea bream, recirculation systems)

The fundamental challenges for development for nearly all EU aquaculture enterprises include the cost and time of obtaining licences, the investments in working capital to build up live standing stocks, access to skilled employees in remote areas, combined with the uncertainties of access to profitable markets in the timeframe before harvest.

New entries into the profession have to face these issues while generation change, in the family-based micro-enterprises, is an upcoming challenge. Within the profession, it is felt that expansion and consolidation of existing businesses will be the trend in the short-term.

[17] Summary of the 2013 Economic Performance Report on the EU Aquaculture Sector (STECF 13-30) – EUR 26368 EN

Inevitably, and particularly for the marine sectors, it is the economic 'value' of the licence to produce which is a major factor. Long-term capital and stock investments on sites where licences have a limited time-frame is seen as risky.

For all SMEs, attaining the right market is a key question to resolve. The dominance of multiple retail stores for seafood and fish products is evident, affecting production and market policies of individual companies. The EU aquaculture sector is characterised by having a large number of SME/Microenterprises and there is virtually no product promotion activity, except when led by Associations/Interprofessional organisations. The CFP/Common Organisation of the Markets foresees the creation of Producer Organisations (that would plan and group production) to facilitate and promote strength in both planning and sales. Such organisations would also have the capacity to promote common processing and marketing. Although not yet widely implemented, professional interest in this possibility has been expressed in all sub-sectors or EU aquaculture.

4.4.1. Coldwater marine fish species

Dominated by UK (Scotland), Ireland, Denmark and Finland, salmon is the main product, followed by ongrowing large trout. Interviews indicated that these will stay as the main products in the foreseeable future, since both cod and halibut remain marginal. The UK and Irish salmon sector is dominated by large companies and sites are increasingly limited. Cost competitiveness in the main markets means that the SMEs face specific challenges, including access to space, investments that increase productivity and focusing on stable or evolving markets (e.g. added-value, organic, localised specialty).

For SMEs, product specialisation – and providing added-value – is an increasing market requirement.

4.4.2. Warmwater marine fish species

Greece and Spain have also seen consolidation of their business structures for the production of sea bass and sea bream, a position exacerbated by the financial crisis. Restructuring of the large public companies in Greece is under discussion at present. Administrative bottlenecks are regularly mentioned for the development of aquaculture in Greece, Spain and Italy but access to adequate financing facilities are also needed.

The support financing for both capital investment and the working capital of SMEs in this sector is the major issue at present. Compared to salmon, the Mediterranean species provide smaller product sizes, rendering added-value (e.g. through filleting) more difficult. This basic fact makes market access more challenging. In addition, competition with production in Turkey (and growing in North Africa) has become more intense.

For SMEs, the major challenge is to increase productivity – so as to improve profit margins – requiring investments in modernisation, supported by improvements in feed quality and livestock (juveniles for stocking). Specialisation in organic or other ecolabels is also seen as an opportunity. The profession has also highlighted the need to improve support services, including veterinary surveillance and information supply (e.g. on markets and technical issues), for the sector.

4.4.3. Freshwater fish species

This sector has not seen the same levels of consolidation and mergers seen for both the coldwater and warmwater marine sectors. There are no publicly-quoted companies for this component. Nonetheless, it is also the sector with the widest diversity; companies may combine aquaculture with other activities (e.g. agriculture, angling, restocking, farm sales….). The markets for the products are less 'boom and bust' – as seen for both salmon and sea bass/sea bream in the last 20 years – although prices are influenced by competitive products. For aquaculture SMEs, the major question is whether to stay within main markets – or focus on specialty products, diversify activities and/or group within cooperative structures and/or producer organisations. The recognition and development of environmental services (which could also include energy provision e.g. solar panels on farms (in France and Germany) which supply local urban areas) is also an important consideration.

4.5. Policy recommendations

The new CFP and accompanying instruments have been the subject of extensive consultation with the professional sector, Member States and non-governmental organisations. The recognition of the contributions of aquaculture have resulted in a range of opportunities for development, where it is too early to assess success levels.

A range of tools, notably providing for the creation of producer organisations and support measures for the profession, have been put forward to support production expansion, market stability and growth.

There is 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.

4.5.1. Strategic Guidelines

The need for multi-annual plans, strategies and operating plans, was put forward in the Strategic Guidelines for the Sustainable Development of European aquaculture and is also a welcome policy, since these should enable identification of the growth anticipated. It also provides outline plans for development.

Follow-up on the efficiency of development, providing the requisite information – particularly on quantified objectives – is an essential component, allowing an assessment of balanced development so as to avoid boom and bust conditions.

4.5.2. The Data Collection Framework

The STECF study underlined the difficulties of obtaining accurate and up-to-date statistics on the performance of the EU Aquaculture Sector. The DCF 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 2014 European Court of Auditors special report[18] on the effectiveness of the EFF support for aquaculture.

4.5.3. Environment

Clarification of the position of aquaculture within the existing environmental legislation has been initiated with recommendations existing for Natura2000 and is under development for

[18] ECA Special Report No. 10 available at http://www.eca.europa.eu/Lists/ECADocuments/SR14_10/QJAB14010ENC.pdf

the WFD and for the MSFD. 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.

4.5.4. Health and Welfare

Establishment of uniform availability throughout the EU of therapeutic agents and products required for the welfare of farmed fish.

4.5.5. Calculation of the Fisheries Fund (for aquaculture)

The total budget for the EMFF is divided into amounts between the Member States according to the size of their fisheries sector, the number of people working in the sector, the adjustments considered necessary for the fishing industry and continuity of the measures in hand. It is not clear whether aquaculture development is fully considered within the attribution of this Fund, particularly for regions/States where production is low.
It is recommended that the EMFF allocation for aquaculture be made in the light of the multi-annual plans of the Member States, separated from fisheries.

4.5.6. Governance

The Fisheries Committee of the European Parliament could consider the creation of a sub-Committee dedicated to aquaculture.

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Annex

Annex 1. Frameworks for ecological and environmental comparisons and assessments

When considering key indicators or drivers for ecological impact assessment it is also necessary to consider how these can be brought together and used to support decision making. Three prior frameworks have been considered as basis for this study. Firstly the Global Aquaculture Performance Index (GAPI) (Volpe et. al. 2013). This focused on marine finfish and particularly those produced in cages, and is based on a more general Environmental Performance Index (EPI) (Emerson et. al. 2012).

Figure 21: The ten GAPI indicators (Volpe et. al., 2013)

GROUPING	INDICATOR	INDICATOR DESCRIPTION	INDICATOR FORMULAS*
INPUTS	Capture-Based Aquaculture (CAP)	The extent to which a system relies on the capture of wild fish for stocking farms, taking into account the sustainability of these wild fish inputs	∑(Amount from Wild Capture (kg) × Sustainability Score) / mT Fish Produced
	Ecological Energy (ECOE)	Amount of energy, or net primary productivity (NPP), that farmed fish divert from the ecosystem through consumption of feed ingredients	∑Net Primary Production of Feed Inputs (mT carbon) / mT Fish Produced
	Industrial Energy (INDE)	Energy consumed in production and in the acquisition and processing of feed ingredients	∑(Proportion Fish/Livestock/Plant/Production System x Knife Coefficient (Megajoules/mT) × Total Feed Consumed (mT)) / mT Fish Produced
	Sustainability of Feed (FEED)	Amount, efficiency, and sustainability of wild fish ingredients of feed	∑(Proportion of Feed by Species × Sustainability Score of Each Species) × Fish In: Fish Out Ratio / mT Fish Produced
DISCHARGES	Antibiotics (ANTI)	Amount of antibiotics used, weighted by a measure of human and animal health risk	∑(Amount Active Ingredient (kg) × WHO-OIE Score) / mT Fish Produced
	Antifoulants (Copper) (COP)	Estimated proportion of production using copper-based antifoulants	mT Fish Produced × % Production Using Copper-Based Antifoulants / mT Fish Produced
	Biochemical Oxygen Demand (BOD)	Relative oxygen-depletion effect of waste contaminants (uneaten feed and feces)	BOD (mT O_2) × Area of Impact (km^2) / mT Fish Produced
	Parasiticides (PARA)	Amount of parasiticides used, weighted by measures of environmental toxicity and persistence	∑(Amount (kg) × [(1/LC50)+1] × Persistence (Days)) / mT Fish Produced
BIOLOGICAL	Escapes (ESC)	Number of escaped fish, weighted by an estimate of the per capita risk associated with escapes	GAPI Invasive Score × # Escaped Fish / mT Fish Produced
	Pathogens (PATH)	Number of on-farm mortalities, weighted by an estimate of wild species in the ecosystem that are susceptible to farm-derived pathogens	∑Pathogen-specific Wild Losses (mT) / mT Fish Produced

The GAPI considers ten indicators in three groups: Inputs, discharges and biological, which are shown in Error! Reference source not found.. Each indicator has a numeric score which is calculated from industry performance data. To generate an overall performance score, the individual scores are firstly calibrated to a target of zero impact. Each score is then expressed in terms of proximity to that target (from 0 to 100 where 100 represents the target value). In order to combine the individual indicators into an overall score, a weighting is applied to each indicator based on a Principal Component Analysis of the data to determine how much of the total variation in the data is explained by each indicator. This is not the same as an assessment of which indicator is more important, but is a transparent approach. Finally the weighted scores are combined and normalised to a score per tonne of production. This gives both an indicator unbiased by the actual level of production, or allows it to be multiplied by production to obtain a more meaningful comparison of actual (or potential) impacts.

The main limitation of GAPI for the purposes of this study is that it is limited to systems that can be reasonably compared (i.e. broadly similar types of system) otherwise the scores become meaningless. It also does not take into account the first principle raised in connection with ecological assessments that should take full account of specific context. Nevertheless, if properly used it can provide useful insights and benchmarks for more specific industry or project analysis.

A second framework, again for marine aquaculture, is under development through the FAO General Fisheries Commission for the Mediterranean. The InDAM Project (Indicators for Sustainable Development of Aquaculture and Guidelines for their use in the Mediterranean) has been funded by the EU DG Mare as part of a larger initiative on sustainability in aquaculture (GFCM, 2011). The focus is on a broad assessment of sustainability incorporating four pillars (or dimensions): governance, economic, social and environmental. The project identified 156 indicators using a formalised stakeholder consultation procedure to agree on methodology and then on principles and criteria. This followed the earlier EU funded CONSENSUS Project coordinated by EAS. Unlike the GAPI, the indicators are not intended to be reduced to a single score, so can be expressed in whatever units are appropriate to the indicator. However, to make their use easier, pilot studies and further meetings suggest that a minimum of 22 indicators are required, but that these could be a different combination depending on national or regional needs. Furthermore, the indicators could be expressed using a simple traffic light system to indicate whether or not sustainability targets are being met (using 3-5 levels).

Figure 22: PCI Methodology used in the InDAM Project

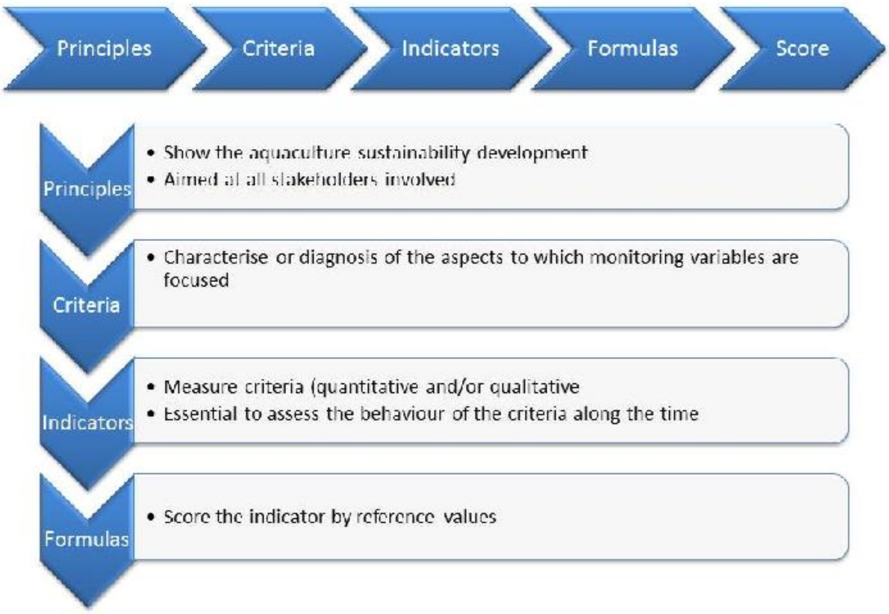
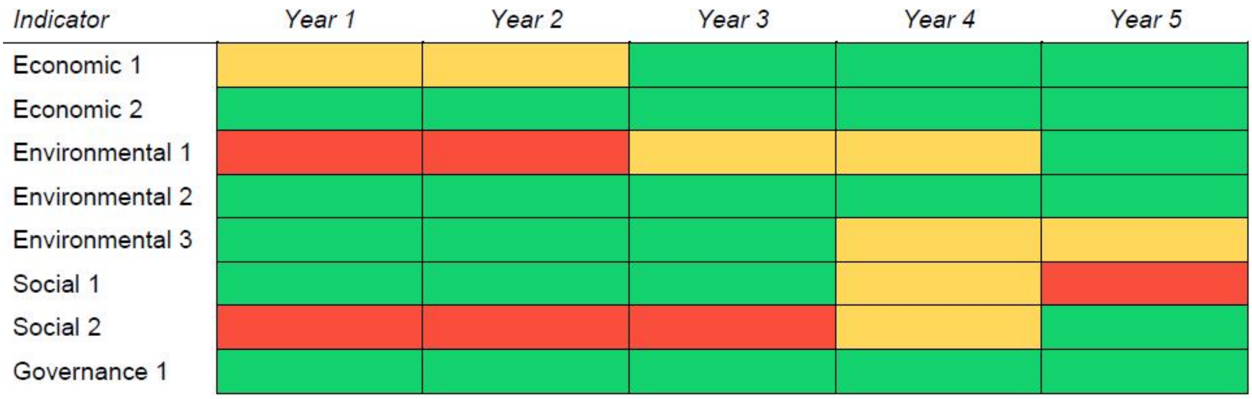


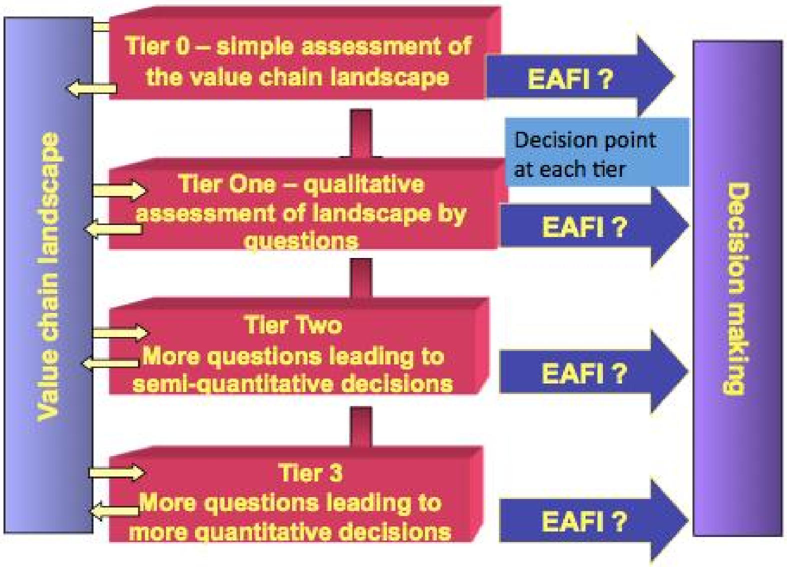
Figure 23. Example of 3 category traffic light assessment used to compare performance across 5 years (InDAM Project)



This approach has proved to be flexible for use in different regions and can also be used at different scales (e.g. national and company levels).

A third framework has been developed through the EU FP7 SEAT Project[19] (Sustaining Ethical Aquaculture Trade). The Ethical Aquatic Food Index (EAFI) is intended to encompass a wide range of ethical and sustainability criteria but is distinctive in taking a tiered approach which allows basic assessments to be made on limited data, and more complex and quantitative assessments made as better data becomes available.

Figure 24: Key features of the EAFI as a tiered iterative hierarchical framework



Tier 0 indicators are designed to be simple (e.g. "Is there a potential for negative environmental impact from the farm?"). A basic scoring system can be applied (e.g. 0-5) and scores from different indicators combined (with weightings if appropriate) to give a quick overview of general compliance with established baseline standards. The subsequent tiers use semi-quantitative and then quantitative data. For instance Tier 1 might ask whether a farm uses any treatment chemicals; Tier 2 which chemicals are used; and Tier 3 the quantities of each chemical used. The EAFI is therefore an adaptable decision support tool for use by companies and other organisations, rather than a frame of reference for

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policy makers. Target users are the multiple retailers that need a more consistent approach to sourcing decisions or voluntary standards bodies requiring a more flexible approach to assessment where data is limited.

Since ecological impact is an important consideration in a wide range of voluntary certification schemes, the increased adoption of these through the aquaculture value chain is an indicator that these issues are being addressed by the industry as encouraged by the EC Strategic Guidelines for Sustainable development of EU aquaculture (COM(2013) 229 final).

Annex 2 : Indicators for environmental comparisons and assessments

Table 1: Potential Ecological Indicators for European Aquaculture Systems

Code	Primary category	Secondary Category	Indicator	Type	Values
01/01/001	Input	Seed	Source	Cat. Value	0=Full cycle hatchery, 1=Wild broodstock, 2=Wild seed, 3=wild juveniles
01/02/020	Input	Feed	Type	Cat. Value	0=Natural, 1=fertilized, 2=supplemental, 3=complete
01/02/021	Input	Feed	Content	Cat. Value	0=No fishmeal or oil, 1=fishmeal only, 2=fish oil only, 3= fishmeal and oil
01/02/022	Input	Feed	Plant protein	Value	Percentage of protein provided by terrestrial plant material
01/02/023	Input	Feed	Marine protein	Value	Percentage of protein provided by all sources of marine animal meal
01/02/024	Input	Feed	Fishmeal protein	Value	Percentage of protein provided by fishmeal direct from capture fisheries
01/02/025	Input	Feed	Plant oil	Value	Percentage of lipid provided by terrestrial plant material
01/02/026	Input	Feed	Marine oil	Value	Percentage of lipid provided by marine sources of all types
01/02/027	Input	Feed	Fish oil	Value	Percentage of lipid provided by fish oil
01/02/028	Input	Feed	FCR	Performance	Typical food conversion ratio
01/02/029	Input	Feed	PCR	Performance	Typical protein conversion ratio
01/03/040	Input	Energy	Input energy efficiency	Value	MJ/tonne production
01/03/041	Input	Energy	Energy to protein ratio	Value	MJ/tonne food protein production
01/03/042	Input	Energy	Renewable use	Value	Percentage of direct energy input from renewable sources
01/04/060	Input	Infrastructure	Reliance	Cat. Value	1=Minimal, 2=Moderate, 3=Substantial
01/05/080	Input	Labour	FTE for production	Value	FTE (production only)/tonne of production
01/05/081	Input	Labour	FTE total	Value	FTE (value chain)/tonne of production
02/05/100	Resource	Water	Type	Selection	Freshwater (surface), Freshwater (ground), Brackishwater, Seawater
02/05/101	Resource	Water	Significant consumption	Value	m^3 removed from environment/tonne production
02/05/102	Resource	Water	Significant consumption to protein ratio	Value	m^3 removed from environment/tonne edible protein production
02/05/103	Resource	Water	Degraded water ratio	Value	m^3 of degraded quality /tonne of production
02/05/104	Resource	Water	Indirect water consumption via feed	Value	m^3 /tonne production
02/06/120	Resource	Spatial	Type	Selection	Inland, freshwater body, coastal land, tidal zone, sheltered marine, offshore

02/06/121	Resource	Spatial	Single or multi-use	Selection	Single use of resource or multi-use of resource
02/06/122	Resource	Spatial	Culture Area use effiency	Value	m^2 occupied /annual tonne of production
02/06/123	Resource	Spatial	Culture areal use protein production effiency	Value	m^2 occupied /annual tonne of edible protein production
02/06/124	Resource	Spatial	Feed area use efficiency	Value	m^2 occupied /annual tonne of production
02/06/125	Resource	Spatial	Feed area use protein production efficiency	Value	m^2 occupied /annual tonne of edible protein production
02/07/140	Resource	Habitats	Ecological sensitivity	Cat. Value	0=non sensitive, 1=slightly sensitive, 2=moderately sensitive, 3= sensitive, 4=Very sensitive
03/08/160	Outputs	Food	Primary output	Value	Tonnes WFE/annum
03/08/161	Outputs	Food	Protein output	Value	Tonnes protein/annum
03/09/180	Outputs	Income	First sale value	Value	Euro/annum
03/10/200	Outputs	Seed	Use	Cat. Value	0=use in aquaculture, 1=use in culture based fisheries, 2=use for wild stock enhancement
03/11/220	Outputs	Nutrients	Total phosphorus discharged	Value	kg P/tonne of production (all forms)
03/11/221	Outputs	Nutrients	Phosphorus discharged to protein ratio	Value	kg P/tonne of edible protein production
03/11/222	Outputs	Nutrients	Total nitrogen discharged	Value	kg N/tonne of production (all forms)
03/11/223	Outputs	Nutrients	Nitrogen discharged to protein ratio	Value	kg N/tonne of edible protein production
03/11/224	Outputs	Nutrients	Carbon solids discharged	Value	kg solid C/tonne of production
03/11/225	Outputs	Nutrients	Carbon solids discharged to protein ratio	Value	kg solid C/tonne of edible protein production
03/11/226	Outputs	Nutrients	Dissolved organic carbon discharged	Value	kg dissolved organic C/tonne of production
03/11/227	Outputs	Nutrients	Dissolved organic carbon discharged to protein ratio	Value	kg dissolved organic C/tonne of edible protein production
03/12/240	Outputs	Escapees	Impact risk cagegory	Cat. Value	Scale: 0=None, 1=slight, 2=moderate, 3= substantial, 4=High
03/13/260	Outputs	Parasites	Impact risk cagegory	Cat. Value	Scale: 0=None, 1=slight, 2=moderate, 3= substantial, 4=High
03/14/280	Outputs	Chemicals	Impact risk cagegory	Cat. Value	Scale: 0=None, 1=slight, 2=moderate, 3= substantial, 4=High

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