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Prospective Analysis of the Aquaculture Sector in the EU

PART 1: Synthesis report

John Bostock, James Muir, James Young,
Richard Newton, Susan Paffrath
Editor: Ilias Papatryfon

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PART 1: Synthesis report

John Bostock, James Muir, James Young, Richard Newton, Susan Paffrath (University of Stirling, UK)

Ilias Papatryfon (editor, IPTS)

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Executive Summary

This report is based on the outcome of the study on "Prospective analysis of the aquaculture sector in the EU", launched and coordinated by the JRC (IPTS) and carried out by the University of Stirling. The report consists of two parts:
1) "Prospective analysis of the aquaculture sector in the EU – Part 1: Synthesis report", and
2) "Prospective analysis of the aquaculture sector in the EU – Part 2: Characterisation of emerging aquaculture systems"
This first report sets out the context for the future role of aquaculture in the EU, and the potential directions to be taken within the sector. It builds from materials reported in Part 2, and is structured by the outcomes of a review/expert panel meeting carried out in Sevilla, in November 2006 in which a process and system of synthesis was agreed. It follows a format in which we:

- Project potential future demand for aquaculture-derived product, recognising domestic supply and international trade features, emerging consumer trends, and expected price positioning commensurate with sector production costs.
- Develop further detail with respect to species, subsectors, systems, locations, and their interactions.
- Set out issues and discussions on implications for future policy.
- Develop conclusions.

These projections and details were further developed through a process of discussion and comment with the expert panel during the period March-August 2007.

The study was conducted between January 2006 and November 2007, the data collection taking place in the early stages followed by the analysis in the later stages.

Policy context
The Common Fisheries Policy (CFP) covers the fishing and aquaculture sectors including the processing and marketing of fisheries products. Since the late '70s, Community intervention in aquaculture (mainly through research and investment aid measures) has stimulated production growth, but recently this was changed, as overproduction is perceived as a threat for some branches.
The Commission developed a strategy in 2002 based on a ten-year vision for the sustainable development of the aquaculture sector in recognition of its importance in the framework of the reform of the Common Fisheries Policy[1]. The strategy identified a number of actions to be taken at different levels (Community, Member States, economic operators). Actions identified at EU level mainly consist of creating a support framework to encourage the sustainable development of aquaculture (through fisheries structural funds), stimulating research and innovation (through Community Research Programmes), while establishing a regulatory context which ensures a high level of environmental consumer and animal protection.
The 2002 strategy set a target to increase annual production growth from 3.4% to 4% per year, mainly as a means to the creation of new jobs in the aquaculture sector (for the period 2003-2008). Therefore, an increase in aquaculture production was still envisaged, but Community financial support was to focus on new market outlets, species diversification and environmentally friendly production.

[1] "Strategy for the Sustainable Development of European Aquaculture", COM (2002) 511 final.

Structural assistance to the fisheries and aquaculture sectors in Europe has been mainly provided through the Fisheries Instrument for Fisheries Guidance (FIFG), recently replaced by the European Fisheries Fund (EFF)[2] covering the period 2007-2013. The central objective of this instrument is to ensure sustainable fisheries and diversify economic activities in fishing areas. One main focus is on aquaculture, processing, and marketing of fisheries/aquaculture products, aiming at guiding and facilitating restructuring, particularly at balancing supply and demand while securing long-term employment, environmental protection and product safety and quality.
To take stock of progress made so far and to explore the need for any potential follow-up actions, the Commission launched a debate in 2007 with all stakeholders on the further development of sustainable aquaculture in the European Community.[3]

Results
Our analysis suggests that the European Commission's 2002 target for 4% annual growth in domestic aquaculture production is conservative in relation to anticipated EU demand for aquatic foods, particularly if capture fisheries production continues to decline. However, statistics show that over 2000-2005, EU-25 aquaculture output actually decreased by an average 1.83% p.a. Expansion of most aquaculture subsectors has been constrained through lack of allocatable space, water supplies, and concern about waste outputs or other potential impacts. Investment outside the EU has often been more attractive in building supply for EU markets, and tight margins in existing sectors have limited efficiency-driving technology investment. Substantial advances in resource access policy and/or efficiency investment will be required to reverse trends towards the targeted 2.7 fold increase in output by 2025.

The scenarios explored foresee apparent total demand ranging from near zero growth to a maximum of some 1.3% pa due to rising population and per-capita consumption. This sets overall EU-25 apparent demand in 2005 at almost 10 million tonnes, rising to over 14 million tonnes by 2025. With a combined fisheries and aquaculture production of ~ 6.5 million tonnes in 2005, the EU-25 deficit was ~ 3.4 million tonnes. If demand and capture fisheries levels remain static, and the 4% growth target for aquaculture is achieved, this deficit would be reduced to 1.3 million tonnes by 2025. If capture fisheries decline at current rates (nearly 2% p.a.), aquaculture growth at target rate would only cancel this out. However this would be more favourable in value terms, as higher value domestic aquaculture production would compensate for the loss of lower value fishery supply. If total demand rises, these deficits will also rise correspondingly, up to 4 million tonnes more than for static demand.

Growth in aquaculture at higher than 4% p.a. is technically feasible but difficult to accommodate under current technology and global policy and socio-economic conditions. The circumstances for such change are noted in the report, but the key issue will be the comparative international cost bases and the realism of economic returns to EU resource assets, whose alternative uses may place too high a cost for their use in aquaculture. The practical focus would therefore be on building more substantial growth and returns in more valuable aquaculture subsectors.

The report shows that EU territories and economies have considerable potential for upgrading sectoral investment, technology application, production and economic output, and it would be appropriate to define medium to longer term horizons for achieving these. Fish will continue to compete favourably with substitutes and can command good and potentially improving

[2] Council Regulation (EC) No 1198/2006
[3] http://ec.europa.eu/fisheries/cfp/governance/consultations/consultation_100507_en.htm

prices. Variations and differentiations within the market will create further niche positions and commodity opportunities to differentiate supplies. EU aquaculture businesses are generally robust, innovative and competitive, and have used technology in the process of considerable change over the last two decades. With structural change and growing sectoral agglomeration, technology application is likely to become an increasing discriminant in competitive position within and outside the EU.

Though the size of the domestic industry has grown significantly in recent decades and has the potential to expand further, margins on its turnover and on associated supply and service sectors have not been sufficient to create and support a major technology incentive comparable to those in other technically driven sectors such as energy, ICT, health care and pharmaceuticals. Whilst the EU has an active and high quality science and technology base related to aquaculture, and its processes of knowledge exchange and building are improving, links between industry and research centres are still not strong enough to create a genuinely productive objective-led approach to sector development. A mix of investment incentives and collaborative focus will be required to deliver change and improve impacts. Emerging examples of best practice can be found regionally or in current initiatives internationally.

Drivers associated with energy, carbon footprint, resource use and protection are likely to dominate future global supply options and market sourcing decisions, closely matched with growing concerns for food safety and for ethical/welfare standards. Current and emerging technologies will be critical in addressing such demands, and could confer competitive advantages on producers, market intermediaries and retailers alike. Arguably one of the biggest drivers at EU level is the ability of its food retailers to establish an even more pre-eminent position in global markets. Energy, carbon and other resource-related drivers in supply choice will become more clearly defined, moving away from cruder food miles debates to incorporate accurate assessments of consumption, including how food is purchased and prepared locally. Amongst other impacts, this has potentially positive implications for local small scale aquaculture production.

The EU's role in the international market as a higher income consumer of global aquatic products also gives it a prominent position in defining product standards and quality attributes, which in turn creates technology drivers in supplying countries. This role may be particularly important in developing countries dependent on supplying the EU. There is a strong regional argument for ensuring EU expertise through partnerships, commercial ownership or joint initiatives across the global supply networks. Related to this, commercial information, and a clear sense of the competitive advantages achievable through different policy environments, agroecological conditions, technology application, enterprise behaviour and technical skill, needs to be developed further, so that EU States can be intelligently positioned for domestic supply, export of products and services, productive investment and sustainably high returns on its natural resources.

There remains a need for holistic technology perspectives for the aquaculture sector, in which the overall efficiency of performance – judged by key criteria linked to profitability, environmental risk and social acceptability, can be defined and targeted. This array of criteria corresponds to the reality of sustainable development for the sector. Simple stand-alone measures such as energy efficiency, food conversion or volumetric productivity will not in themselves be sufficient, and policy makers, industry and technology developers will require to share and develop perspectives to ensure better overall technology performance targets. From this in turn could be derived more effective sectoral goals and better criteria for R&D

investment. At the same time, these issues will link with other emerging policy areas – in food, environment, industry and social welfare, for the EU.

A number of global perspectives will also be expected to connect with this broader theme – examples include the ''ecosystem approach to aquaculture'' currently being explored as a policy tool, perspectives on ecosystem-linked economic risk, concepts of corporate social responsibility and technology partnerships bridging higher and lower income countries; expansion of global rights to safe food, and changing global security and trading relationships. It is beyond the scope of this review to comment on the potential scenarios across this wider field, but important to note that a well developed sectoral technology perspective will be essential, not just theoretically, but as a shared resource amongst EU stakeholders and external partners associated with the sector.

The JRC thanks the following individuals and institutions for their contributions to the study:

Expert review panel

- Courtney Hough, Federation of European Aquaculture Producers, Belgium
- Philippe Ferlin, Conseil Général du Génie Rural des Eaux et des Forêts, France
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UK	Mark Rigby (Llyn Aquaculture Ltd); Kathleen Grady (University of Stirling); Ramzi Arabi (Aquasystems)
Tuna costs	Giovanni Basciano (AGCI Pesca)
Breams	Lamans SA subcontracted work - George Triantaphyllidis, Nikos Anagnopoulos

1 Introduction

The aim of this report is to set out the likely context for the future role of aquaculture in the EU, and within this, the potential directions to be taken within the sector. It constitutes the main conclusion of the study, for carrying out a prospective analysis of the aquaculture sector. The report builds from the materials developed in Part 2, and in particular is structured by the outcomes of the review/expert panel meeting carried out in Sevilla, in November 2006 in which a process and system of synthesis was agreed. These were then further developed and refined through a process of interaction with the expert panel during the period March-August 2007. The report follows a format in which we:

- Propose an approach for projecting potential future demand for aquaculture-derived product, recognising evolving domestic supply and international trade features, emerging consumer trends, and expected price positioning commensurate with sector production costs.
- Develop further detail with respect to species, subsectors, systems, locations, and their interactions.
- Set out discussions on implications for future policy.
- Develop conclusions.

Broad analyses of market trends, within Europe but also globally, indicate increasing demand for seafood products, based on rising populations (especially in Asia), increasing affluence, and appreciation of the health benefits of seafood consumption. The prospects for capture fisheries are at best for stagnation, at worst for significant collapse and at 'most likely' levels, for uneven or possibly declining maintenance of output around major fisheries, with possible ecosystem replacement ('fishing down the food chain') towards species which are currently at lower value. The growth in aquaculture over the last 3 decades has been spectacular - globally in excess of 10% per annum for much of the period, but is now slowing. In the very fast growing higher-value sectors in Europe, this is particularly so, though somewhat compensated by Europe's global investments in aquaculture. An overall perspective suggests that it is becoming harder to achieve further substantial productivity gains to maintain profitability for aquaculture in expanded lower price markets, and that industry growth in Europe appears to fall more into line with a demand for products in the mid-to-high price market ranges, where demand is clear or where added value can be obtained.

Aquaculture productivity has to date been improved through increased use of mechanisation and scale of production effects (e.g. through consolidation) that are lowering the labour and overhead costs per unit of production. These have combined with biological efficiency gains associated with better quality seedstock, feeds and feed utilisation, and with better managed (though still troublesome) risks associated with aquatic diseases. However, rising input costs (feeds, energy, water etc,) and environmental charges (waste disposal costs or increasing barriers to environmental resource use), combined with potential technical limits to further biological performance gains (excluding possible options available through GM technology) may make it increasingly difficult to break further production cost and price barriers.

As with many other primary food industries, aquaculture is heavily dependent on natural resources. Their availability and cost are an important determinant for its size and expansion potential. The primary requirement is for water. Most of this is returned to the environment, commonly slightly enriched with nutrients, organic wastes and sometimes lower in oxygen content. Capacity limitations on assimilating these wastes are therefore key constraints. For freshwater fish farming in Europe, this has limited the size and clustering of individual units and discouraged the type of expansion and consolidation seen in the salmon sector. Marine farms have been less constrained, allowing higher levels of production from individual sites, and greater opportunities for consolidating central services and facilities. However, a slow-down in the rate of marine fish farm expansion is also apparent in many areas. Though expansion of sites or operations would appear to have potential for further efficiency gains, this suggests that companies are unwilling to invest at this stage, that local or area level resource regulatory limits are being reached, or that the policy balance is changing and that barriers (regulatory or cost) are now preventing further expansion.

After water (and associated land where needed), the second primary input for aquaculture is feed. For most bivalve culture (or seaweed farming where practised), and some extensive fish and crustacean farming, this is closely associated with the water supply. For more intensive aquaculture, feed is supplied externally, with a significant component (fishmeal and oil) derived from industrial capture fisheries, most of which is now remotely sourced. This is a renewable but finite resource, of which aquaculture is utilising a growing share. Real prices for qualities suitable for inclusion (with increasing concerns for persistent organic contamination) have been rising, suggesting this to be another important growth limiting factor. Research indicates that much of the current requirement could be substituted with terrestrially derived proteins and oils, and although these are not necessarily cheaper, and may be subject to supply impacts from the growing demand for bioenergy, they represent further scope for growth. Notwithstanding this, further ethical, environmental and food quality issues could influence rates of adoption of such feeds, and it may also influence shifts to less carnivorous aquaculture species for which such alternative feeds are considered to be more 'natural'.

The third primary input is seedstock. For production to be independent of natural seed supplies, the reproductive cycle must be closed and juveniles produced efficiently and cost-effectively through breeding and hatchery operations. The number of marine species for which this is possible is still small, and investment in R&D relatively risky, though technology transfer from one species to another has gradually improved the prospects for further gains. Market demands and site/system use efficiency also increasingly require out of season seed supply, and this level of controlled production is as yet available for only a smaller number of species. Again, however, technology transfer may accelerate progress.

In developing more detailed scenarios for the sector, it is important to recognise its diversity. The FAO Fishstat database lists over 400 species cultivated worldwide, and over 100 within Europe. There is also a great variety of enterprise types, ranging from part-time subsistence activities for rural families, to publicly traded international corporations. Such a variety is unlikely to be sustained within a single segment (such as the salmon industry), but across the range of species, many business models remain feasible. In a globalised economy, production of commodity species such as salmon, tuna, cod and shrimp will be attractive to corporate investors, whilst smaller scale investors will focus on more specialist market opportunities accessed through product differentiation, such as the cultivation of rarer species, a focus on local production and supply, the use of organic or other special labels etc. All of these are likely to feature in the future European perspective.

The future opportunities for European aquaculture will also depend to an important extent on the state of capture fisheries, both regionally and globally. Most likely, there will be a gradual reduction in fisheries production, either through stock decline, or as a result of stronger fisheries conservation measures. Within this also, as currently seen with EU cod, key species may be substantially removed from production for significant periods, resulting in specific market gaps. There may also be longer-term shifts in capture fisheries away from traditionally higher-valued species if these are increasingly fished out, though the largest gap for aquaculture to supply would probably still be for lower-priced products. Currently, carp is the only European aquaculture species that approaches these lower prices. However, large scale expansion of traditional carp farming is unlikely to be viable. More likely, such gaps would be filled by increased imports, including lower-priced aquaculture produce. At present the leading example is Vietnamese catfish (*Pangasius*), but imports of tilapia are also rising, with Africa a prime candidate for development as a lower-cost supplier to Europe. In the longer-term, Asia is also likely to utilise a greater proportion of its own production as its domestic demand rises at a faster relative rate. This may also expand, albeit still at a limited scale, opportunities for European exports of high-value coldwater species.

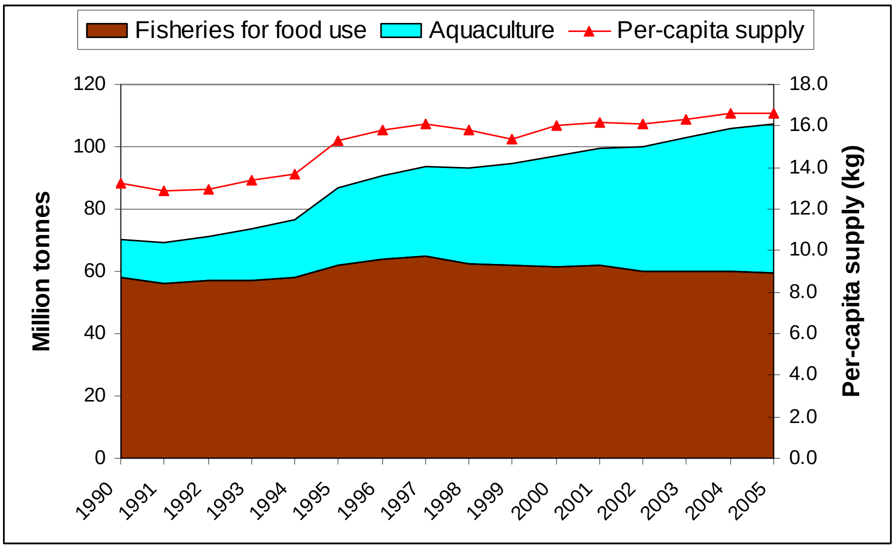
The key to any substantial growth in the European aquaculture sector will be innovation. A focus on using limited environmental resources better through improved ecological efficiency (e.g. through MTA or multi-trophic integrated aquaculture systems) could support modest expansion and diversification of existing coastal activities and some freshwater systems, whilst market options such as specialist labelling schemes will help strengthen niche producers and also support smaller-scale species and product diversification. However, major change and growth such as that shown historically in the salmon or bass and bream sectors, will require more widespread adoption of new technologies such as offshore aquaculture or recirculated water systems. Both technologies could break through water resource constraints, but have very different characteristics, although both necessitate considerable investment and effective management of technology risk. For the near to mid-term, recirculation systems would be most likely to be used for higher unit value species – in hatcheries and nurseries and for premium fish production closer to main markets. Offshore aquaculture is most likely to emerge out of the salmon, tuna, bass and bream industries as the favoured technology for large-scale commodity fish production, particularly if export opportunities strengthen. However, this will require development of appropriate legal and regulatory frameworks, probably linked to coastal zone planning systems. Land-based developments could similarly be boosted by the establishment of aqua-industry technology parks. Both of these areas in turn could be linked with strategic infrastructure for energy supply and development, e.g. through wind, wave, geothermal, solar and tidal energy.

2 Apparent demand for seafood

2.1 Global context

World fisheries are at a stage where there is little if any room for further exploitation, and capture of seafood is likely to remain at best static for the foreseeable future. At worst there could be a dramatic collapse. Worm *et al* (2006) described the collapse of 29 percent of all fished species by 2003 and proposed that on current trends fish catches (current species) could fall below 10% of current levels by 2048. Whilst this is at the extreme of current scenarios and its methodology is questionable, the related concerns for fisheries management arrangements in many regions are widely shared. Climate change may place further burdens upon resources, with highly exploited species not being able to absorb the extra pressures. Meanwhile global populations are still set to rise, although much of this will be in Asia, whose rising incomes will increasingly draw supplies, changing potential balances of supply and trade for the EU and other major seafood markets. This may have implications both for domestic sourcing and for export opportunities. Based on population and capture fishery trends, we aim in this section to identify the current state of EU fish supply and demand, the likely trends in demand and how this can be met to the year 2025.

Figure 1: Global fisheries and aquaculture production for food and per capita supply 1990-2005



Source: FAO 1996, 2000 and 2007

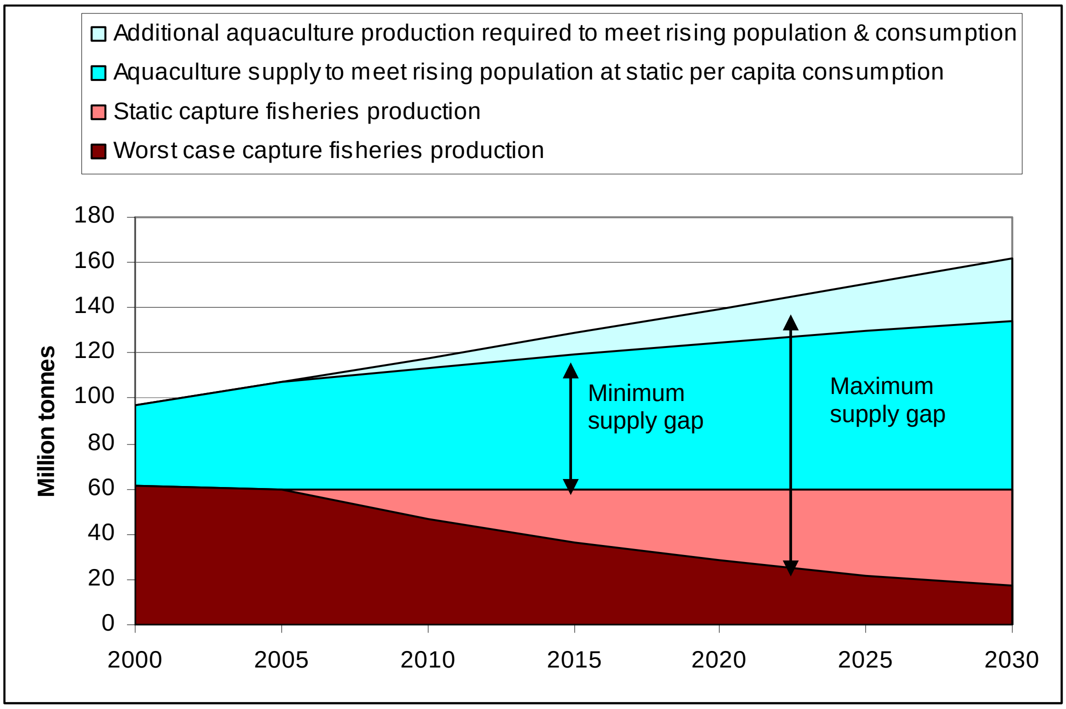
The world population in 2005 was approximately 6.44 billion. Projections by the International Institute for Applied Systems Analysis (IIASA) suggest this will rise to approximately 7.83 billion by 2025 (min 6.9 and max 8.76 billion). According to the Food and Agriculture Organisation (FAO, 2007), apparent consumption[4] of food fish (live weight equivalent) in 2004 was 16.6 kg per person. This equated to 107.2 million t of product for human consumption in 2005, from a total fisheries sector production of 141.6 million t. If per capita consumption remains static, and population increases at the mid rate predicted by the IIASA,

[4] Recorded production of fish and shellfish (excluding plants, fish and shellfish for non-human consumption, marine mammals etc) divided by population number. Including plants and fisheries production for non-human uses (but excluding marine mammals, amphibians and reptiles) gives a value of around 21.52 kg per person.

demand for food fish should rise to 113.4 million t by 2010, 119.4 million t by 2015 and 130 million t by 2025 (ignoring price effects). This compares with a 2005 production of around 59.4 million t of food fish from capture fisheries (FAO, 2007). The balance of around 47.5 million t was provided by aquaculture. On current trends, this would lead to an average per capita consumption of 19.2 kg and a total fish consumption of 150.6 million t by 2025. In many countries, per-capita fish consumption is rising as populations become more affluent, as witnessed within some parts of the EU, China, India, Brazil and elsewhere. Conversely, average per-capita consumption could also fall if fish becomes more expensive in real and/ or relative terms. In short estimates of future consumption levels are problematic because of the dynamics of change-drivers and, as such, must be held as a backcloth to the discussion.

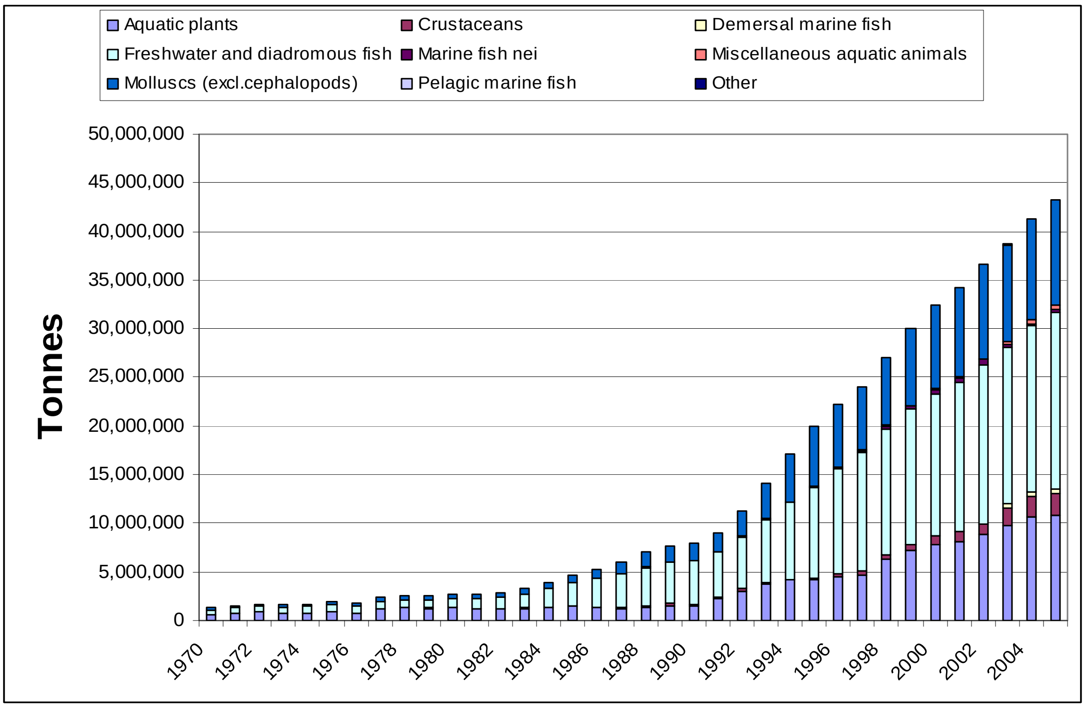
If capture fisheries is sustained at current levels, aquaculture production will need to rise to approximately 70 million t by 2025 to maintain current consumption levels with assumed population increases, and to 91 million t if per capita consumption continues to climb. If capture fisheries were to collapse to the levels proposed by Worm *et al* (2006), aquaculture production would need to rise to 128 million t to maintain current per capita consumption. This would represent a lower growth rate of 2.4% and upper growth rate of 8.5% per year. This can be compared with the historic growth rate of aquaculture between 1970 and 2004, of 8.8% (FAO, 2007). This was the fastest growth rate in the animal food protein sector as terrestrial meat production only increased by 2.8% per year. Figure 2 outlines potential scenarios.

Figure 2: Projections of demand for fish and seafood for human consumption



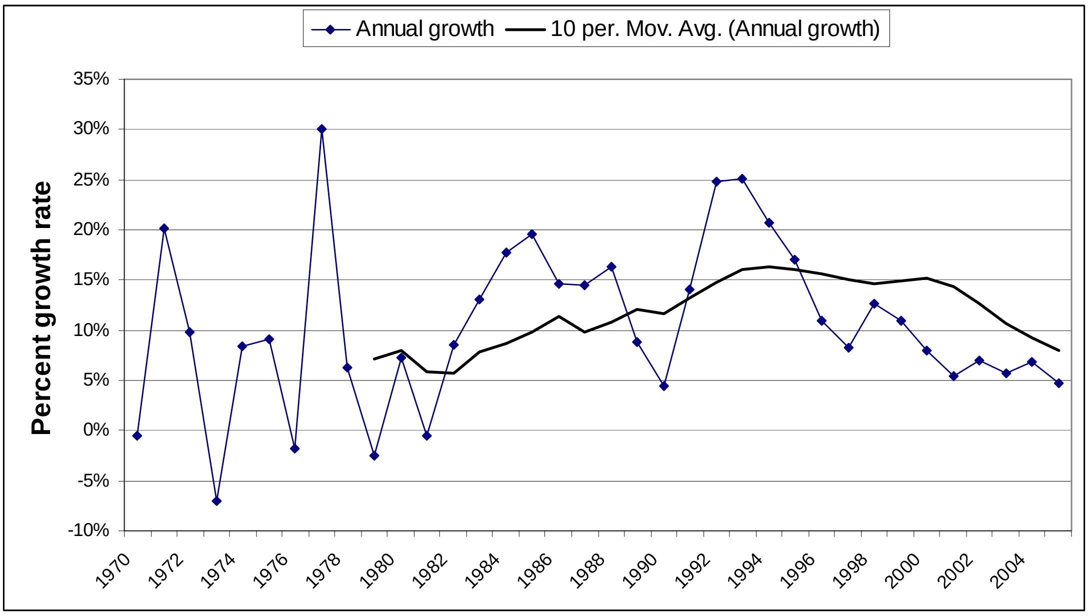
Whilst past growth suggests that aquaculture could meet rising demand, this assumes natural resources to be available, ongoing compliance with legislation and that it can provide an appropriate mix of products, in species and price, corresponding with demand. The rate of growth in global aquaculture is falling slightly, and global figures are strongly influenced by China (Figure 3), with 69.6% by volume and 51.2% by value of world production.

Figure 3: Development of Chinese aquaculture 1970-2005



Source: FAO Fishstat Database, 2007.

Figure 4: Annual growth rate for Chinese aquaculture (1970-2005)



Source: FAO Fishstat database. Smoothed line is 10 year moving average.

In virtually every continent, the growth of aquaculture between 2004 and 2005 was well below the trend of the previous 10 years. The only exception was Oceania, which has the smallest aquaculture production of all the continents, and thus perhaps greater potential. Single year growth rates in North America and Europe were actually negative, indicating lower production in 2005 than 2004. The strongest 10-year growth rates are seen in Africa and South America, where combined production is currently only 3.5% of that in Asia.

Table 1: Comparative growth rates by continent (Excluding aquatic plants)

	Production 2005 (tonnes)	10 year growth rate	2004-05
Africa	647,155	48.7%	15.5%
America, North	862,159	5.4%	-11.2%
America, South	1,149,943	22.0%	2.5%
Asia (Excluding China)	10,793,410	8.6%	4.5%
China	32,418,248	10.4%	5.9%
Europe	2,140,152	3.5%	-2.5%
Oceania	158,007	6.7%	8.5%
World excluding China	15,750,826	8.5%	2.8%
World including China	48,169,074	9.76	4.9%

Source: FAO Fishstat database, 2007

As discussed later, resource constraints appear to be a major factor slowing aquaculture development in Europe, Asia and North America. In some instances growth has been curtailed through legislation seeking to influence the allocation of resources between competing demands and elsewhere financial returns and perceived risks have not proven conduicive to expansion. Greater potential exists for expanding aquaculture using well established technologies in Africa, South America and Oceania, where lack of infrastructure, good governance, capital or technical expertise have commonly been more significant constraints.

2.2 EU-25 apparent demand

Analysis of European seafood supply and consumption in further detail is more complicated than for a broader global perspective, as there are important volumes of cross trade, processing, and product transformation which occlude detail. Our primary focus is EU Member States, and in particular EU-25 countries since relevant data is not yet available for EU-27, nor indeed did it exist at the inception of this project. However, for some analysis, it is appropriate to include Norwegian production and trade as Norway is a major exporter to the EU and closely connected in supply and other sectoral linkages. Norway is also a partner to the Acquis Communauitaire whereby its production criteria are essentially the same as the EU and generally compliant with Community legislation (Haugh, 2007).To develop a perspective for Europe, we examine the mix of population growth and trends in per capita fish consumption. Consumption trends combine income effects with distribution and developments in product form, consumer attitudes and behaviour. The aim is to provide a wider context in which more specific issues can be drawn out to examine likely trends for aquaculture production, regional effects and species/product developments.

The future development of the aquaculture sector in Europe and the context for technology change and investment will be influenced by four main external and two internal elements:

- Market demand (domestic and export).
- Production volumes and consumer acceptance of capture fisheries.
- Constraints on aquaculture (resources of space and water, limits on environmental discharges, investment, consumer acceptance etc[5]).
- Trade and international competitiveness.

[5] These factors are discussed in more detail in subsequent sections of the report.

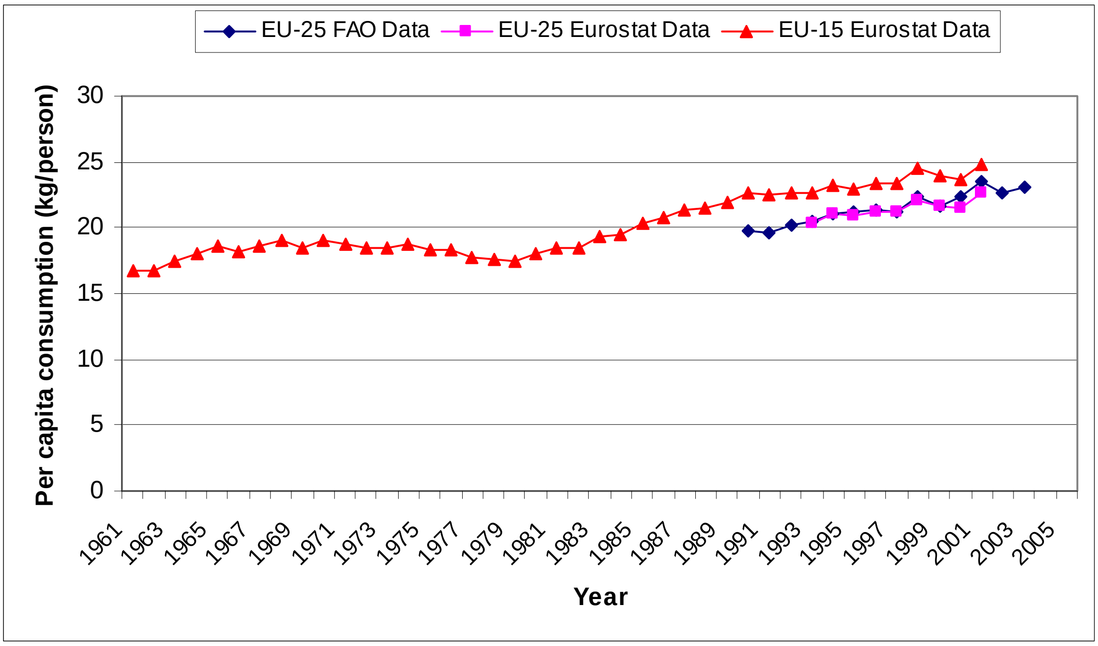
The key internal variables will be:

- productivity development.
- unit cost of production.

Establishing demand levels for the full basket of aquaculture products across Europe is difficult, since any measures should include both volume and price, and take into account factors such as product substitution and changing affluence and consumer wants. Such comparable detail is not available, and would in any case over-complicate analysis. We therefore use apparent demand indicators, based on measures of apparent per-capita supply. Supply for human consumption can then be further separated from total supply (which also includes industrial fisheries and other non-food products). A key technical problem is that fisheries products are traded and reported in various product forms; these are sometimes grouped and may consist of varying species mix. The edible portion of fish and shellfish may be less than 30% and some products may include additional non-fish elements (e.g. packaging, water in frozen products and other non-fish food items in ready meals).

Figure 5 shows 3 different supply measures plotted in kg per capita. The longest series available is from Eurostat, for EU-15 countries. Data for EU-25 countries is only available from 1993 to 2001 from Eurosat and 1990 to 2003 from FAO. All figures are based on apparent consumption of seafood (capture and aquaculture supplies plus imports, minus exports and fish for non-food use) converted to live weight fish equivalents. These statistics show a gradual increase in apparent consumption since 1961, although with a slight dip during the 1970s.

Figure 5: Comparison of per capita supply statistics



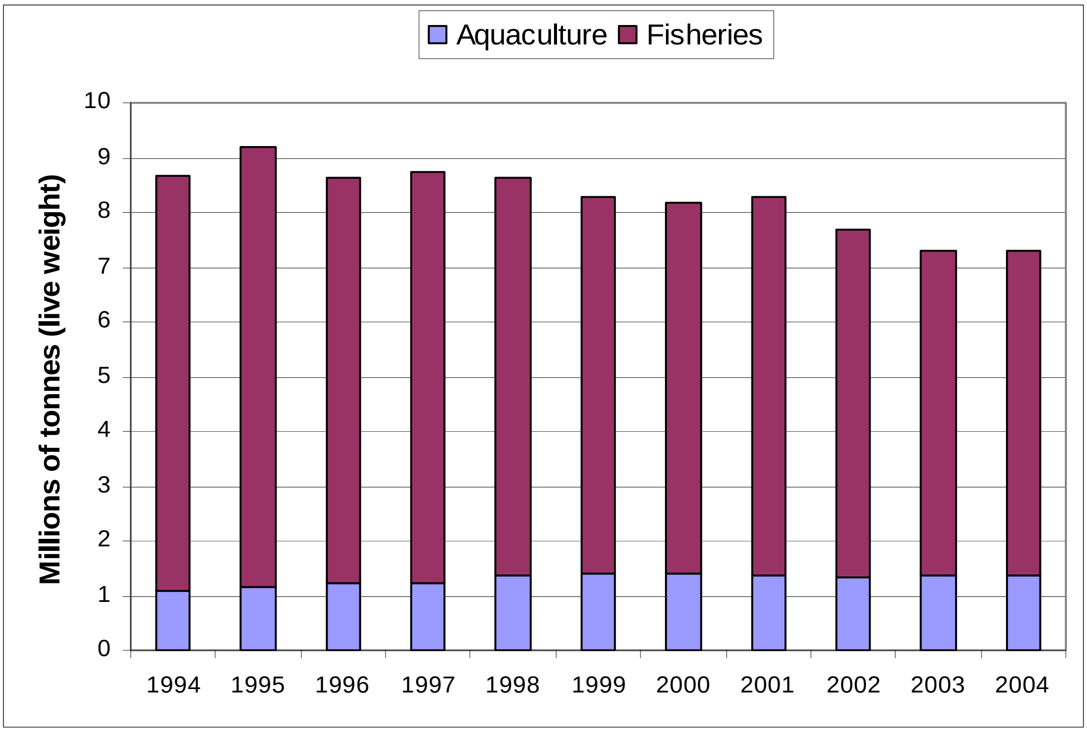
Source: FAO & Eurostat databases.

2.3 Setting demand projections

The use of Eurostat apparent consumption data makes conversion back to production data more straightforward, although such projections would ignore non-food fisheries and aquaculture for angling or ornamental purposes. However, this is a relatively small segment of the European aquaculture industry. Fish for re-stocking usually enter the food chain, although possibly at a higher average weight than recorded in re-stocking production statistics (extra growth would need to be balanced against stocking mortalities). Since the proportion of fish in this category is well below the margins of error in forward projections, further adjustment is not considered necessary.

The most recent data suggests that European fish production, dominated primarily by capture fisheries, is declining. In 2004, the combined production from capture fisheries and aquaculture was 7.314 million tonnes (live weight equivalent) (Figure 6). The average production for 2002-2004 was 16% lower than the average for 1994-96. The aquaculture component rose from 12.4% in 1994 to 18.8% in 2004.

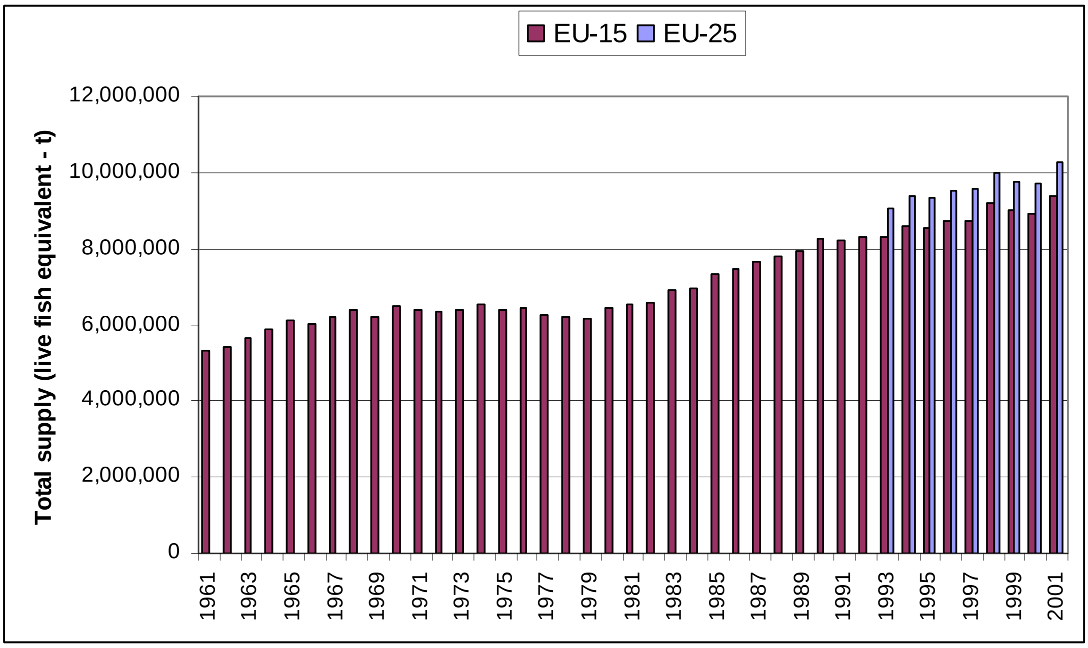
Figure 6: EU-25 fish production (aquaculture & capture fisheries - live fish equivalent)



Source: Eurostat 2007

Total fish supplies have risen substantially over the last 40 years, as reflected in the per-capita consumption data. Since the mid 1980s, this has mainly been driven by rising imports.

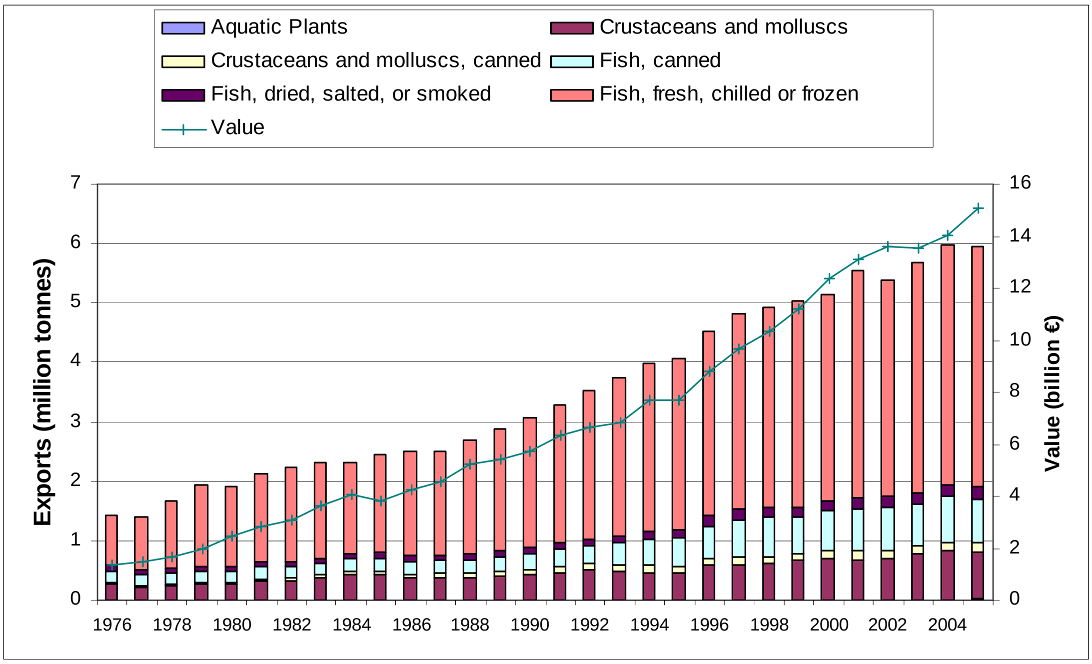
Figure 7: Total fish supplies (live fish equivalent)



Source: Eurostat, 2007

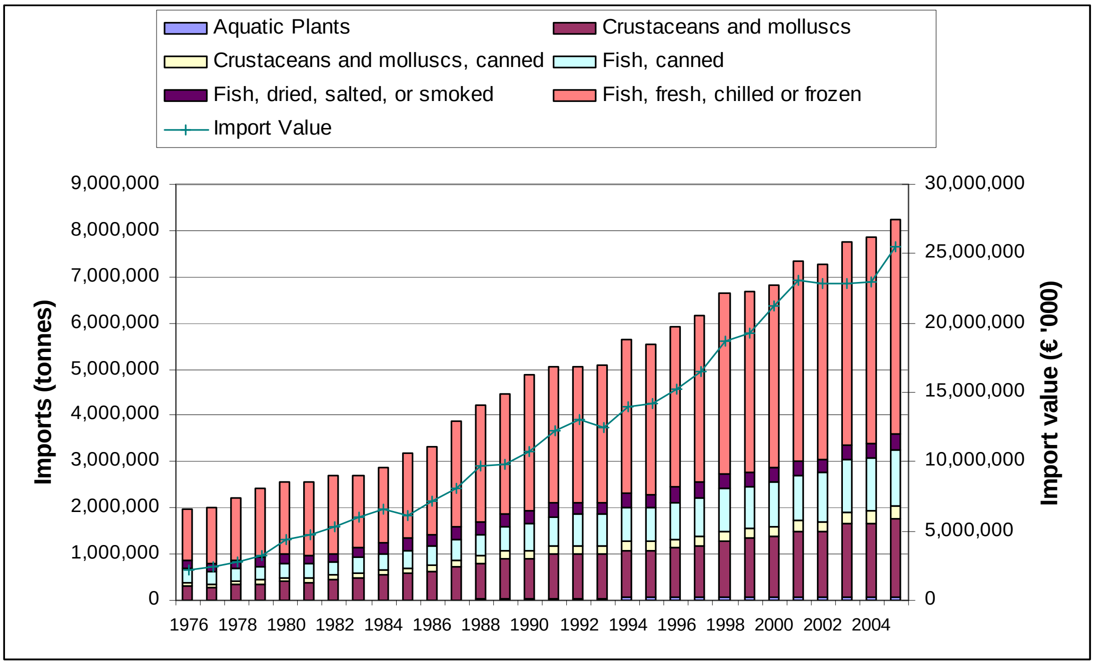
Trade in fisheries products has grown strongly over the 30 years for which data is available in terms of both imports and exports by volume and value.

Figure 8: Fish exports (actual product weights)



Source: FAO, 2007 (Note, Euro value is converted from US$ data)

Figure 9: Fish imports (actual product weights)

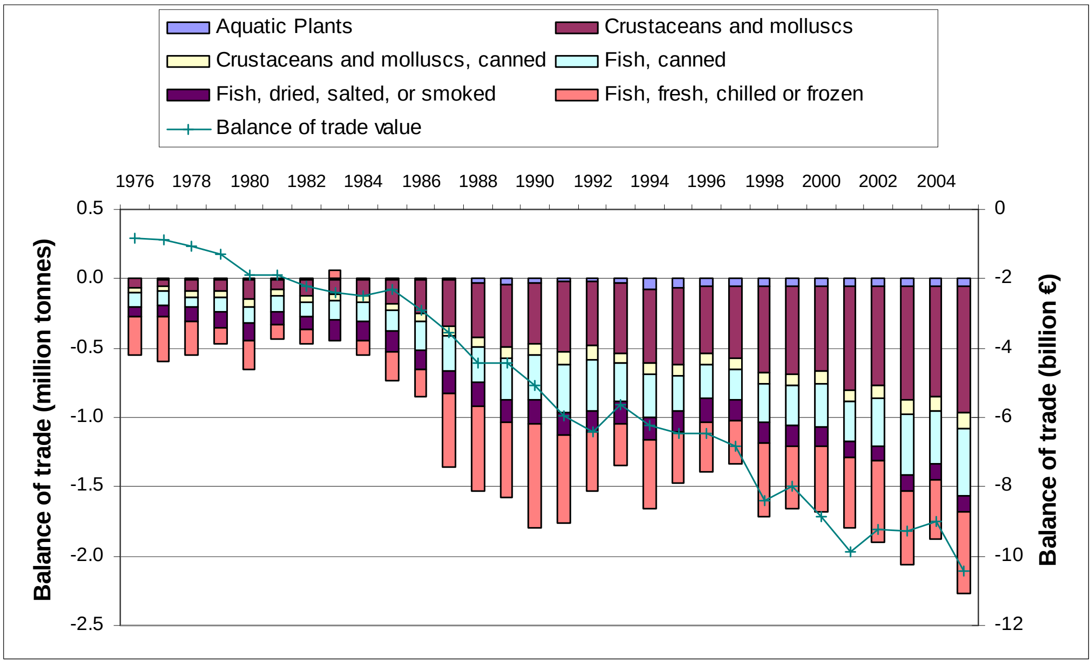


Source: FAO, 2007 (note Euro value is converted from US$ data)

Since the mid 1980s there has been a growing deficit in fisheries trade, reaching around 2.27 million tonnes (not adjusted to live weight equivalent) valued at € 10.45 billion in 2004. Glitnir (2007) estimated EU seafood self-sufficiency to have declined from 53% in 1997 to 40% in 2006. Net imports (imports minus exports) for key species groups have shown marked increases; for white fish imports have expanded tenfold from 0.1 to around 1 million t between 1984 and 2004. Crustaceans and molluscs also exhibit substantial increases whilst somewhat lower rates of increase were found in canned products.

Whilst aggregate data enables identification of broad trade patterns its composition of different product forms species mix does create difficulty in attempts at more detailed analysis. This problem is compounded as the scale of analysis is extended to include more countries and their diverse supply chains.

Figure 10: Balance of fish trade (actual product weights)



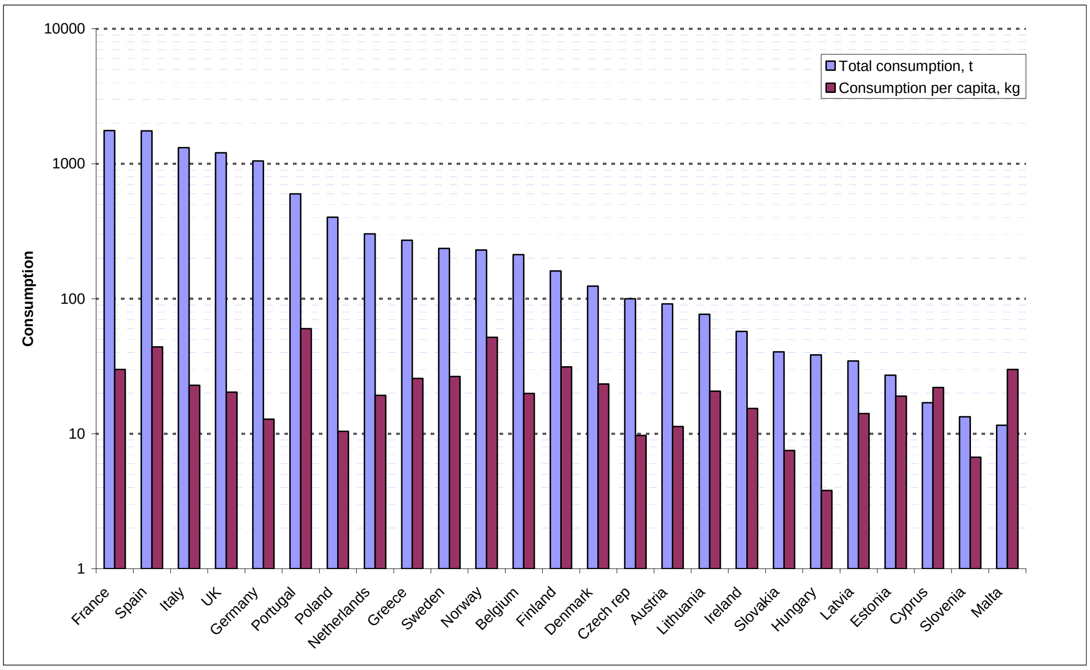
Source: FAO, 2007 (note Euro value is converted from US$ data)

Total consumption is a product of population numbers and average per-capita consumption. Apparent consumption should therefore rise with growing population assuming consumption patterns remain the same. The effect of increasing affluence is potentially more complex. In most cases, this is related to increased consumption of fish, though subject to limits. This will also influenced by changes in income distribution, as currently many countries with rising average wealth show static or even declining median incomes. In some cases changes in the value of fish consumption will be more significant than changes in volume. Shifts within the population structure, notably the increased proportion of older consumers, might also be expected to influence patterns observed.

Given current demographic projections, the population of EU25 countries is set to increase by only around 2.5% from 2005 to 2025[6] compared to some 16.8% globally. Most of this is likely to be seen in Spain, the UK and France given current trends, while the population of many Eastern European states is currently decreasing, at least in part due to emigration to Western Europe. This may of course reverse, or slow, if there is greater convergence of living standards in future. Traditionally these Western countries have had some of the highest levels of seafood consumption in Europe (see Fig. 11) together with relatively high per capita apparent consumption levels.

[6] Eurostat population projections (http://epp.eurostat.ec.europa.eu/) For comparison and corroboration, IIASA European population projections indicate growth of around 0.1% per annum, but include many non-EU Eastern European countries.

Figure 11. Total and annual per capita consumption of fish and seafood in Europe



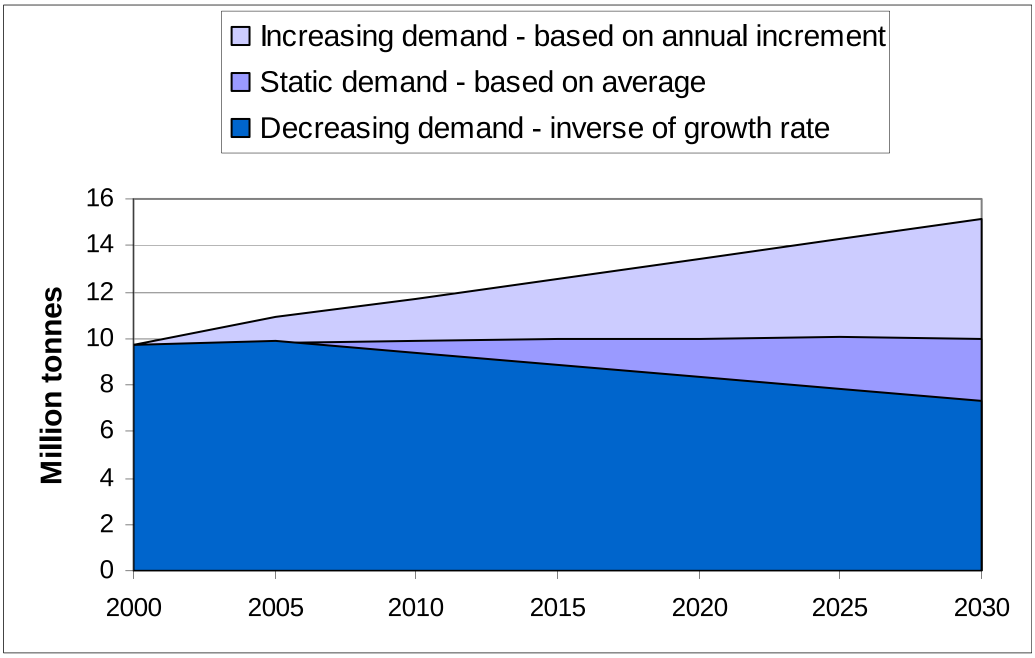
Source: Calculated from Eurostat data on total apparent seafood consumption and population statistics Note log scale to accommodate the wide spread of values (Norway included for comparison)

After wider analysis of data sources, trends in per capita seafood consumption were derived from extrapolated Eurostat apparent consumption data over 1993 to 2001. This showed a mean increase in consumption at around 1.27% per annum, albeit masking considerable variation, especially for the newer Eastern and Central European Member States. In these countries divergent trends in fish consumption have been noted over relatively short periods of time reflecting first decline, then expansion at rates between 2.5 nd 5% pa between 2002 and 2006 in some cases (Ferlin, 2007, personal communication). Nonetheless, at the aggregate level, the data suggest a continued increase over a longer period and so this projection was used for the upper general consumption trend used in subsequent analysis. More specific analyses were also carried out using FAO data for supply and consumption of species groups, but because of conversion discrepancies these could not consistently be aggregated. These were however used where applicable and possible in later sections on perspectives for key product groups.

To define a lower level trend, we developed an average based on Eurostat apparent net consumption between 1992 and 2001 of 21.6 kg/cap/year. These apparent consumption estimates were multiplied with projected population numbers to derive demand estimates for 2010, 2015 and 2025 (Figure 12). The overall envelope for changes in demand for fish as a generic commodity is therefore calculated as:

- Increasing demand - projected population change multiplied by projected demand change extrapolated from historic annual increases in per capita consumption (data from Eurostat 1992-2001)
- Static demand – present per capita consumption, multiplied by population change projections
- Decreasing demand - Calculated as for maximum demand, but with negative growth rate.

Figure 12: EU-25 supply needs to 2025, low and high projections



Source: Developed from Eurostat data 2007

The market for fish and seafood follows conventional supply and demand economics, which indicate that if supplies decrease, the price will rise and dampen demand. Conversely, if supplies increase, the price will fall and increase demand. The strength of this relationship is measured through calculations of demand elasticity[7]. The literature on demand elasticity for fish has been reviewed by Asche *et. al.* (2005). This highlights considerable variations in results, due to local markets, cross substitution, income, temporal, and value chain effects. It concludes that overall, the market for seafood is probably elastic, implying demand could grow if production rises and prices decrease, and fall if prices rise. It has also been noted, (Bjorndal, 2007, personal communication) that demand elasticity studies have been mainly concerned with salmon, and much less with other products; moreover values observed also change over time. Indeed some seafood market segments, such as tinned tuna, appear inelastic. In general, elasticity is lower at the consumer end of the value chain and highest at the primary producer point of first hand sale in capture fisheries.

Delgado *et. al*. (2003) considered the issue of price sensitivity when examining anticipated fish supply and demand to 2020, drawing on earlier work by Asche and Bjorndal (1999). This review suggested reasonable values of own-price elasticities for modelling purposes of between -0.8 to -1.5. The work of Delgado and Courbois (1998) was also cited here as source for cross-price elasticity between poultry and fish of 0.3 (i.e. a 1% rise in poultry prices would lead to a 0.3% rise in fish demand). The Delgado *et. al*. (2003) study utilises the IFPRI International Model for Policy Analysis and Agricultural Commodities and Trade (IMPACT) which is based on a set of country or regional sub-models within each of which, supply, demand and prices of agricultural commodities are determined. IMPACT uses a system of supply and demand elasticities for each commodity, variable for each of the 36 markets incorporated into the model. Each commodity is modelled using an appropriate linear or non-

[7] The simplest expression of price elasticity of demand is: (% change in quantity demanded)/(% change in price). Ignoring any negative sign, values greater than 1 indicate price elasticity whereas values lower than 1 are price inelastic.

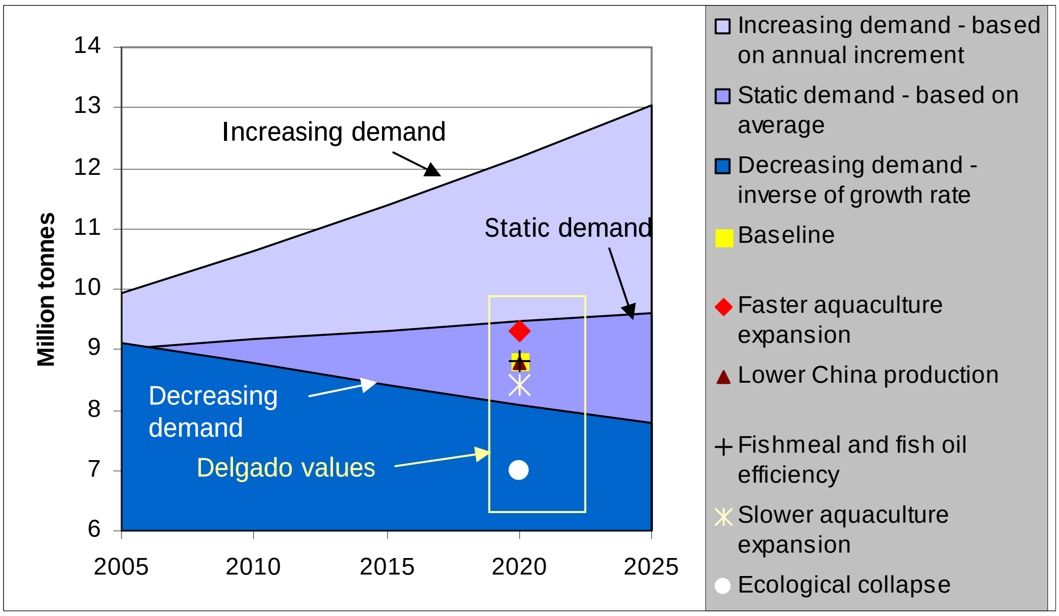
linear equation to approximate the underlying supply and demand functions. Cross price elasticities are included, as are intermediate demands (such as fishmeal and soya meal for fish feed production). Demand within each market is modelled as a function of prices, income and population growth. The main outputs of the model for EU15 countries (EU25 not disaggregated) are shown in Table 2. Replication of this analysis within this study is beyond the agreed remit, but might be noted for future research needs.

Table 2: EU15 projections for 2020 from Delgado et. al. (2003) (t '000)

EU 15 Scenarios	Total Production	From Aquaculture	From Capture	Total apparent Consumption	Implied net imports
Baseline (most likely)	6,716	1,972	4,744	8,807	2,091
Faster aquaculture expansion	7,020	2,339	4,681	9,307	2,287
Lower China production	6,716	1,970	4,746	8,763	2,047
Fishmeal and fish oil efficiency	6,763	2,007	4,756	8,825	2,062
Slower aquaculture expansion	6,456	1,653	4,803	8,413	1,957
Ecological collapse	5,988	2,038	3,950	7,004	1,016

A number of scenarios were considered which resulted in supply projections for EU15 countries of between 7 and 9.3 million tonnes. The baseline scenario was considered most likely, and at 8.8 million tonnes, was close to the scenarios modelling lower Chinese production or improved utilisation of fishmeal and fish oil. The faster and slower aquaculture expansion projections are based on 50% higher or lower growth rates than used for the baseline (variable within the global model of 36 regions). All the projections except that of "ecological collapse" fall within the limits of static and minimum demand projections in our model (Figure 13). The scenario for ecological collapse is based on a decline in all capture fisheries (including fishmeal and oil) of -1% per annum between the baseline year of 1997 and 2020.

Figure 13: EU-15 projected supply needs to 2025, compared with Delgado *et. al.* projections for 2020



Source: Developed from Eurostat data 2007 with the addition of data points from Delgado et. al (2003) EU15 supply scenarios

Account also needs to be taken of value adding through processing and distribution. This typically raises the unit price consumers pay for fish products, but may increase their appeal and acceptance and may therefore increase total consumption. For instance, sales of convenience foods have grown strongly with cash-rich, time-poor consumers especially seeking ready-to-cook, skinless and boneless fish products or ready-prepared shellfish. This leads to an increase in the total value of the fish segment, even if volume does not increase (Borg, 2005). The demand for fish and seafood through the food service sector (restaurants, hotels and catering) is also increasing in some countries (Seafish, 2007) with yet further unit value addition through incorporation of additional service values.

2.4 Conclusions

Available statistics show a declining trend in fish production (capture plus aquaculture) in the EU since the mid 1990s. Conversely, apparent consumption is rising with supplies from imports growing. Extrapolation of trends provides some insight into future directions and the possible magnitude of changes. However, they become more unreliable the longer the timescale involved. Extrapolating recent trends in consumption forward to 2025 results in fish consumption increasing by almost 50%. This is feasible if supplies (of products attractive to consumers) increase and prices fall. If supplies are constrained, prices are likely to rise and demand dampened.

Reference to the more complex global model used by Delgado et al (2003) suggests that extrapolating growth rates encompasses the range of values considered likely by other analysts. However, as discussed later in this report, there is a substantial challenge in maintaining current supplies, such that a decline in per capita fish consumption appears more likely than an increase. Some account must also be taken of trends in consumer choice and the impact that value addition through processing and otherwise adding value, certification, ecolabelling, packaging and distribution can have on total consumption, not to mention parallel events in substitute markets.

3 Seafood supply balances

3.1 Overview

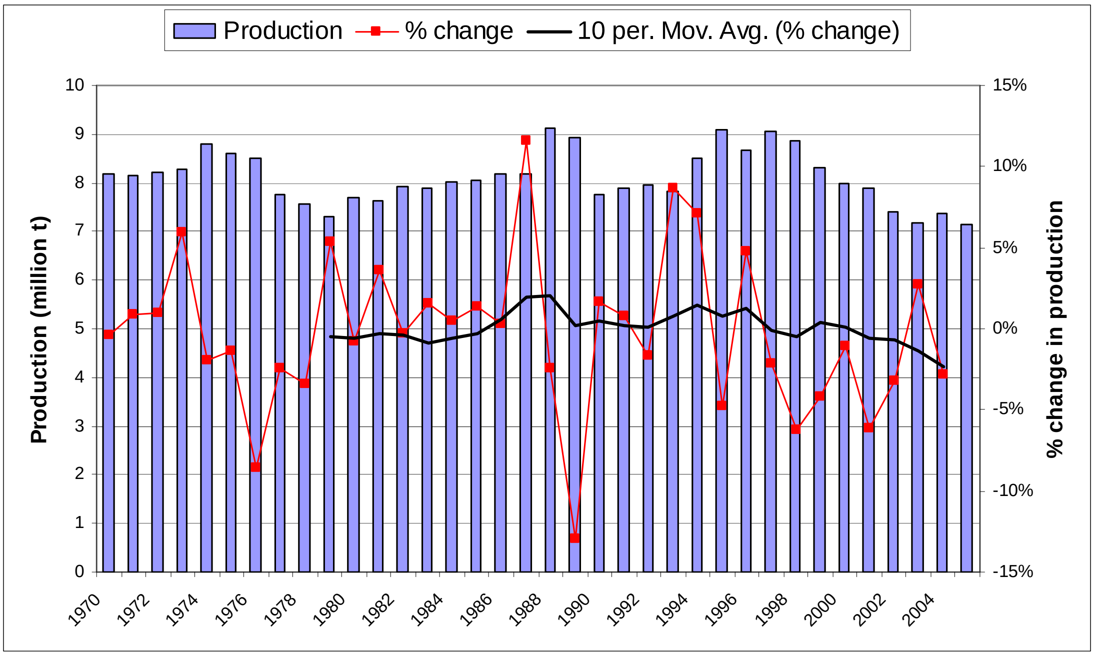
Having considered patterns of demand in the previous section, this section examines European fish supplies and sets out potential aquaculture production scenarios which are explored in further detail in Section 6. In 2005, aquaculture represented around 25% of European seafood production. This proportion is gradually rising, in part due to a trend of declining capture fisheries. The 2005 catch was the lowest since 1970, although only slightly below 1980 values (Figure 14). The largest fishing nation is Denmark (16% of capture supply including industrial fisheries), followed by Spain (15%), the UK (12%) and France (11%) (Glitnir, 2007). If EU capture fisheries output declined by 10%, aquaculture production would need to increase by over 32% (in reversal of current trends) to maintain a current European supply. This assumes that there is straightforward substitution between aquaculture and fisheries products. Until relatively recently, consumers in many countries were relatively unaware of aquaculture, and its products were often not labelled as such (GIRA, 2001). This has substantially changed since the introduction of clearer labelling (under Commission Regulation (EC) 2065/2001) and increased attention given to aquaculture by the media. For products such as sea bream and sea bass that are available from both fisheries and aquaculture sources, the wild product normally commands a substantial price premium (Monfort, 2006).

The degree of separation between aquaculture and fisheries products (indicated by the extent to which the price of one influences the other) is less well studied, and is probably variable. A comprehensive analysis of the market for salmon by Asche et. al. (1998) found that frozen wild Pacific salmon is in the same market as fresh and frozen farmed Atlantic salmon, whereas a more subjective assessment by the UK Competition Commission (2000) found farmed salmon to be a separate market from that of wild (Atlantic or Pacific) salmon. As aquaculture supplies increase the distinction between captured and farmed product is likely to be increasingly influenced by the extent of any product positioning strategies adopted within the chain.

However, at this overview level, it is assumed that aquaculture has the capacity to substitute for capture fisheries providing it can supply broadly similar types of products at similar prices. The latter point is critical, and is explored further in the following projections, as the average value (first sale, wholefish equivalent) of EU-25 aquaculture produced fish in 2005 was Euro 3.25/kg[8]. Comparative statistics are not produced for the value of EU-25 capture fisheries. However, data from the UK indicates an average value of Euro 0.96/kg for capture fisheries landings[9].

[8] Calcuated from FAO Fishstat data for 2005, EU-25 countries, finfish only.
[9] Developed from summary data presented at http://www.seafish.org/sea/business.asp (marine fish species only)

Figure 14: Trends in capture fisheries (seafood species) EU-25



Source: Developed from FAO Fishstat database, 2007

An envelope for estimates of future EU-25 capture fisheries production is therefore defined as follows:

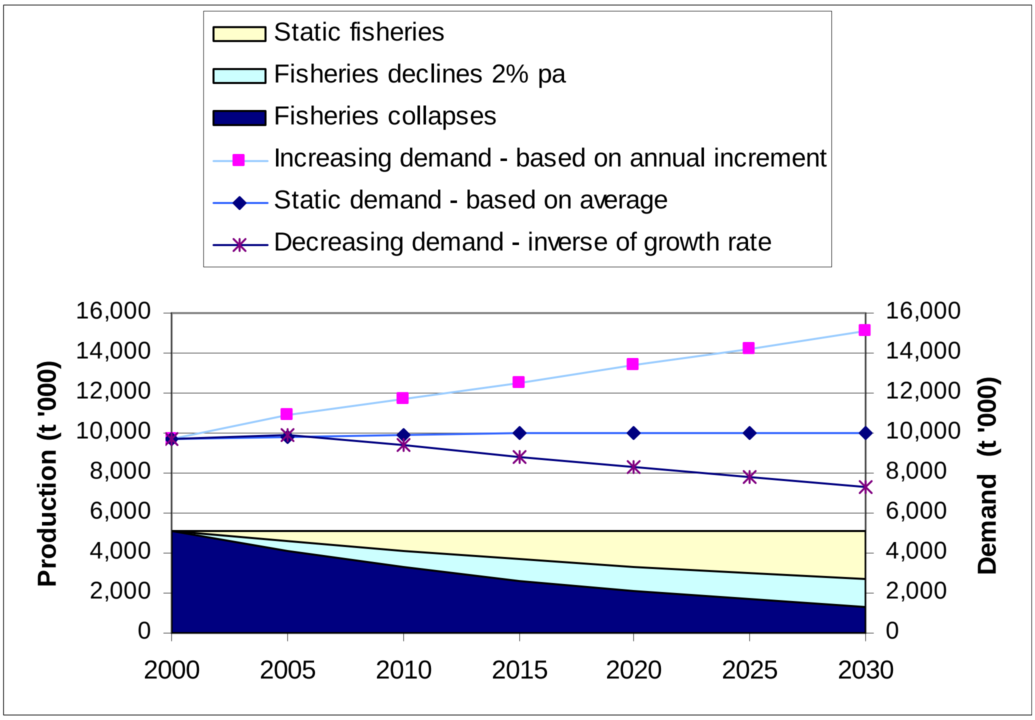
- Maximum production – assumes average annual capture volumes of food fish (1994-2004) are maintained between 2005 and 2025
- Minimum production – assumes capture fisheries production decreases at 4% per year between 2005 and 2025.
- Moderately declining production – assumes fisheries production decreases at 2% per year between 2005 and 2025 (in line with recent trends)

For most of our models (presented in more detail in Section 6), in line with the balance of industry and scientific expectations, it is not assumed that capture fisheries will fall catastrophically, but that the present rate of decline will continue. This is not inevitable, but effective conservation measures have so far proved difficult to implement. If supplies become more constrained, prices are likely to rise, providing even more incentive for fishermen to exploit remaining stocks. Other trends such as ecosystem shifts due to temperature changes and nutrient loadings may also impact on stock levels and/or change the distribution of higher value stocks.

3.2 Production Scenarios

Figure 15 shows an apparent gap between projected capture fisheries supplies and demand which would need to be met from aquaculture production and imports. For the purposes of this study, the key question is how the aquaculture sector will develop in light of anticipated rising demand. This would be set against the most recent EU-25 data which suggests that aquaculture production cannot be assumed to necessarily increase, and could in fact decline on the basis of current trends.

Figure 15: Scenarios for capture fisheries supplies of seafood (EU-25)

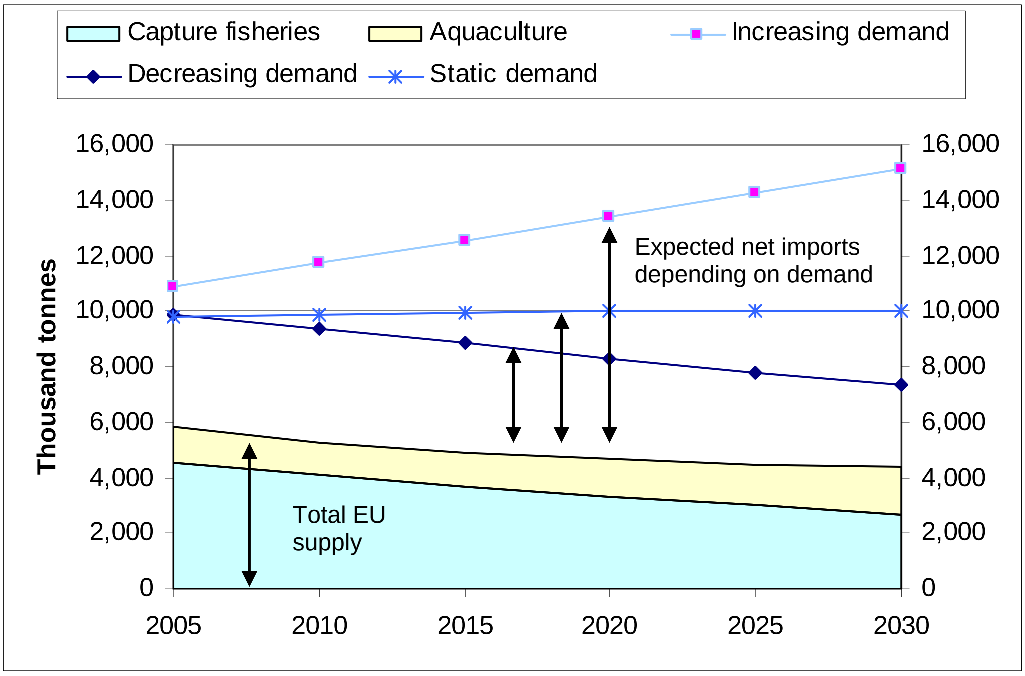


Source: Developed from Eurostat data 2007

3.2.1 Scenario 1: Baseline - minimal development of aquaculture

If it is assumed that there are no major advances in aquaculture technology, no further gains in productivity, and that environmental/ resource access considerations severely limit further expansion for most system types, aquaculture production overall may continue to fall for the next 5-10 years within the EU-25 countries. Nevertheless, there could be further growth in the production of higher unit value marine species, as tightening fish supplies would be expected to raise all prices and make it more viable to use more expensive production technologies. However the additional volume of premium species would not be likely to compensate for decline elsewhere. This baseline scenario is shown in Figure 16, essentially based on minimal development within the sector. It assumes positive growth in aquaculture production resumes by 2015 as the gap between supply and demand projections widens and prices strengthen, attracting further investment in production.

Figure 16: Scenario 1 (baseline) for EU-25 seafood production



Source: Developed from Eurostat data 2007

The data used for Figure 16 is shown in Table 3. Net import requirements are calculated as the difference between projected demand (3 demand scenarios as discussed in Section 2) and projected total EU fisheries and aquaculture production.

Table 3: Summary of production scenario 1 – minimum aquaculture development (EU-25)

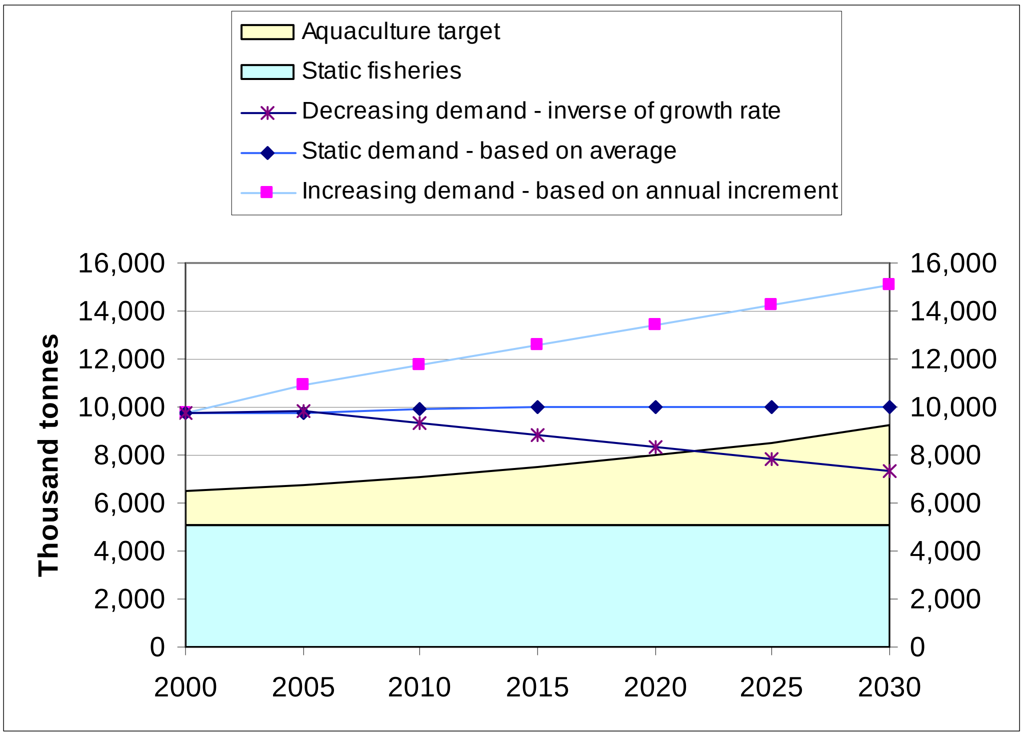
Thousands of tonnes

Demand (from Section 2)	*2005*	*2010*	*2015*	*2020*	*2025*
Increasing demand	10,903	11,725	12,543	13,383	14,243
Static demand	9,785	9,905	9,973	10,016	10,033
Decreasing demand	9,866	9,364	8,840	8,324	7,817
Production					
Aquaculture	1,261	1,175	1,200	1,318	1,483
Capture fisheries	4,577	4,119	3,707	3,336	3,003
Total production	5,837	5,293	4,907	4,654	4,485
Net import requirements					
Increasing demand	5,066	6,432	7,636	8,729	9,757
Static demand	3,948	4,611	5,066	5,361	5,548
Decreasing demand	4,029	4,070	3,933	3,669	3,332

3.2.2 Production scenario 2: Aquaculture expands to meet output derived from EU target of 4% per annum growth to 2025

In 2002, The European Commission proposed a target growth rate for EU aquaculture of 4% p.a[10]. So far, there is little indication that this is being achieved. However, it is useful to set this target within our analysis. If capture fisheries production remains static, this rate of growth, had it been maintained since 2000, takes overall production close to meeting current demand (adjusted for population only) by 2030 (Figure 17). This would assist the balance of trade, especially if import prices increase in the future.

Figure 17: Production scenario 2: Aquaculture expands to meet output derived from 4% per annum growth from 2000 with static capture fisheries (EU25)

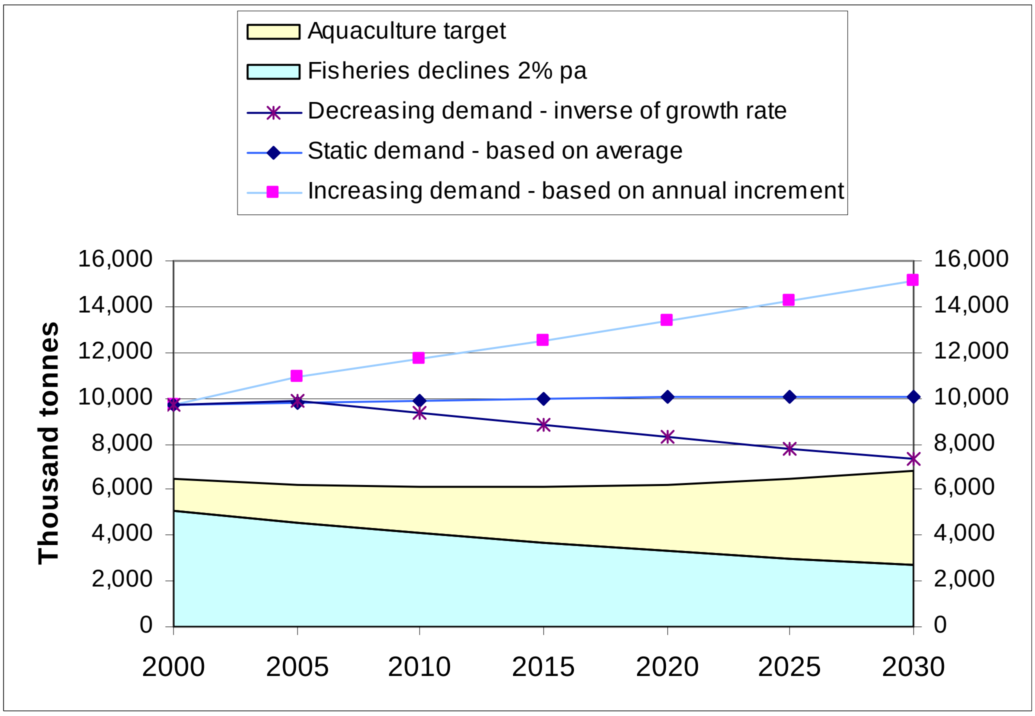


Source: Developed from Eurostat data 2007

If capture fisheries were to continue to decline at a rate of 2% per annum, a 4% per annum rate of growth in aquaculture production since 2000 would not fully compensate for declining EU supply until after 2015 (Figure 18).

[10] European Commission, 2002. The target was set with a 10 year vision (the growth of jobs was foreseen to take place between 2003-2008), but due to the lack of another reference, it was used for the whole period of this analysis.

Figure 18: Production scenario 2: EU-25 Aquaculture expands to meet output derived from 4% p.a. growth rate from 2000 with declining capture fisheries (2% pa)



Source: Developed from Eurostat data 2007

Table 4: Summary of scenario 2 – Aquaculture expands to meet output derived from target growth rate of 4% p.a. since 2000 with declining capture fisheries (2% pa)

Thousands of tonnes

Demand	*2005*	*2010*	*2015*	*2020*	*2025*
Increasing demand	10,903	11,725	12,543	13,383	14,243
Static demand	9,785	9,905	9,973	10,016	10,033
Decreasing demand	9,866	9,364	8,840	8,324	7,817
Production					
Aquaculture	1,261	1,842	2,444	3,021	3,370
Capture fisheries	4,577	4,119	3,707	3,336	3,003
Total production	5,837	5,961	6,151	6,357	6,373
Net import requirements					
Increasing demand	5,066	5,764	6,392	7,026	7,870
Static demand	3,948	3,944	3,822	3,659	3,660
Decreasing demand	4,029	3,402	2,689	1,966	1,444

Since the target growth of 4% did not exist in 2002 and has not been achieved since, this scenario represents a historic target for comparison. To meet the targets set for aquaculture in 2010, 2015 and 2025, growth rates considerably greater than 4% per annum would be required. Two further supply scenarios are therefore examined to explore alternative development patterns for European aquaculture production, particularly in relation to emerging systems.

3.2.3 Production scenario 3: Aquaculture develops to fill the supply gap left by declining capture fisheries

In this scenario, aquaculture development more or less keeps pace with an anticipated decline in output from the EU capture fisheries (2% per annum). This could for instance be driven by rising prices for fish stimulating investment in aquaculture, especially marine species such as cod, turbot, sole, halibut, yellow tail, and perhaps alternate bass and bream species.

Figure 19: Production scenario 3: Aquaculture grows to the supply gap that would emerge if capture fisheries declines at 2% per annum (EU-25)

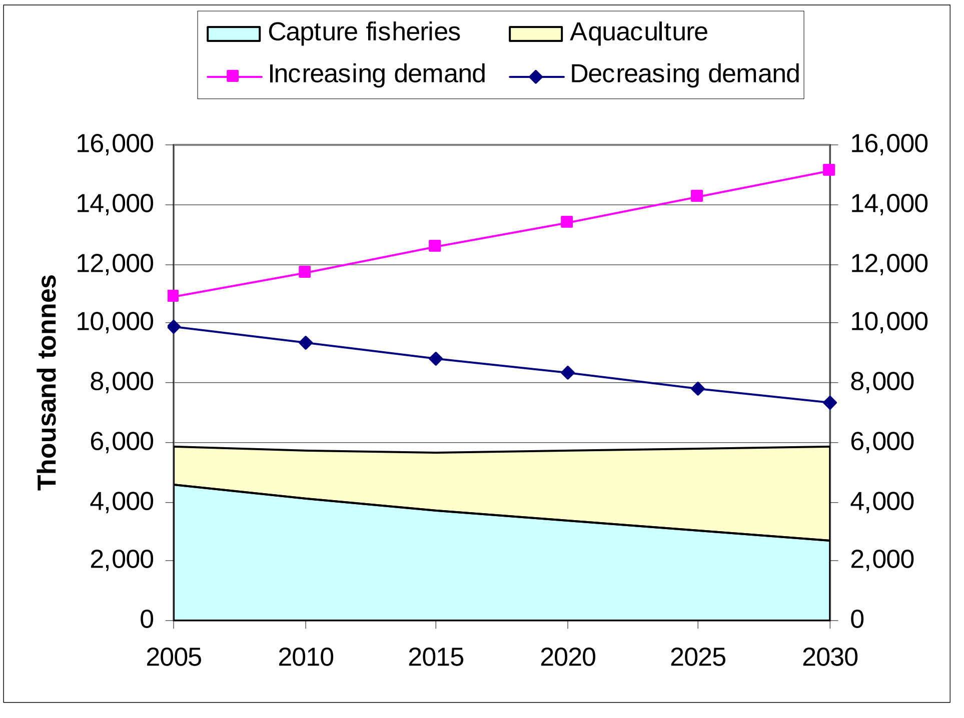


Table 5: Production scenario 3 – aquaculture supply rises to match capture fisheries decline (EU-25)

Thousands of tonnes

Demand	*2005*	*2010*	*2015*	*2020*	*2025*
Increasing demand	10,903	11,725	12,543	13,383	14,243
Static demand	9,785	9,905	9,973	10,016	10,033
Decreasing demand	9,866	9,364	8,840	8,324	7,817
Production					
Aquaculture	1,261	1,566	1,936	2,403	2,804
Capture fisheries	4,577	4,119	3,707	3,336	3,003
Total production	5,837	5,685	5,643	5,740	5,806
Net import requirements					
Increasing demand	5,066	6,040	6,900	7,643	8,436
Static demand	3,948	4,220	4,330	4,276	4,226
Decreasing demand	4,029	3,679	3,197	2,584	2,011

3.2.4 Production scenario 4: Aquaculture expands to fill all the supply gap between capture fisheries and static demand

This scenario would be driven by constraints on import supplies, or very high transport costs, making aquaculture in Europe financially attractive. As with other growth scenarios, it assumes that technology and input resources are available.

Figure 20: Aquaculture grows to fill the supply gap between capture fisheries and static forecast demand (EU-25)

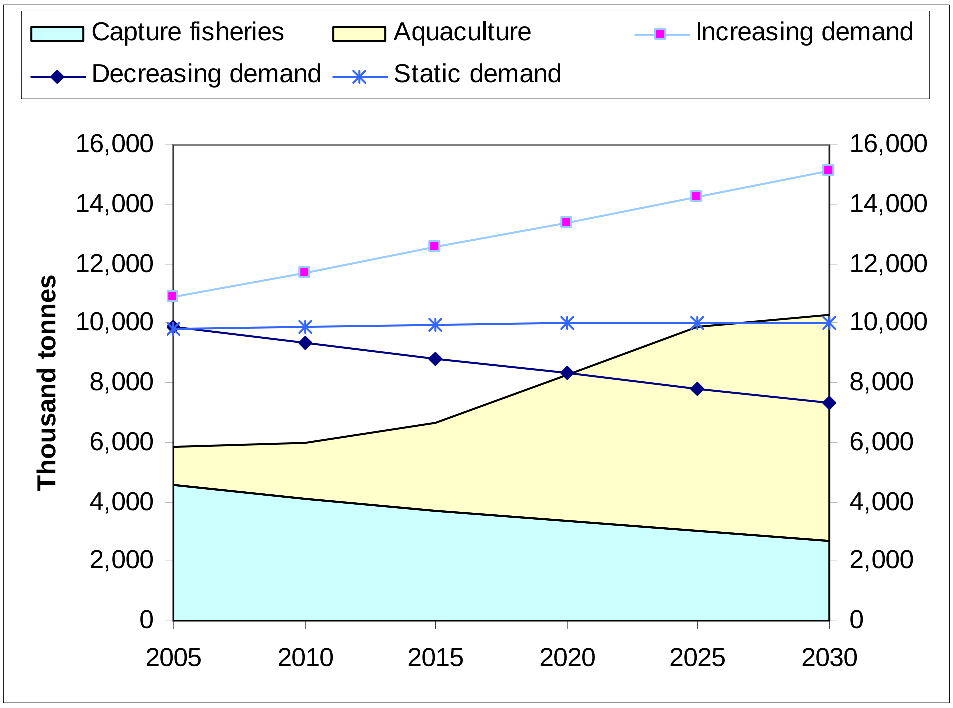


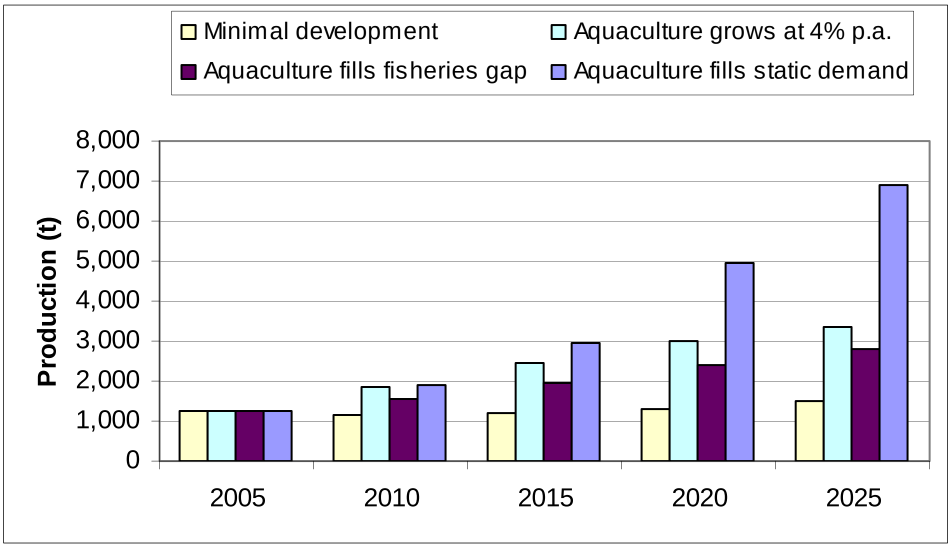
Table 6: Scenario 4 - Aquaculture grows to fill the supply gap between capture fisheries and static forecast demand (EU-25)

Thousands of tonnes

Demand	*2005*	*2010*	*2015*	*2020*	*2025*
Increasing demand	10,903	11,725	12,543	13,383	14,243
Static demand	9,785	9,905	9,973	10,016	10,033
Decreasing demand	9,866	9,364	8,840	8,324	7,817
Production					
Aquaculture	1,261	1,878	2,953	4,938	6,885
Capture fisheries	4,577	4,119	3,707	3,336	3,003
Total production	5,837	5,997	6,660	8,274	9,887
Net import requirements					
Increasing demand	5,066	5,729	5,884	5,109	4,355
Static demand	3,948	3,908	3,314	1,742	146
Decreasing demand	4,029	3,367	2,180	49	-2,070

This scenario envisages a 5.46 fold increase in aquaculture production between 2005 and 2025 – double the increase anticipated by the 4% per annum EU target.

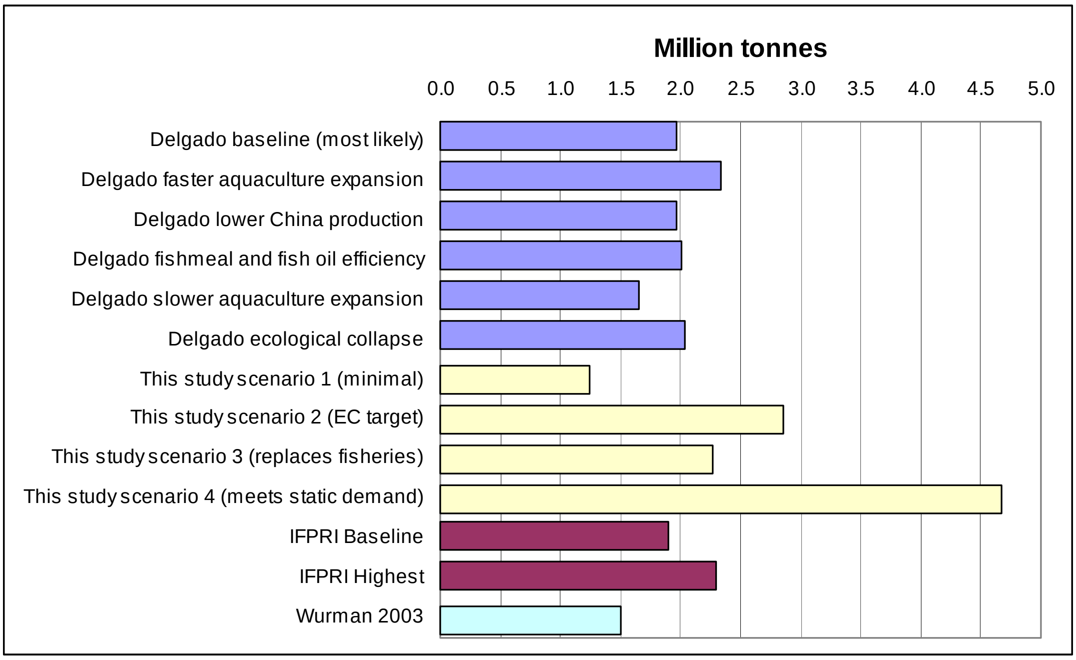
Figure 21: Summary of aquaculture projections (EU-25)



3.2.5 Comparison of EU aquaculture production scenarios

Forward projections of aquaculture production have been previously prepared for EU-15 countries by Delgado et al (2003), Brugère & Ridler (2004) and Wurman. (2003). These provide a variety of scenarios for production in 2020 (Figure 22).

Figure 22: Comparison of aquaculture projections (EU-15) for 2020



Note: scenario projections from this study (yellow bars) have been reduced by 5.477%, the historical difference between EU15 and EU25 production levels in 2005. Other data from Delgado et al (2003) and Brugère & Ridler (2004) (IFPRI and Wurman data).

Comparing these published values with the aquaculture production scenarios outlined here (Figure 22), it can be seen that our scenarios encompass a wider range of values than these other source, with scenario 3 the closest to most other projections.

The factors affecting the development of the aquaculture sector are examined in greater detail in Section 5 following a closer examination of the European market for fish and seafood in Section 4. We then return to these aquaculture development scenarios in Section 6, with more detailed consideration of species groups, systems and likely consequences with respect to social and environmental parameters.

3.3 Trade scenarios

Key issues are the potential for European seafood demand to be met by imports from third countries, and the ability of European producers to be competitive and export to other countries. EU-25 fishery imports in 2004 were around 7 million t for food use (9 million t including fishmeal and industrial fish). These are offset to some degree by exports. Less than 20% of this is aquaculture produce, mainly salmon from Norway, tropical shrimp, some cultured freshwater fish and other miscellaneous species. If world fisheries are around sustainable limits and demand continues to rise, the prospects for greater quantities of capture fishery products reaching Europe appear unlikely. Projections prepared in 2004 (Josupeit, 2004) anticipate demand to grow more strongly in developing countries through population growth, and at least in Asia, increasing prosperity.

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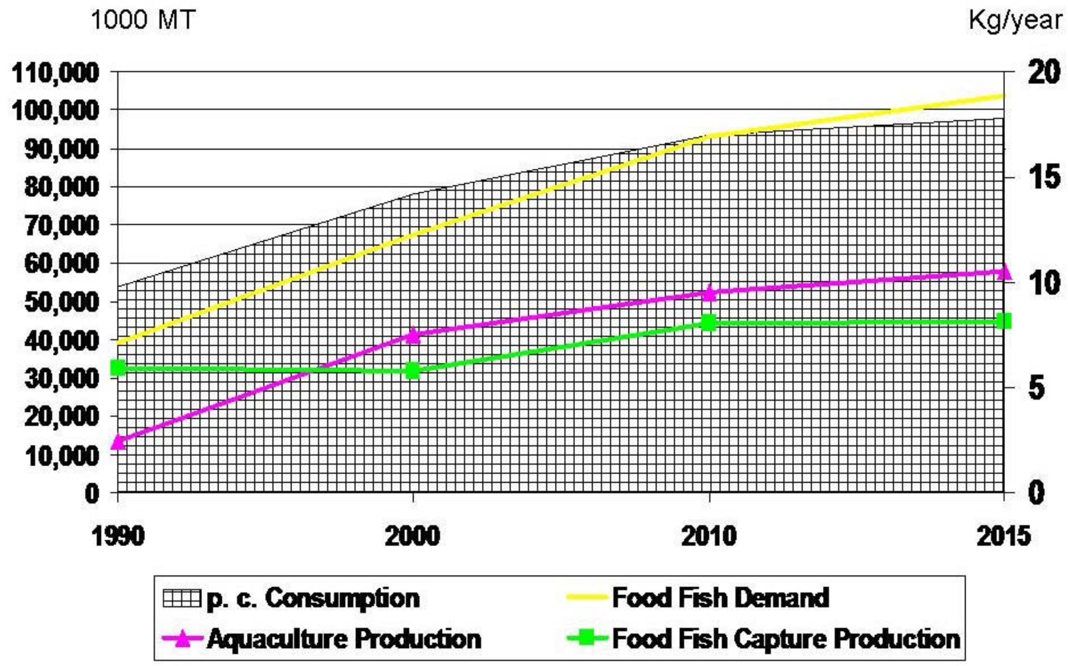
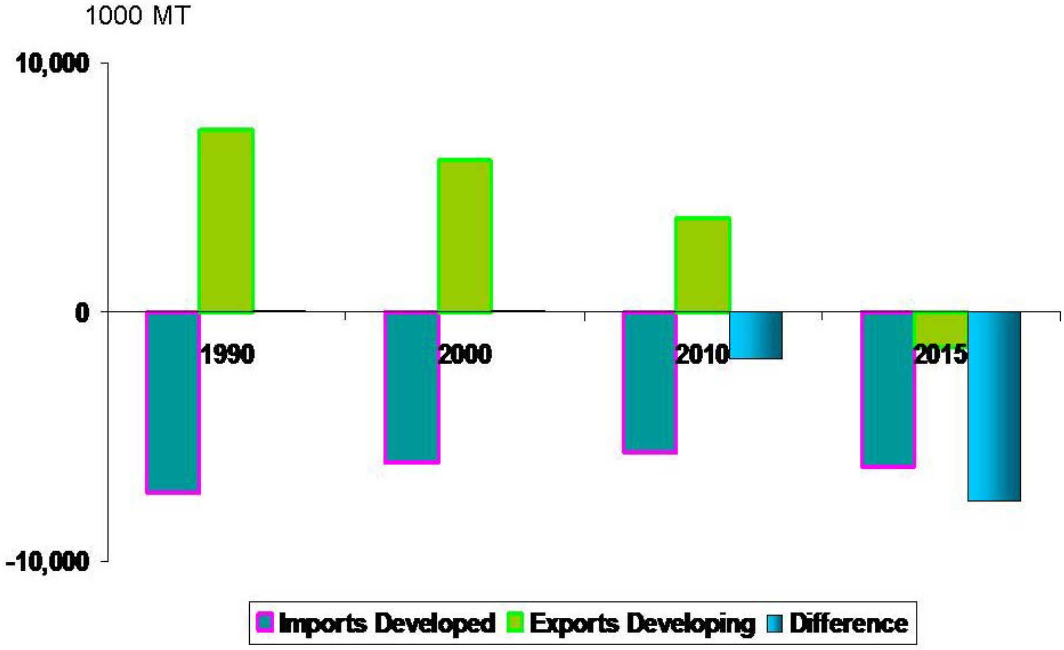
Figure 23: Forecast demand and production profiles for developing countries



Source: (Josupeit, 2004)

The consequence of this is that many developing countries that currently have a trade surplus for fish products will see this eroded, such that by 2010, a negative supply gap is forecast for both developed and developing regions.

Figure 24: impact on trade of rising demand in developing countries

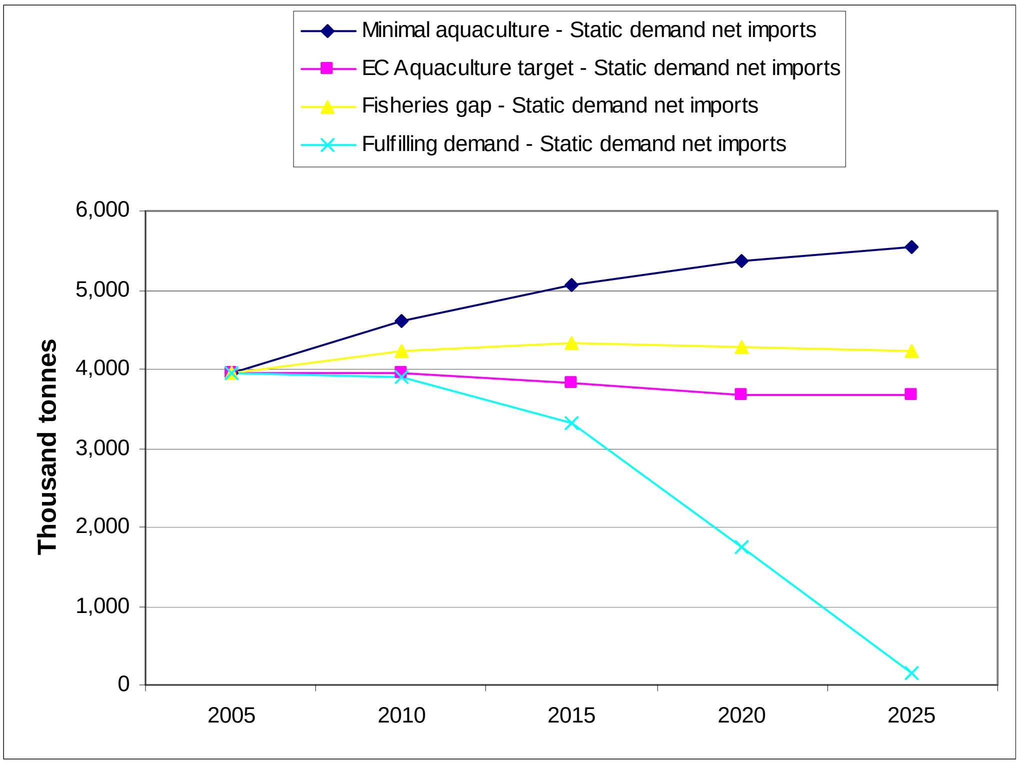


Source: (Josupeit, 2004)

This in turn will drive rising real prices for fish and seafood products, stimulating investment in aquaculture, with higher unit values making some species that are currently uneconomic to culture, more attractive. High prices could also make Europe even more attractive as a market for aquaculture producers in lower-cost countries if it is willing to pay higher prices. In 2004 between 1.5 and 2 million tonnes of whitefish valued at under Euro 2.0 per kg were imported into EU-25 countries. This segment could be increasingly targeted by overseas aquaculture producers in the future. The primary example is Vietnamese *pangasius* catfish (*tra* or *basa*) which probably accounted for a significant proportion of the 140,000 tonnes of freshwater fish imported into EU-25 countries in 2004. More recently market penetration of *pangasius* in Europe has expanded apace and has become available in increasingly more sophisticated product forms. There has also been growth in African and Jamaican tilapia production and export into Europe.

The envelope for net imports is defined by the gap between production and demand. i.e. for each scenario, the difference between the calculated supply from aquaculture and capture fisheries production (food fish only) and projected demand (low, static and high). This shows that the net imports by 2025 could reach 5.5 million tonnes if consumption remains static and only minimal further development of aquaculture takes place (Figure 25). These imports would have an approximate value of €13.7 billion (Table 7) assuming there was no change in average unit value. However, the objective at this point is not to identify the most likely scenario, but to quantify a range of net import volumes to help assess prospects for emerging aquaculture systems. Investment in those systems will be driven largely by their economic viability and potential returns. However, these will link with key policy parameters such as employment, environmental resource use and environmental impacts via the volumes of production potentially stimulated.

Figure 25: Net trade projections for the 4 scenarios, based on static demand



Source: developed from analysis of previous supply and demand scenarios

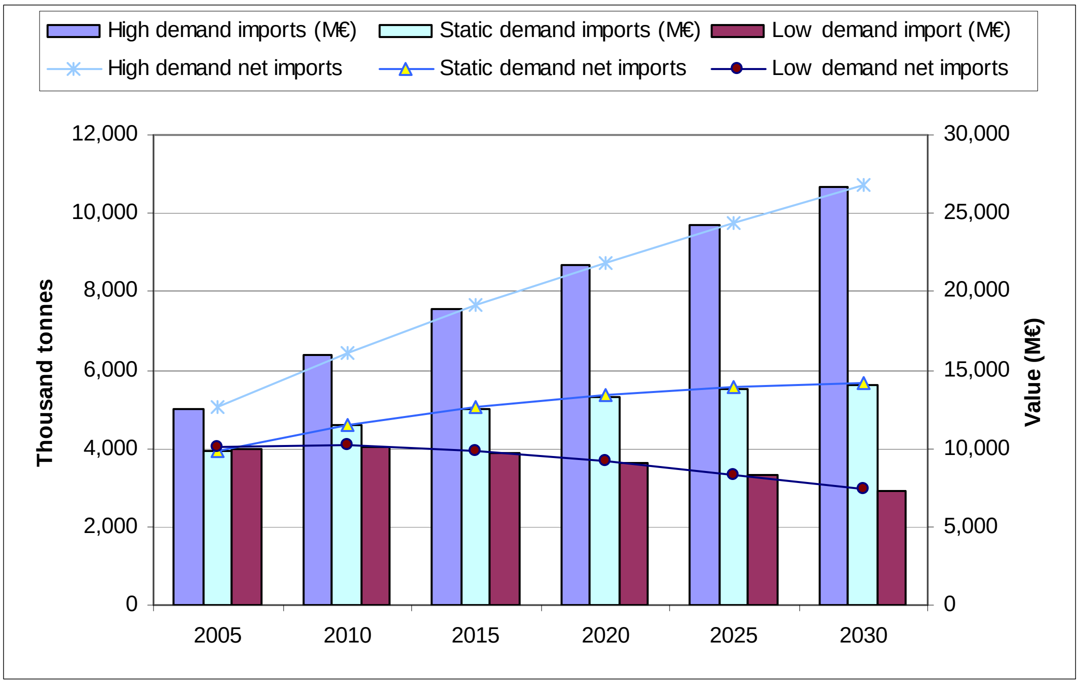
Table 7 reflects the same patterns shown in Figure 25, but in value terms. This is only indicative, using a constant value per unit of volume assumed to be (€2.48/kg) based on analysis of Eurostat trade data for 2005.

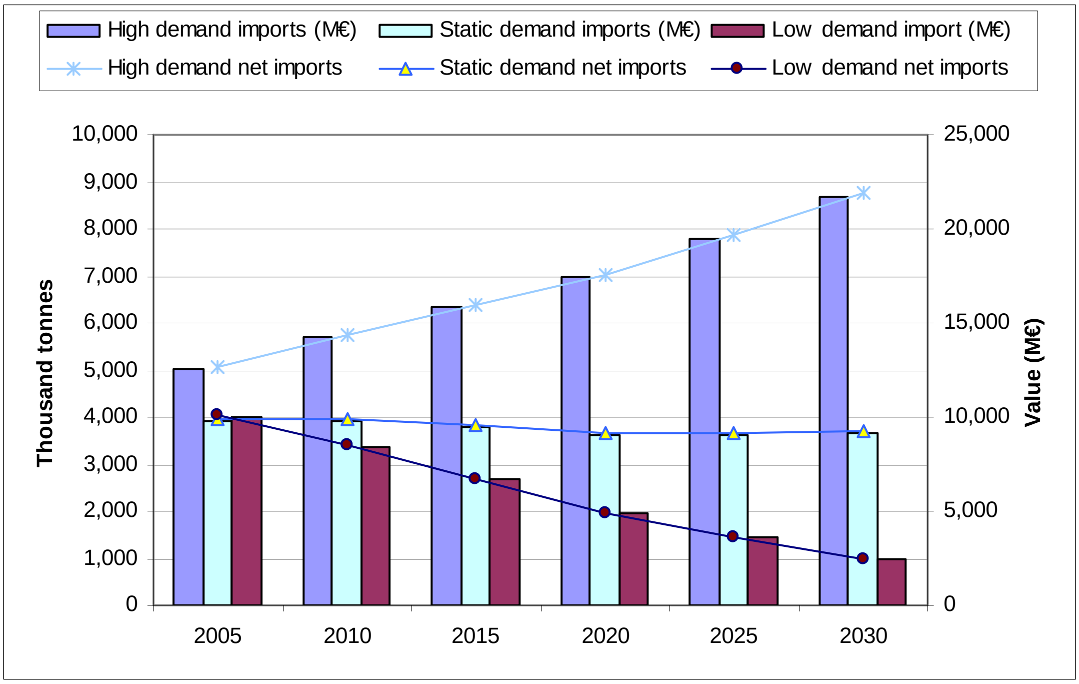
Table 7: Estimated value of imports using 2005 mean - Euro Million

	2005	2010	2015	2020	2025
Scenario 1: Minimal aquaculture					
High demand net imports	12,563	15,949	18,936	21,644	24,195
Static demand net imports	9,790	11,435	12,563	13,295	13,756
Low demand net imports	9,992	10,093	9,753	9,098	8,263
Scenario 2: EU Aquaculture target					
High demand net imports	12,563	14,294	15,851	17,422	19,514
Static demand net imports	9,790	9,779	9,478	9,072	9,076
Low demand net imports	9,992	8,437	6,668	4,876	3,582
Scenario 3: Meeting fisheries gap					
High demand net imports	12,563	14,978	17,110	18,953	20,919
Static demand net imports	9,790	10,464	10,737	10,604	10,480
Low demand net imports	9,992	9,122	7,927	6,408	4,987
Scenario 4: Fulfilling static demand					
High demand net imports	12,563	14,205	14,589	12,668	10,800
Static demand net imports	9,790	9,690	8,217	4,319	361
Low demand net imports	9,992	8,348	5,406	122	-5,133

Note: This is based on dividing the apparent supply gap in 2005 (tonnes) by the value of the balance of trade – calculated at Euro 2.48/kg from available data (i.e. excluding consideration of product form).

Figure 26: Projected import requirements (lines = tonnes, bars = value) EU-25 for scenarios 1 (minimal aquaculture development) and 2 (output derived from EU target of 4% growth from 2000)





Besides filling any indigenous production gap, imports also increase the variety of products on the European market, and balance the price/demand profile.

Export of all fisheries and aquaculture products from EU-25 countries in 2004 was around 6.88 million t (8.86 million t including Norway). Most of this is from the capture fisheries, or may include re-exports (imports further processed in Europe and then exported – e.g. including salmon from Norway, smoked in Denmark for export). Probably less than 10% of exports by weight from the EU were from aquaculture. Particularly notable was over

400,000 t of Atlantic salmon products (although not differentiated between Atlantic and Pacific salmon), around 50,000 t of trout products, over 200,000 t of mussels, 12,600 t of oysters, and 10,000 t of live carp. Also notable was over 15,000 t of Atlantic bluefin tuna, much of which will have been fattened in cages for up to 6 months between capture and slaughter.

3.4 Future directions for trade

For commodity products, globalisation has favoured lowest-cost producers. Concern for instance is expressed that in aquaculture, Chile has a lower cost base than Northern Europe for salmon, and will out-compete Europe in the long term. However, there are important modifying factors. Particularly important with fresh produce is time to market and distribution costs. Here, European producers will have the advantage within Europe and to growing markets in the Near East and Southern Asia. Another global level consideration is that production cycles in the north and south hemispheres are 6-months out of phase, and hence complementary in providing a consistent year round range of products. Europe has relatively uncompetitive labour rates, but these are becoming a smaller element as production is increasingly mechanised and scaled up. In some areas, such as technology supply and access, it should have an advantage. As input costs become more even around the world, key factors will be ready access to markets and costs associated with regulatory and tax regimes.

Globalisation of trade should equally offer export opportunities for producers of niche and higher-value products that can either only be produced in Europe, or can attract a premium through higher quality and European branding (e.g. labels of origin, quality schemes or trusted producer labels). European aquaculture production need not therefore be capped once European demand for premium products has been satisfied. It could be argued that greater focus should be given to this sub-sector for future development, although much will depend on how the forces of globalisation vs renewed interest in the localisation of food production play out internationally.

The potential for aquaculture exports will effectively move the demand curve for aquaculture products upwards. Given the starting point, particularly within EU-25 countries, of aquaculture supplying only 25% of seafood requirements, and a significant deficit in trade, the existence of export markets is expected to be a factor, but will probably not lead to European aquaculture production rising to levels that result in a seafood surplus for Europe. The upper level of demand is not, as a consequence, altered in our projections.

Following more detailed discussion of major species groups in the next section, and in section 5, where the specific shaping factors likely to influence the development of the sector are discussed, these scenarios are set out in more detail in section 6 and so leading to our main conclusions on emerging aquaculture systems.

4 Major species groups

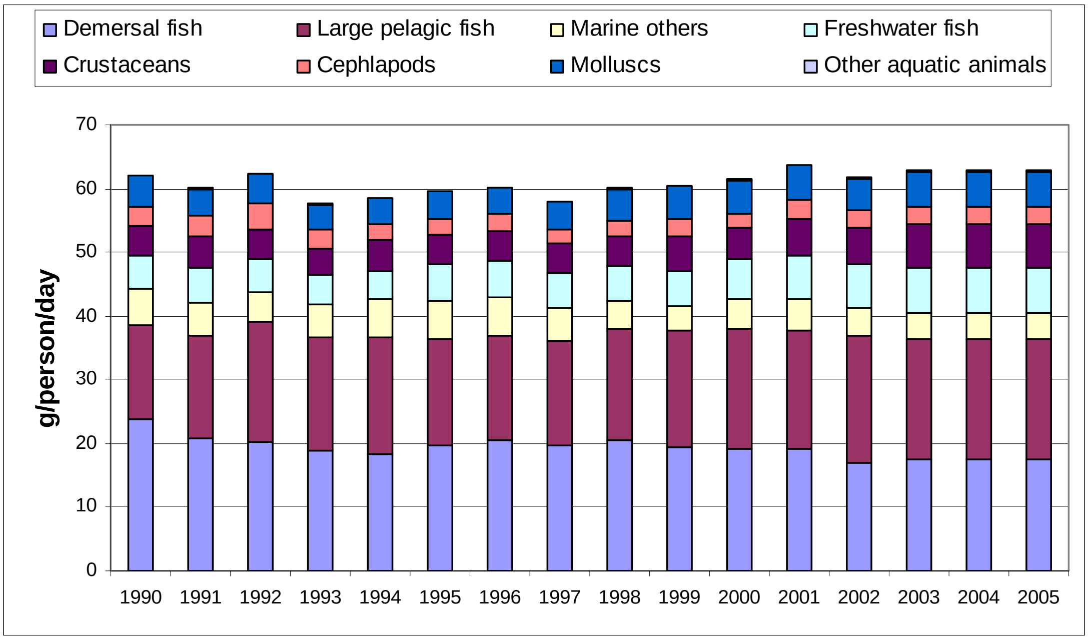
4.1 Patterns of consumption

While the previous section has outlined the wider targets for supply, the segmentation of demand based on species groups, price levels and other product attributes is more challenging to address. Current supply, market conditions and changing consumer preferences are already altering the shape of the sector significantly. Seafood markets are becoming much more complex with a widening array of segments based on a range of products created from an increasingly diverse range of species. In addition to the coexistence of discrete and shared market segments evolving from individual species, a wider variety of product forms, incorporating an escalation of attributes from simple convenience to fully prepared with safe provenance reassured, has emerged. One of the primary distinctions to develop is likely to be that of the increasing clarification of markets focused on fresh and traditionally processed products which are highly defined by species, and those in which seafood raw material can be used much more flexibly. European aquaculture has tended to focus on the former whilst consumer trends and constrained capture fisheries supplies suggest that the greatest gap will be in the latter.

Until relatively recently, there has been little differentiation between aquaculture and fisheries production within the European seafood market. Whilst this is gradually changing, with mixed implications for aquaculture produce, the sector is probably best understood with respect to key types of seafood, and broad price bands. A first level of grouping might differentiate between:

- White fish
- Non-white fish (mostly oily fish)
- Seaweeds & aquatic plants
- Molluscs
- Crustaceans

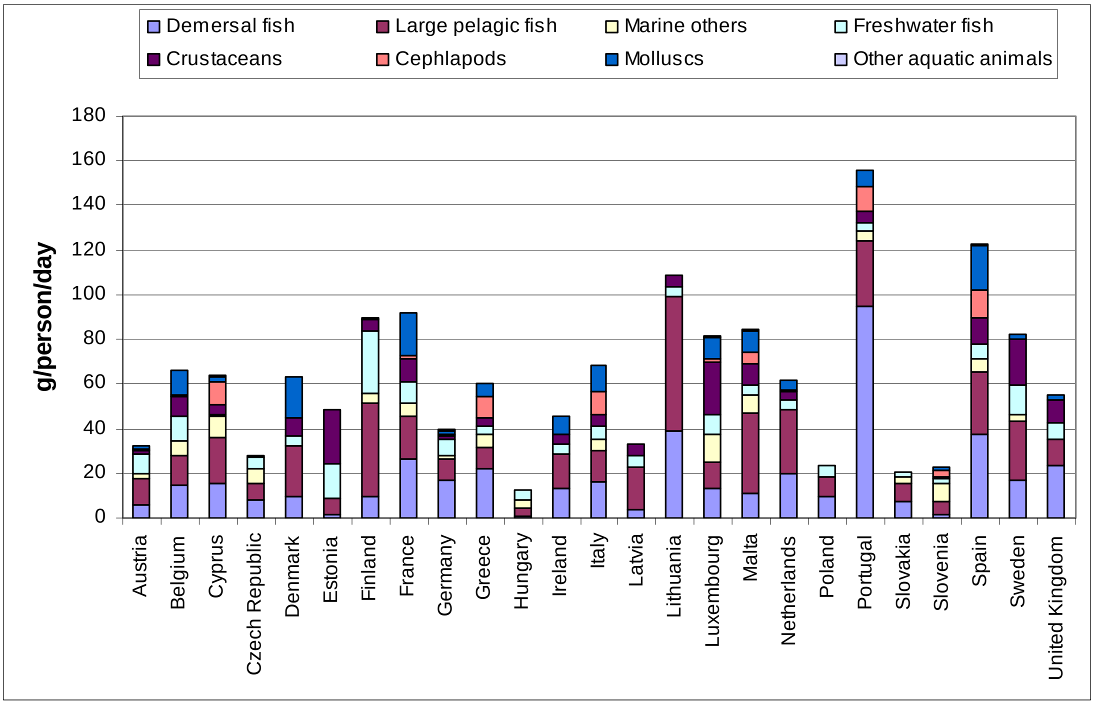
Figure 27: Apparent consumption of major species groups (EU-25)



Source: developed from Eurostat data (Note chart is cumulative bar with demersal fish at the base followed by large pelagic fish, then marine others with other aquatic animals at the top)

Figure 28 shows the most important component to be whitefish (approximately one third comprising most of demersal, freshwater and marine other) with non-white fish (mainly pelagics) and salmonids comprising the second third, and crustaceans and molluscs the final third. The relative proportion of crustaceans and molluscs has risen in recent years, with the proportion of non-white fish declining. Patterns of consumption also vary significantly between countries.

Figure 28: Apparent consumption of major species groups by country, 2005



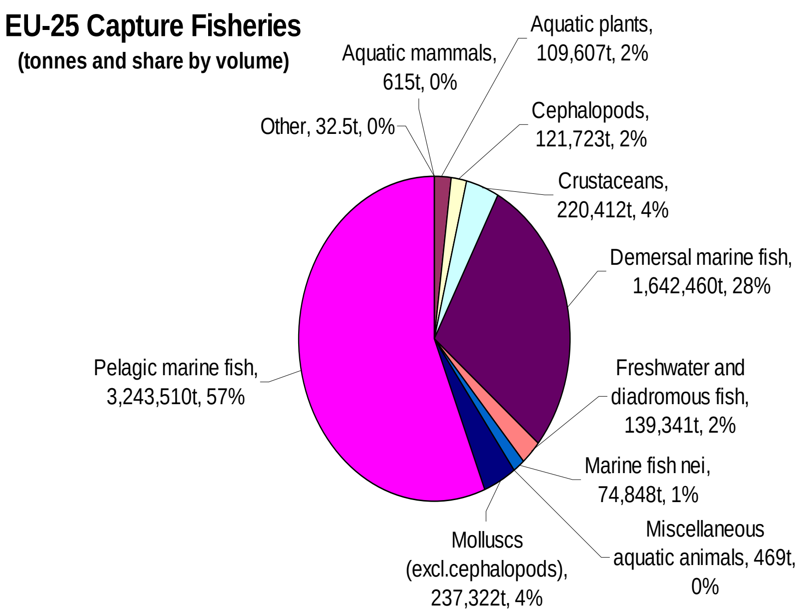
Source: developed from Eurostat data (Note this is a cumulative bar chart with demersal fish shown at the base of each column, followed by large pelagic fish, marine others and finally other aquatic animals at the top)

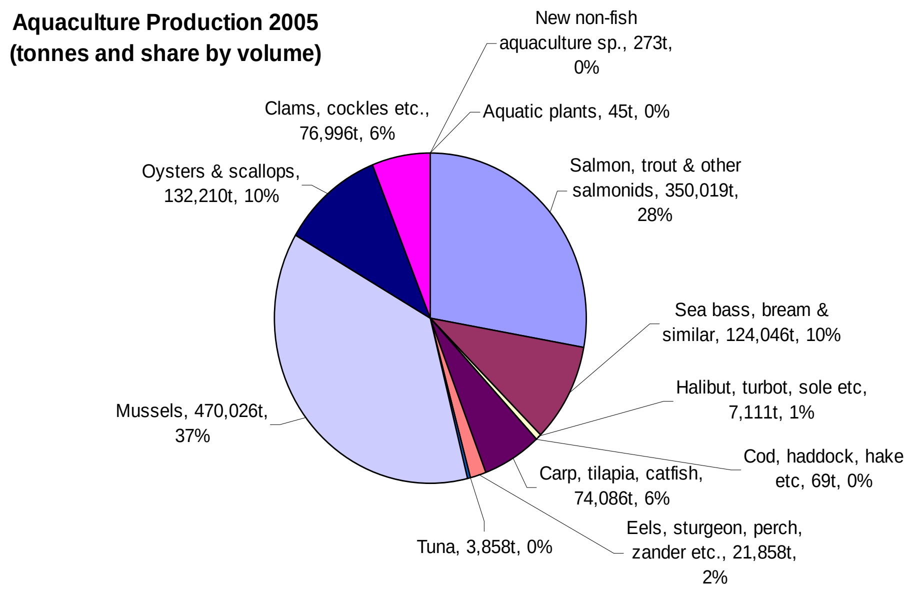
Seafood products can also be categorised according to unit value (e.g. value at first hand sale divided by volume), e.g.: < €2.00 per kg; €2–4 /kg; >€4/kg etc Unit values will of course change as products flow downstream along the value chain so it is important to retain some cross-reference to the point of comparison within the channel when comparisons are being made eg first hand sale, farm gate, wholesale, retail etc. In addition to different species having different unit values at the same points in the chain, unit values will also alter within the same species. Typically these may reflect standardised market preferences such as grade sizes, and quality perceptions; but they may also be influenced by other parameters according to the intended use of the product. For example fat content, which may vary seasonally, may be sought at a given level for smoked products which would render it less suitable for other purposes. Unit values may also change over time. Historically salmon, and most other aquaculture species, tended to command a high unit value when first launched onto the market, as did seabass and seabream in the 1990s, but these later fell to much lower unit values as supplies expanded. Despite these potentially anomalous influences on unit values, the measure does enable some useful generalisations to be made about fish production.

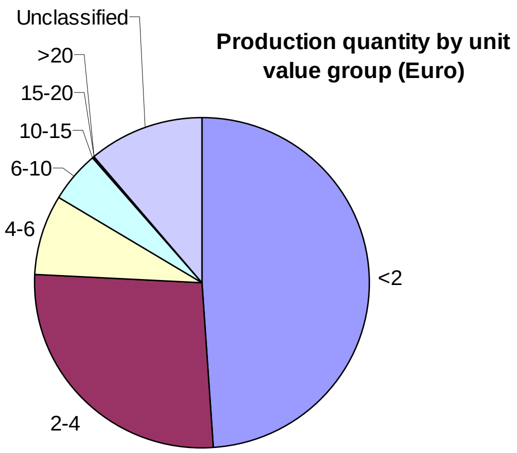
4.2 Production

An initial perspective on the balance of product types and value categories can be gained from Figure 29.

Figure 29: Perspectives on production of major species groups (EU-25)

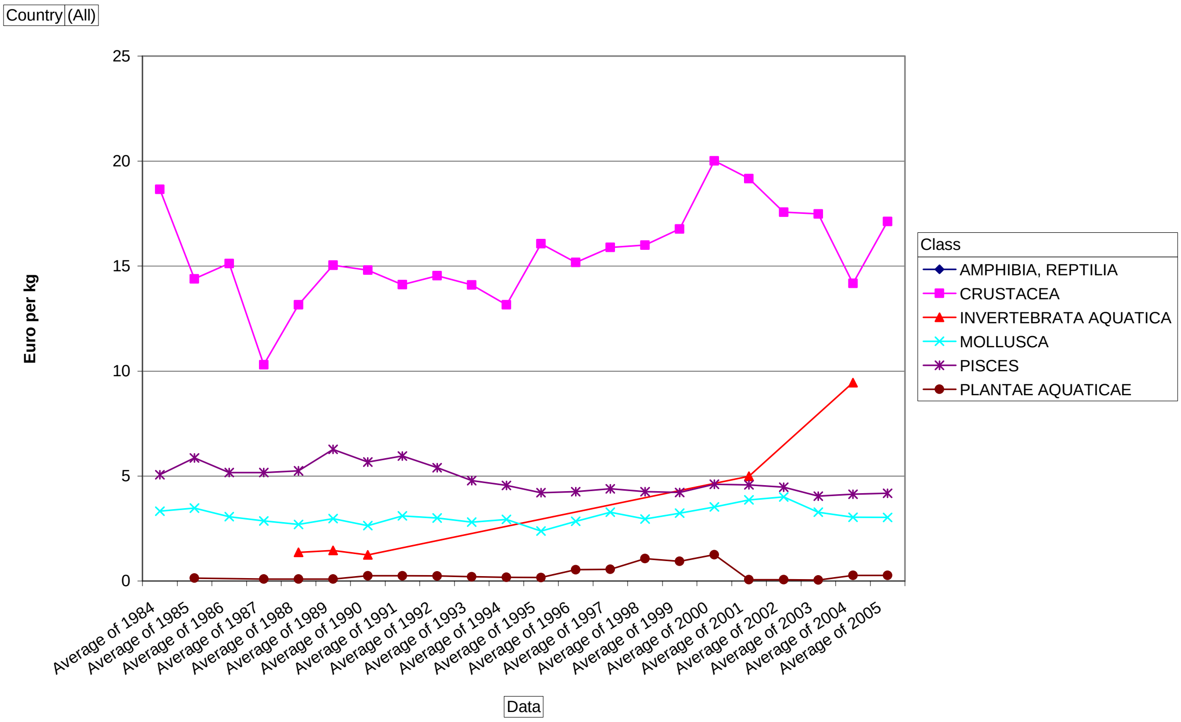






Source: developed from FAO Fishstat database

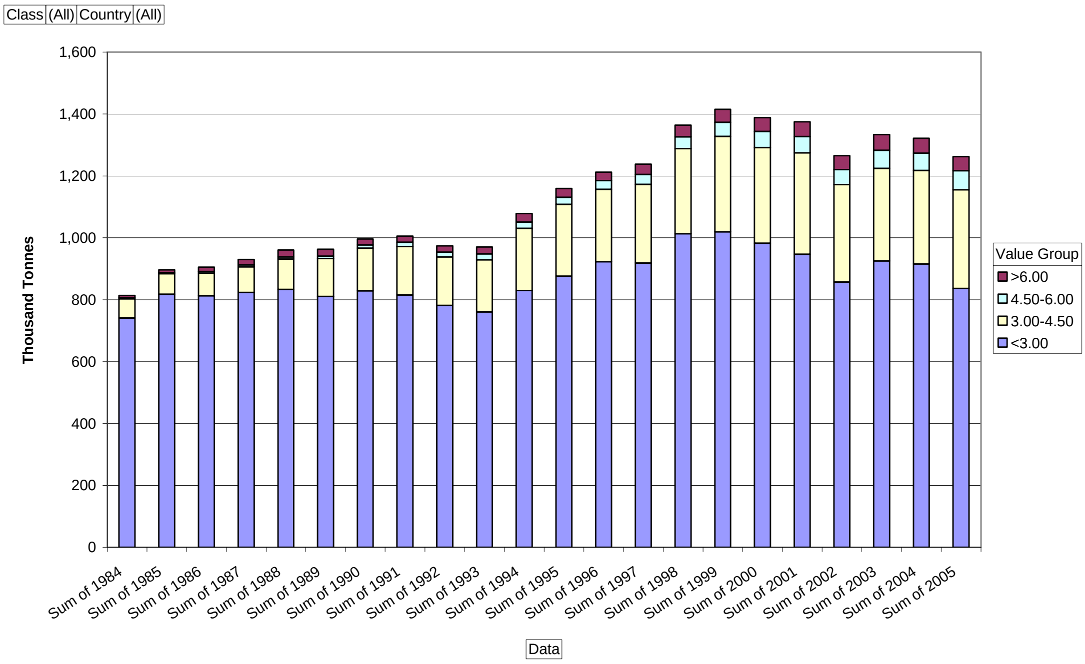
Figure 30: Average unit values of EU-25 aquaculture products 1984-2004 by species class



Source: developed from FAO Fishstat databases by dividing value at first sale by volume produced

Crustacean aquaculture production in the EU is very low (mainly freshwater crayfish), but unit values are much higher than for molluscs and fish, although quite variable when plotted against time. The average unit value of aquaculture produced fish has declined over the past 20 years, whilst that for molluscs has more or less remained constant. The unit value of echinoderms appears to have risen sharply in recent years, but this is on the basis of very low production.

Figure 31: Contribution of different product value groups to total EU-25 aquaculture production

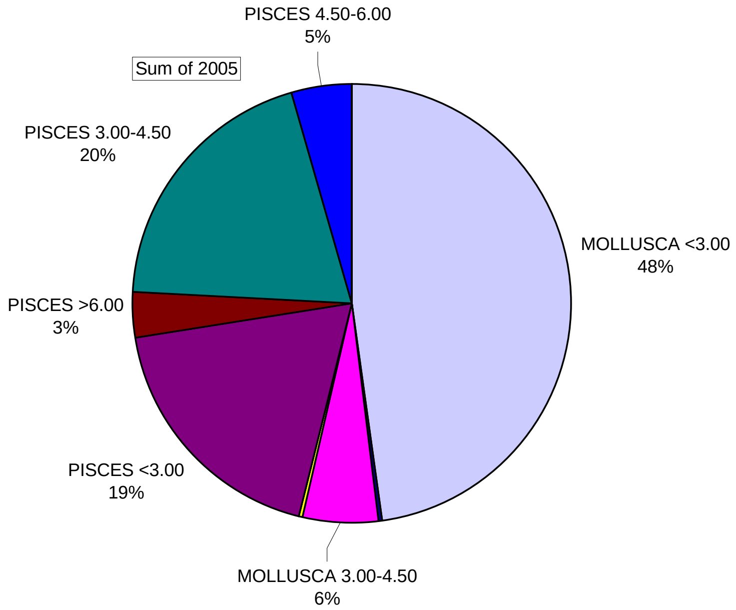


Source Developed from FAO Fishstat database, 2006. (Value groupings based on average unit value between 2000 and 2005, unless no production during this period, in which case, an average value between 1984 and 2000 was used)

The most dramatic increases in aquaculture production have been in higher unit value fish species, largely dominated by sea bass and sea bream and in some formerly higher, now lower unit value species such as Atlantic salmon and rainbow trout. Mollusc production has remained fairly constant for the last ten years, dominated by mussels and oysters. Crustacean aquaculture has also remained fairly constant but at much lower levels in Europe. Large increases in some minor species are not shown in this aggregated analysis.

A further perspective on EU-25 aquaculture production by major group and price category is shown in Figure 32.

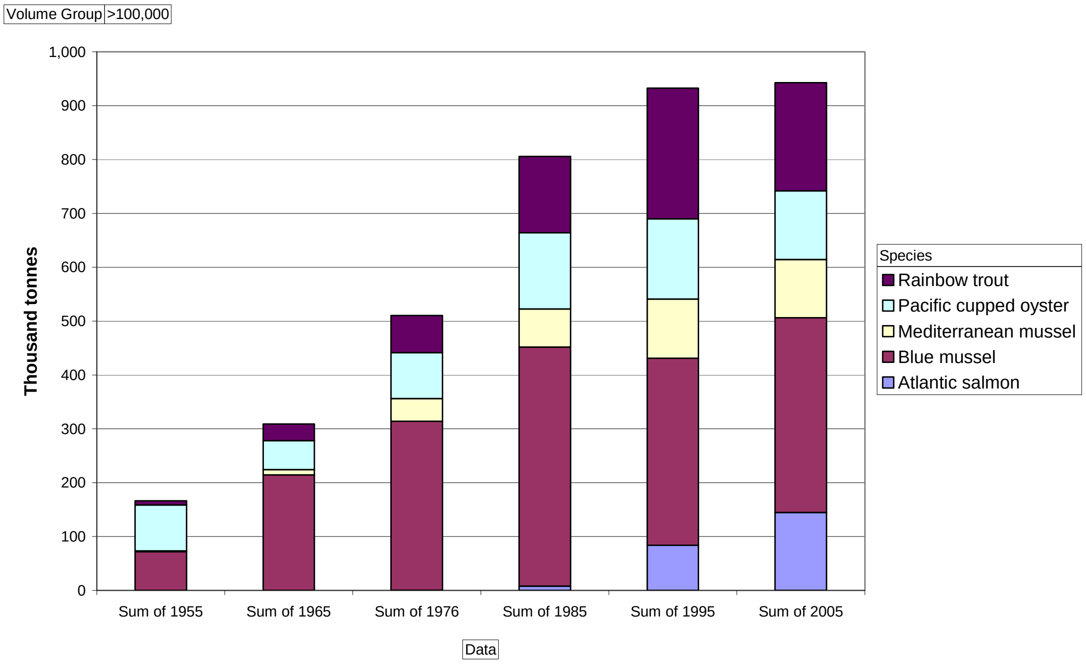
Figure 32: Share of EU-25 aquaculture production by volume in 2005 by major grouping and value



Source Developed from FAO data 2007. Values are Euro per kg. Categories comprising less than 1% of total aquaculture supply are excluded for clarity.

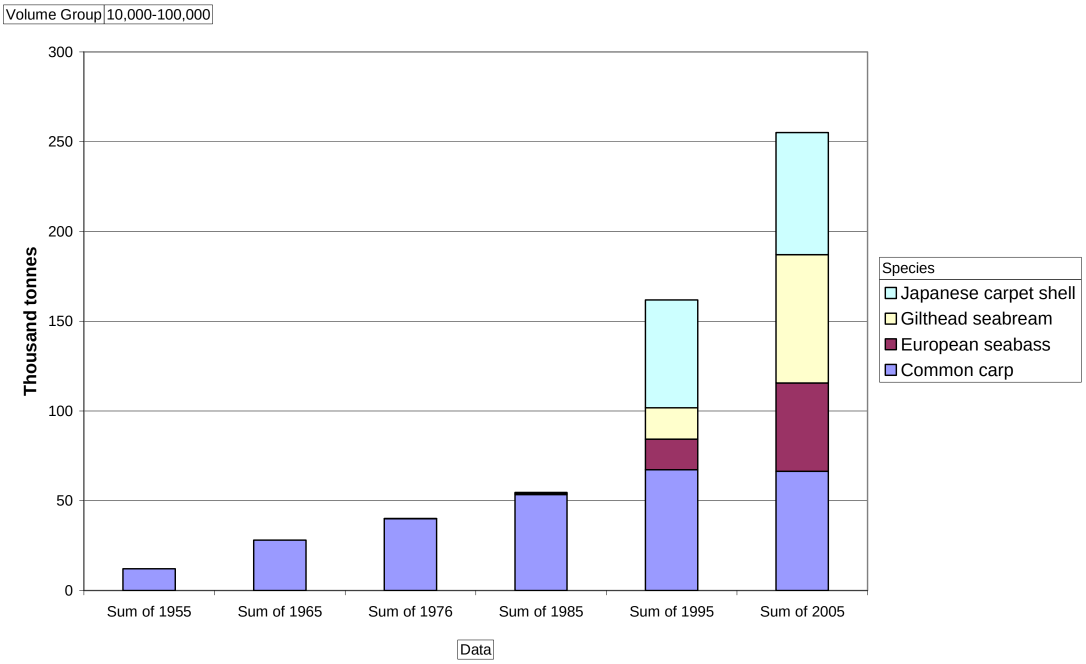
Figure 33 shows the species with the highest volumes of production and their development each decade since 1955. The most important species with respect to volume are blue mussel and Mediterranean mussel, rainbow trout, Atlantic salmon, and Pacific cupped oyster. These are followed (Figure 34) by Japanese carpet shell, sea bass, sea bream and carp.

Figure 33: Development of production of the main cultured species in EU-25 countries by volume 1955 to 2005



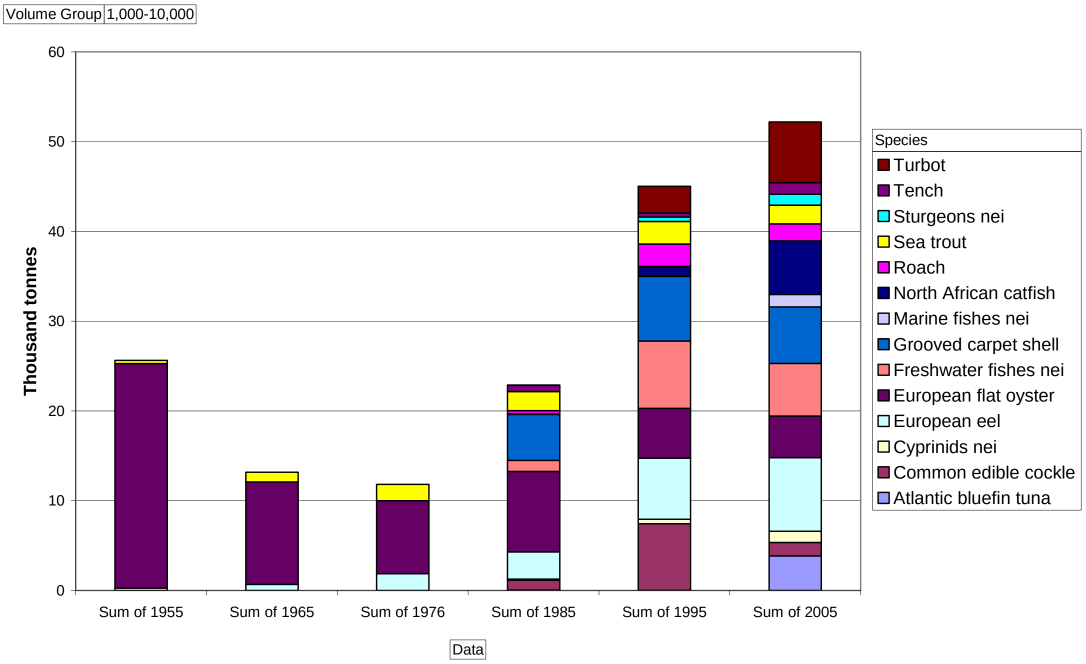
Source Developed from FAO data 2007. Species shown are those with production in excess of 100,000 tonnes in 2005.

Figure 34: Development of secondary cultured species in EU-25 countries by volume 1955 to 2005



Source Developed from FAO data 2007. Species shown are those with production between 10,000 and 100,000 tonnes in 2005.

Figure 35: Development of other significant cultured species in EU-25 countries by volume 1955 to 2005

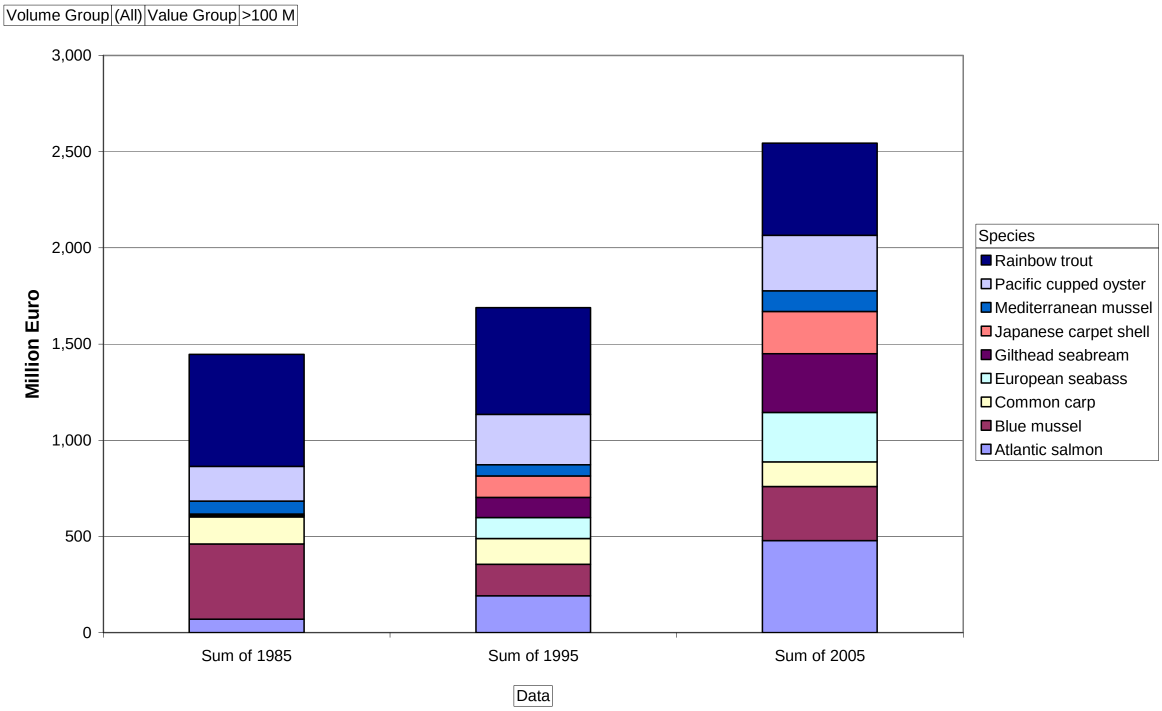


Source Developed from FAO data 2007. Species shown are those with production between 1,000 and 10,000 tonnes in 2005.

In addition to the species listed in the above figures, a further 106 species were produced by EU-25 aquaculture over the period 1984-2005, but with volumes below 1,000 tonnes in 2005 they are not shown in the above charts.

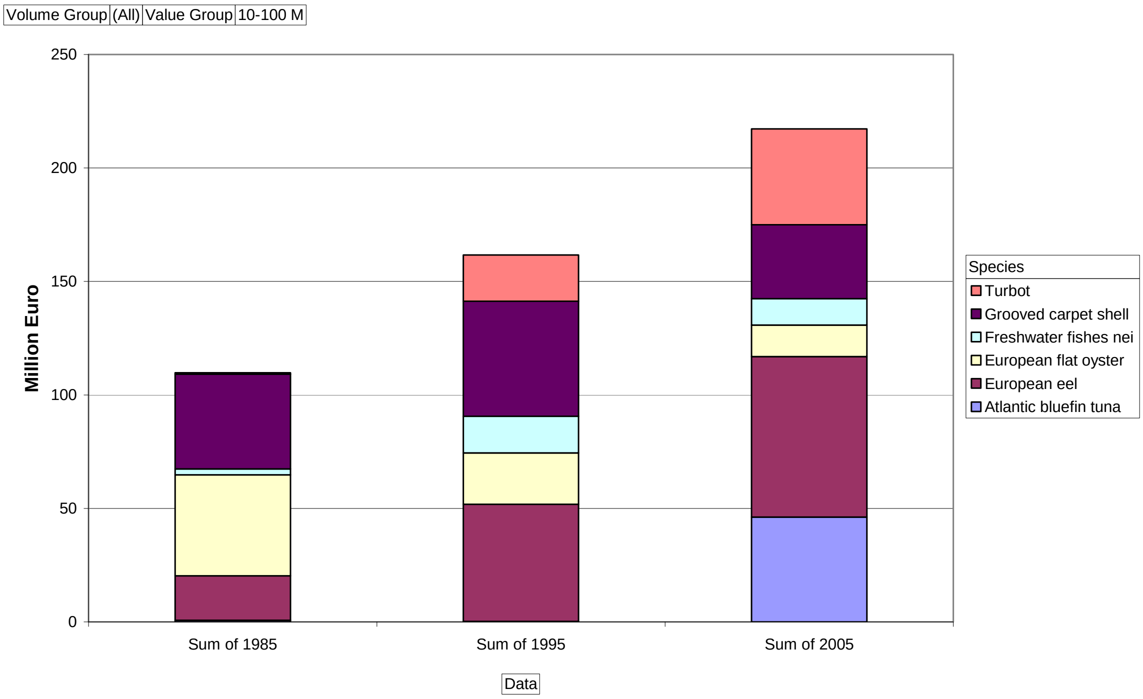
Considering the most important aquaculture species with respect to total value (EU-25 aquaculture produce at first sale values), The order of importance changes, but the list of species remains more or less the same. Dominant species with respect to value include rainbow trout, Atlantic salmon, blue mussel, Pacific cupped oyster, seabass, seabream, carp and Japanese carpet shell (Figure 36).

Fig. 36: Most significant aquaculture species by value, 1985-2005 (EU-25)



Source Developed from FAO data 2007 with dollar values converted to approximate Euro equivalent Species shown are those with a value of over Euro 100 million in 2005.

Figure 37: Aquaculture species with production valued at between Euro 10 and 100 million in 2005 (EU-25)



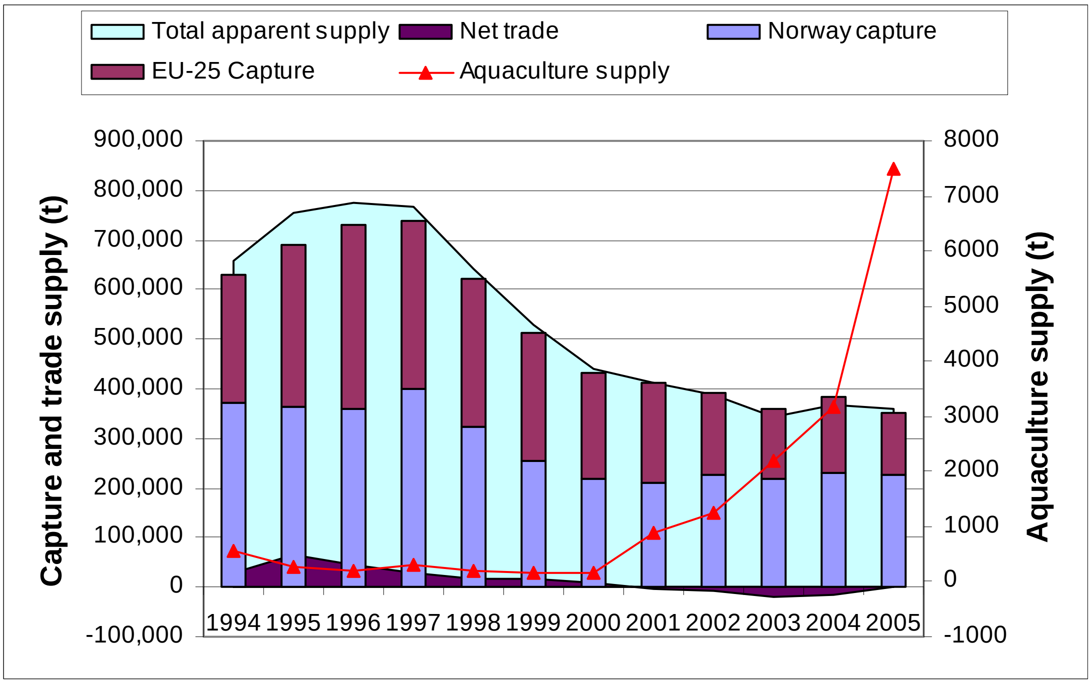
Source Developed from FAO data 2007 with dollar values converted to approximate Euro equivalent Species shown are those with a value of between Euro 10 and 100 million in 2005.

Although European fish culture continues to be dominated by salmonids, sea bass and bream and carp, the most notable growth rates in production over the past 5 years have come from higher unit value fish species, particularly turbot and bluefin tuna. Eel has also achieved significant growth but it has been observed to have a relatively low saturation level (Hough, 2007, personal communication) which it is unlikely to breach. Some investors have also addressed the lower-value but higher volume segment with species such as cod and catfish, with mixed results so far.

The situation for Atlantic cod is very different from that of salmon as aquaculture suppliers are still dwarfed by the capture fishery supply, despite large reductions in catches since the 1970s. Although cod aquaculture has been rising steadily since 2000 output is relatively small. Unit values for cod have increased as overall supplies have become more constrained, almost doubling between 1998 and 2004. Most cod farming is currently conducted in Norway, where there has been little product differentiation and ex-farm prices appear at best to reflect commodity trade prices (Figure 38). The approach by the one major UK cod producer has been to develop a differentiated, high value niche market based on an organic product, with ex-farm prices almost double those of Norway in 2005. Although company turnover rose from almost nothing in 2005 to €6 million in 2006[11], it remains unlikely that this can develop into a mainstream market for many producers and certainly not whilst maintaining current price differentials.

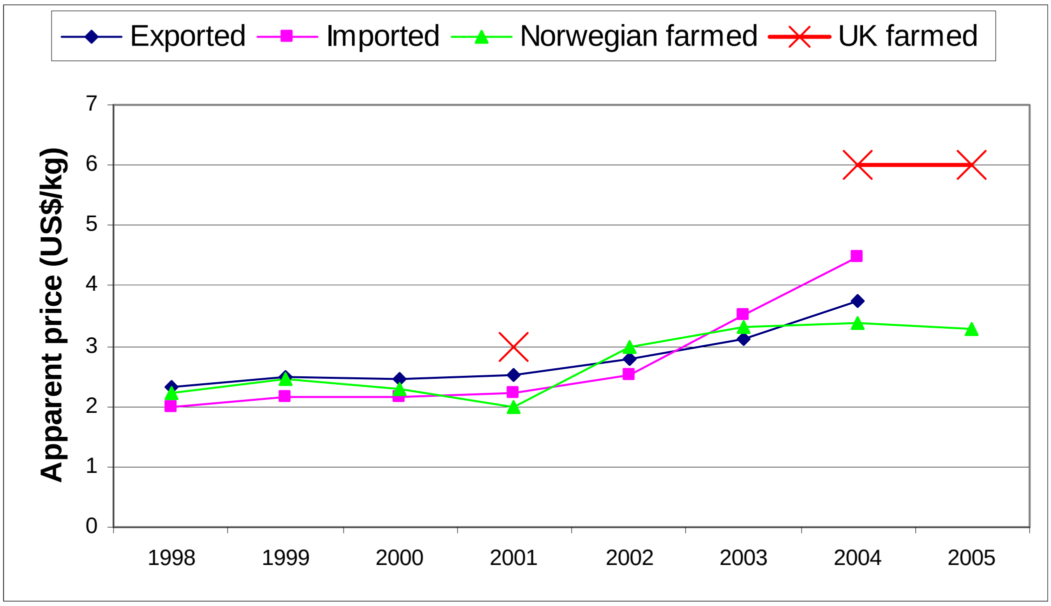
[11] Intrafish 22 March 2007. http://www.intrafish.no/global/news/article130570.ece

Fig 38. Atlantic cod EU and Norway, supply from capture fisheries, aquaculture and trade EU.



Source: FAO Fishstat 2007 (Note aquaculture production on different scale; net trade is imports minus exports; total apparent supply is the sum of capture fisheries, aquaculture and net trade). Norwegian capture is shown separately to give a more complete picture of European supplies.

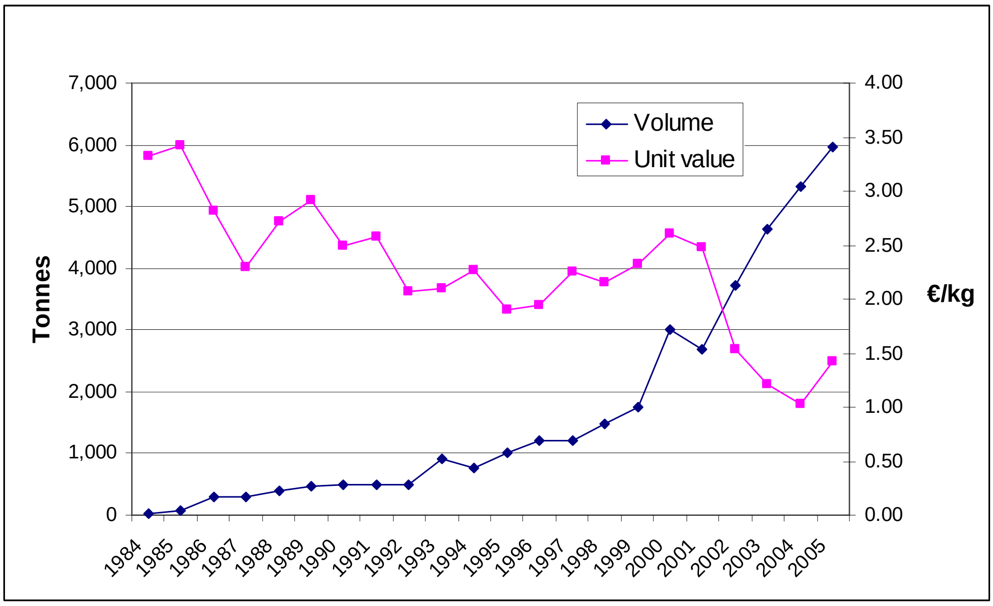
Figure 39: Cod prices, 1998-2005



Source: Developed from FAO Fishstat database (Note, values are given in $US according to FAO data as exchange rates and inflation have changed at different rates between the individual EU member states and Norway. Apparent prices are calculated by dividing total value of production by total quantity given in the FAO data)

Unlike cod, where so far it appears that prices have either been maintained or improved as production volumes have risen (albeit from very low levels), this is not the case for African catfish with relatively similar levels of production. The volume of African catfish has increased from just over 1000t to around 5300t whilst the unit value has varied between €2.61 and €1.02 per kg over the period 1995 to 2005.

Figure 40: EU African catfish aquaculture quantity and unit value



Source: Developed from FAO Fishstat database 2007.

This suggests that even with relatively low production compared to that of salmon and trout, the demand for African catfish is currently being met, possibly by imports of *Pangasius*. Formerly African catfish had been promoted in some parts of the EU, notably the Netherlands, but there remained significant consumer resistance to the products marketed. A quite similar history has been evident with European eel aquaculture, as noted above, where the more specialist range of products has largely been unable to break through market volume barriers.

This experience of resistance has implications for attempts to substitute currently over-exploited capture fish with cheaper alternatives. Although prospects for species discussed in the Part 2 Report have shown promise, they do not seem to be meeting the potential, highlighting the need for more imaginative uses and marketing for such species. If such strategies are to be adopted successfully it would seem logical to encourage more proactive marketing so that product solutions can be developed concurrently, if not in advance of, new species development. Alternatively the patterns observed may simply illustrate the willingness of buyers to substitute across a range of low unit value species where the key characteristics are perceived to be relatively homogeneous or their differences are perceived to be of little importance.

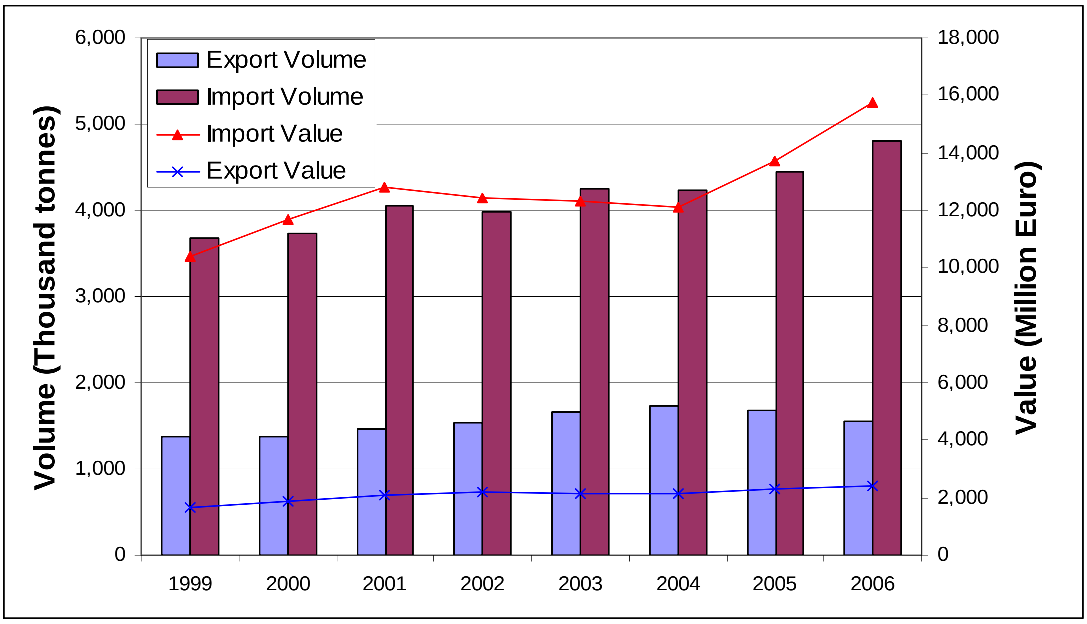
4.3 Trade

4.3.1 Trade overview

The EU is a significant and increasingly large net importer of fish and seafood products. In 2005, it imported 4.8 million tonnes of seafood produce from third countries worth €15.7

billion, with exports out of the EU of 1.5 million tonnes valued at €2.4 billion (Figure 41)[12]. This gave an overall EU-25 trade deficit in seafood products of 3.2 million tonnes and €13.3 billion in 2005.

Figure 41: EU-25 External trade in seafood - import and export volumes and values



Source Developed from Eurostat data, 2007 for EU-25 countries trading with external partners.

Total seafood trade was however substantially higher than this, due to trade between EU countries. The equivalent figures for total EU-25 seafood trade in 2005 was total imports of 10 million tonnes valued at €26.5 billion and exports of 6.9 million tonnes valued at €15.7 billion.

Table 8: EU-25 Total and external trade in seafood balance calculations

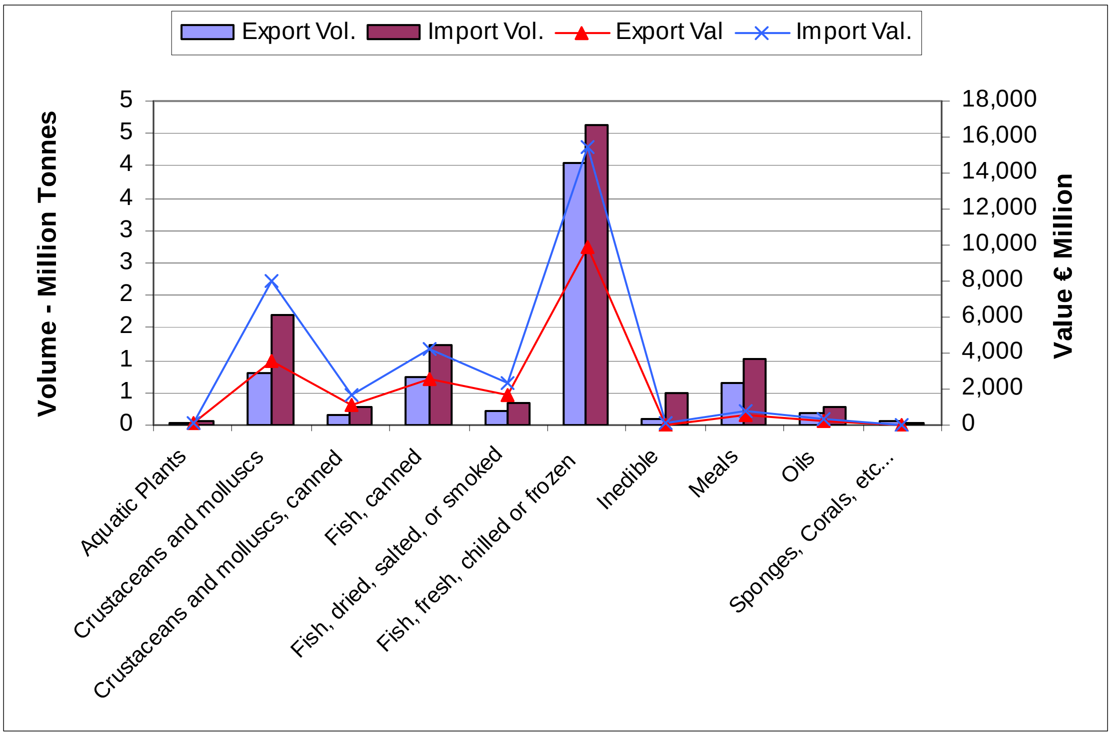
	2004	2004	2005	2005
	Volume (t M)	**Value (€ B)**	**Volume (t M)**	**Value (€ B)**
Exports				
External	1.673	2.286	1.546	2.426
Total	6.876	14.594	6.956	15.734
(Calculated inter-EU)	5.203	12.308	5.410	13.308
Imports				
External	4.443	13.688	4.809	15.732
Total	9.731	23.896	10.067	26.529
(Calculated inter-EU)	5.288	10.208	5.258	10.797
Balance calculations				
External balance of trade	-2.77	-11.402	-3.263	-13.306
Total balance of trade	-2.855	-9.302	-3.111	-10.795
(Calculated internal balance of trade)	-0.085	2.100	0.152	2.511

Source External trade data from Eurostat 2007. Total trade data from FAO Fishstat, 2007.

Considering total trade, the largest category for both imports and exports is fresh, chilled or frozen fish (Figure 42).

[12] Note – volumes are reported product weights, not adjusted to whole fish equivalent and include fishmeal, oil and other products not for human consumption

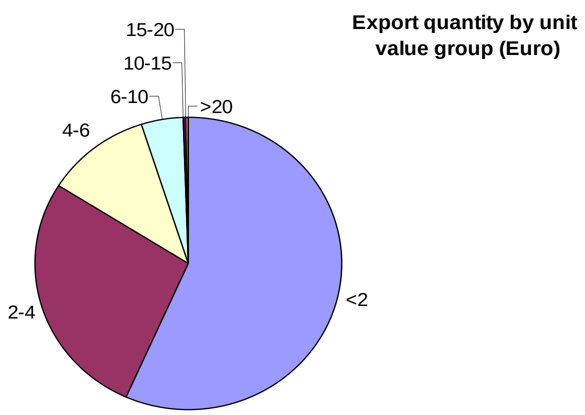
Figure 42: EU-25 import and export volumes and values 2005 by category

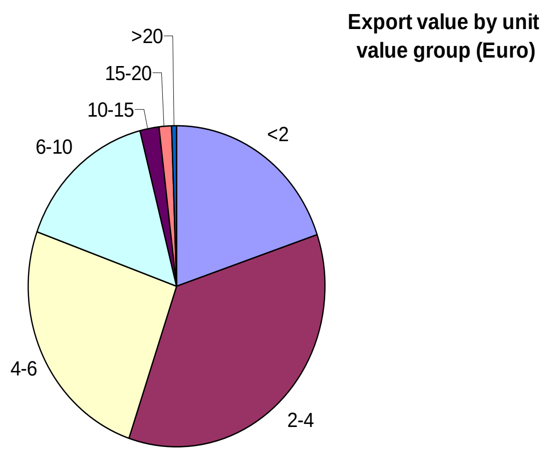


Source Developed from FAO Fishstat data, 2007 (Inter- and Intra- EU-25 trade)

For exports, the largest category by volume is in products valued at less than €2.00 per kg, although export earnings were higher for products valued at €2-4 or €4-6 (Figure 43).

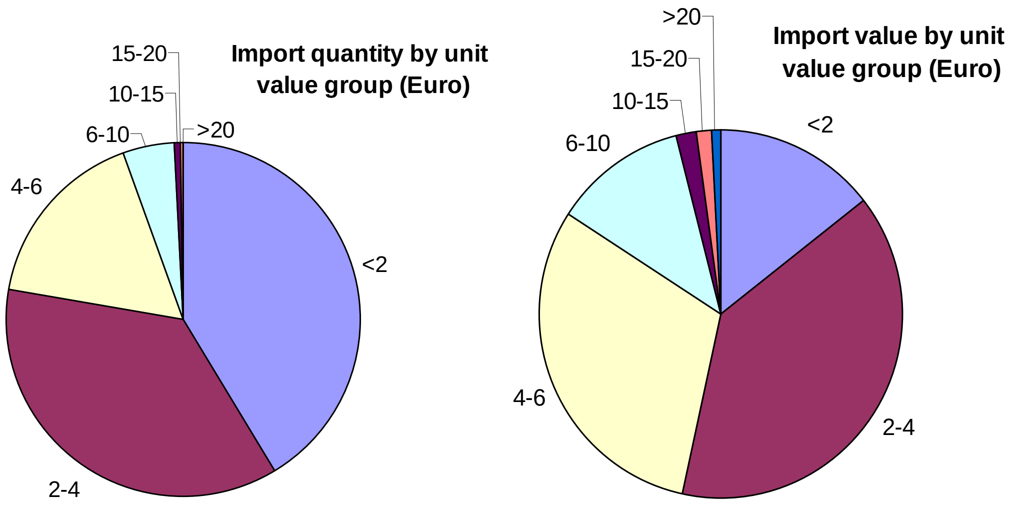
Figure 43: EU-25 Exports by unit value category





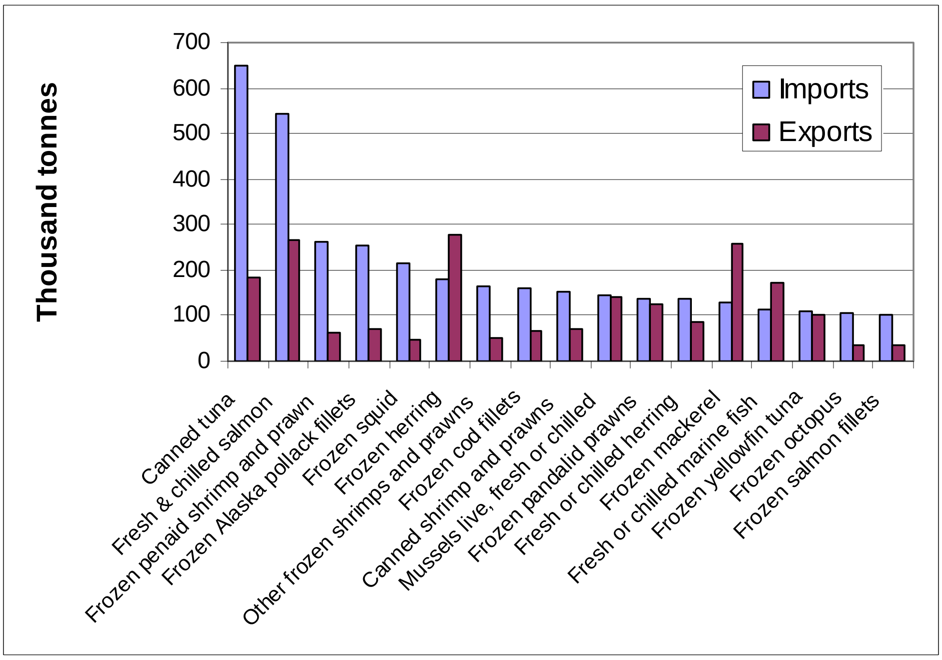
The sub-€2.00 products also dominate imports by volume, although the €2-4 category is also important. By value, the €2-4 and €4-6 categories again contribute the greater earnings (Figure 44).

Figure 44: EU-25 Imports by unit value category



Examination of the top 17 product imports (by volume) (Figure 45) shows that for three of the products (frozen herring, frozen mackerel and fresh or chilled marine fish), exported volumes are higher than imports and for a further three (fresh or chilled mussels, frozen pandalid prawns and frozen yellowtail tuna), export volumes are close to import volumes, suggesting much of the trade is between EU Member States. The most significant products with respect to net consumption (indicating substantial imports from third countries) are canned tuna, fresh and chilled salmon, frozen penaeid shrimp, frozen Alaska pollock fillets and frozen squid.

Figure 45: EU-25 Primary imported seafood products by volume – comparative import and export volumes for 2005



Source Developed from Fishstat data, 2007 (Data is aggregated from EU25 countries reporting import and export quantities and therefore includes inter-EU trade.

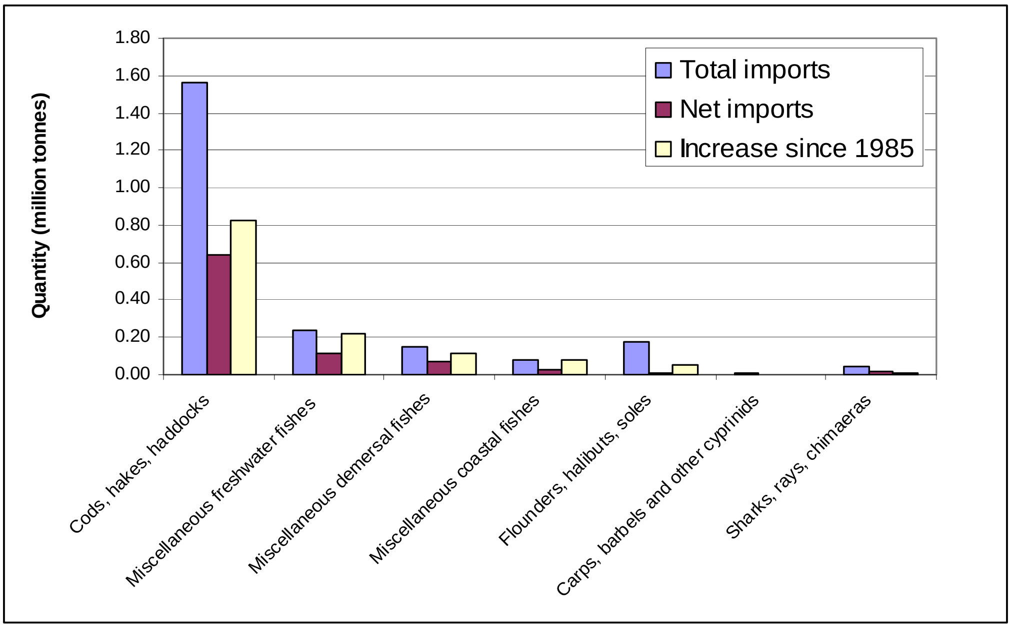
4.3.2 White fish species

The major whitefish species caught in Europe are cod, haddock, hake, saithe, Atlantic redfish and plaice (A.I.P.C.E., 2006). The total catch in 2006 was 379,310 tonnes, down 6.3% from 2004 (400,691 tonnes). Notably this was below quota (524,159 tonnes), suggesting either that stocks have declined further than expected, or that the imposed fishing restrictions had made it difficult for the industry to achieve this target.

Whilst the overall fish supply base is reliant on imports to a level of 60%, for the whitefish sector this is around 90%. An early return to higher catches in EU waters appears unlikely. There is therefore an increasing challenge in supplying a versatile white fleshed raw material that can be used in a range of products. However, the culture of marine white fish still has major technological barriers to cost-effective production. This suggests that either Europe will need to continue to increase imports of equivalent or substitute species; or will have to make a breakthrough in technology to produce premium white fish such as cod cost-effectively; or find easily and cheaply cultured alternative species that are versatile and acceptable to consumers.

Examination of FAO/ Eurostat trade data suggests that net imports[13] of whitefish have increased by around 400,000 tonnes between 1985 and 2005. There have been marked increases in certain products, most notably frozen Alaskan pollock fillets which have risen from negligible trade to around 270,000 t, peaking at nearly 290 thousand tonnes in 2001. Fishery production of pollock is dominated by the U.S., Russian Federation and Japan but has declined from nearly 6 million t in 1984 to around 2.7 million t in 2004. There have also been large increases in net imports of cod products over the same period.

Figure 46: EU-25 imported white fish products: Total and net import quantity in 2005 and by increase in import quantity between 1985 and 2005.



Source, FAO Fishstat database, 2007 (note: reported product weights, not whole fish equivalent)

[13] Import quantity minus export quantity

Significantly, there has been a large increase in freshwater fish fillet imports, from under 10,000 t in 1995 to over 85,000t in 2004. This may suggest increased substitution by freshwater fish products. However, exports have increased at a similar rate, suggesting that much of the trade is being conducted within the EU and Norway, and that processors are increasingly looking for flexible switching opportunities.

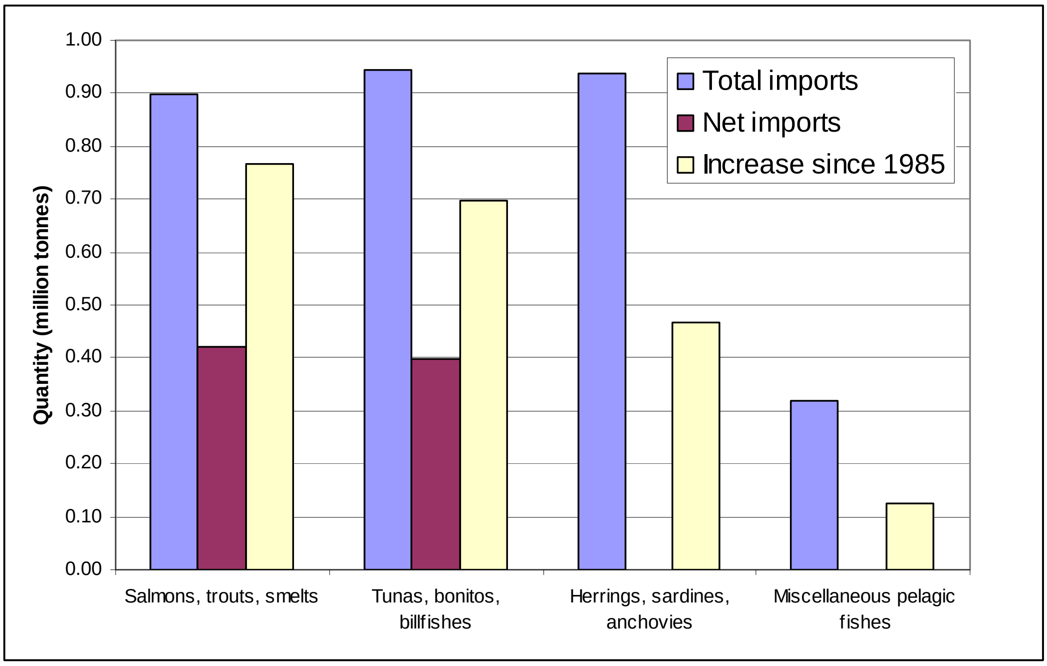
Whether this emerging supply gap will be made up from imports of currently inexpensive aquaculture raw materials from SE Asia remains to be seen. Although certain species have proven popular, such as *Pangasius*, this region is likely to have problems with supply of its own, and an increasingly affluent adjacent market demand. Although fish is very highly regarded in China, consumption per capita is still low compared to that of Japan (FAO 1989) and will be likely to rise significantly with increased production and economic growth, as China's emerging middle classes demand more fish products. Consumption of fish and seafood products in China doubled between 1990 and 1998 but has remained stable since at about 25 kg/yr per capita, with the majority coming from freshwater fish. According to the FAO however, consumption is proposed to rise to 35.9 kg/yr per capita by 2020, an increase of 41% from 2004 levels (Glitnir seafood industry reports-China, 2006). Existing product flows, such as exports of *Pangasius*, mainly from Vietnam, will be determined by the relative attractions of profits available in existing and emergent markets. Thus whilst Europe has rapidly become a main target for *Pangasius* since 2000, accounting for over 37% of Vietnamese frozen freshwater fish exports in 2005 (Eurofish, 2005), there can be no certainty that this flow will continue.

It may be possible to produce other white fish species cheaply for use in traditional processed products such as fish fingers, portions, cakes and other added value products. However, more innovative producers and processors of contender species such as *Pangasius* and tilapia, are already showing signs of attempting to reposition at higher unit value points in selected markets. These moves might curtail the tendency to utilise these species as raw material blocks for further transformation. Currently the difficulties associated with the culture of cod and other marine species mean that the final product is often more expensive than the wild caught, despite the critical status of these wild stocks. If these culture systems are to become competitive, production cost will have to lower, particularly through breakthroughs in hatchery technologies by increasing survival to juvenile stages. Even then, such emergent species are liable to remain vulnerable to any upturn in supply stability through more effective resource management.

4.3.3 Other fish species

Non white fish production increased strongly from the mid 1980s to the mid 1990s, after which it decreased to the level of the early 1990s. Meanwhile imports decreased in the early 1990s before stabilising in the mid 1990s where they have stayed. Much of the increase in production can be attributed to salmonids. The production of Atlantic salmon and rainbow trout combined has increased by over a million tonnes during this period and this may have contributed largely to a negative value for net imports, especially towards the latter end of the trend as net exports of salmonids were around 210,000 t in 2004 compared to a net import of 20,000 t in 1984. Exports of non-white fish are dominated by herring, Atlantic salmon, mackerels and tunas with the biggest increases in net exports coming from herring and mackerel.

Figure 47: EU-25 total imports of non-white fish products, net import and increase in import quantity between 1985 and 2005*



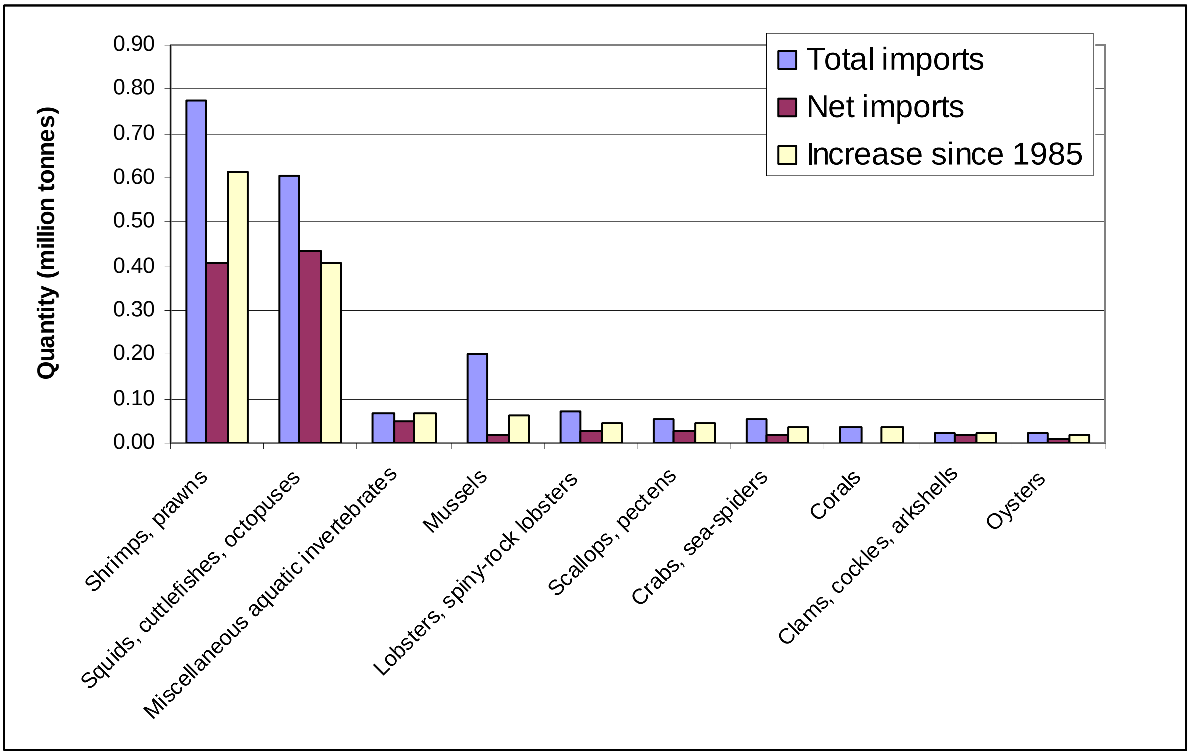
Source, FAO, 2007 * including products used in the manufacture of fish meal and oil.

There have also been substantial increases in the net imports of fresh salmon and canned tuna as well as fresh Atlantic mackerel. In the case of salmon and tuna, these increases have been steady for the last 20 years, but for Atlantic mackerel, imports and exports peaked around the turn of the millennium and have since been in decline. Import quantities of pelagic fish have also increased over the past 20 years, but much of this is processed and re-exported, as the EU is a net exporter of herring, sardine and anchovy products.

4.3.4 Crustaceans, shellfish and other aquatic invertebrates

There have been substantial increases in imports of shrimp, prawns, squid, cuttlefish and octopus products over the past 20 years. Total imports of shrimp and prawns increased by 613,626 tonnes between 1985 and 2005, with net imports rising by 325,640 tonnes. Total imports of squid, cuttlefish and octopus increased by 408,659 tonnes, with net imports rising by 377,919 tonnes. Although net imports are high, exports are also significant, indicating an active processing sector. Net imports of mussels, scallops, clams and oysters have also increased, as have lobster and crab.

Figure 48: EU-25 total imports of shellfish products, net import and increase in import quantity between 1985 and 2005



Source, FAO Fishstat database, 2007 (note: reported product weights, not whole fish equivalent)

5 External shaping factors

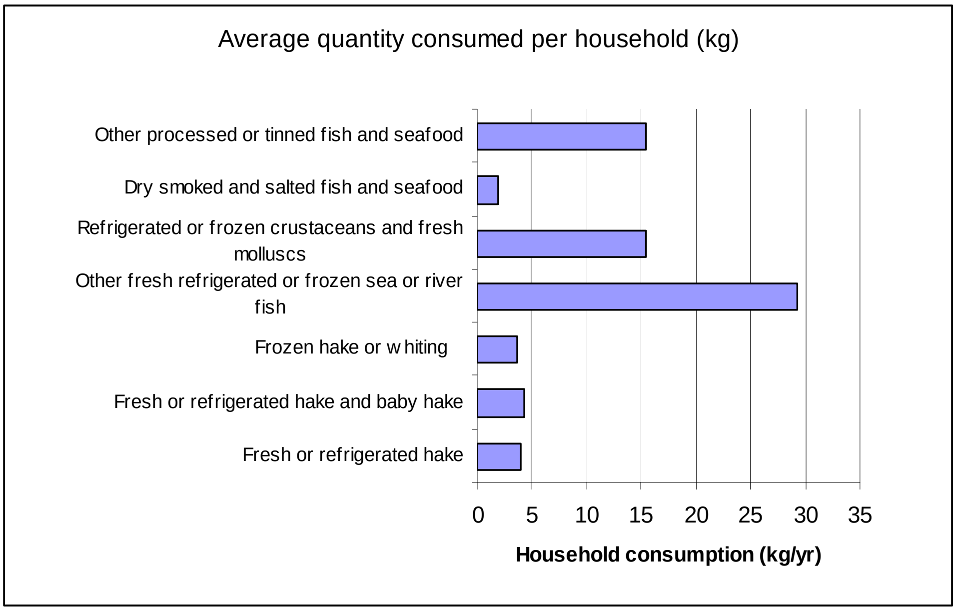
5.1 *Consumer trends*

5.1.1 Products and formats

The seafood market in Europe has developed to reflect the traditional pattern of availability from wild stocks. However, this is increasingly changing as aquaculture enables production to be better geared to market demand. It should therefore be expected that as aquaculture production continues to grow, the balance of seafood items and product options will also change. The desires of consumers will be an increasingly important driver for aquaculture development. Considerations will include tradition, convenience, price, supply, health and environmental issues. All could have an important role in determining the popularity of different products as well as affecting future production costs.

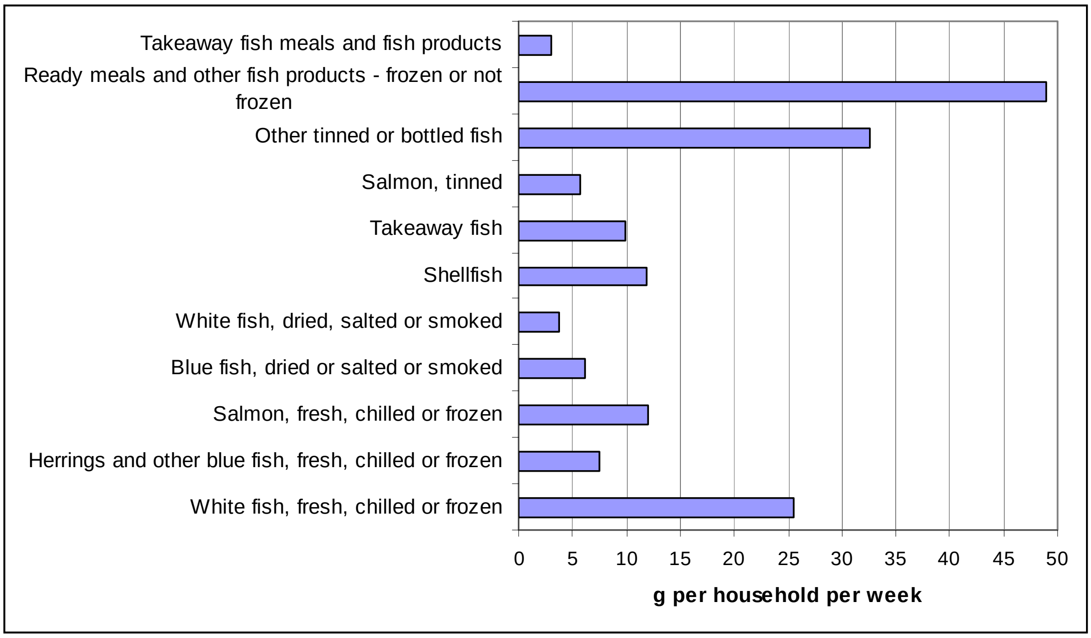
The market for seafood products varies widely across Europe. Marine fish and shellfish predominate in countries such as Norway, UK, Ireland, France, Portugal, Spain, Italy and Greece, whereas freshwater fish have traditionally dominated the land-locked countries of Eastern and Central Europe. Across this also are profound historical socio-cultural and economic differences, particularly between N and S Europe, and associated with the scope of national fishing practices. Some indication in the differences between Northern and Southern Europe seafood consumption is also illustrated in the following figures on household consumption in Spain and UK.

Figure 49: Consumption pattern – Spanish households



Source: http://www.ine.es/inebase/cgi/axi

Figure 50: Consumption pattern – UK households



Source: Defra National Food Survey 2005-06

The primary focus of much of Europe's aquaculture production has been on higher value product forms, traditionally fresh, or only moderately modified – eg filleting, steaking, shelling or smoking. Traditional preservation formats such as freezing and canning, associated with lower priced seafood 'staples' and poorer margins had largely been avoided, but the strengthening focus on convenience foods, with options for attractive packaging, had provided a major area for potential growth and addition of value to aquaculture materials. During the 1990s and early part of the new millennium, a trend was seen towards higher consumption of "ready meals", particularly in the UK, Sweden and Denmark within the EU, evolving more widely in N Europe and into S Europe, associated with growing urbanisation and the increasing role of multiple retailers. This has been a reflection of people's busier lifestyles and changing preferences for food purchasing. In the UK, figures suggest that there may have been a slight reversal of this trend in most recent years. This could be because people are becoming more aware of healthy food options as many pre-prepared meals often contain high levels of salt and fat, with few vegetables. The high consumption of convenience foods, whether as ready meals or accessible takeaway formats may well continue, however, as according to various market and social surveys, younger generations may become increasingly unable to cook raw material based meals from scratch either through skill shortfalls or time constraints. (Seafish, 2006).

In most parts of Europe, takeaway food formats are increasing in presence and diversity, with seafood occupying a variable position. In the UK, the traditional convenience food format of "fish & chip" shops, has held up well against more recent alternatives such as burger bars and various ethnic options. Currently there are over 8,500 such shops, with fish and chips still being the UK's favourite takeaway meal (Seafish 2006a). In N Europe also, traditional quick-access products such as moules are being extended, with wider availability of fish products in fast-food outlets, and with many fast food chains offering fish and salad dishes as healthier options to traditional meat and burger products. The increased popularity of convenience foods may offer further opportunities for aquaculture, especially if it can be promoted as a healthy option as well as being convenient. This may be the case especially for more cheaply produced species such as the tilapias and carps, as the challenge is to process them in an attractive way to consumers. So far, compared with Asia and N. America, Europe had been the least exploited region with regards to tilapia consumption with less than 2000 tonnes in 2002, whereas sales increased threefold to 70,000 tonnes in the USA in the seven years up to 1999, and have increased substantially further. Here, there are already tilapia pre-packed ready meals, fillets in sauces and also tilapia burgers and nuggets. (Eurofish 2002). However, the recent rise in the very versatile and cost-competitive *pangasius* catfish products from Asia, has demonstrated much greater drive for change, also with increased prospects of pre-prepared product forms reaching EU markets direct to customers specifications. At the EU sector level, the challenge for aquaculture producers might be to benefit from such drivers by connecting in higher-value options to the baseline of accessible fish based fast foods, and in prepared meals, to offer more specialised and regionally distinctive variants to baseline products. In both cases, comparative margins, and the shares available through the supply chain, will be critical in determining investment and growth potential.

5.1.2 Ethical and health drivers

The benefits of fish as a healthy food option have been widely documented not only as an animal protein source, low in cholesterol, good for prevention of heart disease and cancer but also as being beneficial for the nervous system and brain development in children. This is primarily due to the high levels of omega-3 fatty acids which are now commonly advertised as an additive to many other foods such as cereals and bread. Although some consumers are willing to get their omega-3 from these supplemented products, there is a strong underlying trust in the natural product source. The benefits of omega-3 are now so well known amongst consumers that 26% of people who said they commonly ate fish in the UK, did so for health reasons alone, and is the next biggest driver after taste. (Seafish 2006b). The oils in fish, especially from products such as cod liver oil, have also long been known as being beneficial for cartilage in joints, and more recently, for a range of related anti-inflammatory effects.

Despite the known benefits from eating fish, during the early part of the new millennium, there were health scares concerning the consumption of farmed fish, particularly farmed salmon because of the potential build up of contaminants such as PCBs in the fat. A report by Hites *et al* (2004) suggested that people should eat no more than one farmed salmon meal per month because of the high level of contaminants, posing a cancer risk. This advice was quickly counteracted by responsible authorities; however the reputation of farmed salmon was undoubtedly compromised as indicated by short-term sales response, the ease with which the issue re-surfaces in uninformed comment, and the residual doubt about the product. Whilst the sector has not experienced a sustained scare such as that of BSE in the meat industry, there is arguably a need for proactive preparation to deal with any other potentially health-negative suggestions. Health is an important positive attribute that fish holds in its favour, but one which can readily be undermined through adverse media coverage from which recovery can be prolonged and slow.

Global environmental issues have been at the forefront of many people's concerns in recent years following the Kyoto Climate Change agreement, EU and national policy responses and in the publication of the influential Stern Review in the UK (Stern, 2006). These connect in turn with public concerns about the state of the world's oceans, forests and other ecosystems, and about opportunities to share in their protection. The Seafood Choices Alliance (2005) stated that 71% of consumers preferred to buy seafood that is environmentally responsible and were willing to pay between 5-10% more for this assurance. In addition a Europa poll

(2004) found that 72% of people thought that environmental issues had a direct bearing on their quality of life with water pollution at the top of the list of the five main environmental issues.

Concerns raised in relation to seafood span a range of issues including animal welfare, conservation and biodiversity, sustainable use of resources, and pollution. Key concerns raised in relation to capture fisheries include sustainability of stocks, the fate of bycatch associated with trawler fishing, damage to habitats from fishing gear, and damaging interactions with wildlife, especially marine mammals and seabirds (Earthwatch 2006). Government and industry bodies have responded to these challenges through supporting and responding to initiatives such as the 1992 FAO Cancun Declaration on Responsible Fisheries, the FAO Code of Conduct for Responsible Fisheries (1995), the certification of fisheries by the Marine Stewardship Council, or at the national levels such as in the UK, the Seafish certification of individual vessels for responsible fishing practices (part-funded by EU FIFG), with similar approaches being developed elsewhere.

Environmental concerns relating to aquaculture focus on the reliance on industrial capture fisheries for fishmeal and oil, localised pollution effects through the discharge of solid and dissolved wastes, interactions with wildlife and wild fisheries (e.g. through disease transfer, or modification of wild fish gene pool from inter-breeding escapees), farmed fish welfare and the use of chemicals and pharmaceuticals by the industry. As with capture fisheries, government and industry bodies are developing regulatory frameworks, codes of practice and certification schemes to address both the practice of aquaculture, and the assurance needed by consumers. The WWF-supported 'salmon aquaculture dialogue' more recently extended to tilapia and catfish, and the GAA (Global Aquaculture Alliance) sustainable shrimp guidelines are typical examples. The FAO is also currently addressing overarching guidelines for such standards, to ensure that producing countries are not disadvantaged by applications which restrict trade rather than ensure sound practice. For both capture fisheries and aquaculture, product traceability is an important component of delivering that quality assurance, and is gaining increasing importance in modern supply chains.

Another issue to gain prominence is that of food miles (the distances over which food items are transported prior to reaching final consumers). Thus DEFRA (2005) indicated that 1.8% of UK carbon emissions were from food transport and the social and economic costs were as high as £9 billion. The increase in food miles has come largely through the trend in supermarket shopping, and their aim to provide both a greater range and more consistent supply of food products. This leads to global sourcing from major suppliers, as smaller producers are unable to provide the quantities or consistency required. There has also been an increasing trend for offshore processing on grounds of cost such that in the fishery sector, fish produced in Europe may now be transported to Asia for processing and then returned for distribution and sale. There is growing awareness and concern on this issue, which has encouraged supermarkets to visibly stock more local and in-season produce, thereby making it easier for consumers to shop with this criterion in mind. This is also accompanied by increasing interest in the prospects of defining food miles associated with specific products and to propose including these or related indicators on labelling.

The importance of local production may rise in any case if fuel prices continue to increase in real terms and concerns about the links between fossil fuels and global warming become more acute. More precisely too, the concept of total energy or carbon footprint is also gaining ground, involving more widespread application of product life cycle analysis (LCA), in which the complete production and distribution system is accounted for the food product in question. Here for example a low energy production system (eg semi-intensive aquaculture) could be combined with a higher-energy transport system to deliver food which has similar or even lower carbon impact than a more local but energy intensive production system. The number of products assessed in this way is still relatively small, but include some from aquaculture and fisheries[14] and is likely to increase and assume greater significance. Distant agricultural producers such as S America, Kenya, Australia and New Zealand are for example already refining their competitive positions in such terms. However, for LCAs to be widely carried out and used by retailers and consumers, there will be a need for standards defining implementation and measurement, and certification processes to provide assurance. As with other types of certification, this will add a financial overhead[15].

5.2 Natural resource issues

Aquaculture relies on a range of natural resources. As already noted, the most important is water, as the medium in which all aquaculture species are grown. Aquaculture related water consumption through evaporation and seepage can be important in some environments, but is usually less important in most of Europe. Indeed the potential for aquaculture to lengthen water residence in time in catchments, provide buffering capacity and local evapo-transpiration benefits can be a positive feature in hydrological management. However in Europe, the demand aquaculture places on the local aquatic environment for processing its wastes is often the most significant issue. If water consumption is measured with respect to throughput and change in quality per unit of output or value, aquaculture is one of the highest agricultural or industrial users of water resources. The most significant exception is for recirculated aquaculture systems, where water consumption per unit of production is greatly reduced, typically to 1% or less of 'open-flow' conditions. Depending on the intensity of production, aquaculture can also require significant land or water area, competing spatially with other activities. The significance of this varies, but land areas associated with good water resources commonly have significant use and amenity value. Most fish and crustacean aquaculture systems also rely on formulated diets (compound feeds) that contain comparatively high levels of fishmeal and fish oil, mostly derived from the industrial capture fishery. All these are finite resources, although not necessarily ones that have been fully costed in the past, and aquaculture is competing with other potential users for them. Access, use and management of these resources are therefore important drivers for the sector.

5.2.1 Freshwater resources

The sustainability of water abstraction is measured by the water exploitation index, WEI which is the amount of abstraction as a percentage of long term renewable resources[16]. In the

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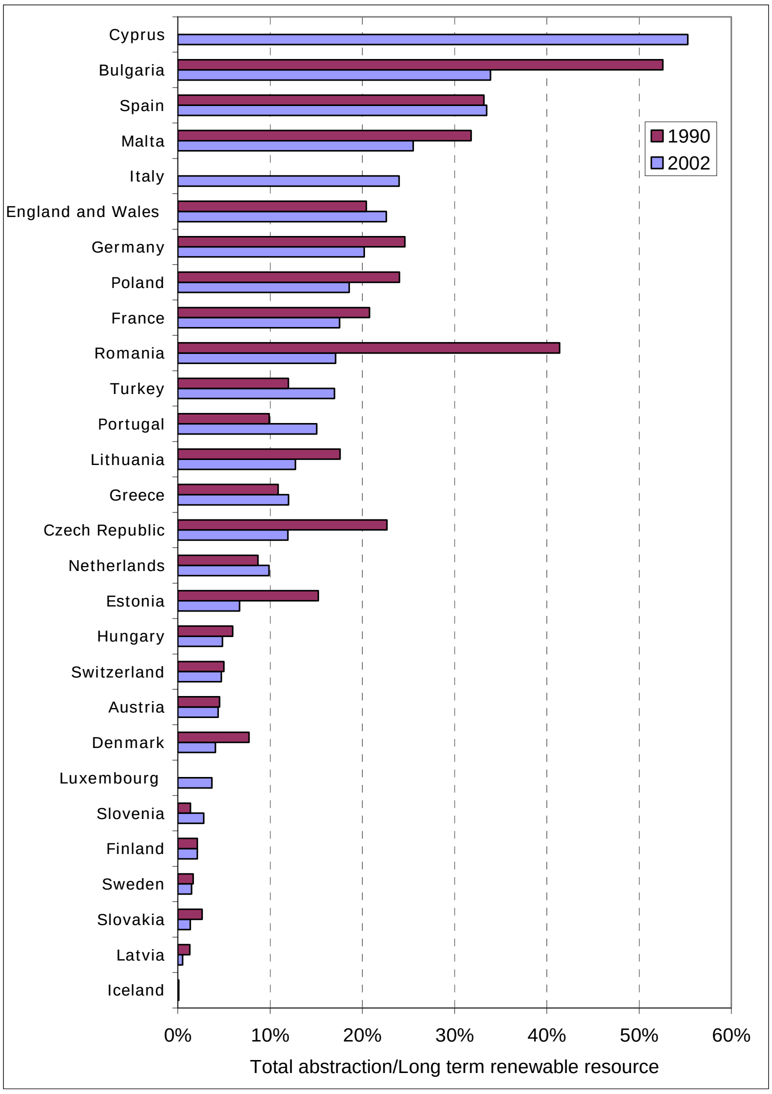
[14] see eg : Pelletier N, Ayer, N, Tyedmers, P, Kruse, S., Flysjö, A., Robillard, G., Ziegler, F., Scholz, A., Sonesson, U., (2007) Impact Categories for Life Cycle Assessment Research of Seafood Production Systems: Review and Prospectus Int. Journal of Life Cycle Assessment (6) 414-421 (2007), also eg http://www.ecotrust.org/lca/)

[15] Likely to range from a few € cents upwards depending on the inspection procedures and changes in production and distribution required.

[16] WEI is defined by the European Environment Agency, as mean annual total abstractions of freshwater divided by the mean annual freshwater resources. See http://themes.eea.europa.eu/Specific_media/water/indicators/WQ01c,2004.05/WQ1_WaterExploitationIndex_130504.pdf and http://eea.eionet.eu.int:8980/Public/irc/eionet-circle/water/library?l=/eionet_reporting_2007/soe-meeting_2007/reporting_sheet/_EN_1.0_&a=d for method of calculation.

EU the WEI decreased in 17 countries between 1990 and 2002, showing an overall decrease in abstraction. However the European Environmental Agency (EEA) estimates that nearly half of EU population live in water stressed countries, defined as where the WEI exceeds 20%, and severely stressed where the WEI exceeds 40%.

Figure: 51 Water Exploitation Index in European countries.



Source: EEA 2006.

Of the eight countries under water stress, Cyprus, Spain Malta and Italy all use the majority of abstraction for consumptive purposes such as irrigation, where as the other counties, Bulgaria, England and Wales, Germany and Poland use the majority for non-consumptive purposes such as cooling for industrial processes and energy supplies. The pressures on water supplies are expected to increase, especially if predicted global warming effects place greater burdens on irrigation demands.

Climate change is also predicted to increase the likelihood of floods. In 2002 a flood in the Danube and Elbe river systems resulted in around 700 fatalities and widespread economic damage. It is also estimated that around 10 million people live at risk of flooding along the Rhine system and the value of assets within 500 m of the European coastline is between €500 and €1000 billion. The growing dangers from flooding along river systems have implications for freshwater aquaculture, for which many sites are linked with or set out on floodplains.

These could include damage to structures and equipment, and/or loss of stock through escapes and associated environmental issues (EC, 2006). However, in some cases, as with wetlands, aquaculture installations can also provide important flood absorption capacity, allowing ponds and drainage channels to full up with overflow, albeit at the risk of stock mixing or release.

The discharge of waste in fresh water systems is usually regulated by environmental agencies, based on control levels of suspended solids, ammonia, nitrite or other parameters. It is anticipated that with greater enforcement and regulation associated with the implementation of the EU Water Framework Directive (WFD), regulations will become stricter, further limiting the size of operations or forcing operators to introduce more efficient waste mitigation procedures or technologies. Costs of adaptation will be very site-specific, depending also on flood protection requirements, but simple water reuse (see Part 2 report) can protect against drought risks and allow discharges to be better managed, typically at capital cost levels no more than around 15-20% above normal open-flow systems.

5.2.2 Marine resources

The availability of coastal sites is of major concern for the potential expansion of marine aquaculture as many of the more sheltered and accessible sites are already taken up and there is frequent conflict of interest and competition from other users. This can be seen particularly in the Mediterranean where busy shipping lanes and port activities create specific physical exclusion needs, and where tourism pressures are high and continuing to grow. Population in coastal areas also continues to grow substantially faster than in inland areas, with development highest in Portugal, Ireland and Spain followed by France and Italy.

In response to the growing problem of coastal degradation and of limited space for development, the EU initiated an Integrated Coastal Zone Management (ICZM) Strategy, to attempt to regulate further expansion and optimise usage and protection objectives. This encompasses economic, environmental, recreational, social and cultural considerations into spatial and regional development contexts. However, currently the ICZM Strategy relies on voluntary action by member states and implementation is inconsistent. Further development of EU Marine Policy, integration with the WFD and the efforts of national and regional government suggest that the level of planning and control in the coastal zone will continue to increase and that the designation of specific zones for aquaculture will become more common. At present, legislation covering coastal developments is commonly restricted to the nearshore zone, though this is likely in the longer term to be extended across all territorial waters. Aquaculture operations proposed for offshore sites may, though less restricted spatially, be relatively unprotected by legislation.

It is the responsibility of each member state to regulate the discharges from fish farming activities and each country has legislation and environmental authorities to achieve this. (Fernandes *et al* , 2001). To date this has been strongly influenced by consideration of the discharge of feed and faecal waste and its impact on the local environment. Modelling tools such as DEPOMOD and the UoS GIS based system are used to predict the accumulation of carbon or other wastes below fish cages, depending on loading and hydrographic conditions. Offshore sites, being more dynamic are less prone to waste accumulation and might therefore be expected to be granted licenses (or discharge consents) for much higher production capacities. The effects of dissolved nutrient discharges are less clear. As with solid discharges, local eutrophication effects can often be detected, and here the role of limiting or triggering nutrients may be important. However, the significance of these at a larger scale can be much harder to detect. Mitigation of aquaculture discharges through IMTA (integrated multi-trophic aquaculture) may be attractive, especially for near shore sites. However, some of the algal blooms associated with nutrient enriched systems can be harmful (ASP, PSP, DSP etc.) suggesting there may be limits to this approach, and unless sufficiently valuable bycrops or saleable environmental services are produced, higher capital and operating costs might be difficult to recover.

5.2.3 Feed materials

A major issue concerning the sustainability and scope for expansion of intensive aquaculture is its reliance on fish meal and oil from the industrial capture fishery. This is a finite but renewable resource which aquaculture is using an increasing share. The production of fishmeal and oils is a major world-wide industry with a large proportion coming from anchovy fisheries in South American waters (Table 9).

Table 9: Global sources of fishmeal and species used in its manufacture

COUNTRY / REGION	FISHMEAL PRODUCTION mean of 1999/2003 (t)	SPECIES
Peru	1,849,000	Anchovy
Chile	800,000	Jack Mackerel, Anchovy, Other, Sardine
Iceland	275,000	Capelin, Blue-whiting, Herring (including trimmings)
Norway	235,000	Blue-whiting, Capelin, Sandeel, Trimmings, Others
Denmark	297,000	Sandeel, sprat, blue whiting, herring, other
Other EU*	134,000	Trimmings, Sandeel, Sprat, Blue whiting, Herring, Other
China	600,000	Various
Thailand	390,000	Various
U.S.A.	337,000	Menhaden, Alaska Pollack
S. Africa	102,000	Anchovies, Pilchard
Others	1,307,000	Mainly Anchovy
TOTAL	**6,326,000**	

Source: International Fishmeal and Fish Oil Organisation, IFFO.

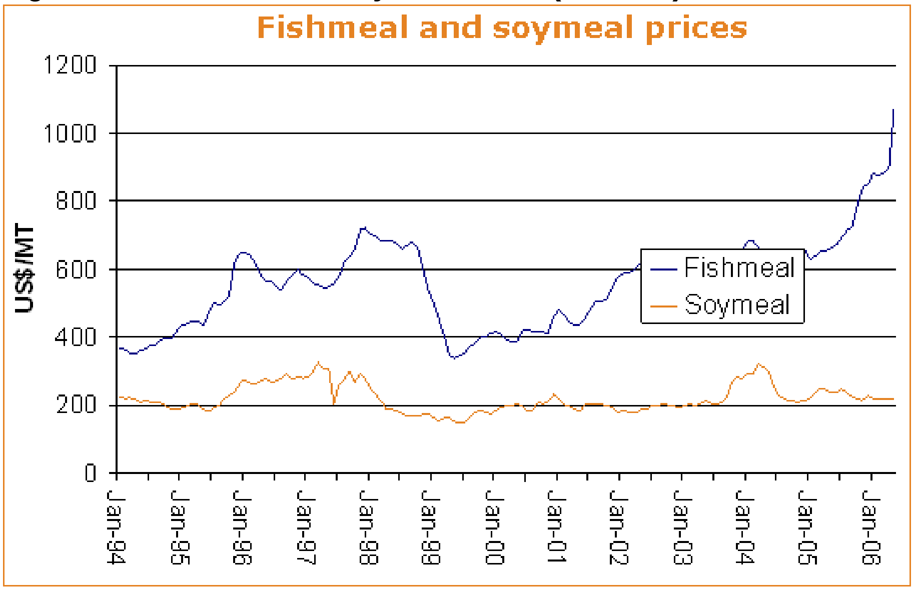
Europe also has its own fishmeal and fish oil production but this is small compared to that of the southern oceans.

Fish oil is a more immediate constraint than fishmeal, and nutrition research in Norway, UK, France and elsewhere has examined the potential for partial or complete substitution of these with vegetable oils. Trials confirm that this is possible, with the potential additional benefit of further reducing the concentrations of dioxin and DL-PCBs compounds in the final fish products, but the disadvantage of also reducing the levels of beneficial omega 3 fatty acids[17]. In the case of salmon, one of the major target species for feed development, one solution may be the use of diets high in vegetable oils during most of the production cycle, but switching to a high fish oil diet in the last four to six months prior to harvest. Data on the most effective timing for switching back to fish oil is still to be reported, as well as baseline fish oil levels required to ensure health and welfare of the fish.

[17] Bernstten *et al.* 2005

Fishmeal and oil supply is not only finite, but also variable, particularly with respect to the South American El Niño and La Niña events where the Eastern Pacific surface sea water temperatures become respectively warmer or cooler than usual. El Niño events occurred in 1986-87, 1991-1992, 1993, 1994 and 1997, while La Niña events occurred in 1985 and 1995. Catches of anchovy are particularly affected by these changes, with consequent impact on fishmeal and oil prices. The combination of rising demand and supply instability is affecting average prices, which are now well above that of soya protein[18]. (Figure 52).

Figure 52: Fish Meal and Soymeal Prices (US$/MT)



Source: Fish Information Network Market Report: March 2006 & www.eurofish.dk

Combined with growing instability of prices for vegetable alternatives as energy crop market demands are starting to impact, the challenges of combining flexible substitution with containable prices are greatly increasing, and there is renewed research effort on the potential for substituting fishmeal with alternative proteins to widen and stabilise supply options. Vegetable proteins such as soya can lack sufficient essential amino acids, have poorer digestibility resulting in the production of more solid wastes and sometimes contain anti-nutritional factors. Research is therefore focusing on finding appropriate terrestrial-based ingredients and mixes of ingredients, amino-acid supplementation and processing technologies to improve digestibility[19].

Other alternative protein sources are under investigation for aquaculture, most notably and controversially, krill, for which there is already a fishery for 200,000 tonnes, with projection to expand this to nearly 5 million tonnes[20]. However, the technical potential to incorporate krill into diets is still unresolved, and its practical use will depend much on the costs of supply (energy costs of capture are high) and the market and social acceptability of tapping into what many consider to be the world's last major unexploited biomass.

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[18] Note that soymeal and other plant protein grades selected for higher quality fishfeeds may show less price differential from base price fishmeals, but the broad trend is as shown; supplementation with amino acids and other balancing materials may however very easily bring reduced fish meal/oil diets

[19] E.g, see ongoing EU-funded project AQUAMAX, http://www.aquamaxip.eu/

[20] Fishmeal Market Report - November 2006

Also critical to future supply volumes is the sustainability of industrial fishing. Key elements are the degree of control that governments can exert over fishing vessels to ensure catch limits and fishing seasons are respected, whether the underlying fisheries models used for management are accurate, and whether there are other ecological changes that cause decreases in industrial fish populations beside fishing pressure. Most industrial fisheries are considered to exploited within sustainable limits at the present time[21].

5.2.4 Fossil fuel energy

Energy use in aquaculture is highly variable, depending on the type of farming system in use. When subject to life cycle analysis (LCA), the most significant energy input is in on-farm consumption of energy which varies widely, from virtually zero up to about 3 kWh per kg trout at farms with comprehensive water treatment[22] and in the production and delivery of feed. (Papatryfon *et al*, 2004, Grőnroos *et al* 2006, Aubin, et al., 2006). However,. For landbased farms, most of the power is likely to be provided by electricity, usually generated centrally from fossil, nuclear or renewable energy sources. Cage-based farms will normally require boats and vehicles using diesel or other fossil fuel. Energy prices have already risen substantially in recent years (the average spot price for a megawatt-hour of electricity on the EEX (European Energy Exchange) was around €24 in 2001, increasing to €43 in 2005) and may be expected to rise further in the future as fossil fuel supplies become more expensive to abstract, and tax and other policy mechanisms seek to reduce consumption due to concerns for climate change. For instance, EC Directive (96/2003) on energy taxes aims to;

- Reduce distortions of competition that currently exist between Member States as a result of divergent rates of tax on energy products
- Reduce distortions of competition between mineral oils and the other energy products that have not been subject to Community tax legislation up to now
- Increase incentives to use energy more efficiently (to reduce dependency on imported energy and to cut carbon dioxide emissions)
- Allow Member States to offer companies tax incentives in return for specific undertakings to reduce emissions.

One of the more innovative and widely promoted solutions to reducing fossil fuel use and to promoting activities that might mitigate the effects of global warming, is carbon trading. A European Emissions Trading Scheme (ETS) has been operating since 2005 in a first phase that involves around 12,000 of the largest energy users, primarily larger industries, rather than the agriculture sector, though potentially creating the means by which carbon impacts at all levels can be internalised into production costs. Certificates issued for the emission of carbon dioxide were trading at up to €30 per tonne in April 2006, but have since crashed to €1.20 (March 2007) since it became clear that many countries had given generous emission caps. The scheme has also been criticised on the basis that high carbon prices will push industry to invest in non ETS countries, whilst low carbon prices provide little incentive for mitigation schemes. However a phase II is planned for 2008-2012 to include all greenhouse gases and to increase the number of industrial activities included. At a simpler level, the use

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[21] Further discussion of these issues in the context of the Scottish salmon industry may be found at http://www.scotland.gov.uk/Publications/2002/08/15170/9412

[22] Erik Olesen, Højmarklaboratoriet a/s and Per H. Nielsen 2000

of marketed ‘carbon offsets’ – usually related to the costs of planting carbon retaining vegetation, typically tropical forests – is increasingly being used at retail levels, with suppliers automatically adding offset surcharges for ‘green’ products, or allowing customers to elect this voluntarily.

Energy costs are already a significant constraint for commercialisation of many recirculated aquaculture systems, and could be a more important component of offshore aquaculture operations, for example in the movement of materials, and the maintenance of standby supply and support vessels. Detailed accounting is yet to be carried out, and this will depend on site and equipment choices, but energy costs of 3-5% of total operating costs would not be unreasonable. On the other hand, there is also the potential for some aquaculture activities, especially seaweed farming and other potentially sequestering systems[23], to be part-funded through carbon emissions trading or offset schemes, or to be used to reduce the ‘carbon liability’ of related aquaculture production. Though trading schemes may have only limited relevance to aquaculture production at this stage, there are two implications; that agricultural and food supply systems with lower carbon emission levels, or capable of sequestering carbon will have further competitive advantage, and that generically, nutrient/emissions trading within global public goods may open up similar markets in other aquaculture-relevant materials such as nitrogen and phosphorous. In the latter case, some forms of aquaculture could earn valuable credits through their ability to take up nitrogen and phosphorous, while others would find incentives to reduce their outputs.

[23] Most recently (Lovelock, J E & Rapley, C G 2007, Ocean pipes could help the Earth to cure itself *Nature* 449, 403), proposals have been made for a ‘quick fix’ in carbon sequestration, inducing upwelling of cold, nutrient rich lower oceanic waters to stimulate much greater levels of algal production and subsequent deposition; it is not inconceivable for integrated floating systems to be developed combining such functions with offshore energy generation and more conventional aquaculture.

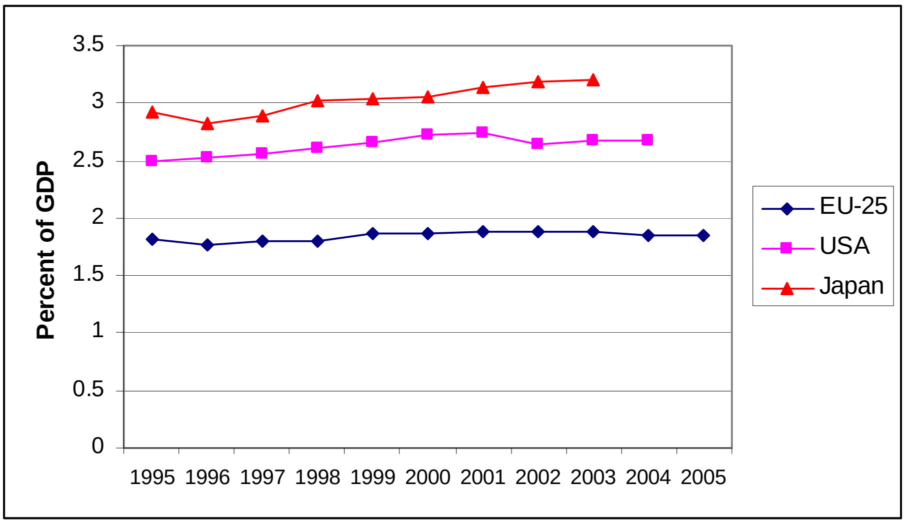
5.3 Innovation

5.3.1 Innovation processes and institutional support

Innovation is taken to include all activities associated with introducing change and improvement, including technical, market, managerial and other elements. Central activities in innovation are research (including testing) and technology transfer (including implementation management). Underpinning these are support measures for education, research, dissemination, protection of intellectual property and entrepreneurial investment. At the regional policy level, support for innovation is drawn from the EU Lisbon Strategy (EC, 2005) for the modernisation of European economies.

Research & development
The funding of research and development (R&D) is seen as a key indicator of investment in innovation. In 2005, R&D expenditure (EU-25) as a percentage of GDP stood at 1.85%, a slight fall from a high of 1.89% in 2002. This figure is significantly lower than in the other major economies of the USA (2.67% in 2004) and Japan (3.2% in 2003).

Figure 53: Expenditure on Research and Development as percentage of GDP



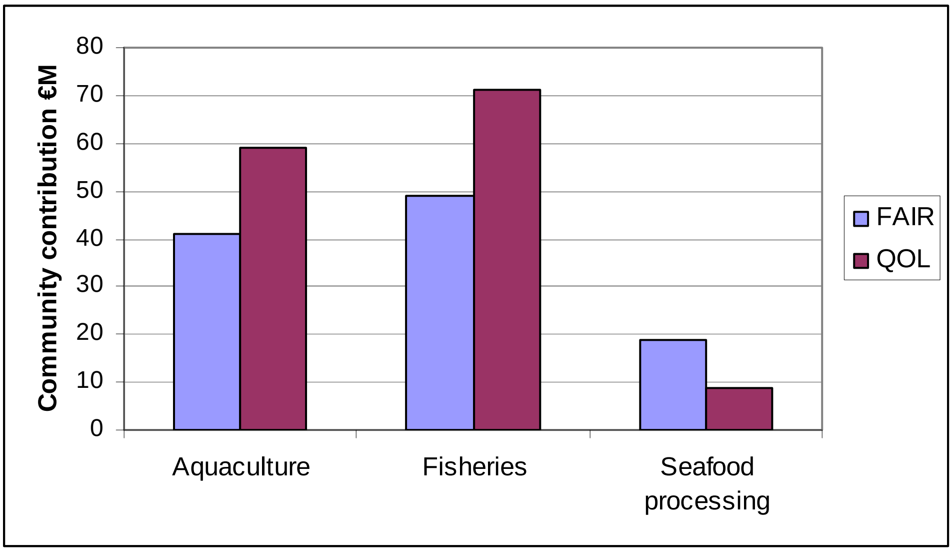
Source: Eurostat, 2007

Within the EU, the economies with the highest expenditure on R&D as a percentage of GDP were Sweden and Finland, followed by Denmark, Germany, Iceland and France. The lowest expenditure was in Slovakia, Cyprus, Latvia, Lithuania, Malta, and Hungary. Approximately 40% of funding for R&D comes from government, with most of the remainder funded by industry. One of the major differences between Europe, Japan and America is that European industry funds a lower percentage of R&D. Reviews of expenditure also note that large enterprises account for the most significant share of expenditure, and that EU companies – typically in manufacturing, electronics, biotechnology and pharmaceuticals are increasing R&D expenditure outside of Europe (European Innovation Scoreboard 2006). In recognition also that the engagement of R&D is vital for regional competitiveness, the EU Innovation Policy initiative, together with other approaches such as thematic and locational clustering, aims to strengthen innovation processes and make them more effective.

At more specific level, R&D in aquaculture is funded through a wide variety of government and private programmes, though there has been little research into total expenditure within the sector, or its distribution across themes, species or systems. A significant proportion however, is through EU RTD Framework programmes. The 4th (1994-1998) and 5th (1998-2002) Framework programmes both contained specific funding areas for fisheries and aquaculture (FAIR and Quality of Life respectively), although some aquaculture research would have been funded under other initiative areas. Within the main thematic areas, EU funding for aquaculture was €41 million under FAIR and €59 million under QOL. With the addition of industrial (partner) funding, these totals rose to €59.8 million and €87.9 million respectively. However, as a proportion of the overall capitalisation and turnover of the sector, these amounts are relatively modest; a nominal aquaculture output of 1 million tonnes represents a turnover of some €1-2 billion annually. Direct international comparisons for R&D funding in the sector are difficult to make, though as indications, in the UK the overall commitment to aquaculture between 1999 and 2007 was at least £28.1 million[24], and Canada's Aquaculture Collaborative Research and Development Program (ACRDP) runs at some $Can 4.5m annually. More thematically, Westwood *et al* (2002) describe total oceanic markets of $747 billion, of which aquaculture represents $22 billion, and associated annual R&D expenditure of $19 billion, of which some 16% is allocated to "marine science'', including oceanography. In the USA, NOAA's total budget for FY 2000 was over $2.5 billion of which $426 million was on 'Building Sustainable Fisheries'.

As an important regional partner, Norway's R&D expenditure in aquaculture is also of significance. The Research Council of Norway has a comprehensive programme in the fisheries sector, and actively encourages linkages with EU programmes for shared knowledge and added value. The Seafood Export Council of Norway and other agencies also carry out significant amounts of commercial and market research. The Norwegian private sector also commits important levels of funds to commercial R&D, albeit usually in proprietary product and system development.

Figure 54: Distribution of Community Funding under FP4 (FAIR) and FP5 (QOL)



Source: EAS, 2006 (FP4 projects initiated between 1994 & 1998, FP5 projects initiated between 1999 and 2002)

A study of the impact of this EU R&D funding (EAS, 2006) found measurement difficult and quite subjective, as people within the industry were not always aware of linkages between R&D and new products or services, and did not directly link company expansion or other

[24] DEFRA UK Aquaculture R&D Expenditure Summary, March 2004

parameters with R&D. Researchers were more confident of the nature of impact, but were often not well placed to quantify it. The major concern was the lack of adequate dissemination of research results and consultation between stakeholders on developing R&D priorities and programmes. Some of these issues were better addressed in the 6th Framework programme (2003-2006), although it had no specific thematic area for aquaculture. Funding for aquaculture amounted to some €77m, provided through a range of instruments including scientific support to policies (SSP) (€18.8m), the thematic area food quality and safety (€32.8m), SME measures (€20m), Marie Curie mobility actions (€2.9m), support for infrastructure (€0.47m) and the INCO programme (€2.1m). The 7th Framework Programme has just started with a budget for aquaculture estimated to be €33m for the first two years.

Intellectual property protection
Patents are the main policy tool designed to encourage inventions and the subsequent innovative work that is required to put them into practical commercial use. The number of patent applications granted is commonly regarded as a useful measure of innovation within a country or business sector, although this must be seen within the wider context of how the patent scheme operates. Patents have traditionally been granted by national authorities, which create problems for inventors within the aquaculture sector, where sales within a single country might be relatively small, but the technology applicable in many other countries. This is increasingly being addressed through internationalisation measures, though patent protection, particularly for smaller and lower-value markets can remain problematic. Within Europe, the European Patent Convention (EPC) established the European Patent Office (EPO) which allows a single application to seek patent rights in all EPC countries (although these must be specified individually at the time of the application). This effectively provides a bundle of national patent rights that must be validated by each country (involving submission of documents and payment of fees). Globally, the main mechanism for international applications is the Patent Cooperation Treaty (PCT). This allows an inventor to file a single international application (PCT application) with a single patent office.

Patents do not appear to have been a major factor in the development of aquaculture. They are mainly used for specific items of equipment, although these may often be within the context of a described farming system. Most common aquaculture practice is not patented, and companies have used internal confidentiality, service and other product attributes, branding and/or general commercial reputation, to protect developments where they feel they have a commercial advantage. Table 10 summarises the numbers of patents recorded as associated with aquaculture.

These reservations notwithstanding, patents can sometimes play a useful role in attracting corporate and venture capital financing to invest in innovation. This is perhaps reflected in relatively high number of patents for aquaculture in the USA, where venture capital financing is more active and where confidence in patent protection and enforceability is generally higher. Such companies are keen to ensure that new initiatives cannot be easily copied by competitors and that early investment in developing the product or service can be properly exploited by those involved. However, balancing this, it would be hard to argue that the US aquaculture industry is in any way better developed than the European industry. From society's point of view, the use of patents may tend to restrain output.

Table 10: Aquaculture patents

Keywords	Europe (EPO*)	WIPO**	Worldwide***	USA****
Aquaculture	23	57	857	1227
Fish farm(ing)	2 (3)	9 (13)	379 (552)	158 (405)
Fish culture	1	19	1041	146
Bivalve culture	0	0	19	4
Mussel farm(ing)	0 (0)	1 (0)	1 (10)	0 (2)

*European Patent Office (www.european-patent-office.org)
**World Intellectual Property Organisation (of the UN) (via EPO database)
*** All patent databases accessible through the EPO
**** US Patent Collection at US Patent and Trademark Office (www.uspto.gov)

Support for investment

In the EU, support for capital investment in aquaculture is currently provided through the European Fisheries Fund (EFF - previously the Financial Instrument for Fisheries Guidance, FIFG). This instrument, operational between 2007 and 2013 requires Member States to establish a National Strategic Plan for fisheries and aquaculture, such that both EU and national funds can be allocated according to established criteria. These will need to reflect the Common Fisheries Policy, the EU Strategy for Sustainable Aquaculture, and the specific objectives defined for the EFF. The overall goals for the EFF[25] are to:

- ensure the long-term future of fishing activities and the sustainable use of fishery resources;
- reduce pressure on stocks by matching EU fleet capacity to available fishery resources;
- promote the sustainable development of inland fishing;
- help boost economically viable enterprises in the fisheries sector and make operating structures more competitive;
- foster the protection of the environment and marine resources;
- encourage sustainable development and improve the quality of life in areas with an active fishing industry;
- promote equality between women and men active in the fisheries sector.

The main priority is for the support of investments that reduce environmental impacts of aquaculture and promote product quality and safety. Funding will mostly be allocated to micro and small scale enterprises, some medium sized enterprises, but not large companies. The EFF has a budget of €3,849 million over the 7 year period, approximately €538-556 million per year split between the Member States. Since the Fund requires a contribution from national budgets (the proportion varies according to region and priority of the initiative), the total funding for fisheries and aquaculture will probably be at least one third larger. The main distinction will be between Convergence and Non-Convergence regions, with around three quarters of the allocation going to the Convergence Regions (least developed regions identified as requiring special measures to speed up economic convergence with the rest of the European Union).

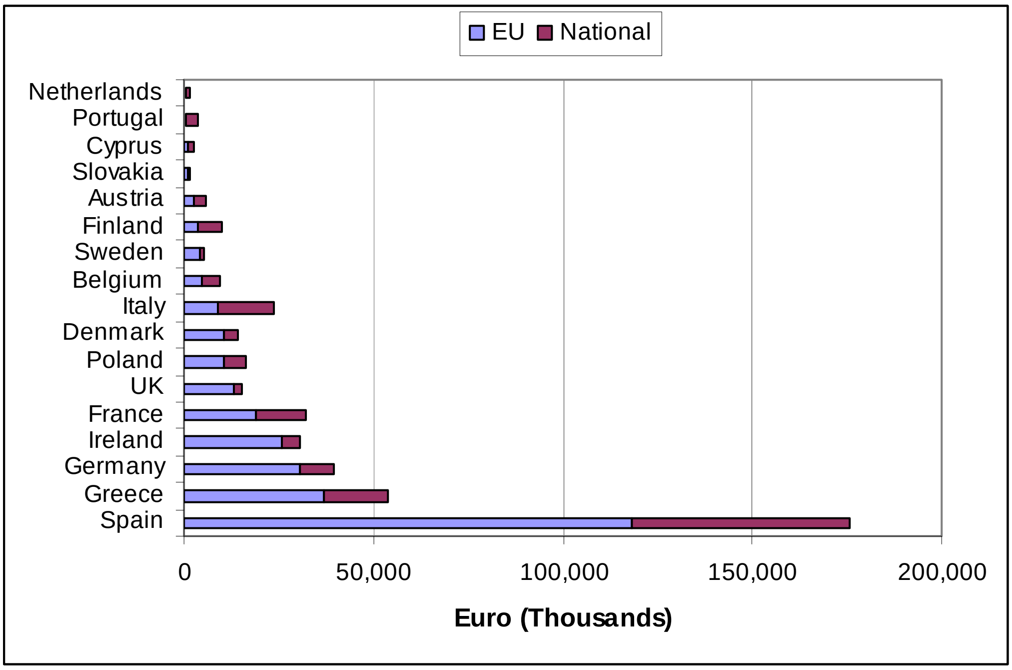
Prior to the EFF, structural funding for aquaculture was through FIFG. During the period 2000-2006, the FIFG budget allocation was €4.1 billion, of which 299.447 million (7.3%) was

[25] http://europa.eu/scadplus/leg/en/lvb/l66004.htm

allocated to aquaculture. National contributions added a further €149.479 million, making the total investment of public funds in aquaculture just under €449 million. This gives an average of €74.8m per year, approximately 6-7% of annual EU-25 turnover from aquaculture (approximately €1.1 billion per annum). Use of FIFG funding for aquaculture varies considerably between countries. Several of the New Member States were unable to implement the scheme prior to closure, although Poland appears a notable exception. The largest user of FIFG aquaculture funding by far was Spain, with a total expenditure of Euro 175.67 million (39% of total EU allocation). This has at least been associated with a steady increase in aquaculture production, particularly in coastal zones, compared with more static levels of production elsewhere.[26]

There appears to have been little research yet on the impact of FIFG on the aquaculture sector, but it has undoubtedly advanced the rate of investment in new aquaculture systems.

Figure 55: FIFG Funding for aquaculture 2000-2006



Source: Redrawn from European Commission, 2006. Facts and Figures on the CFP

5.3.2 Biotechnology development

At the broad level, a range of advances in biotechnology is being utilised within the aquaculture sector, and might be expected to have increasing impact in the future (see eg Dunham et al, 2001). Particular impacts are expected from the increasing use of genomics and proteomics in selective breeding, diagnostics, vaccine development and nutrition research (see eg MacLean et al, 2003). For most marine species, there are significant productivity gains still to be exploited if survival and growth rates can be improved. This has been achieved to a considerable degree with salmon farming, although the need to manage and treat sea lice infestations remains a significant operational cost.

[26] FAO/GFCM, 2006 Status and trends of the aquaculture sector in the Mediterranean; see also University of Stirling review on market for farmed seabass and seabream.

Selective breeding programmes are already in place for major species such as salmon, sea bass, sea bream and shrimp, so far with mixed impact. The development of microsatellite genetic markers has eased the problem of identifying and tracking pedigrees, and research programmes are working on quantitative trait loci mapping which will improve multi-trait breeding programmes, and even full genome mapping projects which should eventually lead to a much greater understanding of the genetic basis of fish development and performance in aquaculture systems.

The potential for genetically modified aquaculture species has also received some attention, particularly with the application for licensing a GMO salmon in the USA. Whilst the technology is not yet perfect, for example, with regards to the mosaic nature of the gene expression (see Part 2 report) GM offers the possibility of reductions in chemical usage, better growth efficiencies, fishmeal substitution and better quality of product with the chance to lower production costs. However, experience with GM plants has shown that the technology is not well accepted by European consumers, for who concerns about long-term health risks and especially impacts on the environment remain uppermost. There are likely to be significant ethical and policy issues to resolve before biotechnology of this form enters the scope of consumer acceptability, and producers would venture further with GM related technologies. However, more precise and closely targeted technologies, and the use of techniques such as autotransgenesis (using genetic materials only from the species produced) may in the future accelerate production gains without the same focus of concern associated with the current generation of technologies.

5.3.3 Information technology development

The use of computers, microprocessors, various sensors and information technology has enabled increased control in many sectors of aquaculture and food production, from fish production to monitoring market trends and consumption. In the farm scenario, the use of sensors linked to computer control allows for tighter control through efficiency of resources and allows for a higher level of monitoring to avoid losses. There are also potential welfare gains, in controlling feeding and rearing environments to optimise husbandry conditions, in picking up early onset disease signs more effectively, and in protecting stocks more effectively from predators. As farms become bigger and operated by larger companies this level of control is likely to increase and production costs should be reduced. The importance of improved communication links (including ready data transfer, video conferencing and streaming), is also enabling large companies to manage many functions at remote operations from a single centre, potentially saving on personnel and travel costs.

Market information and access is also considerably improved through ICT, and opportunities for widening product sourcing and for comparing market prices should improve the function of markets and the efficiency of supply chains. This technology is also employed increasingly as a marketing and consumer assurance tool associated with higher levels of traceability of products. Post harvest product can now be tracked through the distribution chain using small sensors (e.g. monitoring temperature, physical shock and other relevant parameters) hidden in the packaging to help assure traceability, assure quality and improve logistics management. These devices also have GPS receivers to continually update their geographic position, and mobile phone modules, to relay the data to a central Internet-based tracking application. This has allowed for increasing efficiency of distribution of products to consumers. Traceability will also become more important if food bioterrorism becomes a greater concern.

5.3.4 Systems and process engineering

Farming systems
As a relatively small sector, aquaculture has traditionally borrowed heavily from other sectors with respect to technology. In marine aquaculture, technologies have been borrowed from the offshore oil industry, fishing industry and latterly, the marine survey sector. In the future, there may also be opportunities for aquaculture to collaborate with, or draw technology from the emerging offshore energy sector. Land-based aquaculture, especially recirculated systems, uses technologies largely developed for waste and drinking water treatment. With global pressures on freshwater resources expected to intensify in the coming decades, further developments in this area with respect to cost and effectiveness would potentially benefit aquaculture.

Food processing
New innovations in processing such as modified atmosphere packaging using inert gases have allowed more opportunities in the sales of fresh products by increasing shelf life. Vacuum skin packs, retort pouches, new product forms and innovative preparation-facilitating packaging such as oven-ready/microwaveable product forms, all combine to extend the market positions that can be reached. Whilst this allows for more export opportunities, it may also increase competition from outside the EU, as some of the innovations extend the potential for other countries to export added-value products. However, as noted earlier, this may be partially constrained by the push towards reducing food miles – particularly for airfreighted fresh products, and encouraging locally produced goods.

5.4 Globalisation issues

5.4.1 Trade and competitiveness

Globalisation is increasing competition in national markets, but also improving opportunities for exports. By the nature of food markets, much of the larger scale aquaculture output is increasingly at commodity level, where the most important competition is on price. Achieving a lower cost of production is therefore a key factor in successful competition and any regional factors that add to production costs (either directly such as higher labour costs, or site licensing costs) or indirectly (e.g. increased administrative costs due to regulatory requirements) could affect business investment decisions. The alternative competition strategy is niche marketing, where producers are able to differentiate their product e.g. on the basis of quality, locality, service or brand. A good example currently is NoCatch cod from Shetland, and producers in a number of other EU countries are exploring ways to build more distinctive product offers.

The ability of companies to be competitive depends on a range of factors, summarised for example by Garelli (2006a) as (1) The ability to manage a broad spectrum of competences (within a country or firm) with the objective of fully exploiting their capital of resources and knowledge; and (2) The management of change, with the objective of adapting better and faster than competition to an ever-changing competitiveness landscape. At the sectoral level the key issues for competition (Garelli, 2006b) are:

- Economic performance
- Government efficiency

- Business efficiency
- Infrastructure

These hold true for aquaculture as with other sectors, although for most aquaculture systems, across the global perspective, comparative access and the costs of use of suitable natural resources is of primary underlying importance. The question of business efficiency is also particularly important for sectoral analysis in aquaculture. Several traditional species have been produced by family-owned and run enterprises where the full cost of labour is not accounted for and or where other inputs such as system fertility and productivity do not require to be costed. At the other end of the scale, the salmon industry for instance, has become quite highly consolidated with efficiencies increasingly gained though scale economies, technology investment and market leverage. In between these scales a wide range of small to medium sized enterprises have particular challenges in growing capability and technical efficiency in increasingly competitive conditions.

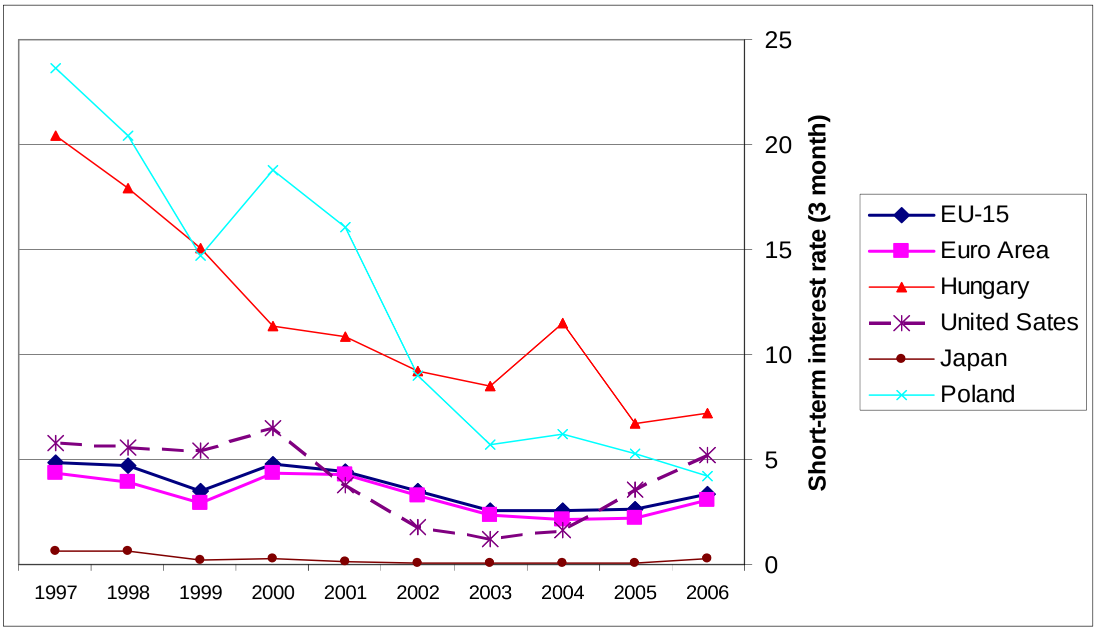
5.4.2 Finance

Aquaculture businesses are subject to the risks of a variable fiscal environment in the same way as most other enterprises. Anecdotally, many aquaculture businesses have failed due to fiscal rather than technical problems, and others have likewise succeeded due to a combination of technical and business factors.

Interest, inflation and currency exchange rates
A key feature of many aquaculture systems is the relatively long production cycle. For start-up operations, this can mean a significant time lag between a loan being taken out for site development, and sufficient product sales to start making repayments. Furthermore, the operating costs also need to be financed throughout that period (working capital), often through overdrafts or other unsecured loans. An important strategy for many companies is therefore to produce multiple batches at different stages so as to achieve regular harvests and sales (depending also on market demand) and thereby reduce the requirement for working capital.

All other things being equal, if interest rates rise significantly above those projected, returns on investment will be lower than projected and a farm can find itself with mounting debts that are difficult to repay, especially if sales prices decline (as can often happen with high unit value food items when economic conditions become tighter). New ventures (or substantial expansions) are particularly susceptible to the onset of high interest rates. More mature businesses that have lower debt ratios are better insulated. All else being equal, also countries with lower interest rates might therefore be expected to support more business investment than those with high interest rates. Although unless enterprises have good prospects of returning more than competing high interest rates elsewhere, it may be difficult to source capital.

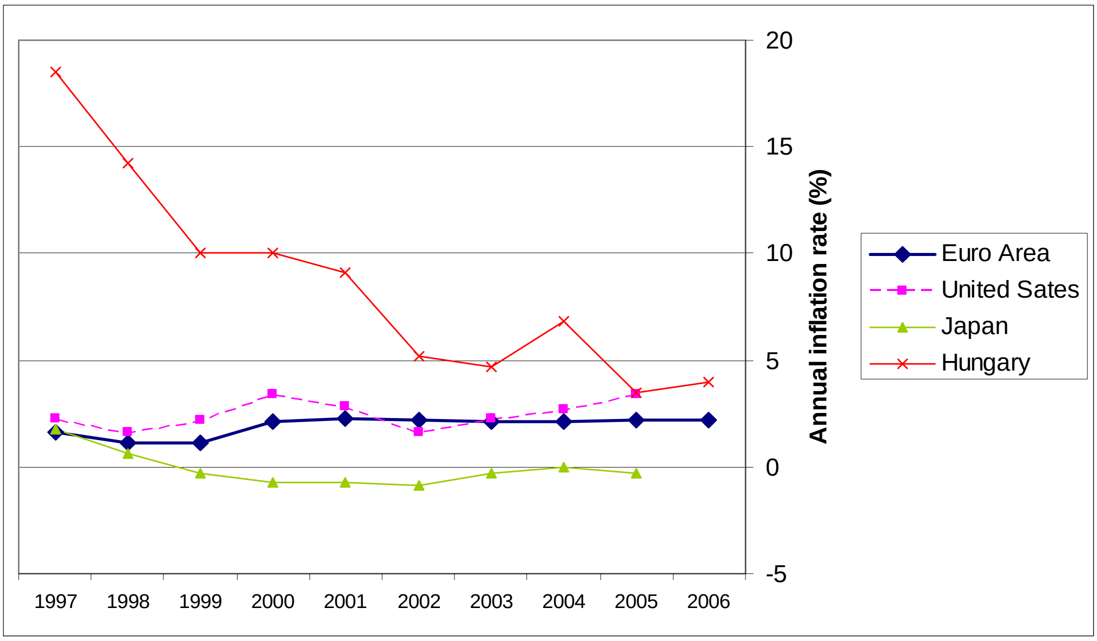
Figure 56: Short-term interest rates in Europe, USA and Japan over past 10 years



Source: Eurostat, 2007

The impact of interest rates on business investment is greatly modified by other monetary factors, the most important of which are inflation and currency exchange rates. High rates of inflation can cause significant management difficulties for companies, as well as deeper economic problems for the country concerned. The European Central Bank and most governments therefore aim to keep inflation stable, and at low levels. Eurostat statistics show this to have been achieved very well within the Euro zone, with inflation between 2.1 and 2.3% since 2000 and an average of 1.9% over 10 years. This compares with rather more variability and averages of 2.5% in USA and a low -0.07% in Japan (with a different set of deflationary problems). Inflation in many Eastern European countries rose sharply after independence in the 1990s, but is now falling towards European averages (illustrated by Hungary in Figure 57).

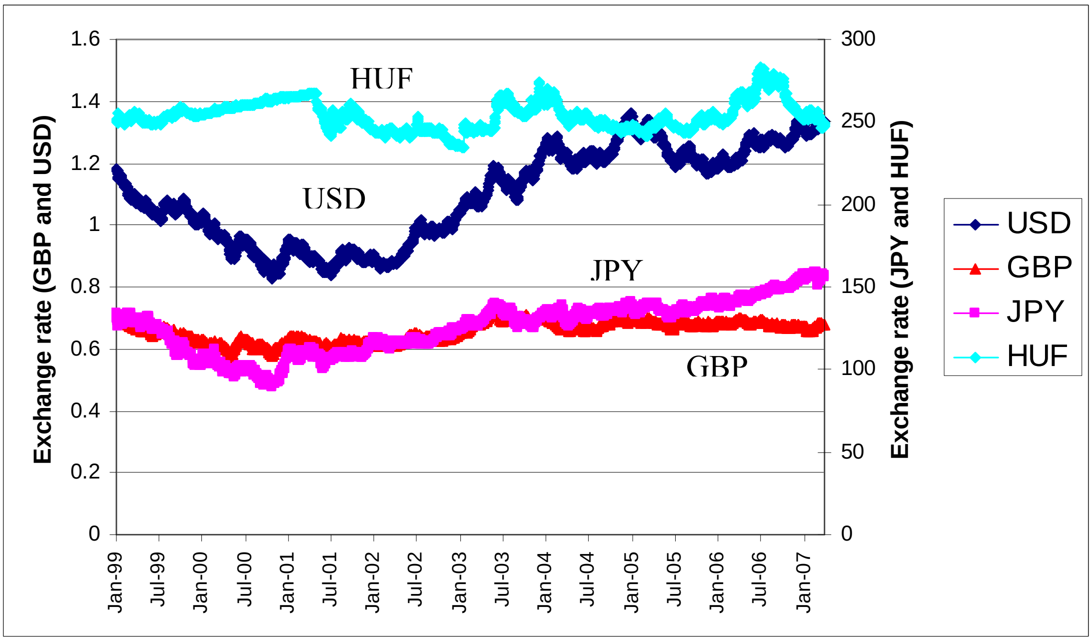
Figure 57: Annual inflation rate in Europe, USA and Japan over the last 10 years



Source: Eurostat

Currency exchange rates are a third interacting component of the monetary environment. For most aquaculture businesses, stable currency exchange rates are desirable, especially where fixed price contracts have to be agreed in other currencies. Companies that rely heavily on imported inputs (feed, seed, fuel etc) or on export sales, are particularly vulnerable to adverse changes in exchange rates.

Figure 58: Selected exchange rates against the Euro, 1999-2007



Source: European Central Bank

In practice, interest rates, inflation and exchange rates are often closely linked and change in one can influence the others. Stability within Europe has improved over the past decade, which should in theory lead to increased confidence and investment activity. However, evidence from the UK at least, suggests that the recent period of monetary stability has not led to higher levels of business investment in general. Arguments range as to whether this is a measurement issue, or illustrates the growing importance of other factors. For instance, official statistics for business investment have not considered investment in research and development, or human resource development. Arguably, both of these are more important in an economy that is increasingly dependent on the service rather than manufacturing sector.

There has also been a dividend to industry in recent years through lower real costs for capital items. This is particularly evident in computing and information technology, where the cost of computing capacity has fallen dramatically. However, the rise of low-cost manufacturing in China has also had a generally beneficial effect on global capital costs, albeit offset in some cases by rising raw material and transport costs. In effect, overall capital investment required for a given production output has been falling in real terms.

Another possible explanation for lower growth in stable economies is that profitability has been constrained and therefore investment less attractive. Various factors might influence this, including higher regulation with respect to social responsibility (e.g. employment legislation and the funding of pensions) and increased competition due to globalisation. The globalisation effect might also be drawing investment away from Europe into countries with cheaper production costs, although in Europe as a whole[27], there is little clear evidence of this as inward investment remains quite strong. Consideration must also be given to risk in relation to expected returns this may lead to some currently attractive areas for investment having a lower long-term rating if prospects for continued economic and political stability are in doubt.

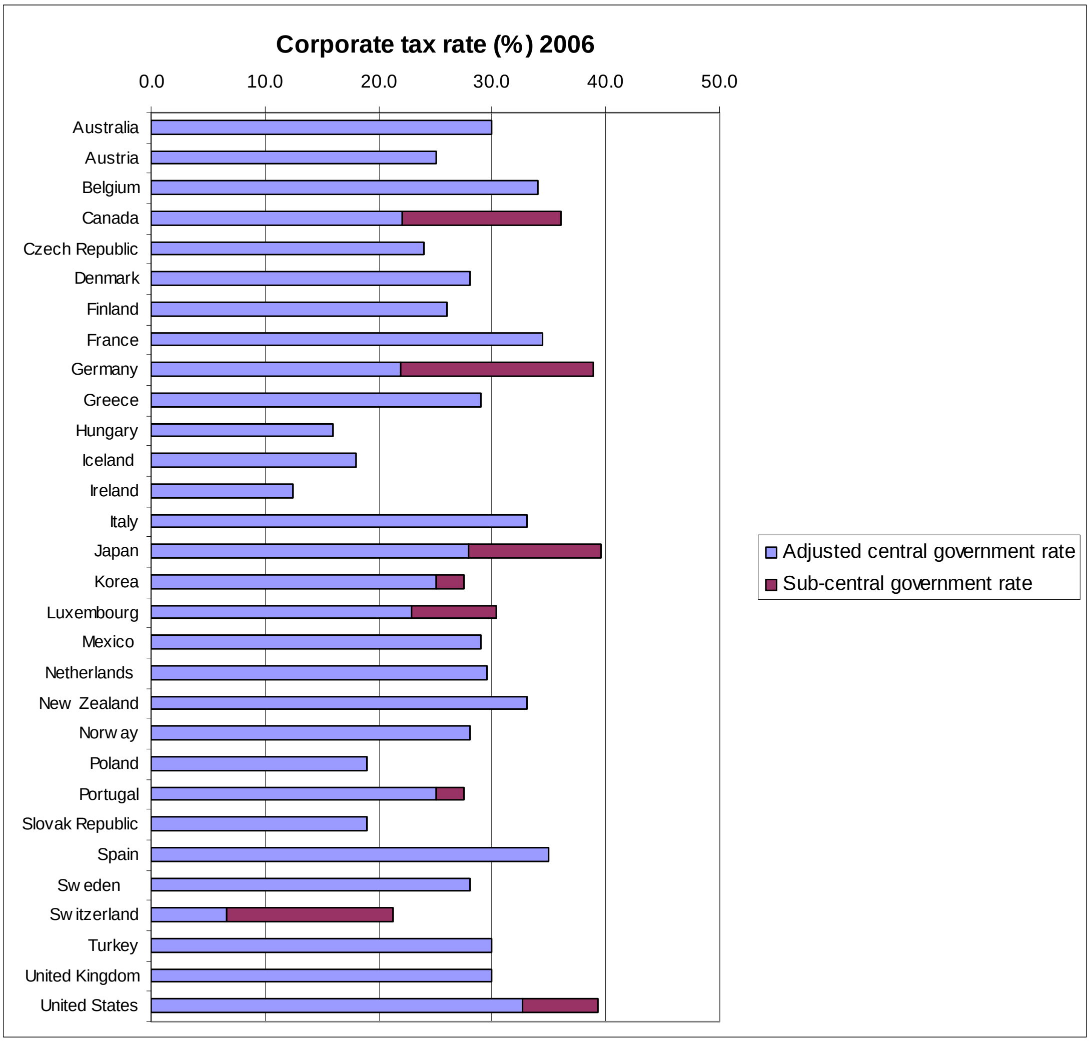
Financial regulation, incentives and taxes

Economic development can be guided by government through a combination of financial incentives and disincentives. Incentives generally take the form of grants for specific activities (e.g. research and development, staff training or capital investment in priority development areas), or sometimes special tax or rates allowances. These are justified on the basis of wider social, national or regional benefits. Disincentives can also be introduced through higher tax rates or rents, for instance when business activities are deemed to impose a wider social or environmental cost. Regulatory measures can also impose additional costs on business and may have a similar impact. Examples of these are more diverse and include the planning and licensing process, permits for resource use and waste discharge.

Differential corporate tax rates between countries have the potential to influence company investment decisions. In a survey of constraints to investment (World Bank, 2005) tax rates are the most frequently cited obstacle to investment in virtually all the European countries studied, e.g. Ireland, Greece, Czech Republic, Poland, Germany and Hungary. In Spain, concern about tax rates was exceeded slightly by concerns over access to, or cost of financing, whilst in Portugal concerns over tax rates ranked 4th after access to financing, business informality[28] and economic and regulatory uncertainty. All else being equal, companies would be encouraged to invest in countries with lower corporate tax rates so that a greater proportion of profits can be retained within the company, or distributed to shareholders.

[27] Gieve, J. 2006.
[28] Informality is measured by the percentage of company business that is officially reported for tax purposes etc.

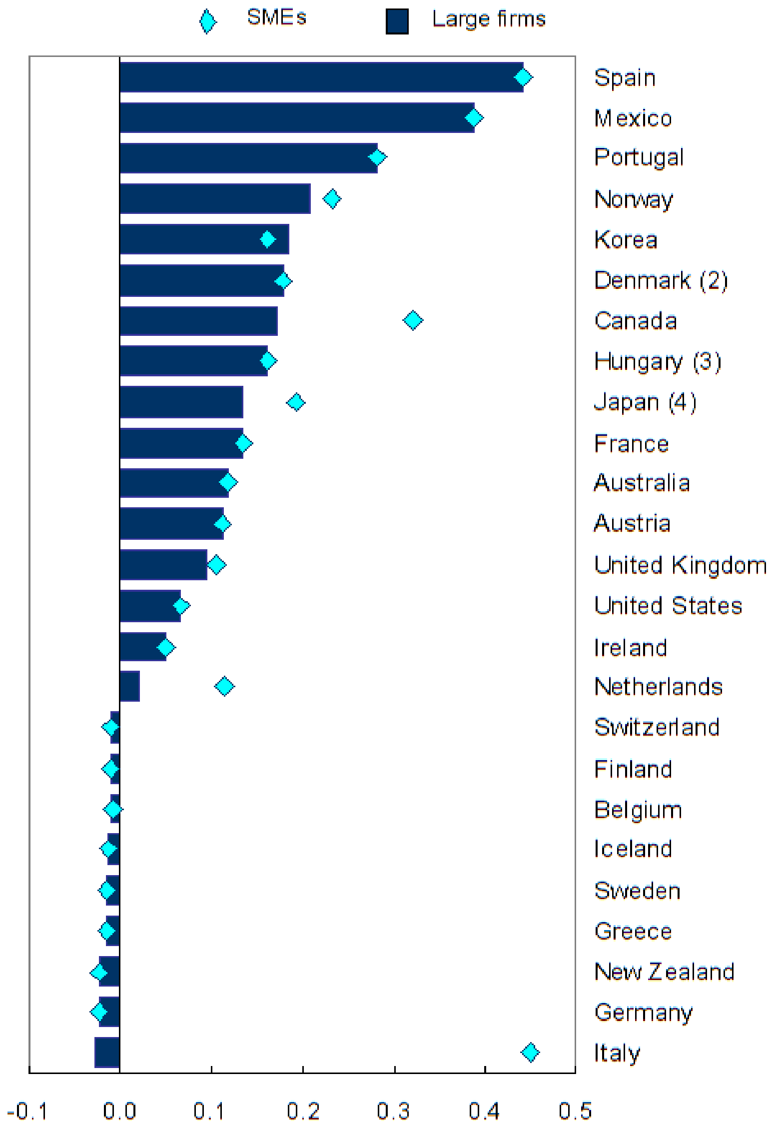
Figure 59: Comparison of corporate tax rates (2006)



Source: OECD

Analysis of differential tax rates can be complex, due to a mix of national and local taxes in some countries, and differences of detail in implementation, including allowances and differential rates according to specific criteria. For instance, many countries allow R&D expenditure to be offset against tax at different rates. Data from OECD (2005) shows that Spain has the most generous allowances for both large and small companies, whilst Italy has large allowances for SMEs (the major aquaculture group) but not large companies. Both countries however, have higher than average basic tax rates.

Figure 60: Rate of tax subsidies for R&D, Large firms and SMEs, 2004 (per US$)



Source: OECD Science, Technology and Industry Scoreboard 2005

Commercial finance for aquaculture

The aquaculture industry is relatively diverse with respect to the risks and returns it offers. Traditional aquaculture systems and products offer fairly poor returns in return for moderate risk, so are rarely of interest to new or corporate investors. Newer systems and products can offer higher returns, especially if the market is seen to be expanding. Risks however, may also be higher. As already noted, the length of many aquaculture production cycles is a major factor in increasing risk through potential changes in the monetary, market, natural or technical environment. Mitigating the risks usually entails good system design and prudent management. However, strategies have also emerged within the industry for risk-sharing, that are particularly important for smaller companies. The first of these is the practice of long credit terms on input supplies such as seed (fish fry or fingerlings) or feed. Small companies that would find it very difficult to obtain bank finance for such working capital items, have effectively obtained credit from companies that are competing for their custom. Perhaps more sustainable is the practice of contract farming, where a smaller company is simply paid to farm fish for a larger company. The payments are geared to meeting the farming costs rather than the eventual output, eliminating the need for the smaller company to obtain bank financing, although also limiting their ability to make larger profits if sales prices rise for instance.

Emerging aquaculture systems will be viewed as higher risk as they rely on less well tested technology, and perhaps also less certain markets. However, they will be attractive to investors if the potential returns, even taking into account the higher risk, are greater than other investment opportunities. Appetite for risk however, varies significantly depending on the characteristics of the investors, is often related to the sector, and is rarely directly related to the size of the investment.

Small and medium scale enterprises mainly rely on private capital and bank loans for commercial financing. A typical new venture at a modest level of gearing (i.e. debt:equity) might be financed by 50% equity and 50% loans, effectively doubling the capital available to investors. The interest repayments associated with this can however place a heavy burden if performance does not match expectations, and can be a primary cause of business collapse. Bank policies on lending for aquaculture vary considerably and in some countries, obtaining bank loans for aquaculture had been difficult, as the sector had earned an uncertain reputation from earlier levels of business failure. Interest rates may be set at higher levels if the risk of default is perceived as being higher and liquidation a risk if banks consider it unlikely that a company will become profitable within a reasonable timescale. Under these circumstances, its assets (farm site, stock, equipment and staff), may be taken over by others at a significant discount. Whilst this can be a major blow for equity holders, it can in some respects benefit the overall growth of the sector, as a lower proportion of income needs to be spent on servicing old debt.

Some of the risk may be offset through insurance. There are four main areas of insurance for aquaculture producers:

- Products liability
- Employers' liability
- Property, plant, vehicles and equipment
- Stock

Of these, stock insurance presents the most challenging area (Anrooy *et. al.* 2006). Aquaculture is both a relatively new industry in many countries, and also high risk. Where the industry has developed strongly, there has been an incentive for insurance companies to develop the required specialist expertise to service the sector. However, in many countries, aquaculture is often seen as too small and risky for insurance companies to consider. Alternatively, stock insurance may be offered, but at rates that are unattractive to farmers.

Table 11: Example status of aquaculture insurance in selected European countries

Country	Insurance companies	Coverage
France	Groupama (mainly provides insurance services to Asia)	Limited insurance available from local companies
Italy		Only a small number of farms insured, mostly directly through London market
Norway	Gjensidige Insurance Co.; IF Forsikring AS; Industrie Forsikring AS; NEMI Norway Energy & Marine Insurance ASA; Uni Storebrand Insurance Co.; Vesta Forsikring AS	Well developed specialist market for insurance – also covers Norwegian companies overseas
Spain	Spanish Insurance Group for Multi-Peril Crop Insurance (pool of >40 insurance compañes) + Consortium for Compensation of Insurance (governmental agency	Insurance for aquaculture stock is highly regulated in Spain, but premiums are also subsidised by the Ministry of Agriculture, Fisheries and Nutrition.
United Kingdom	Sunderland Marine Mutual Insurance Company Ltd; Aquarius Insurance Services/Royal & Sun Alliance; and SBJ Nelson Steavenson Ltd.	Well developed insurance market, with major companies also insuring overseas

Source: Adapted from Anrooy *et. al.* 2006

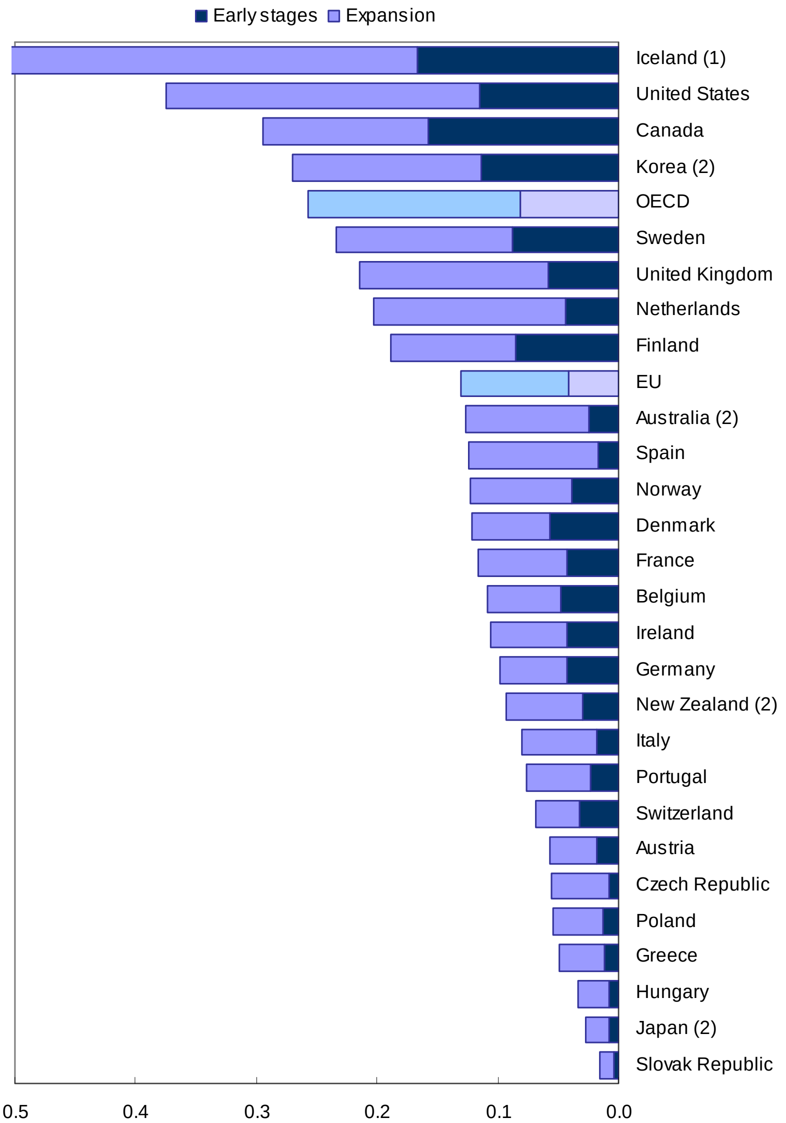
Adequate insurance can play a significant role in supporting the development of the aquaculture industries, especially more innovative projects where the impact of losses may be greater. The provision of insurance can greatly assist with securing finance both from banks and shareholders. To be attractive to insurance companies however, the sector must be profitable (income from premiums exceeding expenditure on claims). This requires risk to be addressed and minimised by all sector participants. Where private sector insurance is not available, governments have sometimes provided national insurance schemes (e.g. the US Federal Crop Insurance Program). However, this can constitute state subsidy and create problems with trade and other legislation

Venture capital financing is sometimes possible, especially for innovative technology-based firms with protectable intellectual property or unique know-how. This is usually provided by specialised financial firms acting as intermediaries between primary sources of finance (such as pension funds and banks) and companies. The sector also includes "business angels" – typically wealthy individuals experienced in business and finance who invest directly in firms. Three financing stages are commonly recognised, with the first two sometimes rolled up into "early stage" financing.

- *Seed capital* – provided to research, assess and develop an initial concept
- *Start-up* – financing provided for product development and initial marketing.
- *Expansion* – financing provided for the growth and expansion of a company that is breaking even, or trading profitably.

The availability/activity of venture capital investment provides some indication of the attractiveness of different territories with respect to investment finance, as capital is increasingly mobile, especially within economic blocks such as the European Union. However, it can also reflect wider aspects of business culture and practice such that it can only be used as another indicator.

Figure 61: Venture capital finance relative to GDP



Source: OECD Science, Technology and Industry Scoreboard 2005

The highest venture capital investment relative to GDP is seen in Iceland, although its small population, and the actions of a small number of key investment vehicles need to be taken into consideration. The USA and Canada are next in the rankings, reflecting both the well established nature of the venture capital market in these countries, and probably higher levels of investment in new technology ventures. Japan is probably an example of a country where investment in new technology is well above average, but comes mainly through existing corporations or other financing mechanisms rather than venture capital companies. The mobility of venture capital is also increasing, suggesting national investment resources will become less significant than the business opportunities offered.

The stock market is also becoming an increasing source of investment finance for aquaculture. This is traditionally a source of financing for well established companies to access additional funds for expansion. However, for a relatively small scale sector such as aquaculture, the barriers to listing shares on the major exchanges are relatively high. The US NASDAQ stock exchange for instance requires companies to have stock worth at least US$

70 million and have earned more than $11 million over the last 3 years. There are also considerable regulatory burdens place on listed companies. However, some, such as the London Alternative Investments Market (AIM) specifically target smaller companies by providing a more flexible framework with lower regulatory requirements. This attracts companies at an earlier stage of development, implying greater risk, but perhaps also opportunity for the investors. For instance the Aquabella Group (Barramundi farming in recirculated systems in the UK) and Aquabounty (Genetically Modified fish and other biotechnology products for aquaculture) are listed on this exchange.

Several major Norwegian aquaculture companies accessed stock market finance during the 1990s and are increasingly using this during the current decade, with increasingly larger mergers and acquisitions often financed through stock listings. For instance Pan Fish (now absorbed within the recently regrouped Marine Harvest, the largest salmon producer) was listed on the Oslo stock exchange by 1997, along with several other Norwegian companies. More recently, Cermaq (parent company of Mainstream and Follalaks fish farming operations and the EWOS feed company) and Akva Group (Aquaculture equipment and IT) became listed on the Oslo Stock Exchange in 2006. Leading Greek companies also turned to the Athens stock exchange, led by Selonda Aquaculture SA in 1994 and followed by Nireus Chios Aquaculture SA, Hellenic Fishfarming SA and Interfish Aquaculture SA (2003). Asian aquaculture is also accessing stock market finance, most recently to fund the rapid expansion in *pangasius* farming in Vietnam. By comparison, e.g. with FIFG/EFF funding, these sources have now become significant drivers in growth and capacity development, greatly increasing the European sector's capitalisation, though at the same time increasing value vulnerability to market volatilities associated with changing perceptions of risk and returns.

Stock market financing is primarily sought for new project development or expansion. However, it is also increasingly used to finance organic growth through company acquisitions, and additional shares may be issued to help with financing working capital to get past adverse trading conditions or simply to finance expansion of turnover. Stock market financing can be attractive with respect to raising funds without conventional collateral or security, but is subject to increasingly stringent regulation, and can subject firms with significant exposure to a range of challenges during market downturns. The shorter-term perspective created in some exchanges can create difficulties for aquaculture projects with relatively long production cycles and variable markets. Finally also unless ownership and share rights are carefully designed within the rules of the exchange and regulatory environment concerned, the accumulation of blocks of shares can influence management and ultimately ownership of the business itself.

Full stock market listing and financing is typically considered for relatively large sums. The average value of an IPO (Initial Public Offering) on the London Stock Exchange in 2004 was £24.5m (€35.6m), increasing to £80m (€116m) in 2006[29]. However, the Aquabella IPO in 2006 was for just £2.28m[30] (market capitalisation £18.2m). It is anticipated that stock market financing will be increasingly important within the aquaculture sector. Most recently however, the rise of private equity, moving publicly traded capital back into private ownership is also becoming a significant phenomenon. Somewhat similar to traditional venture capital, this is usually much more directly managed, with a specific focus of working assets more effectively, realising any unrecognised value, regrouping if appropriate, and

[29] Source: Calculated from information provided by London Stock Exchange Press Releases. http://www.londonstockexchange.com/

[30] http://www.aquab.com/article.asp?nid=6

selling on either to a takeover buyer, or by re-listing the company on a suitable exchange. This approach is increasingly common in the food and retail sectors and is now also observed in the aquaculture sector.

5.4.3 Mobility

It is not only finance that is becoming globalised. Human resources are also increasingly mobile. Economic migration is a significant issue for Europe and is an important consideration with respect to labour-intensive activities such as fish processing. The use of lower-paid migrant labour, allows a company to reduce their cost of production below that which might otherwise be possible. This improves competitiveness for those businesses, but can also have other social and economic impacts that need to be taken into account at the policy level.

It is not only labour that is mobile however, there is also increasing movement of skilled and professional staff, students and researchers between countries. This has considerable potential for enhancing technology transfer over longer timescales and can also be a valuable mechanism for building trade and other links. Changes may be driven more quickly however by the development of the Internet and related improvements in communications and information access. This is leading to an unprecedented transfer of knowledge, and opening up opportunities for teaching, research and other knowledge-based activities to be easily re-located, or distributed in new configurations. The significance of this may increase, both for those aquaculture companies that operate internationally with high reliance on advanced data management and analysis, and for small owner-operators who have previously had virtually no access to external information and expertise.

6 Scenario analysis

6.1 Summary prospective analysis and scenario definition

The factors outlined in Section 2 set out the expected upper and lower limits for development of the aquaculture sector in Europe up to 2025. The objective for the analysis in this section is to examine the identified drivers with respect to the strength of their influence on development, possible interactions between drivers, how the drivers might be modified through policy or other interventions, and the composite impact on the aquaculture development trajectories. Of those identified earlier, only the most significant ones are included at this point, to avoid over-complication. These are:

- Consumer purchasing behaviour – taking into account price changes, actions of campaign groups and responses of the multiple retailers etc.
- Site availability and cost – taking into consideration physical availability, lease costs, environmental costs, and competition with other users
- Support for innovation – taking into account government and business investment in R&D, education and training, and the support of government and financial institutions for commercial (technology-based) risk takers

Species are grouped with respect to culture and market characteristics into:

- Salmon, trout, charr and other salmonids
- Sea bass, bream and similar species
- Halibut, turbot, sole and other flatfish
- Cod, haddock, hake and other quality marine whitefish
- Carp, tilapia, catfish and other low to medium value freshwater fish
- Eels, perch, sturgeon, zander and other higher value freshwater fish
- Tuna and other high value pelagic fish
- Mussels
- Oysters, scallops and higher value shellfish
- Clams, cockles and other lower value shellfish
- Potential new aquaculture species not covered above (squid, cuttlefish, octopus, lobster, crab, shrimp, abalone, echinoderms etc.)
- Aquatic plants (seaweeds)

Previous growth rates for these species groups provide some guidance, but future factors such as technology break-throughs and changes in the marketplace are likely to have greater impact, so more emphasis is placed on foresight rather than hindsight in the scenarios and discussions which follow. It is also important to consider trends with respect to the final products that might be marketed rather just output volumes from aquaculture, as value addition can be more significant in economic terms, than primary production. Other changes in aquaculture practice may also occur in response to market demands. For instance demand for larger-size trout, and to some extent sea bass and bream, suitable for processing (e.g. fillets) has been increasing in recent years. In responding to this, the French rainbow trout production fell from 46,462 tonnes in 2001 to 32,412 tonnes in 2005, although value per kg increased by approximately 12%[31]

Aquaculture production projections for the four scenarios are set out in the next sections. The purpose is not to predict how aquaculture might develop over the next 20 years in Europe, but to use these different projections to reflect on their implications with respect to resource use, economic and environmental impacts, and what changes would be necessary within the sector to achieve differing levels of output. From this, consideration might then be given to which scenario appears more likely in relation to larger external trends that may impact on development.

The first scenario reflects minimal development, but continuation of trends that can already be seen in the industry. The other three scenarios are essentially target-based. The overall growth in aquaculture is set by the target growth assumptions. Which sub-sectors develop and at what rate is then determined with reference to discussed drivers and barriers, but the actual rate is calculated to deliver the target production levels, based on 5-year intervals

In all scenarios it is assumed that a proportion of the aquaculture production will be exported, but that an equivalent or greater quantity of other seafood products will be imported. Table 12 summarises the main drivers that were considered in constructing the models.

[31] Calculated from FAO Fishstat database, 2007, with US dollar values converted to Euro using annual average rates for 2001 and 2005 respectively.

Table 12: Summary of driver effects by sub-sector

Species group	Consumer trends and issues	Resource constraints and sustainability	Policy and investment issues
Salmon, trout & other salmonids	Lower prices and improved range of products are expanding markets. As the highest profile farmed fish in Europe, salmon has been subjected to considerable bad publicity on contaminants, welfare and environmental impacts. However, consumption has also been encouraged by positive health messages. Good potential for further expansion if comparative value continues to improve.	The industry is moving towards using a smaller number of large sites for reasons of operational efficiency. Environmental regulation is constraining this trend, at least in the UK. Other sustainability issues are being addressed through innovations and new guidelines for best practice.	Low prices throughout the first half of the current decade slowed expansion and encouraged further consolidation. The majority of European production is in the hands of a decreasing number of international businesses, which should bring greater stability and provide access to investment finance as needed.
Sea bass, bream & similar	The whole fish format is popular in Southern Europe, but even here, trends have been towards easier to prepare and convenient fish products. Market expansion is therefore somewhat constrained, although further substitution is likely if capture fisheries decline.	There are significant constraints on further inshore sheltered sites, but further expansion at more exposed sites is feasible.	The sea bass and bream industry is only moderately consolidated and suffered low prices in the early part of the decade. Further restructuring is emergent and more is expected.
Halibut, turbot, sole etc	Popular, but nevertheless premium fish species. Prospects for steady growth within limits defined by price. Reasonably versatile fillets/steaks for value addition. Market prices have been comparatively stable.	Most turbot and sole are produced in tank-based systems, sometimes recirculated. Halibut also produced in cage systems. Relatively unconstrained.	Likely to witness only modest expansion given comparatively high production costs and desire to maintain high unit value status of products.
Cod, haddock, hake etc	Traditionally high volume whitefish species. Considerable substitution in lower-value products from other marine species. Some evidence that aquaculture produce may be able to compete on quality and environmental credentials given increasing concerns about overfishing of wild stocks.	Industry still very small and not resource constrained. Possible competition with salmon etc. for resources as expansion occurs.	Further research needed to improve production processes and encourage investment
Carp, tilapia, catfish	The carp market has been declining, although there are some indications that market image and new products can be developed to raise value. Tilapia and catfish are relatively under-represented in the European market, with good prospects for expansion as versatile meat suitable for incorporation in a range of products.	Land based systems for tilapia and catfish feasible. Established processing technology-based solutions for carp and changing market could see expanded interest in carp.	Emergent interest more evident in tilapia with a number of emergent investments seeking to exploit growing market in imported products with those locally based. Competitive advantage remains to be proven for mass market.

Species group	Consumer trends and issues	Resource constraints and sustainability	Policy and investment issues
Eels, sturgeon, perch, zander etc.	Carnivorous freshwater fish are well known and valued in East and Central Europe with some prospects for expansion as prosperity rises and perhaps as the species are introduced to other markets. The main interest in sturgeon is for caviar, although markets exist for sturgeon meat in Central Europe.	Wild stock are likely to be increasingly protected. Intensive culture in ponds and recirculated tank systems are emerging with few immediate resource constraints. Eel production is currently highly constrained by wild elver supplies.	Generally niche products that have not had substantial R&D or structural funding support. Primarily of interest to small and medium scale businesses with relatively limited investment resources.
Tuna	Most tuna produced in Europe is exported to Japan. There would be few obstacles for expansion of European markets if prices fall and sustainability issues can be addressed.	Current reliance on wild seed stock is a major constraint, as is the use of baitfish for feed and associated environmental impacts.	Substantial R&D investment is required to close the tuna production cycle and allow for the development of commercial hatchery/nursery operations. Early weaning of fish onto dry diets would also reduce environmental impacts.
Mussels	Reasonable prospects for market expansion with improved quality, processing and packing technologies.	Traditional production sites are increasingly constrained, but new developments in offshore farming are opening up new opportunities.	Mussel farming is likely to be a central part of IMTAS
Oysters & scallops	Premium shellfish species with potential for market expansion, especially if prices were reduced	Traditional near-shore sites are highly constrained.	These shellfish might form part of IMTAS. The industry is mostly small-scale private producers with limited means for investment.
Clams, cockles etc.	Lower value shellfish commonly incorporated into a range of dishes.		
New non-fish aquaculture sp.	Prospects for octopus, cuttlefish and perhaps squid if economic production technology is developed Some prospects for premium echinoderms and molluscs (e.g. abalone), initially for export or ethnic markets.	New species, sharing only general aquaculture constraints	Substantial R&D required for most species, as well as support for pilot and early commercial projects.
Aquatic plants	There is scope for developing the market for seaweed as food in Europe, given the very low base. Industrial uses exist, but are not high value. Potential for biopharmaceuticals	Potential near-shore space constraints.	Likely to be central to IMTAS development. Difficult for production in Europe to be competitive with other regions at present. Potential for biopharmaceuticals requires substantial R&D funding for development.

6.2 Emerging technologies, practices and systems

6.2.1 Emerging systems

The particular focus of our analysis is to discern the prospects for emerging aquaculture systems, as defined and characterised in more detail in the Part 2 report, in the context of overall prospects for aquaculture development (partly because it is where most development/growth, if occurred, would be based). The emerging systems that were identified, and the anticipated prospects are as follows:

Production technology driven

Recirculated aquaculture systems - The number and scale of commercial recirculated aquaculture systems continues to grow and units capable of an annual output of up to 1000 t are foreseen within the next 5 years. The technology is still only moderately standardised and key components effectively custom built for each development. Expansion of this sector will depend on continued improvements to design and optimisation of both build and operating costs.

Offshore aquaculture systems - The salmon industry in particular is increasing production scale at individual sites, and developing the handling and harvesting systems that would be required for true offshore aquaculture. Support for further R&D is being given by the governments of Ireland and Norway. It is also notable that the USA have prioritised this type of development both investing in R&D and introducing a bill to bring in the regulatory changes required to allow for offshore aquaculture developments in designated zones (http://www.nmfs.noaa.gov/aquaculture/offshore.htm).

Integrated systems - IMTA systems have potential for reducing environmental impacts whilst optimising overall production through making best use of ecological processes to assimilate wastes. However, there are numerous challenges to making such systems work in practice due to commercial and operational factors. Research is ongoing in Canada and Scotland using seaweeds and bivalve mollusc in conjunction with salmon culture. Seaweeds mitigate waste by removing dissolved inorganic wastes such as ammonia, whereas the molluscs are used to remove solids waste (Chopin *et al* 2006). Currently the seaweeds have the least value in the system as they are not widely consumed in the West, despite the reported nutritional value of some species. However they have a wide range of industrial uses, and are increasingly noted as sources for new biopharmaceutical products such as anti-cancer and anti-viral drugs. They may also have potential use for production of biofuel, though the economics of doing so would have to be more specifically defined.

Market driven

Organic and other labels – the market (and supporting legislation) is increasingly demanding assurances of product safety, transparency concerning production and processing, and many consumers are also seeking products that clearly embody ethical and environmental values or quality concepts. Where labels seek to differentiate a product from other similar offerings in the marketplace, the production and/or distribution process must indeed be different. For labelled products to have credibility, it is essential to have a robust and independent certification process that checks that the production and distribution systems do meet the claims made for the label. As the number of participants in any scheme increases so too does the risk of brand degradation through the rogue actions of individual producers. This adds cost and the proliferation of standards, organisations and labels, whilst providing a wider range of consumer choice, is sometimes regarded as potentially confusing, diluting the value individual labels may have. In recognition of this, the European Commission DG Fisheries conducted a survey on certification of aquaculture products during the first half of 2007. This concluded that action at EU level would be helpful, and this is now receiving closer scruitiny[32]. Supermarket chains across Europe seem set to continue their increasingly receptive view of standards which reinforce their ‘green’ credentials; undoubtedly there may be a cost-based constraint on any unbridled enthusiasm, especially if the consumer proves more resistant to its price implications.

New aquaculture species – Interest in producing a wider range of species from aquaculture is driven partly by declining prices for established species as production levels rise. It may also be stimulated through rising demand for greater variety, or increasing prices for some traditional high value or high volume capture fisheries species. Concerns about over fishing also promote interest in a more diverse aquaculture production base among policy makers. This study identified around 50 species that are either produced at small scale or research levels, with potential for expansion. Some species are clearly constrained by technical barriers, such as the reproduction and early rearing of bluefin tuna. For other species, it is usually a combination of technical and market factors which lead to an assessment that production would not be economically viable (or sufficiently attractive for investment given other available alternatives). As technologies and markets develop, it might be expected that new aquaculture species will emerge from time to time as both technically feasible and commercially attractive. However as the range of species expands it might be expected that there will be greater concentration upon a much smaller number of core species satisfying the common determinants of the market.

6.2.2 Emerging technologies and practices

In discerning emerging aquaculture systems, it was also noted that there is continued evolutionary development of technologies and management practices within the mainstream aquaculture systems. Those with greatest impact include:

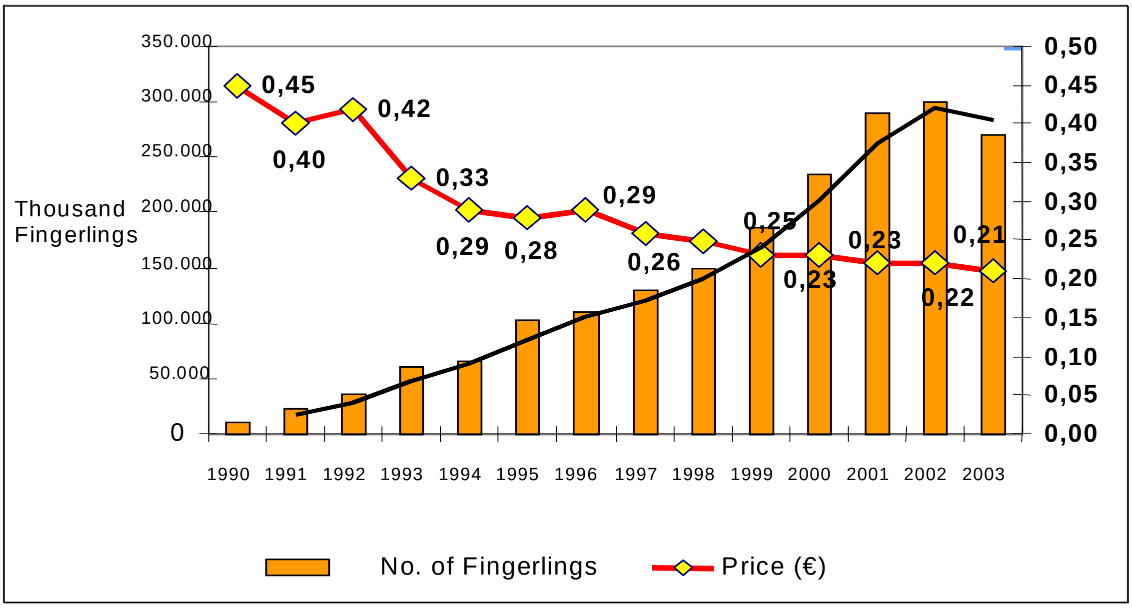
Breeding technology – Closing the lifecycle has been the single most important technical advance for many aquaculture species, especially marine fin fish. This has required a combination of technologies – maintenance of correct environmental conditions, adequate maturation of broodstock with quality gametes, initiation of spawning behaviour; successful fertilisation and hatching of eggs; nursing of larvae and fry through early developmental stages until weaning on artificial diets etc. The Mediterranean sea bass and bream industry effectively started once commercial hatchery production of fry became feasible in the 1980s. Since then, production efficiencies have improved and cost per fry reduced. In 1987, prices quoted for sea bass were approximately €0.34 - €0.40 for 1 g fry and €0.67 to €0.88 for sea bream[33] (Berg & Cittolin, 1987). Survival rates from egg to fry were often less than 5%. One of the most important advances was the introduction of enrichment media for live feed, but

[32] http://www.ec.europa.eu/fisheries/cfp/governance/consultations/consultation_240407_conclusions_en.htm

[33] Prices quoted in Greek Drachma were GRC 50-60 for sea bass and GRC 100-130 for sea bream. At a fixed exchange rate of GRC 340.75 per Euro, this equates to € 0.15 – 0.18 per fry for seabass and €0.29 to 0.38 for sea bream. The given values have been calculated by comparing the US$ - GRC rate for 1987 with the average extrapolated Euro to dollar value calculated from the DEM-US$ and FRF-US$ rates and adjusting accordingly.

there have been many incremental developments such that survival rates are now commonly over 30% from egg to first feeding fry. These improvements have lowered the cost of production (in both real and relative terms) as shown in Figure 62, based on data from Greece. Fry prices reduced from €0.45 from 1991 to €0.21 in 2003, allowing the total cost of bass and bream production to be reduced and markets expanded. Although the industry now has over 20 years experience, further gains in productivity and quality are possible, with consistency still a problem. Such gains might not necessarily lead to further price reductions however, as input costs such as feed ingredients, labour and power are rising.

Figure 62: Evolution of seabass and seabream fingerling production and prices 1990-2003



Source: ICAP 2003 (reported in University of Stirling, 2004)

The status of breeding and reproduction for other marine species is quite varied. Hatcheries for colder water species such as cod and halibut have not yet reached the levels of survival achieved in the bass and bream industry, but have become financially viable for high value end product. The spawning and rearing of bluefin tuna in captivity is still at the research level.

With control over reproduction achieved, the next step is greater control over the genetics of farmed populations. As discussed in Section 5, this is being achieved through selective breeding programmes using a combination of traditional stock rearing approaches and the use of genetic markers and statistical techniques. Ongoing research to identify quantitative trait loci (QTL) and ultimately full genome mapping is likely to allow further advances[34]. This assumes that the "domestication" or improvement of wild species remains ethically acceptable (as it has done in most other branches of livestock, agriculture and horticulture). This may not be a safe assumption, as concerns over the technology of genetic modification appear to have made many consumers more suspicious of any technologies that are seen to artificially interfere with the genetics of farmed species. This may be particularly the case with fish, which are hard to contain securely in open culture systems, and which may then interbreed with wild populations. The comparative recency of farmed fish as a mainstream

[34] The breeding company "Landcatch Natural Selection" has recently announced the introduction of QTL technology into their salmon breeding programmes, allowing selection of broodstock with identified genes with disease resistance or faster growth rather than only on the basis of pedigree performance. http://www.fishupdate.com/news/fullstory.php/aid/8347/_Quantum_leap__in_salmon_breeding_.html

source of food supply is likely to exacerbate this initial disposition, which may recede over time as familiarity and acceptance increases.

Selective breeding programmes have proved to be a fundamental tool in lowering the cost of production for terrestrial livestock, and are having an increased impact on aquaculture. By only breeding from broodstock that have shown the best performance with respect to desired characteristics (usually growth rate, feed conversion efficiency and disease resistance, although flesh fat content and colour or other qualities are increasingly included), average performance can be improved incrementally each generation by up to 20%.

Table 13: Example genetic gain from selective breeding programmes

Species	% gain per generation
Channel catfish	12-20
Pacific salmon	10
Atlantic salmon	11-14
Rainbow trout	13
Tilapia	14-23

Source: Akvaforsk (quoted in Mortensen et. al. 2005)

The main challenge for traditional breeding programmes is that improving one characteristic (e.g. growth rate) can have a negative impact on other characteristics. A multi-trait breeding programme is more complex, but possible using more sophisticated statistical analysis. Traits also vary with respect to heritability. This is often linked with the number of genes (usually unknown) that influence the trait. For traits with relatively low heritability, discerning the genetic effect from environmental influences is more difficult. QTL and genome mapping approaches should ultimately provide much greater levels of information and hence control.

There have been substantial productivity gains in the Atlantic salmon industry over the past twenty five years, partly due to strain and family selection processes. According to Scottish industry records[35], in 1980 the average weight of a two sea-winter salmon at harvest was 3 kg. This had risen to 4.3 kg by 1995 and to 4.4 kg by 2005. Similarly the percentage of salmon harvested as grilse (early maturing fish) was around 30% in 1980, down to 18% in 2005. Again, the use of low-grilsing strains is only part of the reason as photoperiod management has also played a role. The total yield per smolt rose from 1.67 kg for 1990 year class smolts to 3.43 kg for 2003 year class smolts. Again, this also reflects both genetic and other management gains. Studies on the genetic gain of breeding programmes in Norway have shown gains of 4.6% per generation in feed efficiency ratios (Thodesen *et al* 1999), and 8-10% per generation for growth rate, age at maturity and flesh pigmentation (Cited in Gjøen & Bentsen, 1997). Studies on selective breeding programmes for Pacific salmon in Canada found that 55% of the improvement in growth rate was due to genetic selection and 45% from improved animal husbandry (Peterson & Swift, 1999). The same authors quantified the economic benefits of improvements to an Atlantic salmon stock as US$1.43 per fish marketed, or $1.23 per smolt entry if sold early at the equivalent weight of non-selected stock, or $3.66 per fish marketed and $3.07 per smolt entry if grown for the same period to a greater weight.

When considered on an annual basis, species with shorter breeding cycles can be advanced at a faster rate than those with long breeding cycles. The time between generations for Atlantic salmon is approximately 4 years. The time between generations for tilapia can be as little as 9

[35] Various annual Scottish fish farming surveys – most recent at http://www.marlab.ac.uk/

months; the Norwegian company GenoMar claim a 15% annual genetic gain for growth rate (GIFT-strain)[36]. The rate of improvement possible for species such as sturgeon, which have relatively long breeding cycles is therefore more limited.

The breeding and hatchery phase is the most technically complex of the full aquaculture production process and is the key component in the development of any new aquaculture species. Improvements in efficiency and performance achieved through breeding can have substantial economic benefits throughout the production process and hence on market price and volume.

Feed technology – Feed is one of the primary production inputs and therefore of great importance with respect to determining production efficiency and cost. Feed also has a significant effect on the amount and type of waste output from the system. Advances in hatchery feeds have been mentioned above, and include nutrient enrichment of live feeds (expecially rotifers and artemia), development of microalgae and copepod production techniques, progress towards reducing labour requirements through the use of commercially available algal paste, manufactured artemia systems and automated feed delivery systems. Artemia replacement diets also reduce reliance on fluctuating and limited stocks of this creature.

Compounded diets used in growout have been gradually improved throughout the last 20 years. Significant advances include improvements to fishmeal quality through lower-temperature processing, finer milling and the use of extrusion technology, better tuning of diet formulation to meet particular species and life stage requirements, or achieve lower environmental impacts. Further improvements are often constrained by cost considerations, but current issues include the potential for reducing the fishmeal and fish oil components derived from capture fisheries and their substitution with vegetable proteins and oils to enhance sustainability. However, this raises concerns about welfare, especially for carnivorous fish species, and doubts have also been expressed about the acceptability of using supplementary industrially produced amino acids. For the immediate future, modest improvements to utilisation efficiency will allow aquaculture to continue to expand whilst relying on feeds derived from marine proteins and oils. Longer-term, more innovative solutions will undoubtedly be required.

Health management – Disease problems continue to impose serious risk and costs to many aquaculture producers. Only a limited range of therapeutants is licensed for use in Europe. Most development in recent years has focused on anti-parasitics and anti-fungal agents. Due to environmental and residue concerns, prevention of disease through good husbandry, proactive diagnostics and the use of vaccines and immunostimulants is often the preferred approach.

The most successful fish vaccines have been those against gram negative bacteria, although there are a limited number of products for gram positive bacteria and some viral diseases. Vaccines against parasites are under research, but so far no commercial products are available. Vaccines are administered as a bath treatment, e.g. in the hatchery, orally (with feed), or by injection. The latter is the least favoured but currently most effective. The duration of immunity is limited, and booster vaccinations are sometimes required. It appears that the specific immune response in fish is not well developed until they are at least a gram in

[36] http://www.genomar.no/text.cfm?SID=12&ID=57

weight. Shrimp never appear to develop a specific immune system. For these groups, and for providing additional protection for larger fish, immunostimulants are available that boost the non-specific defence mechanisms. A variety of compounds are used, perhaps most commonly beta-glucans derived from yeast, although others are under development. Vaccine development is at the leading edge of biotechnology and several new approaches are under serious development or trial. These include the use of recombinant DNA technology for vaccine and adjuvant production and more revolutionary, vaccines based on direct injection of DNA into the muscle, the cells of which take up the DNA and produce antigenic proteins over a longer period, directly stimulating the immune system.

The use of biotechnology in disease diagnostics is also important, with increasing use being made of molecular (e.g. PCR, RT-PCR) and immunological (immunohistochemistry, immunofluorescence, immunochromatography etc.) techniques for health screening at critical points (e.g. broodstock selection, or seedstock prior to purchase).

Product handling, packaging and distribution – Overall trends in Europe have been for processed fish products that require little or no preparation and are easy to store and cook, preferably skinless and boneless (fish). Freshness is one of the most important product qualities, so minimising the time and temperature control between harvest and final sale has proved important, as have advances in packaging designed to enhance shelf life (e.g. MAP). Improved monitoring of product condition during logistics distribution has been another important element, along with product management and restocking.

For an internationally traded product such as salmon, it is worth noting that farm costs only constitute around 30% of total production and distribution costs (Dempster, 2007), so efficiency gains in processing or distribution can potentially have a greater impact than efficiency gains in the farming phase. As consumers become more accepting of added value products this margin on non-raw material costs can be expected to increase further still. For the foreseeable future, a key issue will be the cost of energy and changes in policy and market environments as greater action is taken to minimise climate change.

Integration into zonal planning – With increasing pressure on coastal zones throughout many parts of Europe aquaculture is increasingly included in coastal zone planning, in some cases with proposed or actual development of aquaculture zones, where existing operations are afforded greater protection, or new developments encouraged. Examples of similar approaches may be found inland, such as the protection of aquaculture activities in traditional ponds in the Czech Republic, or the development of aquaculture parks in France.
As discussed in Section 5, the primary driver for commercial development is ultimately the opportunity to make a favourable return on investments, such that the key issue for any emerging system, technology or practice will be whether it improves sales prices or volumes, or reduces production costs. Table 14 summarises cost of production data from the Part 2 report with some comparison of market prices.

Table 14: Comparative operating cost profiles of different aquaculture systems (percent of total operating cost)

Breakdown of operating costs	Offshore salmon	Organic salmon	Sea bream cages	Tuna cages	Turbot re-circulated	Turbot flow through	Eel re-circulated	Octopus on-growing	Arctic charr cages	African catfish
Feed	46	45.6	54	27	15	18	29	13	43	58.7
Selling costs/Packing	17	7.1								
Seed stock (fry or smolts)	8	13.5	20	48	10	11	29	42	21	7.9
Wages/salaries	7	10	9	6	7	8	9	11	19	7.2
Misc./other operating costs – inc. consumables & contingency	6	0.4		14	10	10	1			9.6
Depreciation	5	7.1	13		35	33	20	11	12	5
Maintenance					4	1		3		2.2
Vet/medicines	3				2	2				1.1
Administration/Overhead costs	3	9.3			4	4	1			2.2
Transport		2.5								
Harvest expenses		4.6								
Stock & general Insurance	3		1	2	2	2	2	15	2	2.2
Legal & professional fees					1	1				0.7
Licensing/lease/discharge costs			0				1	1		
Power and fuel	2		2		11	9	9	3	2	3.3
Loan servicing				3						
Total	100	100	100	100	100	100	100	100	100	100
Cost €/kg NB excludes finance costs	2.33	4.15	4.04	10.50	4.58	3.98	4.88	5.53	2.54	3.61
Comparison – average unit value at first sale, 2005 - €/kg	2.20 – 2.93		3.53 – 8.82	6.78*	8.99	8.99	8.17 -8.78	3.97*	5.10	1.10

Source: Part 2 report. Note these figures are included to illustrate the diversity of cost structures and are not directly comparable due to different analytical approaches used. They also reflect current systems rather than future potential. Average price data from FEAP - http://www.feap.info/Production/euproduction/pricespecieseu_en.asp except values indicated (*) which were calculated from FAO Fishstat commodity trade database.

As illustrated by Table 14, there are wide variations in the cost of production of different species, depending on system type and other inherent characteristics. Estimated costs range from €2.33 to $10.50 per kg for the systems presented in Table 14. Assuming moderate substitution effects, particularly within seafood groups, systems and products with the lower production costs will tend to achieve higher market shares. The major components of production costs are seed, feed, labour, and in the case of recirculated systems, power. The proportion spent on seed is highest for those systems relying on wild sources, especially tuna, eel and currently octopus. Feed is a higher component of costs in cage systems (mostly due to other costs being lower) whilst labour costs are a higher proportion in systems with lower output (charr and organic salmon in these examples). Depreciation is not a cash cost, but is usually included in comparative operating costs to indicate the financial burden of different capital cost structures.

The proportion of costs allocated to different items is a useful indicator of sensitivity. For instance, small increases in feed prices will affect cage salmon farms proportionately more than recirculated turbot farms with respect to impact on overall production cost. On the other hand, recirculated systems are more sensitive to power and capital (depreciation) costs.

6.3 Aquaculture production projections to 2025

6.3.1 Scenario 1: Baseline – minimal development of aquaculture

Our baseline scenario, introduced in Section 3, assumes that capture fisheries will continue to decline over the 15 year time horizon at a rate of 2% per year, aquaculture will not develop substantially, and that the balance of trade will meet the remaining demand. Overall demand estimates are based on apparent per capita supply assuming declining, static or rising per capita consumption levels, based on available Eurostat data.

Consideration of the constraints and drivers discussed in previous sections allows estimates to be made for each of the aquaculture sub-sectors previously identified. These are summarised in Table 15, and discussed in greater detail following presentation of the production projections. Overall, the projections lead to a decline in the EU-25 aquaculture production from 1.26 million tonnes in 2005 to 1.17 million t in 2010, rising again to 1.2 million t in 2015 and 1.48 million t by 2025. The initial decline is based on the most recent statistics, which at least in part reflect the poor producer prices experienced in the early half of this decade. The subsequent recovery and expansion is assumed as fish supplies become more constrained and newer technologies become financially viable. Growth generally remains within historical limits and no brand new technology developments are assumed (e.g. closing of the tuna life cycle).

Table 15: Baseline scenario for aquaculture development - summary assumptions:

Salmon, trout & other salmonids	Negative growth until 2010 due to increasing regulatory constraints and moderate markets. Expanding slightly after 2015 with rising demand.
Sea bass, bream & similar	Modest growth continues until 2015, in part driven by market expansion through widening size and product range, and thereafter affected by environmental constraints
Halibut, turbot, sole etc	Reasonable growth but from low levels driven by improving recycle systems etc.
Cod, haddock, hake etc	Assumes cod farming in particular is developed as a significant aquaculture species, probably utilising redundant salmon sites.
Carp, tilapia, catfish	Assumes modest growth in low-cost recirculated systems – mainly catfish and some tilapia
Eels, sturgeon, perch, zander etc.	Assumes decline until 2015, then some growth as technologies are refined
Tuna	Assumes no development of hatcheries so production limited by declining wild stocks
Mussels	Initially declining and then assumes some further growth as greater industrialisation and offshore culture is introduced, especially from 2015
Oysters & scallops	Currently declining, but small modest growth from 2015, perhaps as part of integrated or offshore projects
Clams, cockles etc.	Small modest growth perhaps as part of integrated projects
New non-fish aquaculture sp.	Currently declining, but some modest development from 2015
Aquatic plants	Currently declining, but small increase associated with integrated projects from 2015.

Table 16: Baseline scenario – EU-25 aquaculture production projections to 2025

	Group growth rate			Production (tonnes)			
Group name	**5 year rate**	**10 year rate**	**Projected rates***	**2005**	**2010**	**2015**	**2025**
Salmon, trout & other salmonids	-1.97%	0.63%	1--2%	350,019	315,017	315,017	347,306
Sea bass, bream & similar	3.47%	22.47%	3-0%	124,046	142,653	149,786	149,786
Halibut, turbot, sole etc	9.57%	13.64%	10%	7,111	10,667	16,000	35,999
Cod, haddock, hake etc			250-10%	69	932	5,589	75,452
Carp, tilapia, catfish	-1.08%	0.06%	2-0%	74,086	74,086	81,495	98,608
Eels, sturgeon, perch, zander etc.	-1.63%	2.29%	2--1.5%	21,858	20,219	20,219	23,353
Tuna	0.96%	2401.25%	0--20%	3,858	3,858	0	0
Mussels	-3.29%	0.27%	3--3%	470,026	399,522	399,522	505,395
Oysters & scallops	-2.25%	-1.55%	2--2%	132,210	118,989	118,989	143,977
Clams, cockles etc.	2.96%	0.14%	2-0%	76,996	88,545	92,973	102,502
New non-fish aquaculture sp.	-15.43%	-8.27%	10--10%	273	137	137	256
Aquatic plants	-19.70%	-9.91%	10--15 %	45	11	8	11
Total			0.88%	1,260,597	1,174,635	1,199,733	1,482,645
EU Target			4%	1,665,600	1,998,720	2,398,464	3,453,788

* * The 5-year growth rate is from 2000-2005 whilst the 10-year growth rate is 1995-2005. Future growth rates are projected in 5-year intervals with the highest and lowest rates used indicated in the table.

Figure 63: Scenario 1 aquaculture projections – minimal aquaculture development (EU-25)

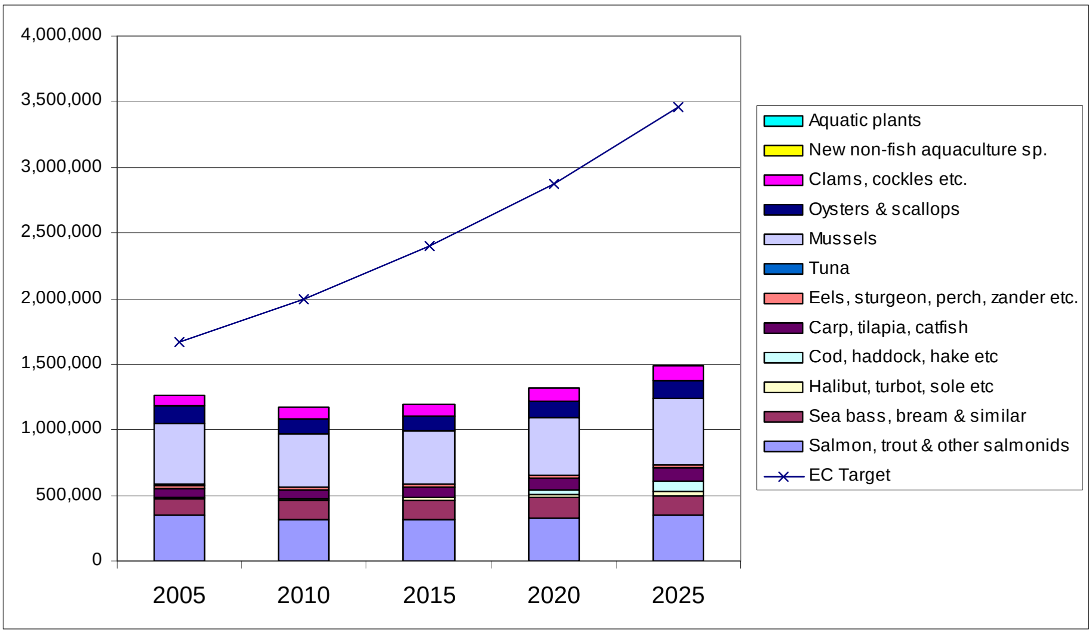
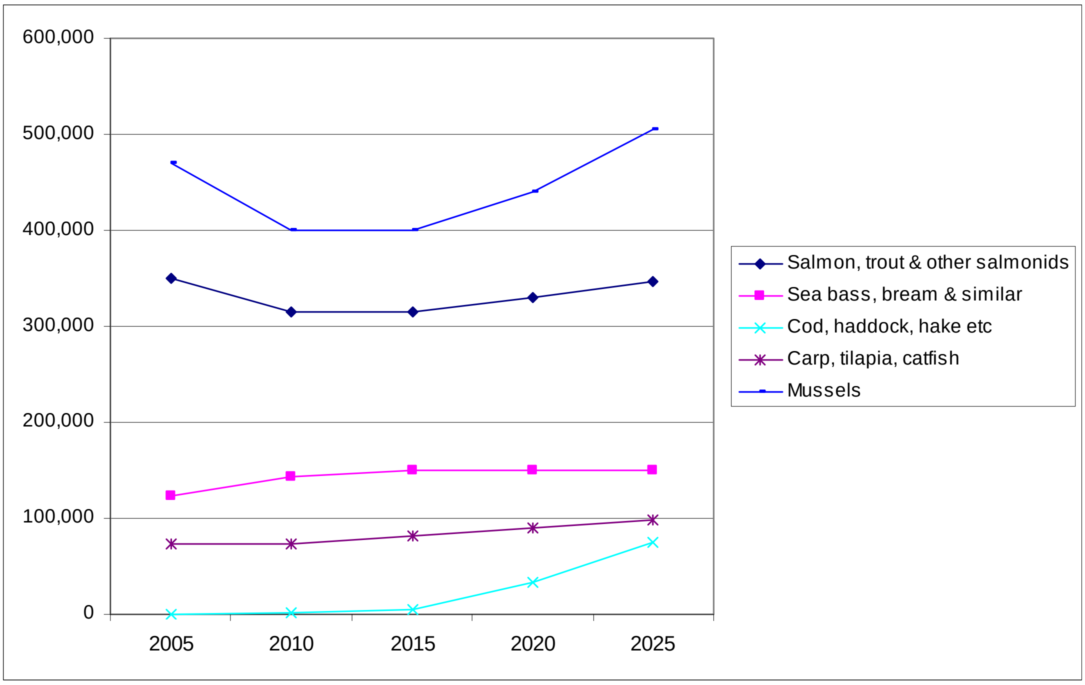


Figure 64: Scenario 1 aquaculture projections – development of major aquaculture species



These projections take account of commercial developments already in progress, such as further investment in cod farming and some recirculated systems. However, it is assumed that increasing constraints through environmental regulation will lead to decreased production from other sub-sectors, especially freshwater ponds and cages, and will severely limit further coastal developments.

6.3.2 Scenario 2: Aquaculture expands to meet output derived from EU target of 4% per annum growth to 2025

Our second scenario, introduced in Section 3, also assumes that capture fisheries will continue to decline over the 15 year time horizon at a rate of 2% per year, aquaculture will develop to meet the output required by assuming the EU target of 4% annual growth in production tonnage was met from 2000, and that balance of trade will meet the remaining demand. Overall demand estimates are determined in the same way for all scenarios.

Consideration of the constraints and drivers discussed in previous sections allows estimates to be made for each of the aquaculture sub-sectors previously identified. These are summarised in Table 17, and discussed in greater detail following presentation of the production projections. Overall, the projections raise EU-25 aquaculture production from 1.26 million tonnes in 2005 to 1.84 mt in 2010, 2.44 mt in 2015 and 3.37 mt by 2025.

Table 17: Scenario 2 - summary assumptions:

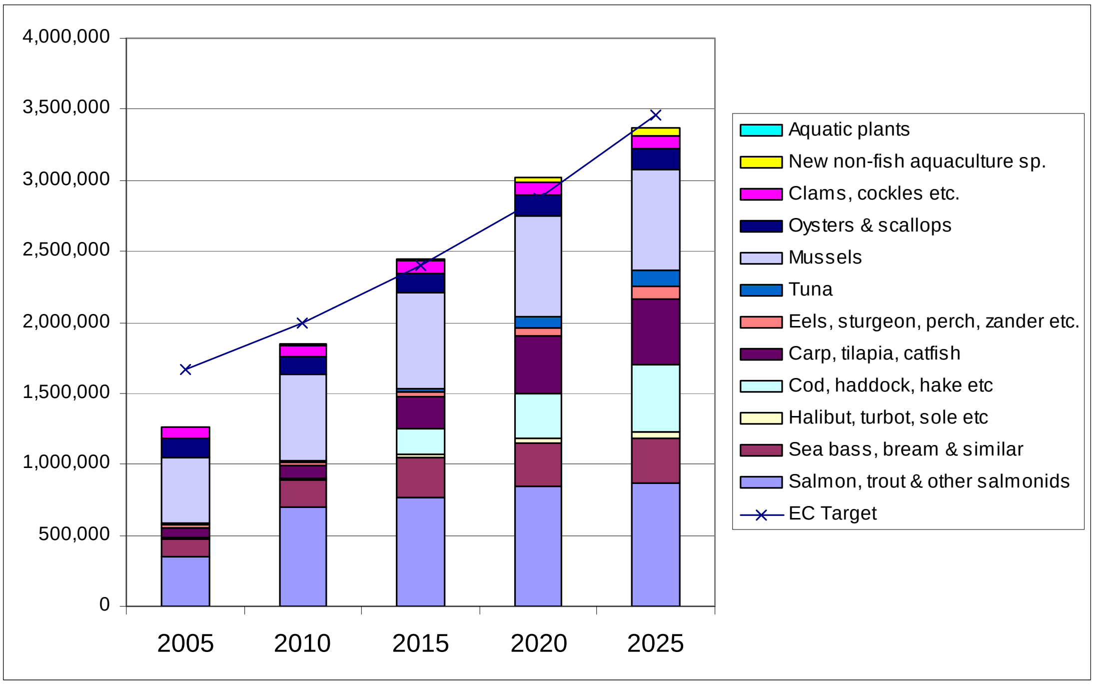
Salmon, trout & other salmonids	Increasing move offshore, triggered by continuing high demand. High growth rate as offshore aquaculture takes off, but levelling off as other species come online later and increase variety
Sea bass, bream & similar	Similarly stimulated to increasingly move offshore and expand, but not as dramatically as salmon – levelling off again as supply equilibrates
Halibut, turbot, sole etc	Reasonable growth facilitated by improving recycle systems etc.
Cod, haddock, hake etc	Assumes cod farming in particular is developed as a major aquaculture species, probably utilising redundant salmon sites initially, but possibly moving offshore with the salmon industry in due course.
Carp, tilapia, catfish	Assumes all growth facilitated by low-cost recirculated systems – mainly tilapia and perhaps catfish
Eels, sturgeon, perch, zander etc.	Assumes all growth to be facilitated by recirculated aquaculture systems
Tuna	Assumes hatchery/nursery technology is developed in next 10 years and continued high market demand
Mussels	Assumes some further growth as greater industrialisation and offshore culture is introduced
Oysters & scallops	Small modest growth perhaps as part of integrated projects
Clams, cockles etc.	Small modest growth perhaps as part of integrated projects
New non-fish aquaculture sp.	Small number of successful projects to help enhance diversity but not a major contributor to volume (developments of cephalopod culture may alter this assessment)
Aquatic plants	Small increase associated with integrated projects, but otherwise difficult to compete with lower-cost regions

Table 18: Scenario 2 – EU-25 aquaculture production projections to 2025

	Group growth rate			Production (tonnes)			
Group name	**5 year rate**	**10 year rate**	**Projected rates***	**2005**	**2010**	**2015**	**2025**
Salmon, trout & other salmonids	-1.97%	0.63%	20-2%	350,019	700,038	770,042	868,222
Sea bass, bream & similar	3.47%	22.47%	10-0.5 %	124,046	186,069	279,104	314,689
Halibut, turbot, sole etc	9.57%	13.64%	20-5%	7,111	8,889	17,778	46,666
Cod, haddock, hake etc			1000-5%	69	3,519	91,494	471,106
Carp, tilapia, catfish	-1.08%	0.06%	30-2%	74,086	92,608	231,519	465,931
Eels, sturgeon, perch, zander etc.	-1.63%	2.29%	10-2.5%	21,858	24,590	36,885	82,992
Tuna	0.96%	2401.25%	75-2%	3,858	4,823	22,907	120,261
Mussels	-3.29%	0.27%	6- 0%	470,026	611,034	672,137	705,744
Oysters & scallops	-2.25%	-1.55%	2- -1%	132,210	125,600	138,159	151,975
Clams, cockles etc.	2.96%	0.14%	2-0%	76,996	84,696	84,696	84,696
New non-fish aquaculture sp.	-15.43%	-8.27%	500-5%	273	410	10,647	55,897
Aquatic plants	-19.70%	-9.91%	100-1%	45	68	405	2,126
Total			8.37%	1,260,597	1,842,341	2,443,747	3,370,306
EU Target			4%	1,665,600	1,998,720	2,398,464	3,453,788

* The 5-year growth rate is from 2000-2005 whilst the 10-year growth rate is 1995-2005. Future growth rates are projected in 5-year intervals with the highest and lowest rates used indicated in the table.

Figure 65: Scenario 2 aquaculture projections –based on output derived from EU target of 4% per annum growth to 2025



The growth rate of aquaculture between 2002 (publication of the EU aquaculture strategy) and 2005 has not met the 4% target, therefore future growth rates would need to be significantly higher now to meet the output targets predicted by a 4% growth rate commencing in 2000. The scenario assumes an overall growth rate of 8.37% between 2005 and 2025, with the highest growth rate (9.23%) between 2005 and 2010 to compensate for earlier lag. This could most likely be achieved through species and systems that are relatively well established, although some change with respect to market, policy or technology is likely be required as trigger. In many respects, salmon is best placed for rapid expansion.

Further use of large cages in more offshore locations would be technically feasible and smolt production capacity could also be increased through further use of recirculated water systems. However, the annual growth rate would need to be increased from almost -2% over the 5 years 2000-2005, to 20% per annum up to 2010, effectively doubling production of salmonids from 350,000 tonnes to 700,000 tonnes. Since it is unlikely that the internal market for salmonids will double over that period without a significant fall in prices (or rapid rise in price of other fish species), much of the expansion in production would have to be export oriented (e.g. the Russian market has been strengthening recently). However, as most of the EU salmon industry is owned by Norwegian based companies with larger interests and lower costs in Norway and Chile, it seems unlikely that they would chose the EU as the production base for market expansion elsewhere unless there were significant incentives to do so.

To achieve the target growth rate, the Mediterranean sea bream and sea bass industry would have to similarly expand. This would take production from a recorded 124,000 tonnes in 2005 to 186,000 tonnes in 2010. The major challenge here would be the development of Northern European markets through the provision of more added value products (most likely chilled MAP fillets based on a wider range of fish sizes), although declining capture fisheries supply might also drive market growth.

Early expansion of production should also be possible through shellfish aquaculture, most notably mussel farming, where technologies are developing for larger-scale culture in more exposed conditions. Potential expansion here is projected from 470,000 t in 2005 to 611,000 t in 2010, with the greatest expansion of sales most likely through prepared products of more consistent quality for home consumption.

Figure 66: Scenario 2 – EU target production- Projections for highest volume aquaculture sub-sectors

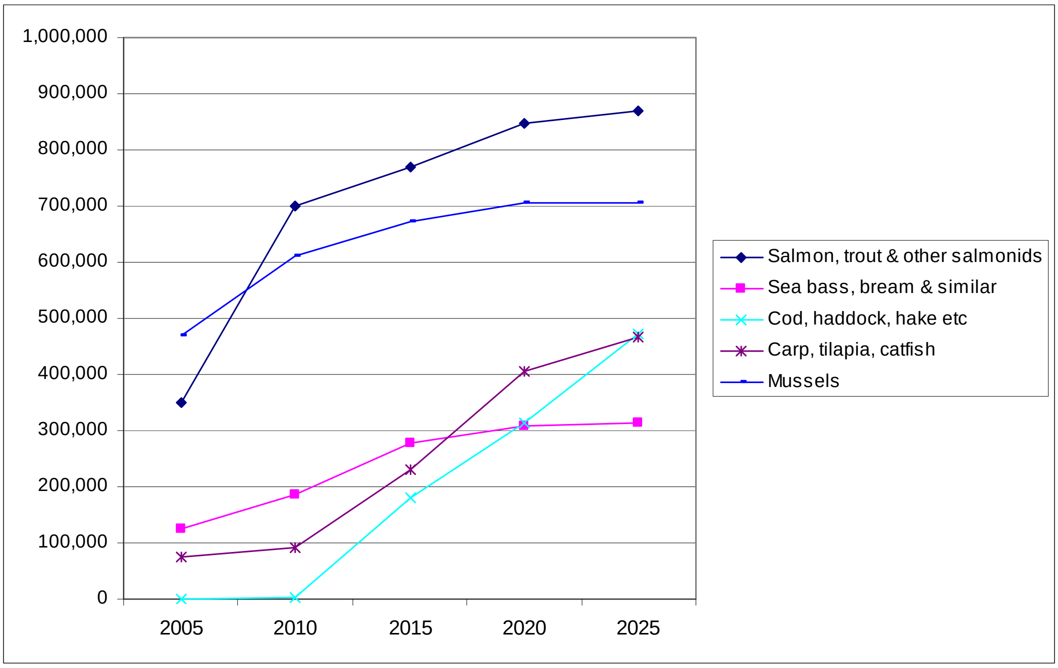


Figure 67: Scenario 2 – EU target production - Projections for medium volume aquaculture sectors

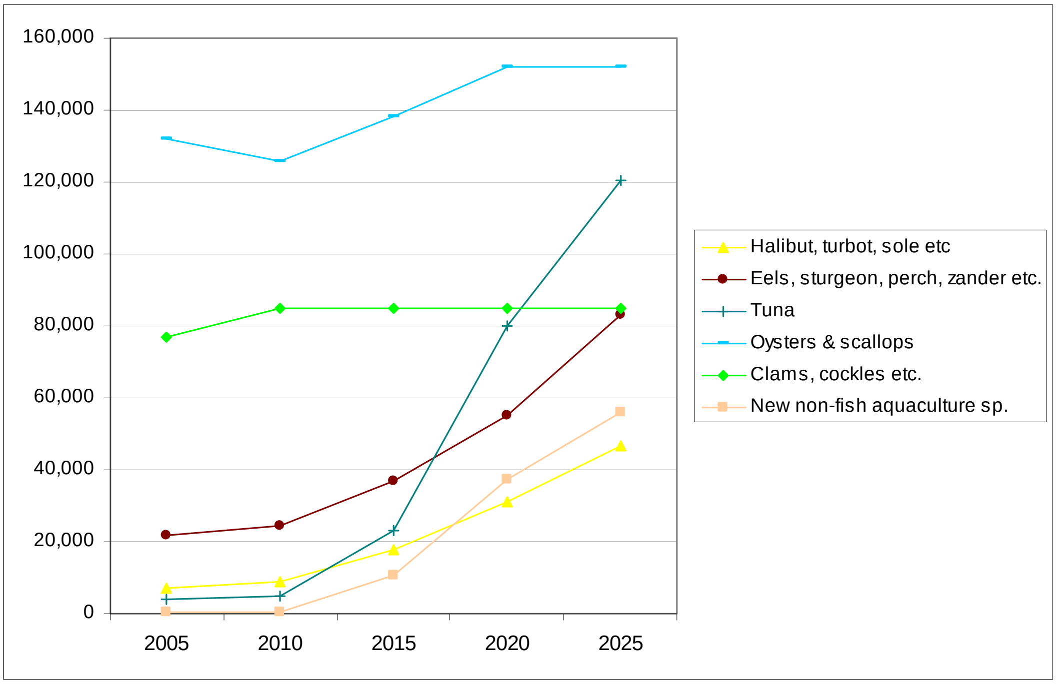
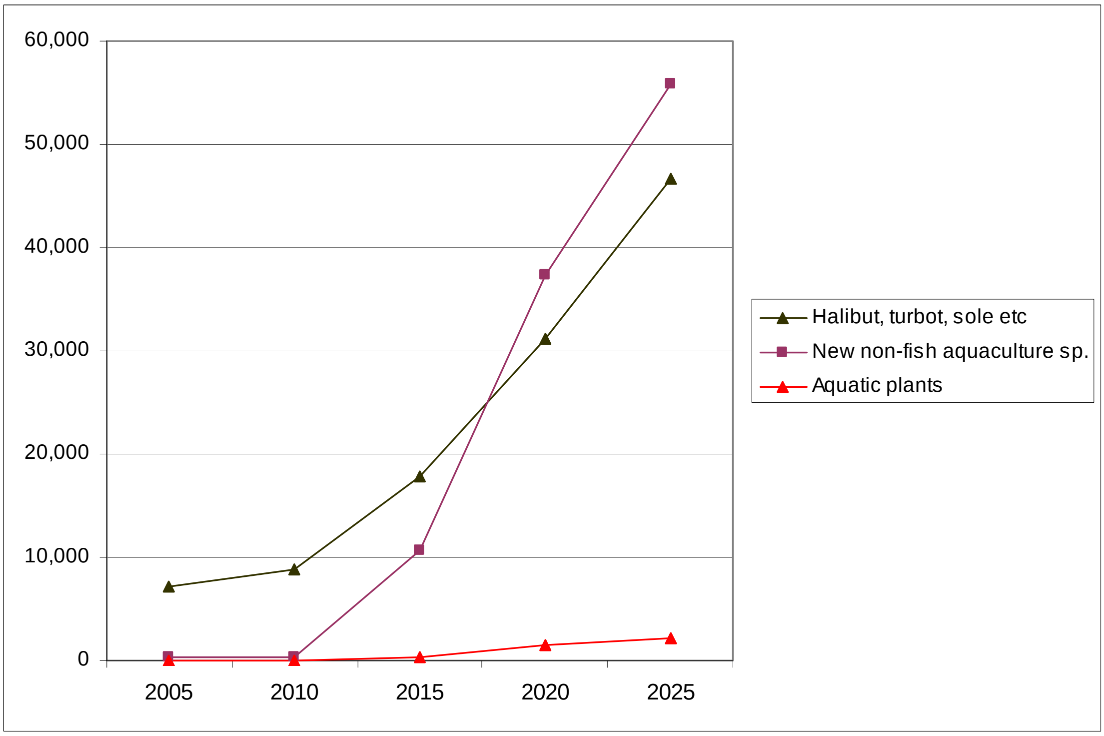


Figure 68: Scenario 2 – EU target production – Projections for low volume aquaculture sub-sectors



For most other species groups, it is assumed that it will take longer to develop production capacity, and that growth rates will be highest between 2010 and 2015. This could be due to the need to develop hatchery systems (especially marine fin fish species), or through the time required for markets to respond substantially to projected falling capture fisheries supplies. It is also assumed that investment costs for recirculated aquaculture systems will fall in real terms between 2010 and 2020 as the market for system manufacturers expands and more efficient production methods can be introduced. Modest growth in aquatic plant and higher-value bivalves are projected as integrated multitrophic aquaculture systems are increasingly developed.

Some growth in the freshwater sector may be facilitated through increased linkages between conservation, recreation and fish production providing continued access to freshwaters for aquaculture. This could be supported by greater emphasis on local or regional food production or low environmental impact food production and eco-labelled and quality certification. Under the alternate scenario where a 4% target growth is achieved and maintained from 2005, output would reach 1.513 mt in 2010, 1.814 mt in 2015 and 2.614 mt by 2025. This 2025 figure is 77.5% of the output calculated under assumptions of an early “catch-up” high growth rate.

6.3.3 Scenario 3: Aquaculture develops to fill the supply gap caused by declining capture fisheries

In this scenario it is assumed that aquaculture grows at a rate needed to make up the losses from a declining capture fisheries (at EU25). It is assumed that most of the growth in Europe is in the higher value species, with rising exports of these and increasing imports of lower value species.

Table 19: Scenario 3 - summary assumptions for aquaculture development (EU-25):

Salmon, trout & other salmonids	Increasing move offshore, triggered by continuing high demand. High growth rate as offshore aquaculture takes off, but levelling off as other species come online later and increase variety
Sea bass, bream & similar	Similarly stimulated to increasingly move offshore and expand, but not as dramatically as salmon – levelling off again as supply equilibrates
Halibut, turbot, sole etc	Reasonable growth driven by improving recycle systems etc.
Cod, haddock, hake etc	Assumes cod farming in particular takes off and probably utilises smaller salmon sites initially, but perhaps move offshore with salmon industry in due course
Carp, tilapia, catfish	Modest development of low-cost recirculated systems – mainly tilapia and perhaps catfish
Eels, sturgeon, perch, zander etc.	Assumes reasonable growth in these species to meet strengthening demand in East and Central Europe. All growth in recirculated aquaculture systems
Tuna	Assumes hatchery/nursery technology is developed in next 10 years and continued high market demand
Mussels	Assumes some further growth as greater industrialisation (and perhaps offshore production) is introduced
Oysters & scallops	Small modest growth perhaps as part of integrated projects
Clams, cockles etc.	Small modest growth perhaps as part of integrated projects
New non-fish aquaculture sp.	Small number of successful projects to help enhance diversity but not a major contributor to volume
Aquatic plants	Small increase associated with integrated projects

Table 20: Scenario 3 – EU-25 aquaculture production projections to 2025

	Group growth rate			Production (tonnes)			
Group name	**5 year rate**	**10 year rate**	**Projected rates***	**2005**	**2010**	**2015**	**2025**
Salmon, trout & other salmonids	-1.97%	0.63%	20-0.5%	350,019	437,524	525,029	756,041
Sea bass, bream & similar	3.47%	22.47%	10-0.5%	124,046	155,058	193,822	302,847
Halibut, turbot, sole etc	9.57%	13.64%	20-5%	7,111	16,000	35,999	78,749
Cod, haddock, hake etc			1000-5%	69	3,519	38,709	203,222
Carp, tilapia, catfish	-1.08%	0.06%	30-2%	74,086	81,495	89,644	108,469
Eels, sturgeon, perch, zander etc.	-1.63%	2.29%	10-2.5%	21,858	76,503	153,006	210,383
Tuna	0.96%	2401.25%	75-2%	3,858	4,244	20,158	105,830
Mussels	-3.29%	0.27%	6- 0%	470,026	587,533	646,286	712,530
Oysters & scallops	-2.25%	-1.55%	2--1 %	132,210	125,600	138,159	151,975
Clams, cockles etc.	2.96%	0.14%	0-2%	76,996	76,996	76,996	76,996
New non-fish aquaculture sp.	-15.43%	-8.27%	500-5%	273	1,638	18,018	94,595
Aquatic plants	-19.70%	-9.91%	100-1%	45	68	405	2,126
Total			6.12%	1,260,597	1,566,175	1,936,231	2,803,763
EU Target			4%	1,665,600	1,998,720	2,398,464	3,453,788

* The 5-year growth rate is from 2000-2005 whilst the 10-year growth rate is 1995-2005. Future growth rates are projected in 5-year intervals with the highest and lowest rates used indicated in the table.

Figure 69: Scenario 3 – aquaculture fills fisheries gap - aquaculture development by species group (t)

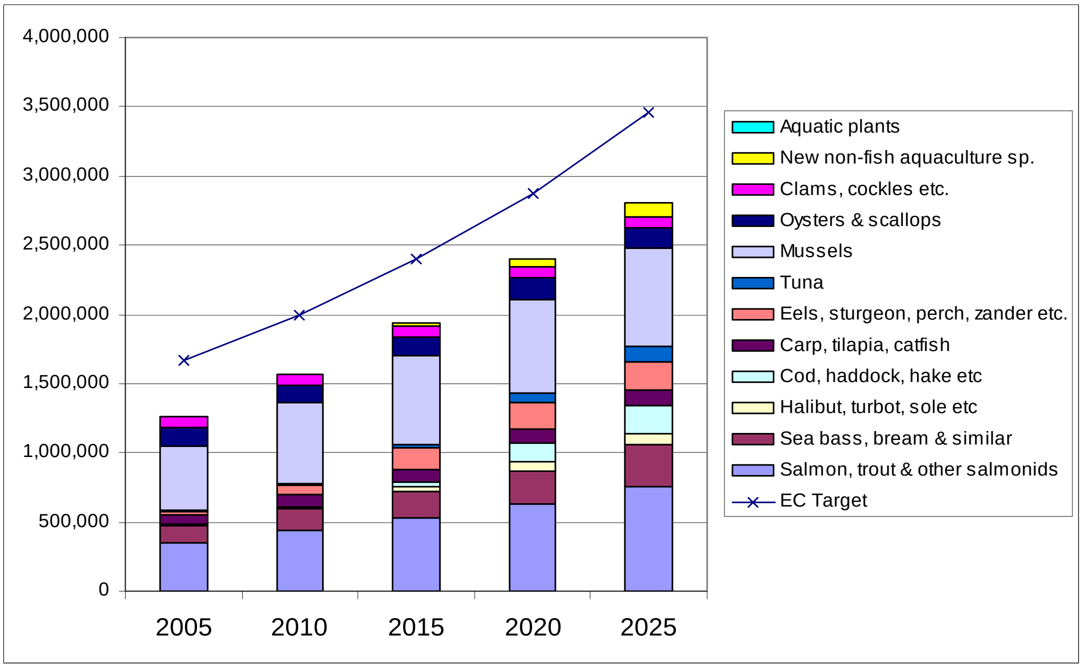
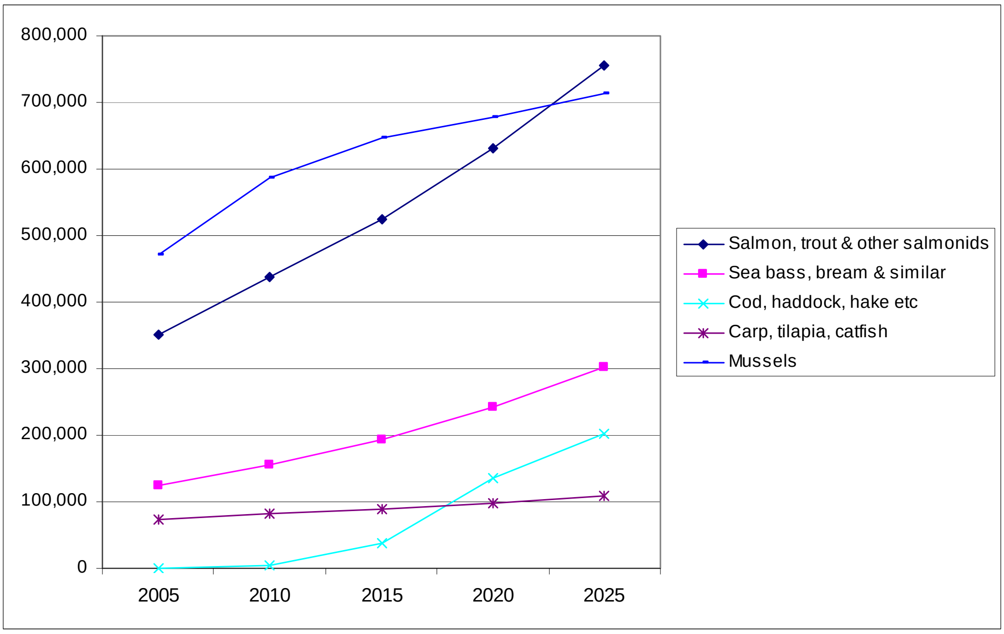


Figure 70: Scenario 3 – aquaculture fills fisheries gap - aquaculture development of highest volume species (t)



6.3.4 Scenario 4: Aquaculture expands to fill the supply gap between capture fisheries and static demand

In this scenario it is assumed that aquaculture grows at a rate needed to meet all of the gap between declining capture fisheries and static projected demand. It assumes that growth occurs in both low-value and higher value species, although the greatest volume growths are likely to be in lower-value species.

Table 21: Scenario 4 - Aquaculture grows to fill the static-demand supply gap -summary assumptions for aquaculture development:

Salmon, trout & other salmonids	Increasing move offshore, triggered by continuing high demand. High growth rate as offshore aquaculture takes off, but levelling off as other species come online later and increase variety
Sea bass, bream & similar	Similarly stimulated to increasingly move offshore and expand, but not as dramatically as salmon – levelling off again as supply equilibrates
Halibut, turbot, sole etc	Reasonable growth driven by improving recycle systems etc.
Cod, haddock, hake etc	Assumes cod farming in particular takes off and probably utilises smaller salmon sites initially, but perhaps move offshore with salmon industry in due course
Carp, tilapia, catfish	Strong growth due to introduction of low-cost recirculated systems – mainly tilapia and perhaps catfish
Eels, sturgeon, perch, zander etc.	Assumes reasonable growth in these species to meet strengthening demand in East and Central Europe. All growth in recirculated aquaculture systems
Tuna	Assumes hatchery/nursery technology is developed in next 10 years and continued high market demand
Mussels	Assumes some further growth as greater industrialisation is introduced
Oysters & scallops	Small modest growth perhaps as part of integrated projects
Clams, cockles etc.	Small modest growth perhaps as part of integrated projects
New non-fish aquaculture sp.	Cephalopod farming is successfully commercialised within 5-10 years
Aquatic plants	Moderate increase associated with integrated projects

Table 22: Scenario 4 – Aquaculture grows to fill the static-demand supply gap -aquaculture production projections to 2025

	Group growth rate			Production (tonnes)			
Group name	5 year rate	10 year rate	Projected rates*	2005	2010	2015	2025
Salmon, trout & other salmonids	-1.97%	0.63%	10-2%	350,019	455,025	682,537	1,535,708
Sea bass, bream & similar	3.47%	22.47%	15-2 %	124,046	173,664	303,913	717,994
Halibut, turbot, sole etc	9.57%	13.64%	100-10%	7,111	42,666	85,332	191,997
Cod, haddock, hake etc			1000-2%	69	3,519	91,494	1,166,549
Carp, tilapia, catfish	-1.08%	0.06%	25-2%	74,086	111,129	250,040	656,356
Eels, sturgeon, perch, zander etc.	-1.63%	2.29%	100-2%	21,858	131,148	295,083	405,739
Tuna	0.96%	2401.25%	75-2%	3,858	4,244	20,158	105,830
Mussels	-3.29%	0.27%	10- 0%	470,026	705,039	881,299	1,165,518
Oysters & scallops	-2.25%	-1.55%	5 -0%	132,210	165,263	206,578	249,960
Clams, cockles etc.	2.96%	0.14%	2-0%	76,996	84,696	93,165	112,730
New non-fish aquaculture sp.	-15.43%	-8.27%	500-10%	273	1,638	42,588	574,938
Aquatic plants	-19.70%	-9.91%	100-10%	45	68	405	1,367
Total			22.31%	1,260,597	1.878.098	2.952.592	6.884.684
EU Target			4%	1,665,600	1,998,720	2,398,464	3,453,788

* The 5-year growth rate is from 2000-2005 whilst the 10-year growth rate is 1995-2005. Future growth rates are projected in 5-year intervals with the highest and lowest rates used indicated in the table.

Figure 71: Scenario 4 – Aquaculture grows to fill the static-demand supply gap -aquaculture production projections to 2025 (t)

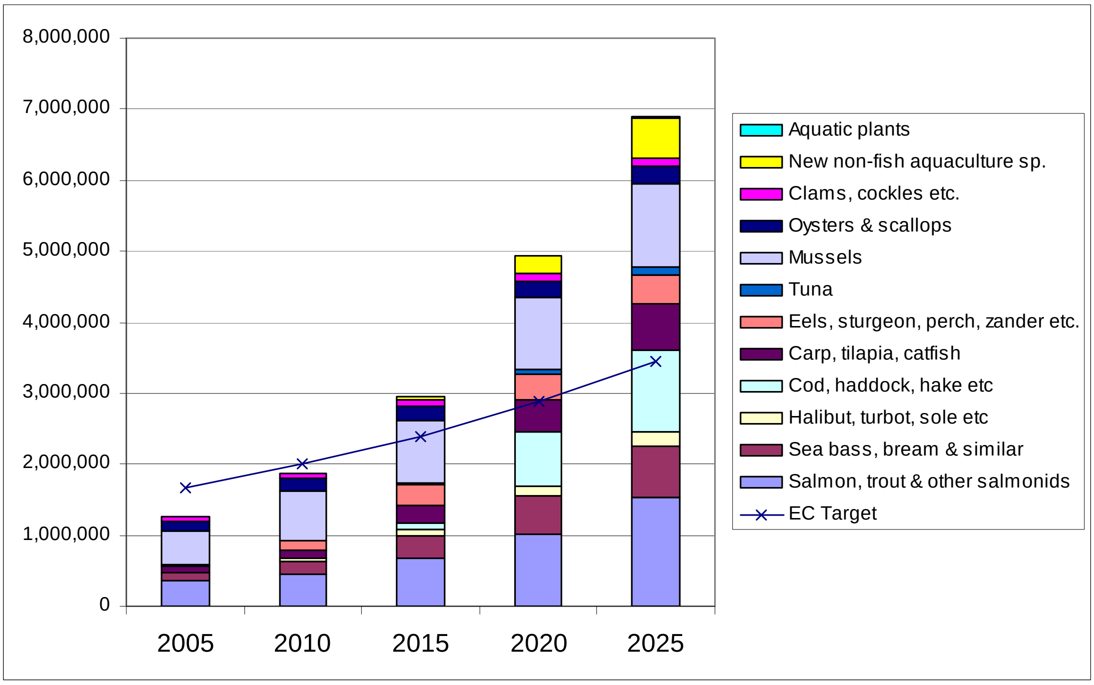
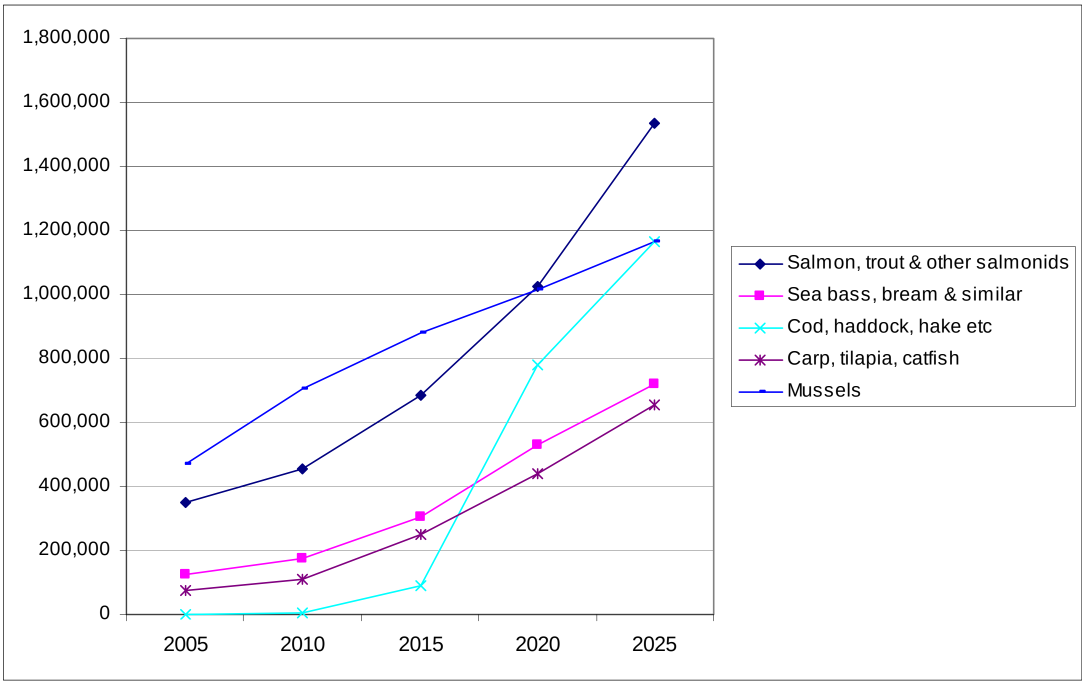


Figure 72: Scenario 4 – Aquaculture grows to fill the static-demand supply gap -highest volume aquaculture products (t)



6.4 Assumptions on regional development

The regional location of aquaculture is primarily determined by where the necessary natural resources exist (sufficient water of the correct temperature, sheltered coastal areas or land adjacent to rivers etc). A secondary consideration is costs, such that locations that are closer to market, or that have cheaper labour rates, are more likely to be utilised. For conventional (incremental) development, it is not anticipated that there will be any major changes in location.

Offshore aquaculture, if it develops as assumed in the above scenarios, will most likely start in countries that already have cage aquaculture industries but where inshore sites are most highly constrained. This includes Ireland, Spain, Italy and Malta, where farming in higher energy sites is already common. Subsequent development however could involve most countries with substantial coastlines.

The decoupling of recirculated aquaculture system from the environment creates opportunities for these systems to be located in areas not previously considered for aquaculture. If these develop for fish production as assumed in later scenarios, proximity, or accessibility, to market may be their key advantage. Locations close to major cities, or distribution hubs could be favoured, with peripheral regions at a competitive disadvantage.

Table 23: Regional considerations by species group

Salmon, trout & other salmonids	North Atlantic for salmon and most European countries for trout
Sea bass, bream & similar	Mediterranean coast
Halibut, turbot, sole etc	Halibut and turbot in Atlantic coasts, Sole and Turbot in Mediterranean
Cod, haddock, hake etc	North Atlantic countries, such as UK
Carp, tilapia, catfish	East and Central European countries with some development of recirculated systems in other countries
Eels, sturgeon, perch, zander etc.	East and Central European countries with some development of recirculated systems in other countries
Tuna	Mediterranean basin countries
Mussels	Blue mussels in North Atlantic and North Sea countries and Mediterranean Mussels further south
Oysters & scallops	Atlantic and Mediterranean coasts
Clams, cockles etc.	Atlantic and Mediterranean coasts
New non-fish aquaculture sp.	Atlantic and Mediterranean coasts
Aquatic plants	Atlantic and Mediterranean coasts

The competitive landscape within the European Union is expected to change over time. Countries that have joined recently have a potential advantage in lower labour costs, which in some cases is taking both production and processing from higher cost countries (e.g. the trout industry and associated processing has increased in Poland whilst contracting in Germany and France). On the other hand, fish consumption in Central and Eastern European countries is well below that of Western Europe, and is expected to increase with expanded market opportunities for all producers.

6.5 Impact of defined scenarios

Sustainability is an increasingly important criteria for guiding policy, as well as an emerging driver for consumer food retailing. It is usually considered in relation to social, economic and environmental goals. Indicators are typically used to measure performance and these can be aggregated at a high level (i.e. to compare performance across different sectors) or at a low-level and highly specific to a particular activity.

6.5.1 Economic and social impacts of farming

Financial turnover is used as the simplest indicator of economic sustainability, giving a direct measure of the scale of economic activity. Similarly, an estimate of the number of jobs (total employment) is used as an indicator of social sustainability. In order to provide a flexible approach to modelling, these indicators are linked directly to production tonnages. In the case of turnover, the link is price per unit (e.g. Euro/kg) based on approximate current farmgate prices for whole fish. This is clearly a crude indicator, as prices are not static, particularly when volumes change substantially within a relatively short period of time. However robust data on demand elasticity does not exist, particularly for longer-term projections where prices may also be affected by broader changes within the food market. Similarly, turnover will vary according to the stage within the value chain and the various activities undertaken thereto.

Labour requirements per tonne of production can be calculated from employment data for a particular industry divided by the production tonnage. The availability and quality of employment data varies considerably between industries and countries. In many cases, only total employment is recorded. We have therefore used this, both as the most widely available indicator, but also because it is a better indicator of social sustainability than full time equivalent (FTE) jobs, which is a better indicator of productivity. Trends such as industrialisation and consolidation tend to reduce the labour requirement per tonne of production, although there may be an increase in employment in downstream processing, as a greater proportion of the output is processed.

Due to the aggregation used in this analysis, some of the species groups combine several different types of production systems with different employment characteristics. For instance salmonids includes large companies with outputs up to 300 tonnes per person, down to small farms which produce less than 10 tonnes per person. Once again, there may be related employment in recreational fisheries, or small-scale processing. For the purposes of this indicative calculation, a mean figure is used for each group. Consideration should also be given to the quality of the jobs created within each sub-sector. and the impact that these may have in encouraging or retaining economic activity elsewhere within the region.

Table 24: Multipliers used for calculation of economic and social sustainability indicators

	Turnover Euro/kg	Labour t/person
Salmon, trout & other salmonids	2.78	89.5
Sea bass, bream & similar	4.65	20
Halibut, turbot, sole etc	6.26	40
Cod, haddock, hake etc	4.82	50
Carp, tilapia, catfish	1.92	12
Eels, sturgeon, perch, zander etc.	4.44	40
Tuna	11.94	120
Mussels	0.83	15
Oysters & scallops	2.29	11
Clams, cockles etc.	3.34	5
New non-fish aquaculture sp.	11.68	10
Aquatic plants	0.29	3

Source: Unit values calculated from FAO Fishstat data, 2007. Labour per tonne is Stirling Aquaculture Estimates using various literature sources for guidance

Figure 73: Comparative economic impact – EU-25 all scenarios

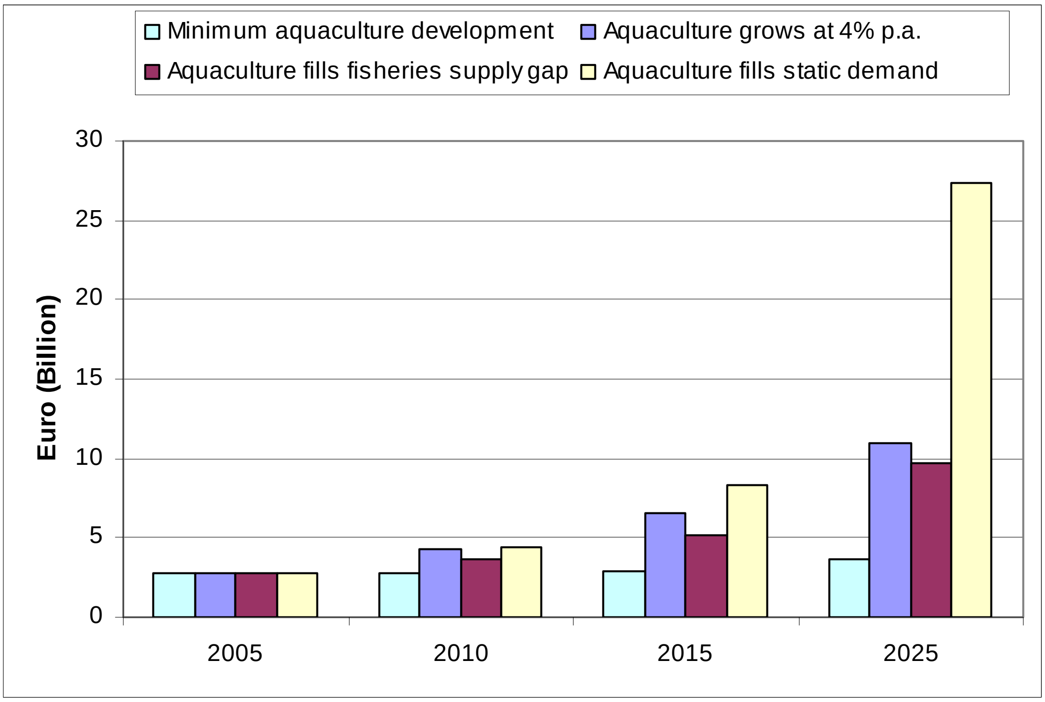


Figure 74: Scenario 1 - Baseline – Minimal aquaculture development - Projected value of aquaculture production

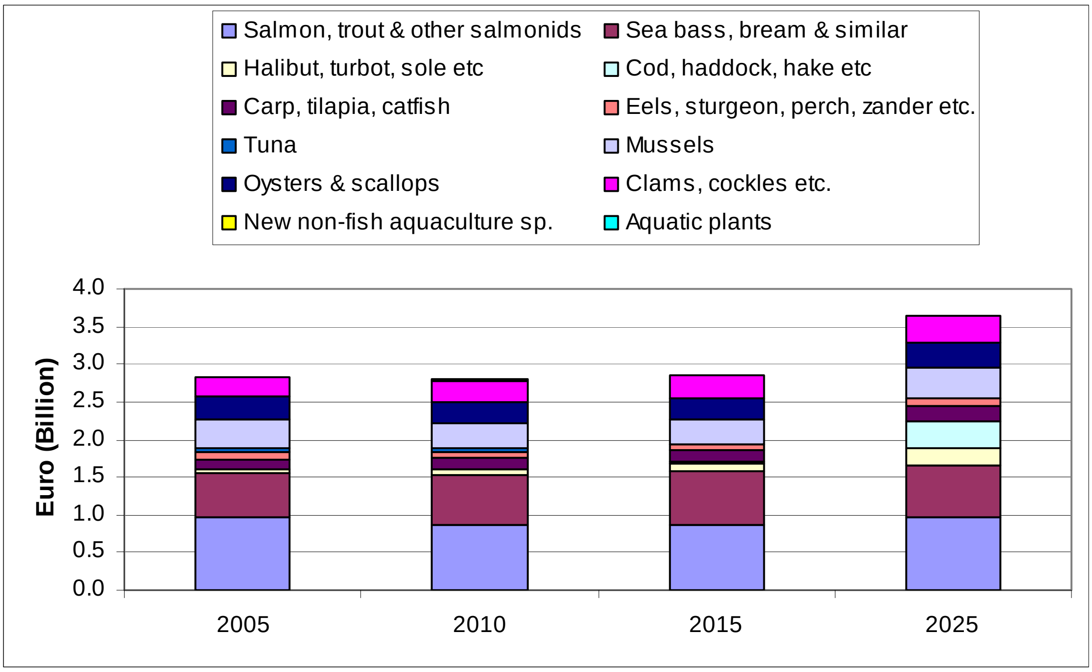


Figure 75: Scenario 2 - Projected value of aquaculture production to meet output derived from EU target of 4% per annum growth to 2025

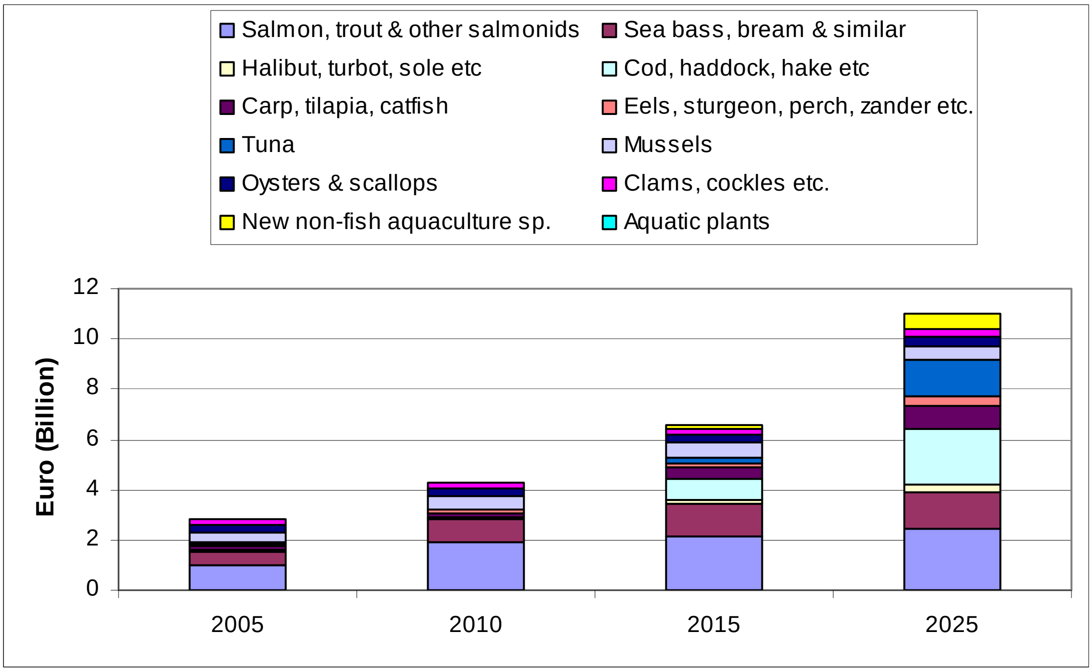


Figure 76: Scenario 3: Aquaculture fills capture fisheries gap - Projected value of aquaculture production

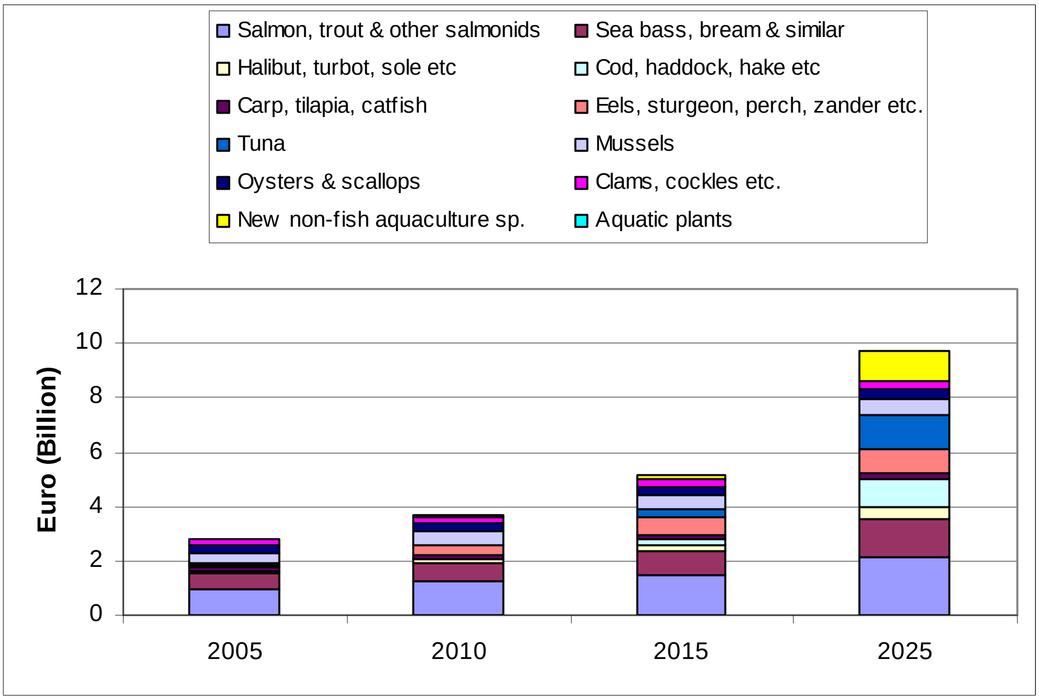
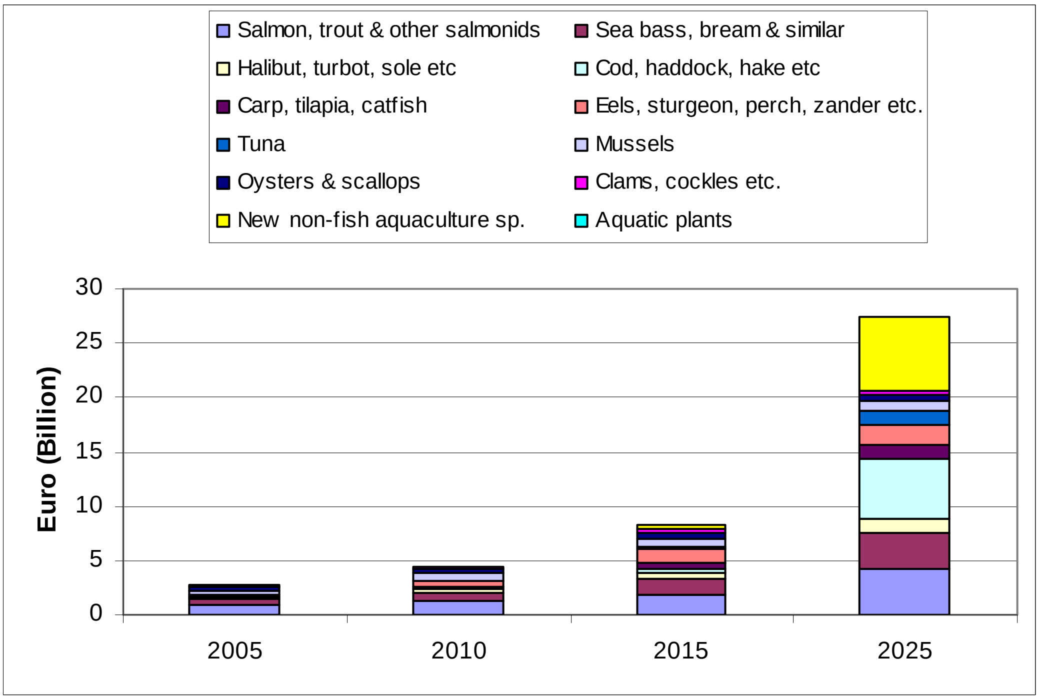


Figure 77: Scenario 4: Aquaculture fills static demand gap - Projected value of aquaculture production



The baseline scenario sees the value of EU-25 aquaculture (at farm gate) rising relatively little, from €2.73b in 2005 to €3.43b in 2025, with both 2010 and 2015 slightly lower than the 2005 value. In the second scenario (EU target growth) farm gate value rises from 2.73b in 2005 to €4.1b in 2010, €5.89b in 2015 and to €9.17b in 2025.

The other scenarios fall either side of the EU target projections. The highest scenario reaches €21b by 2025. These totals are influenced by the ratio of aquaculture products. The greater value in 2005 is contributed by salmon and sea bass/sea bream, whilst the greater volume is in mussels. The baseline projections indicate the average value of aquaculture produce in 2005 was €2.16/kg, rising to a projected €2.32/kg in 2025. If growth in fish production were dominated with higher value fish, then the average value would rise to around €3.06/kg in 2025, which would increase total value to €4.54b (baseline scenario), an increase of 24.5%. Conversely if the growth in lower value species is stronger at the expense of higher value species and average price remained at €2.16/kg, the total value in 2025 (baseline scenario) would be €3.2b, a 7.15% difference. Variations in species mix will therefore change the value of the aquaculture sector by perhaps up to ± 25%.

Figure 78: Comparative social impact – all scenarios

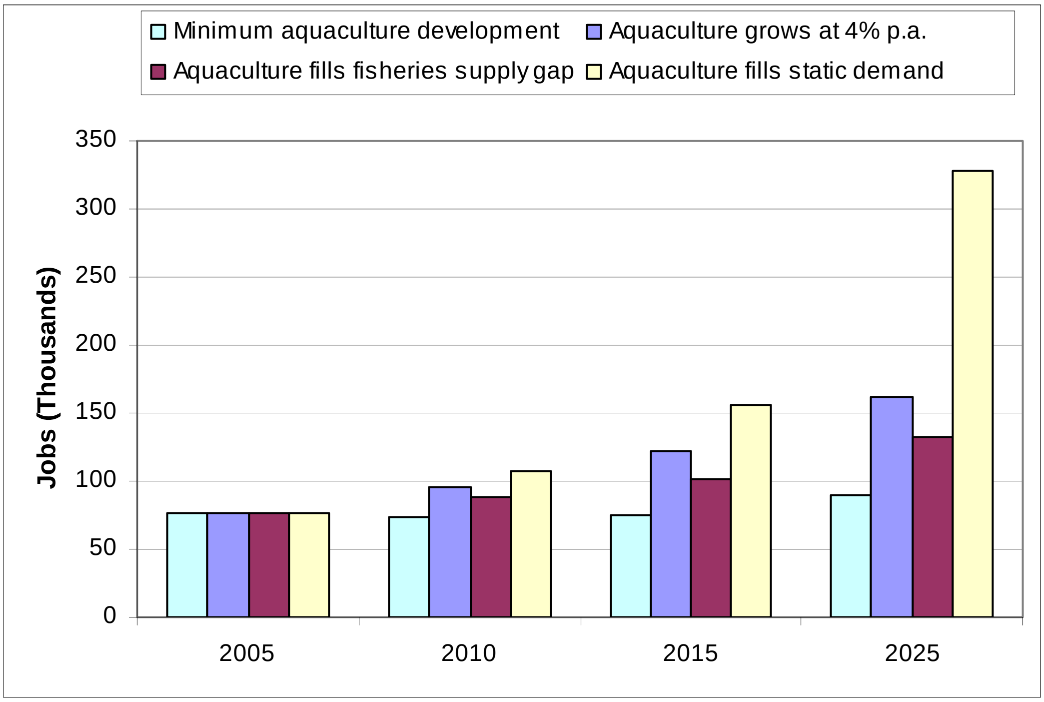


Figure 79: Baseline scenario – Estimated number of jobs with minimal aquaculture development

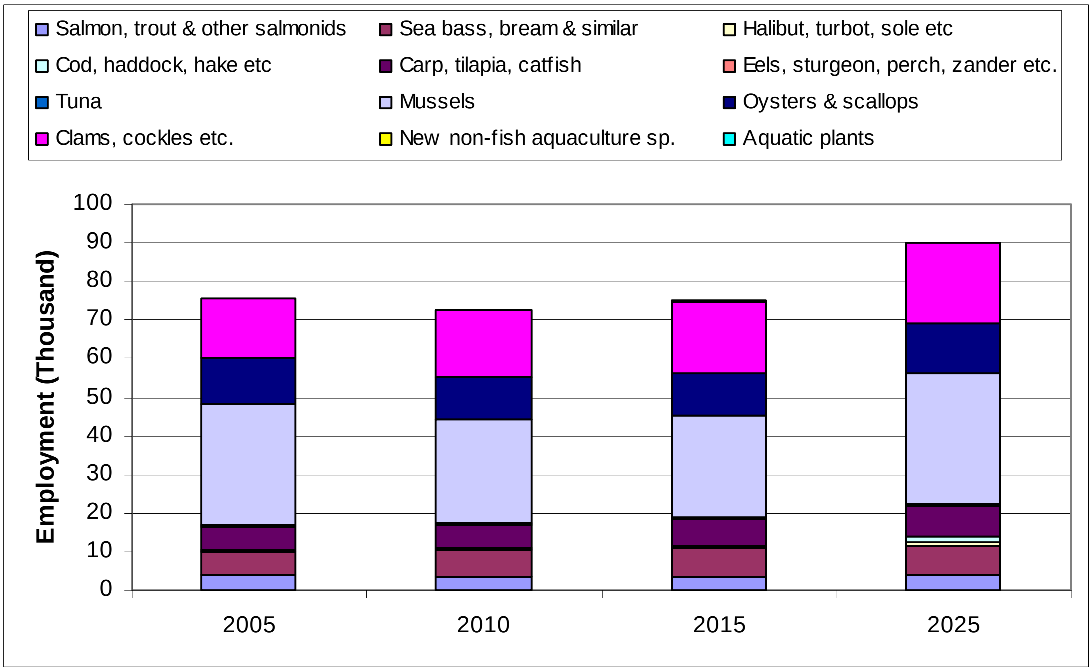
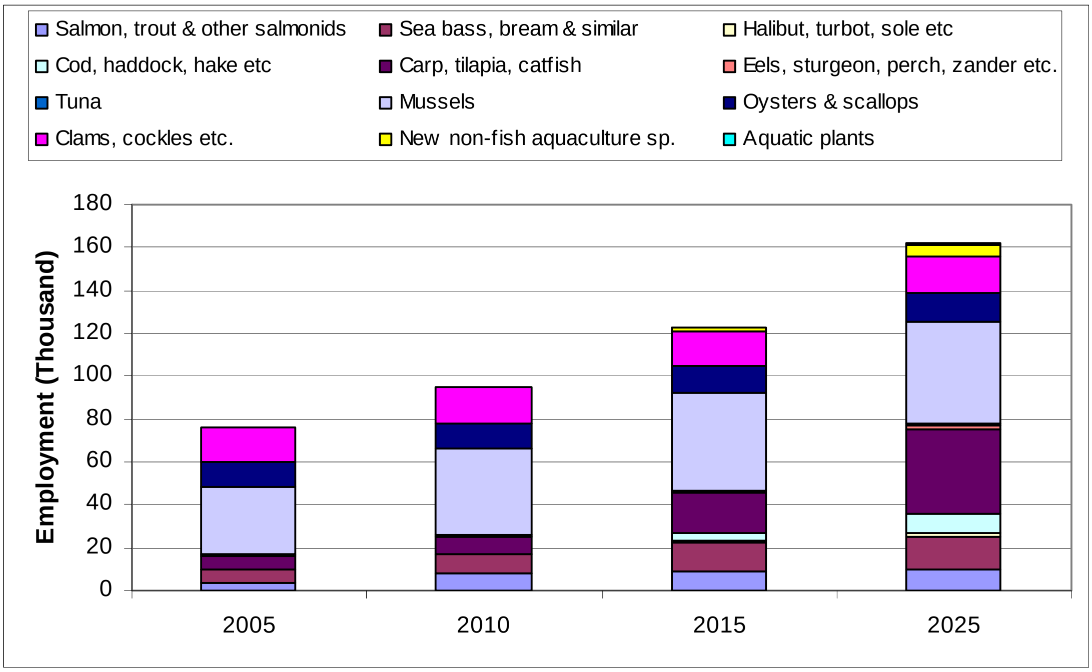


Figure 80: Scenario 2 – Estimated number of jobs if aquaculture expands to meet output derived from EU target of 4% per annum growth to 2025



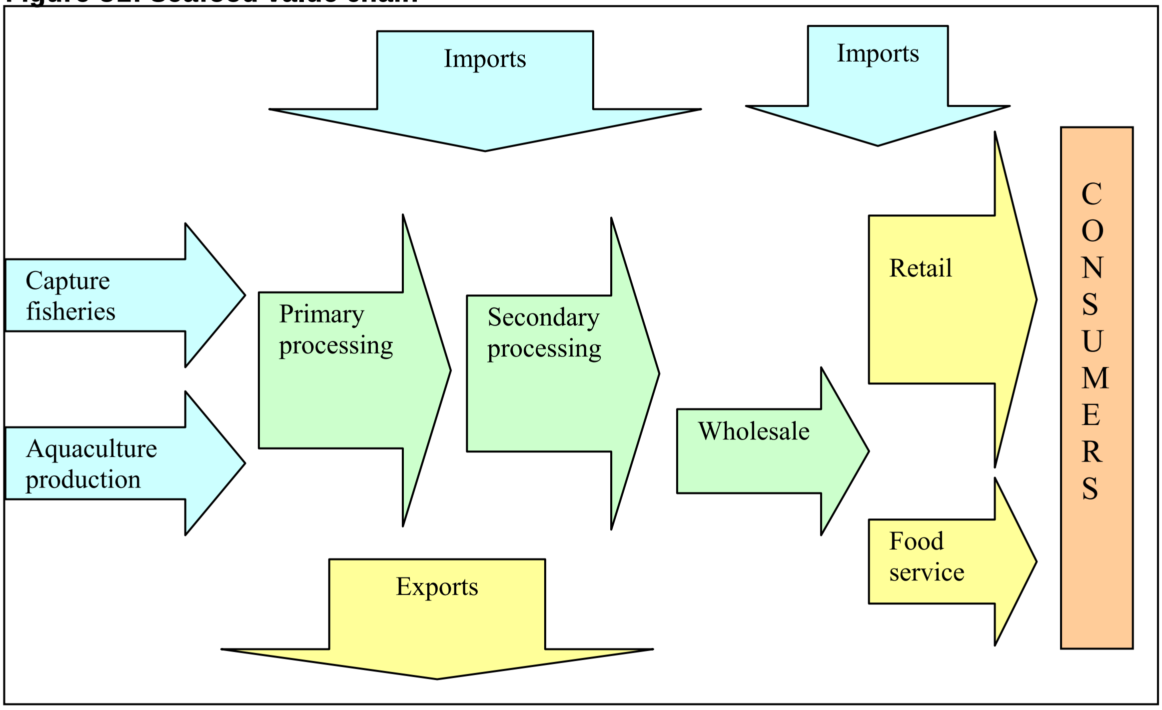
The baseline assumptions calculate the number of EU-25 aquaculture jobs in 2005 to be 75,840. This increases to 89,891 in 2025. The second scenario based on the target of 4% growth rate leads to 162,032 jobs by 2025, whereas the highest scenario leads to 327,831. As with value, the total number of jobs is affected by the mix of species and systems for any given volume. As can be seen from Table 23, it would only take 5 tonnes of cockle or clam production to keep one person employed compared with up to 120 tonnes of tuna. It would therefore appear that a policy of promoting employment opportunities should encourage the development of less efficient and more labour-intensive aquaculture systems. However, these simple figures do not take into account the jobs generated upstream – in the manufacture and servicing of equipment for more capital intensive production systems, or the employment effects attributable to higher disposable incomes for staff of capital intensive farms (assuming they are paid more). Consideration should also be given to the quality of the jobs, and to wider social benefits e.g. to community health from improving availability of cheaper seafood. Nevertheless, whilst increased employment would appear to be best served by promoting a larger number of smaller enterprises that use more labour intensive production methods, this would not be an option in practice unless market protection measures were in place. European producers would be unable to compete with more efficient production systems elsewhere, making enterprises unsustainable.

The total number of jobs in the aquaculture production sector is therefore highly dependent on the species and productivity of the systems employed. If all the fish production systems were to operate at the higher average of 120 tonnes per person, the number of jobs in 2025 for Scenario 2 would fall from 162,032 to around 113,000, a reduction of 30%

6.5.2 Value chain effects

The analysis so far has concentrated on the value created by the farming activities. Processing, distribution, retail and food service can easily triple the value of the primary product with consequent benefits for the European economy. The value chain for individual products can be short and simple or long and complex, but in broad terms, it consists of materials inputs (capture, farming imports), transformational stages (processing, packaging and distribution) and final sales to consumers via shops (retail) or restaurants and catering (food service). The value of the EU seafood processing industry alone was estimated to be approximately Euro 15 billion by Glitnir (2007), with Spain as the leading producer. Exports from the EU are also considered as final sales for the purpose of this analysis as no additional value is generated within the EU (Figure 81).

Figure 81: Seafood value chain



The block arrows in the above diagram are shown unconnected as there are many routes that can be taken to connect the different elements within the system. Some fish farms for instance sell directly to the public (retail) from the pond-side, with no intermediate value addition. Other products will pass through the entire chain, which can also include exporting and then re-importing after overseas processing. Large multiple retailers normally bypass the wholesale stage and buy directly from secondary processors. Products may be exported after primary or secondary processing.

It is beyond the scope of this report to examine all the linkages and product flows in detail, not least because much of this detail is not readily available through official sources at apposite levels of disaggregation. We therefore concentrate on the key input and output values to determine total added value. For the purposes of scenario modelling, mean value addition factors are determined and then multiplied by production from the earlier models. The processing and marketing chain usually results in a reduction in total volume (by weight) of a product (e.g. processing waste etc.). This is taken into account by using a single utilization factor for each product group and is essentially the difference between original live weight of the product, and the final weight sold or served to consumers or exported. . In practice there may be a number of variants on these crude indices for reasons such as the type of fillet cut from the same species. For example a block or butterfly whitefish fillet might yield around 35% whereas single fillets would generate around 50%. Other preparations will have their own peculiarities which can only be averaged in this exercise so that: Total market chain value is taken as:

(Retail vol. x avg. price) + (food service vol. x avg. price) + (export vol. x avg. price)

The contribution of the production sector is included in these figures. The value added to the raw product can therefore be calculated as total market chain value minus primary production value. The value of waste generated during processing is not included in the present models. The value added to imports is not included in this initial analysis, but is discussed later.

Table 25: Multipliers used for calculation of value addition

	Breakdown of route to market				Value multiplier		
	Utilized	EU Retail	EU Food service	Exported	Retail	Food service	Export
Salmon, trout & other salmonids	60%	55%	20%	25%	4.3	8	4
Sea bass, bream & similar	80%	40%	50%	10%	4	8	2
Halibut, turbot, sole etc	77%	40%	55%	5%	4	8	2
Cod, haddock, hake etc	44%	53%	38%	9%	4.4	13.6	1.6
Carp, tilapia, catfish	35%	65%	30%	5%	4	8	2
Eels, sturgeon, perch, zander etc.	40%	40%	55%	5%	4	8	2
Tuna	100%	0%	0%	100%	4	8	1
Mussels	70%	30%	65%	5%	4	8	2
Oysters & scallops	50%	30%	65%	5%	3.5	8.4	2.2
Clams, cockles etc.	40%	65%	30%	5%	3.5	8.4	2.2
New non-fish aquaculture sp.	40%	40%	55%	5%	3.5	8.4	2.2
Aquatic plants	20%	5%	5%	90%	5	10	10

Source: STAQ estimates based on Gudmundsson et al (2006),

Based on the multipliers presented in Table 25, it can be seen that the value chain varies significantly between species groups. This is illustrated graphically in Figure 80 which illustrates those species that have a high proportion of sales through food service (e.g. sea bass, sea bream, halibut and sole etc.), have the highest proportion of value addition overall. The impact of considering the downstream value chain is to take the baseline scenario aquaculture production value for 2025 from €3.64 billion to €12.65 billion (Figure 82).

Figure 82: Contribution of production, retail, food service and export within different product groups – baseline scenario 2005

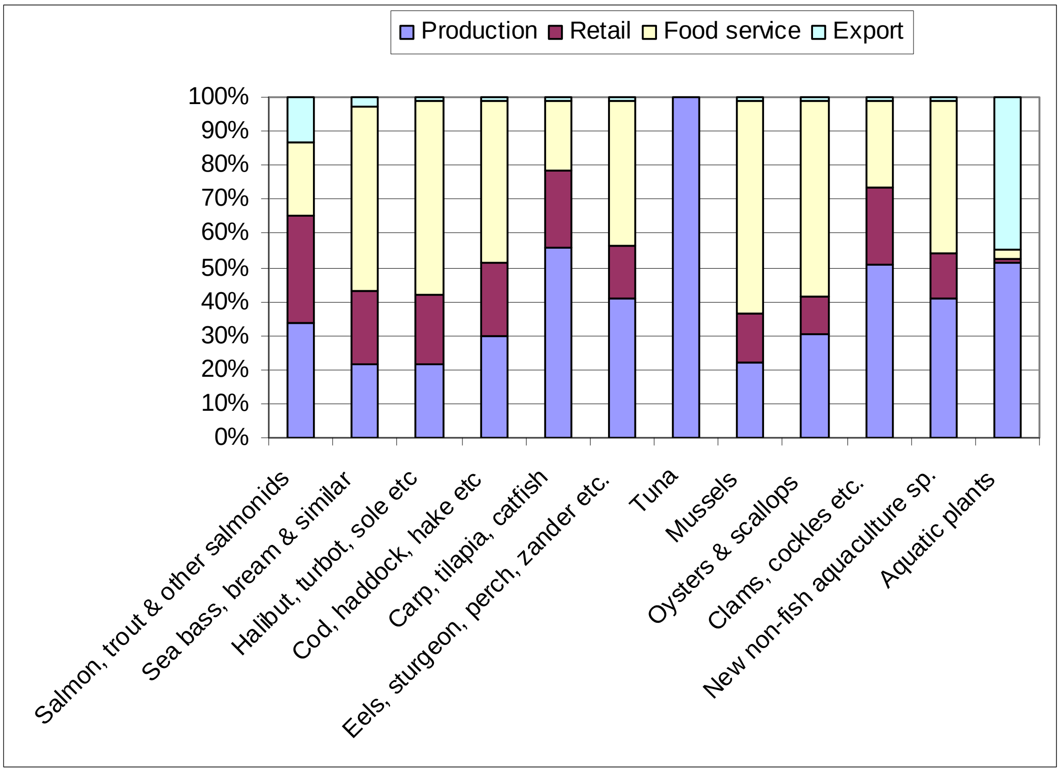
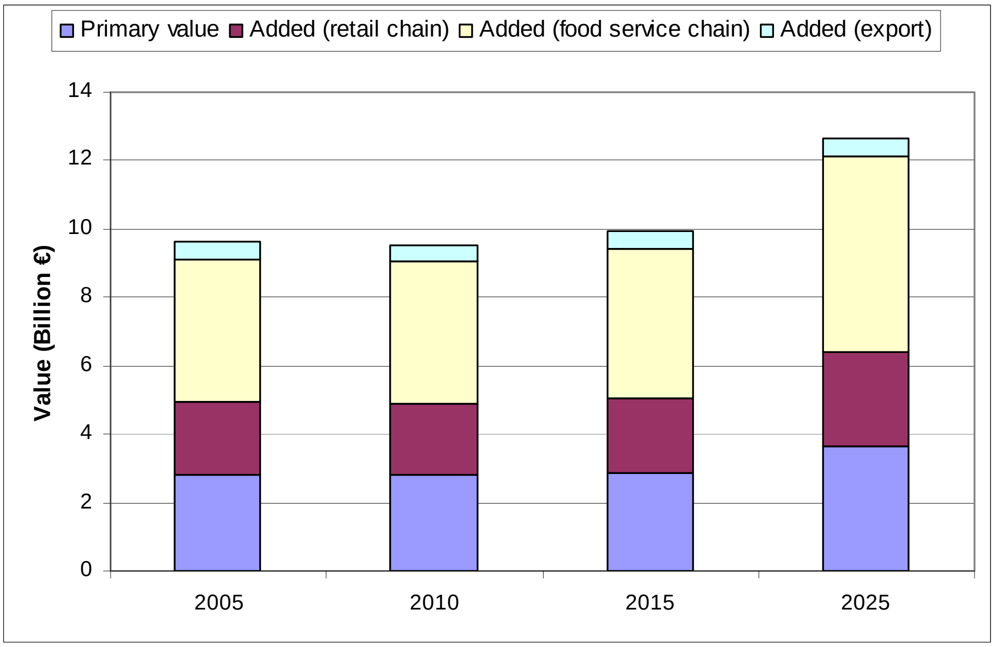


Figure 83: Total value addition – baseline scenario - minimal aquaculture development



The second scenario (aquaculture increases to meet EU 4% per annum target), shows a similar pattern, with an additional €21.9 billion added to the projected €11.0 billion value at first sale (Figure 84).

Figure 84: Total value addition – Scenario 2 - Aquaculture expands to meet output derived from EU target of 4% per annum growth to 2025

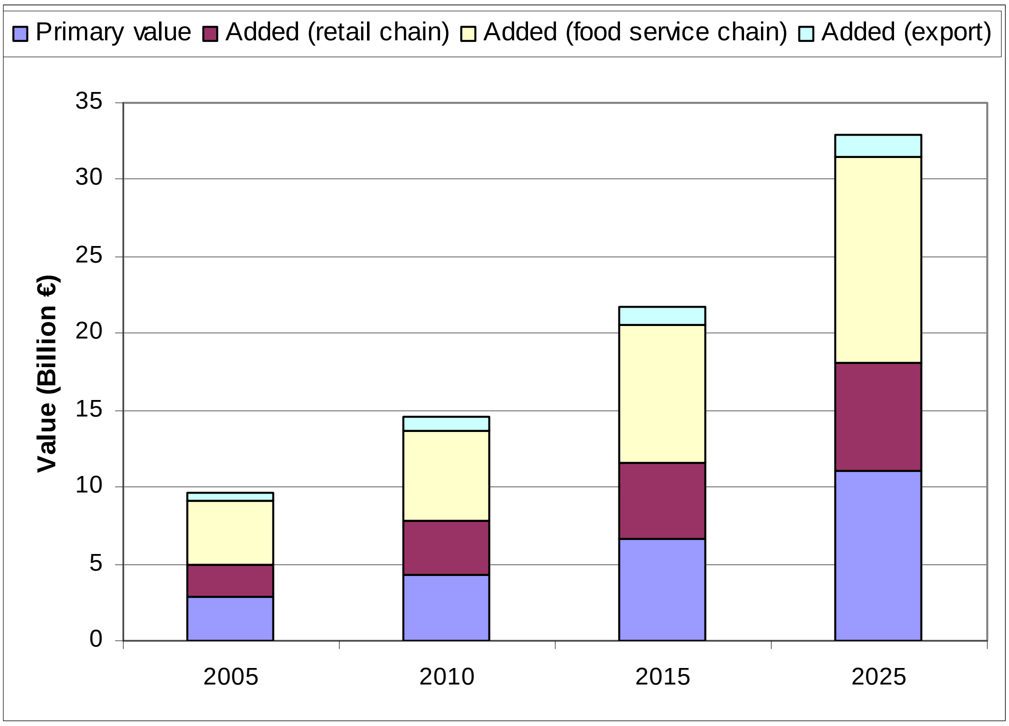
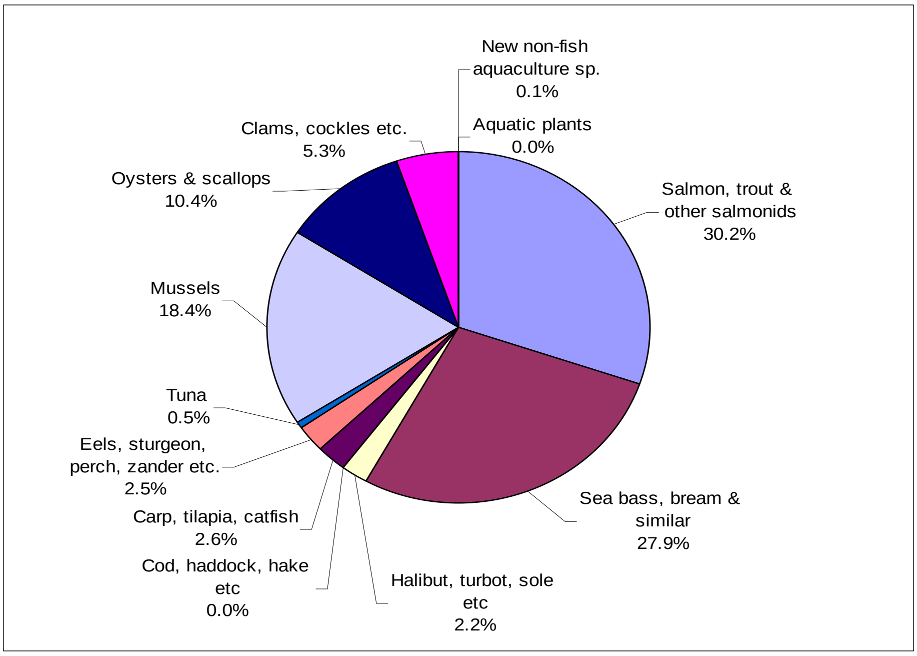
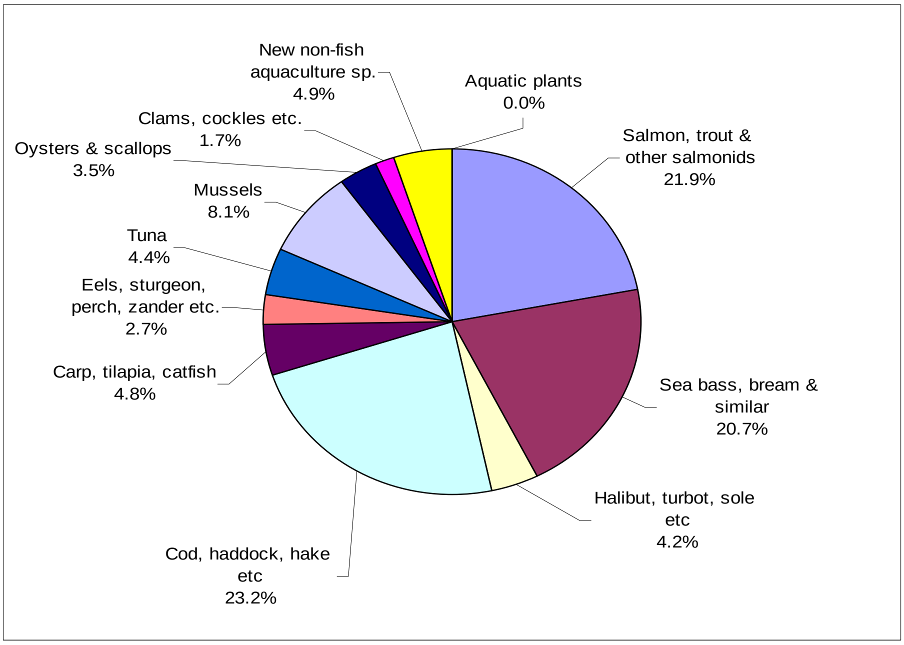


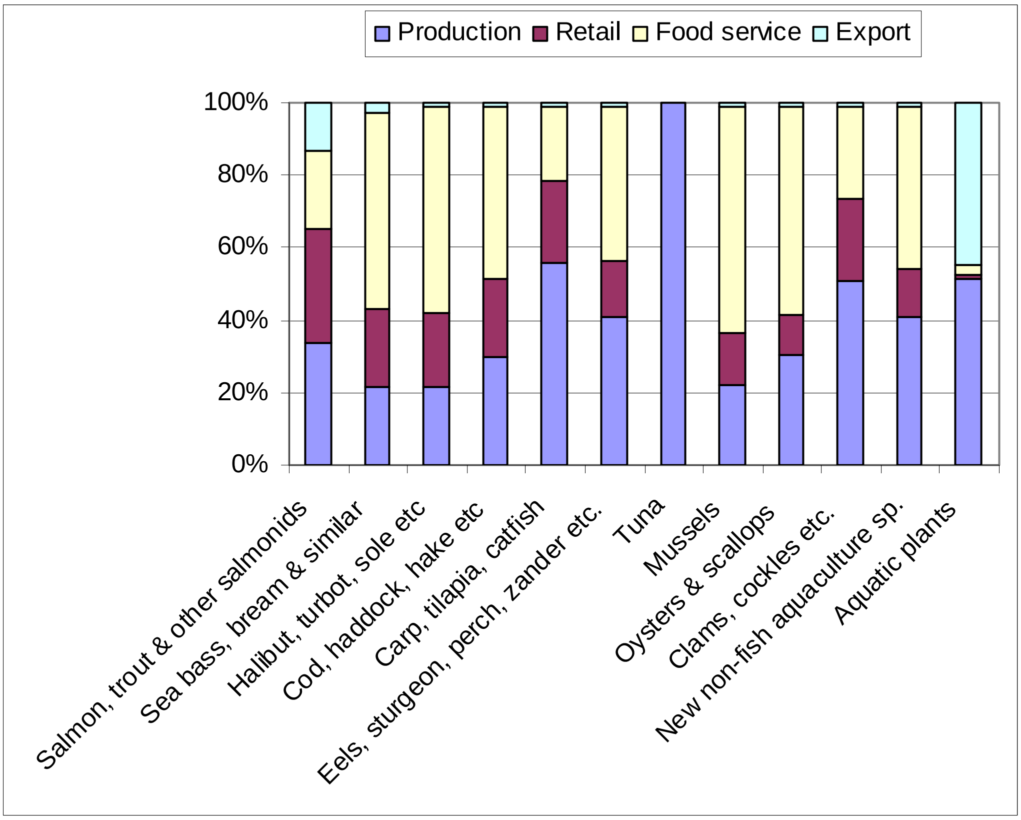
Figure 85: Change in value contribution – Scenario 2 - Aquaculture expands at EU target of 4% per annum, 2005 (top) and 2025 (below)





The overall contribution of different species groups and value segments for Scenario 2 in 2025 is shown in Figure 86.

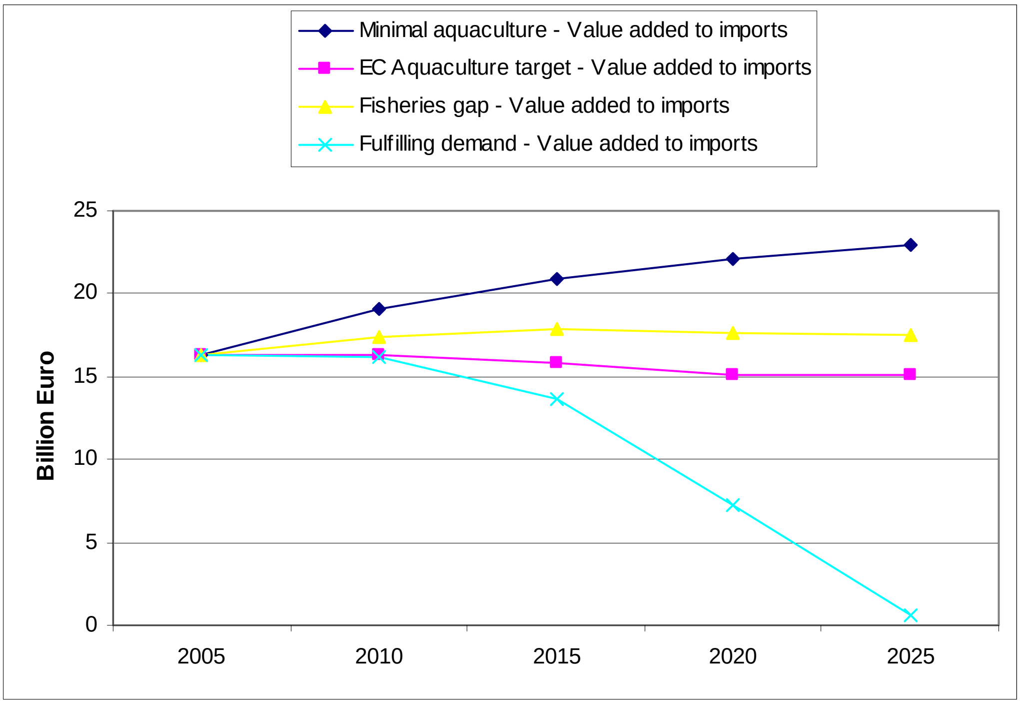
Figure 86: Value contribution by species group – Scenario 2 - Aquaculture expands to meet output derived from EU target of 4% per annum growth to 2025



Most imported fish and seafood products have already undergone primary and often secondary processing. However, there may well be further processing and then distribution through retail, food service and exports as for product produced in the EU. This added value is important, as it will often be greater than the cost of the primary imported material. Gudmundsson *et. al.* (2006), studying four different fisheries products and countries found between 54% and 75% of value addition to be in secondary processing, wholesale and retail. KPMG (2004) studied cod, haddock and nephrops, finding value additions in processing and distribution to be respectively, 69%, 75% and 74%. Removing the primary processing stage reduces these values slightly to 66%, 71% and 74% respectively. These figures compare to an overall average of 58.5% for value addition post first sale calculated for aquaculture products in our model. For the purpose of estimation therefore, Figure 87 shows the additional value that might be generated from imported fish and seafood products under the 4 scenarios and assuming constant consumption, if the imported raw material constitutes on average, 40% of the final price. This reaches €23 billion by 2025 for the minimal aquaculture development scenario.

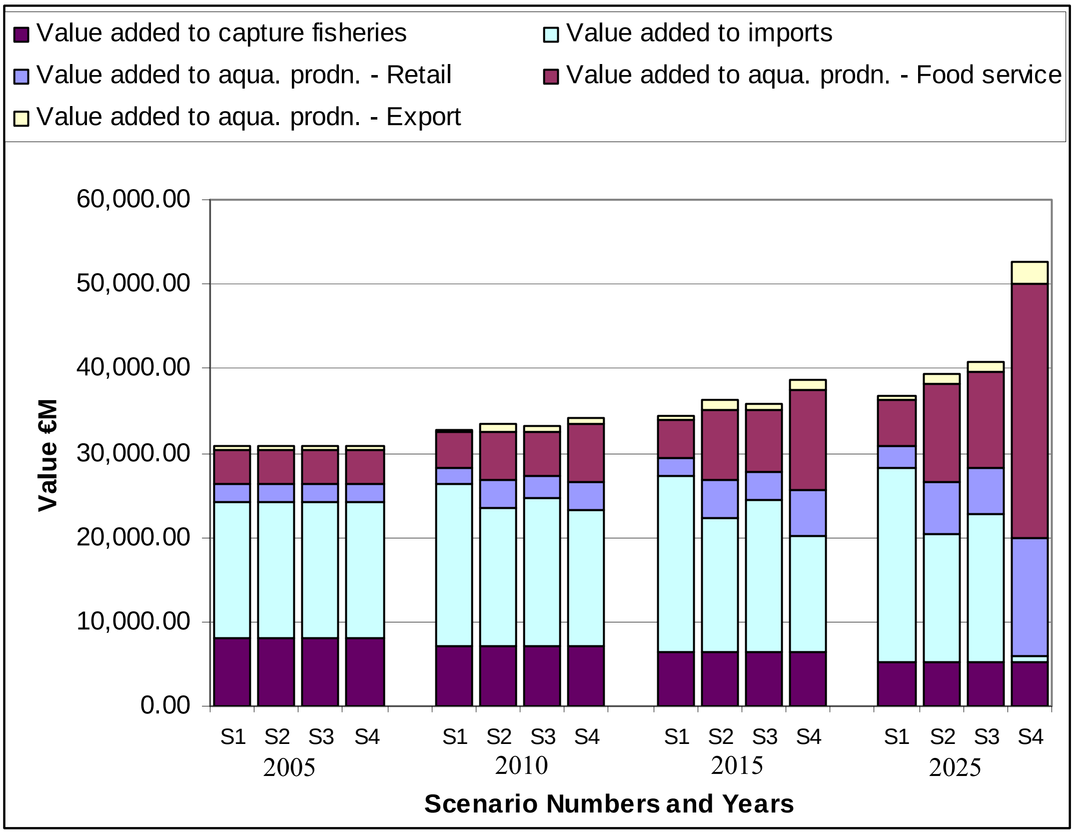
Figure 88 shows the value addition of imports in relation to those contributed by capture fisheries and projected aquaculture production for each of the 4 scenarios to 2025. Overall value addition ranges from €30.9 billion (all scenarios, 2005) to €52.6 billion (scenario 4 in 2025). The contribution of EU aquaculture production to seafood value addition is around 20% in 2005, potentially rising to around 35% in 2025 if the EU growth objectives were met. The value addition of aquaculture products for export contributes less than 2% to total value addition in 2005, rising only slightly to a maximum of 4.8% by 2025 (highest production scenario).

Figure 87: Approximate value added to imported fish and seafood within the EU – all 4 scenarios using static consumption projections



Note: These projections assume an average value addition of 60% within the EU.

Figure 88: Approximate value added to all fish and seafood within the EU – all 4 scenarios using static consumption projections



Note: The estimated value addition to capture fisheries assumes an average post-harvest value of €2.48 and value addition of 70%. The average value addition to imports is assumed to be 60%, whilst value addition to aquaculture varies by product group as set out in Table 25

6.5.3 Resource use impacts

A wider range of indicators have been developed to help inform assessments of environmental sustainability. These can be grouped into indicators of resource use and indicators of waste output impact (only the primary production phase is discussed here). On the input side, we examine land or water area utilised, water throughput, and industrial energy consumed. The area used is an indicator of the intensity of the farming operations. Extensive farming will require higher areas per tonne of output. Water throughput is more complex. Intensive farming operations, including cage farming but excluding recirculating systems, will have a high water throughput per tonne of production. The main significance is that the quality of the water will be changed during its passage through the aquaculture system, although in pond systems, there will also be significant water consumption (or more accurately loss) due to evaporation and soil permeability. Where the same species may be cultured in a variety of system types (e.g. carp), we have assumed that future growth in production will be through the identified emerging systems (particularly offshore cages and recirculated aquaculture systems). Industrial energy input (oil, gas, electricity) per tonne of production is calculated through reference to available data on industrial energy input per unit of protein energy output.

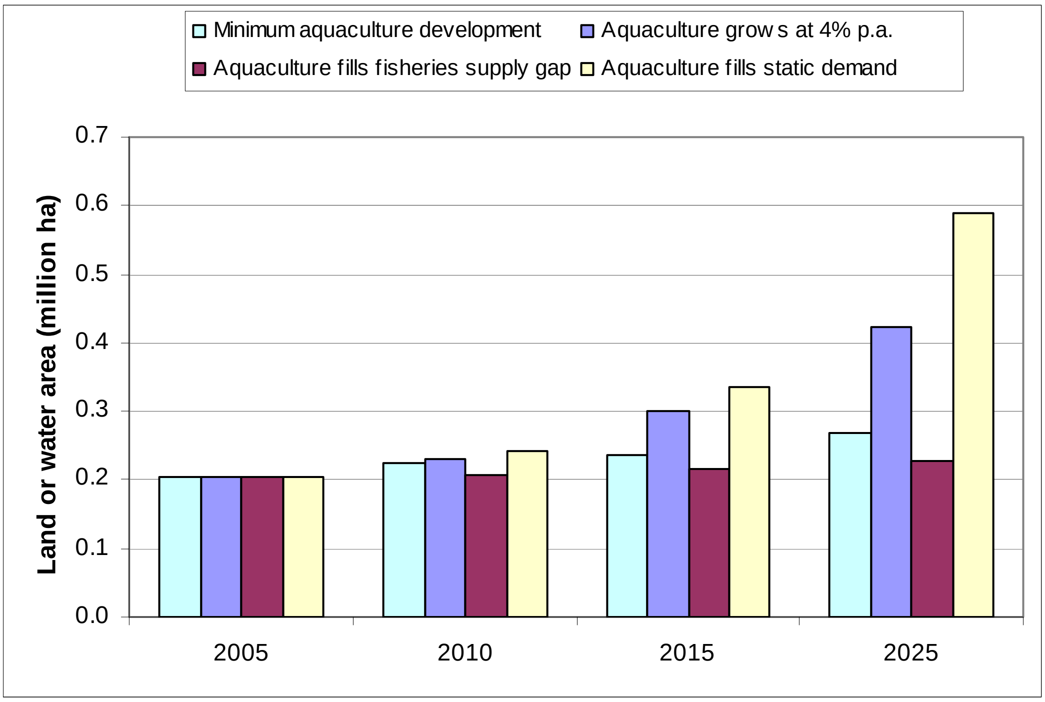
Table 26: Multipliers used for calculation of input environmental sustainability indicators

	Land or water t/ha	Water m^3/t	Industrial energy input to protein energy output (J/J)	Protein energy per tonne (J)
Salmon, trout & other salmonids	1,750	2,260,000	50	4,727,920
Sea bass, bream & similar	1,125	2,500,000	40	4,727,920
Halibut, turbot, sole etc	2,676	2,000,000	45	4,727,920
Cod, haddock, hake etc	1200	2,500,000	45	4,727,920
Carp, tilapia, catfish	2	5,000	30	4,727,920
Eels, sturgeon, perch, zander etc.	190	100	35	4,727,920
Tuna	300	3,000,000	50	4,727,920
Mussels	76	3,000,000	10	4,727,920
Oysters & scallops	25	2,000,000	5	4,727920
Clams, cockles etc.	0.5	2,000,000	5	4,727,920
New non-fish aquaculture sp.	150	200	20	4,727,920
Aquatic plants	1	2,000,000	1	3,545,940

Sources: Muir & Beveridge (1987), FAO Fish Stat, Phillips *et al* (1991), O'Hagan (1999), EIFAC (2000), FishStat (2000), Green & Eagle (2000).

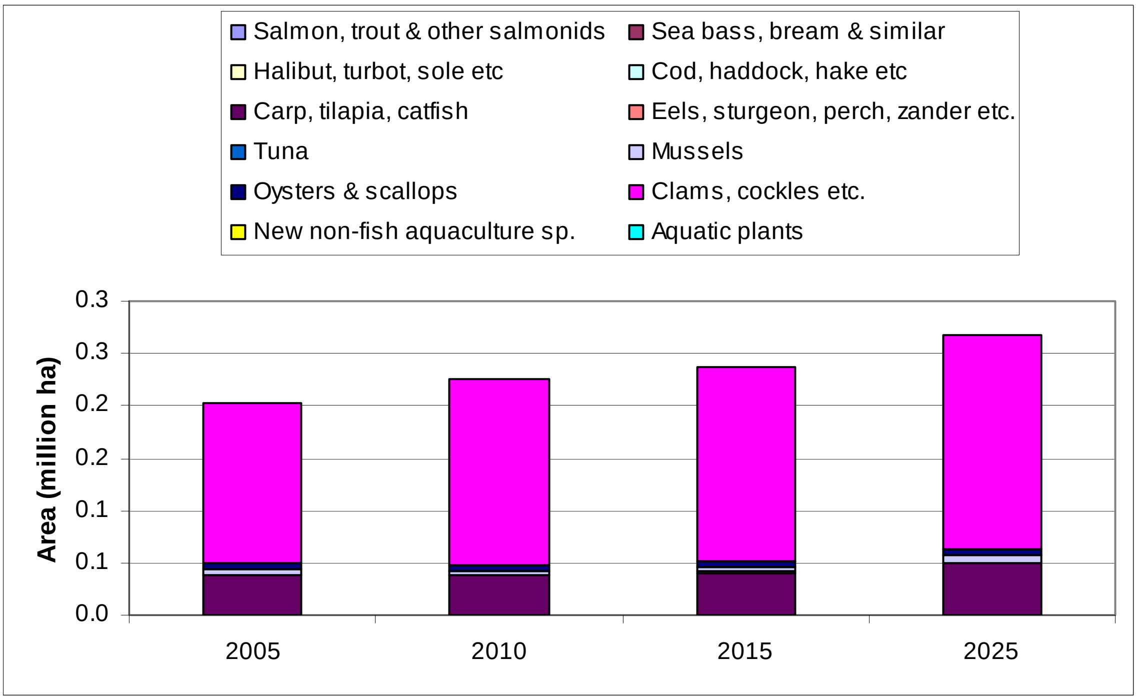
In terms of physical land or water area required for production, shellfish cultivation on beds or trays tends to be least efficient, and therefore dominates the space requirement calculations.

Figure 89: All scenarios – Land / water area requirements



The water area required for marine salmonids, bass and bream in cages is as little as 310 ha, compared with an estimated 165,500 ha for shellfish cultivation. Land areas required for freshwater aquaculture are substantially more than is required for marine cages, but with lower production adds up to around 40,000 ha.

Figure 90: Baseline scenario – Land / water area requirements



Mussels have the highest water requirement due to the extent to which they are cultured, and their need for constant water exchange. However, as this is provided naturally by currents in the sea, the water requirements of salmonid culture, especially in freshwater, may be considered more significant.

Figure 91: All scenarios – Water usage

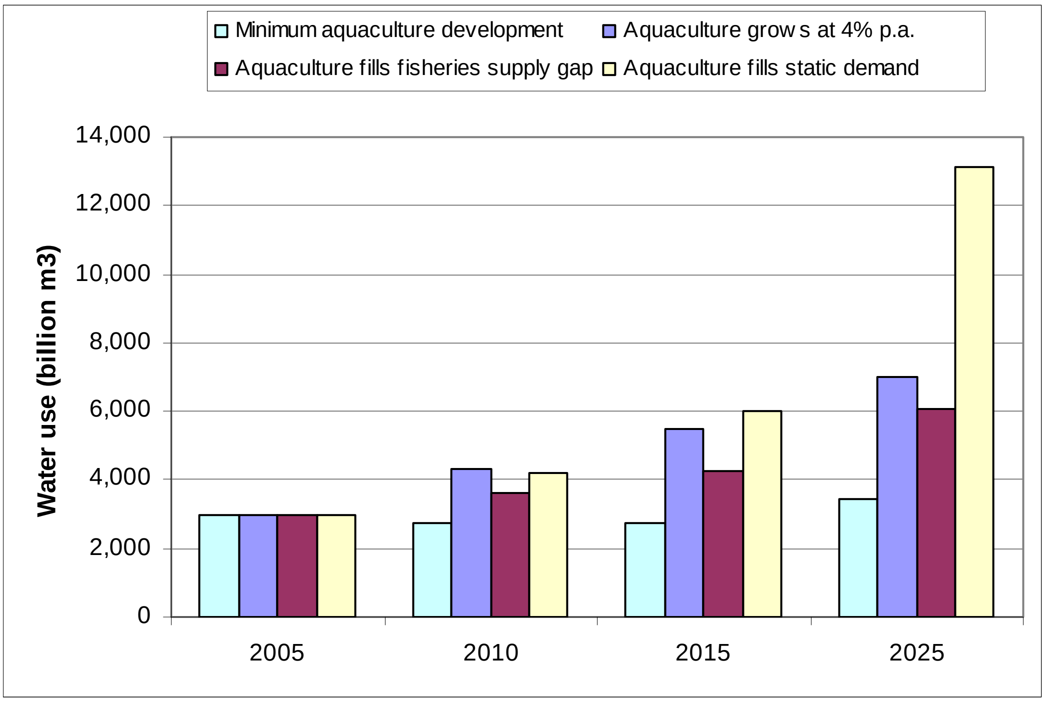
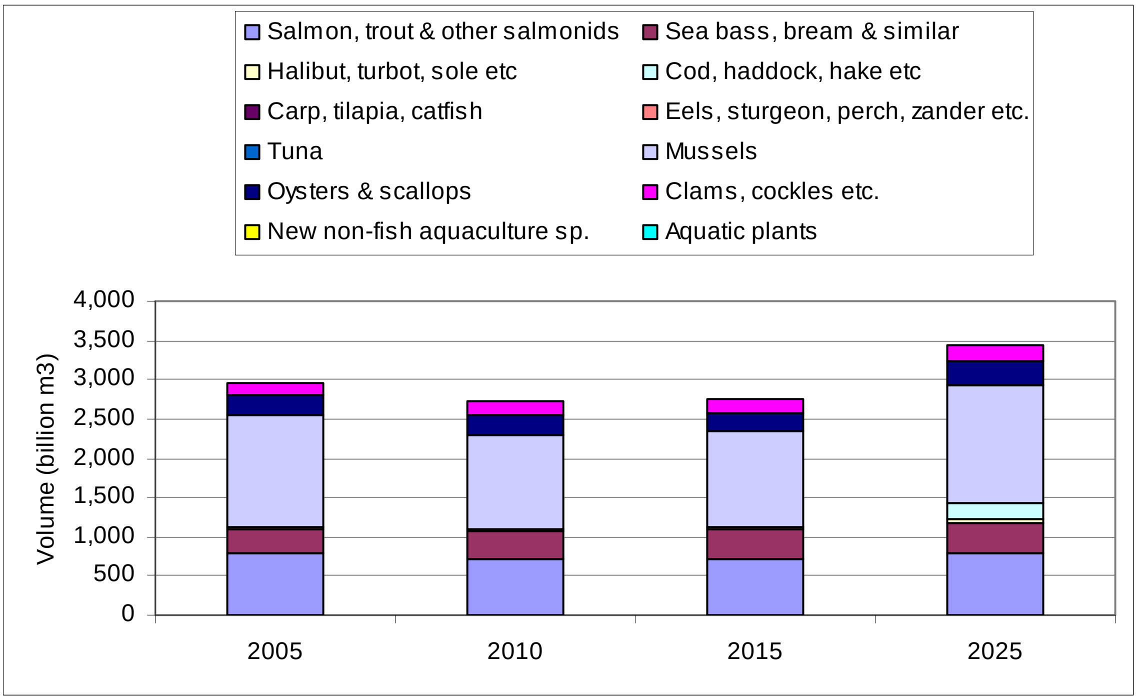


Figure 92: Baseline scenario – Water usage



The expansion of aquaculture would most likely require increased use of coastal resources. Currently 8 t of fish from aquaculture are produced per km of coastline in the EFTA countries (which include Norway) (European Environment Agency, 2005a).

The use of recirculated aquaculture systems can substantially reduce the actual water requirements, but often at the cost of additional energy requirements. The greatest pressure for this is likely to be on intensive freshwater fish farms.

Much of the total use of energy in aquaculture is in the capture of industrial fish and the production of compounded fish diets. Downstream processing and distribution also add substantially but is not included herein. Otherwise, aquaculture systems vary considerably in their use of energy, even between units of broadly similar type due to efficiency factors and degree of mechanisation.

Figure 93: All scenarios – Industrial energy use

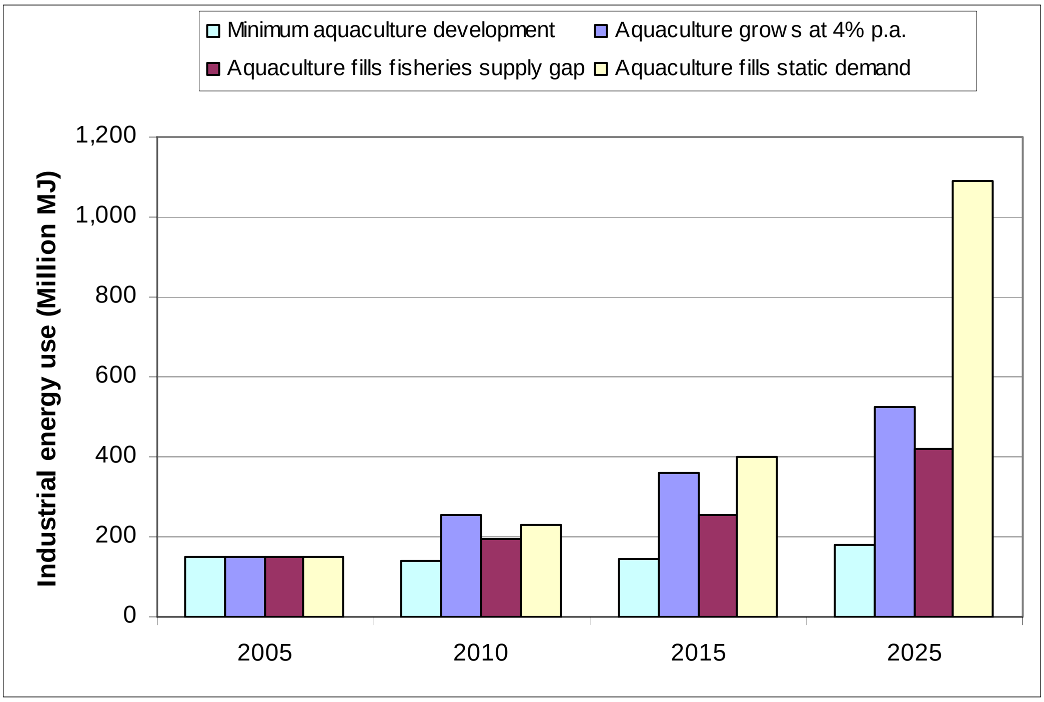
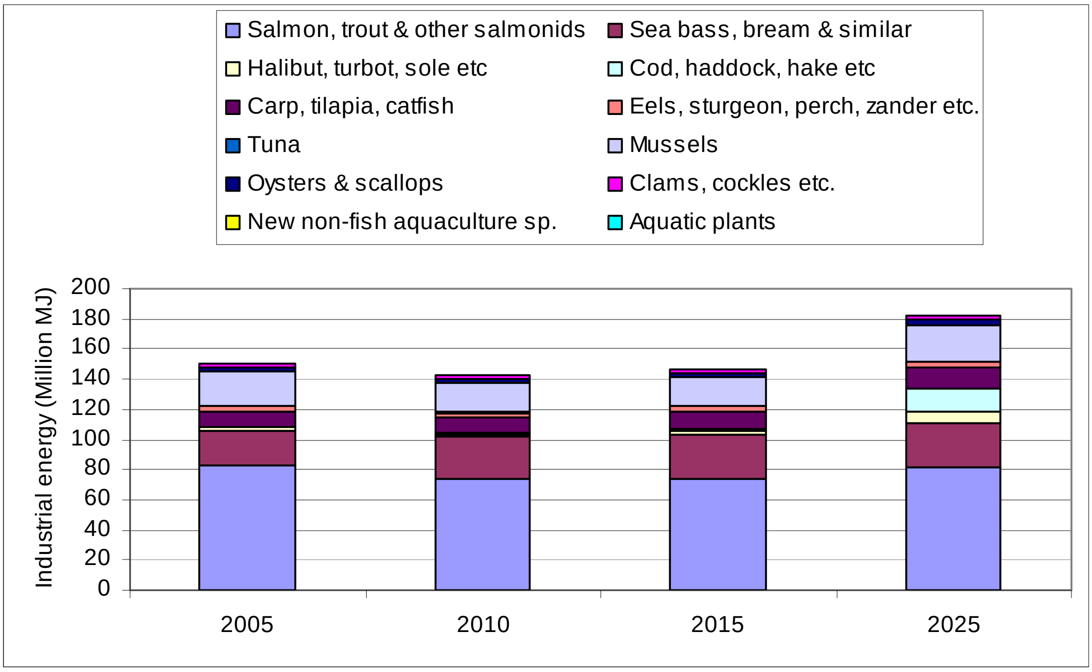


Figure 94: Baseline scenario – Industrial energy use



6.5.4 Environmental pressures

On the output side, the emissions considered are nitrogen, phosphorus, and organic carbon (excluding carbon dioxide from respiration or fuel combustion, or carbon monoxide from fuel etc). These were selected as being the most relevant in a broad scale and most amenable to this analysis, although other environmental issues related to aquaculture exist. These elements are released in both solid and dissolved compounds with the prime concern being those that are discharged directly to the aquatic environment. For fish and crustaceans, these figures will be influenced by a range of factors, including nutritional content of the diet, digestibility and efficiency of feeding systems, and any waste removal mechanisms that are in place before discharge to the environment. For shellfish it is assumed these will be net consumers of nitrogen and phosphorus, but will have a net carbon output due to the discharge of pseudofaeces. Aquatic plants, once harvested, remove nitrogen and phosphorus, but also organic carbon, albeit sourced from the fixation of carbon dioxide. The figures used in the model are shown below. Values presented in the literature can vary widely even for similar species/system combinations. For fish, the output will be dependent on feed conversion ratios achieved, the composition of the diets, and any treatment processes conducted within the system.

Table 27: Multipliers used for calculation of output environmental sustainability indicators

	Nitrogen output kg/t	Phosphorus output kg/t	Carbon output kg/t
Salmon, trout & other salmonids	40	6.7	200
Sea bass, bream & similar	105.4	13	170
Halibut, turbot, sole etc	75	55	200
Cod, haddock, hake etc	67	15.6	200
Carp, tilapia, catfish	90	13	200
Eels, sturgeon, perch, zander etc.	67	15.6	200
Tuna	101	32	200
Mussels	-3	-1	100
Oysters & scallops	-3.33	-1	100
Clams, cockles etc.	-3	-1	100
New non-fish aquaculture sp.	67	15.6	200
Aquatic plants	-47	-6.67	-300

Note – No adjustment is made for recirculated systems as most of these still produce discharges, although they may not be discharged immediately back into the environment. Sources: Musango et. al. (2007), Papatryphon et. al. (2004), Aubin et. al. 2006. Aquatic Sciences Inc (1999), Johnsen et. al. (1993), Alvarado (1997), Islam (2005), Davies & Slaski (2003), Bergheim & Brinker (2003), Wu (1995), Siddiqui & Al-Harbi (1999) and Stirling Aquaculture estimates.

Figure 95: All scenarios – Nitrogen output

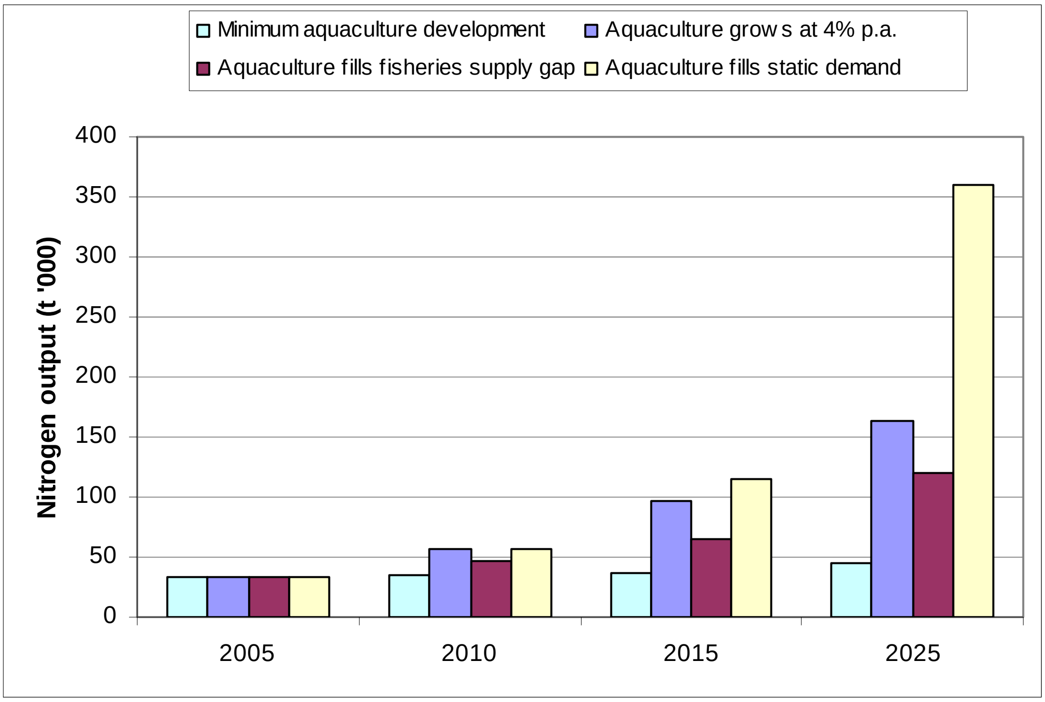


Figure 96: Baseline scenario – Nitrogen output

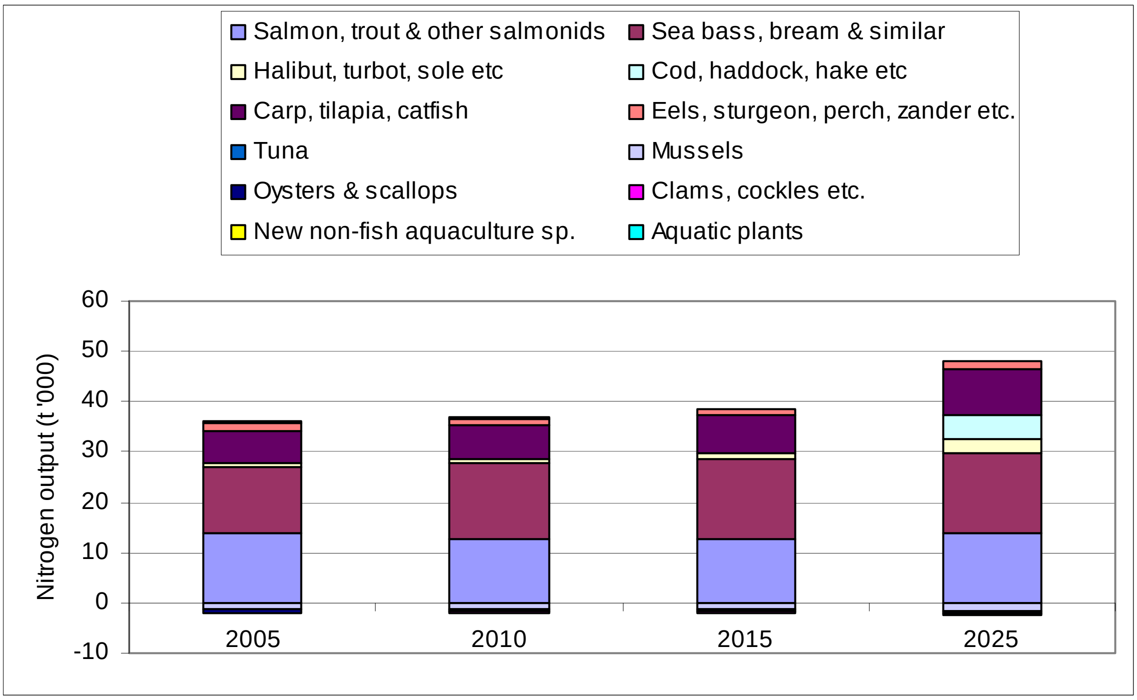


Figure 97: All scenarios – Phosphorus output

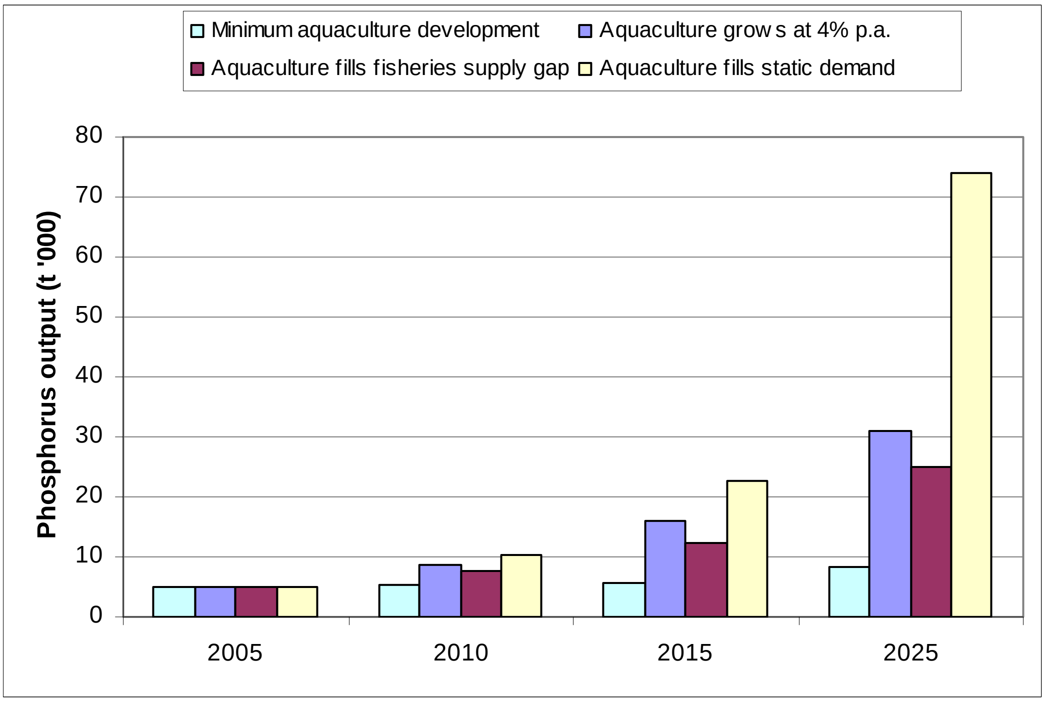


Figure 98: Baseline scenario – Phosphorus output

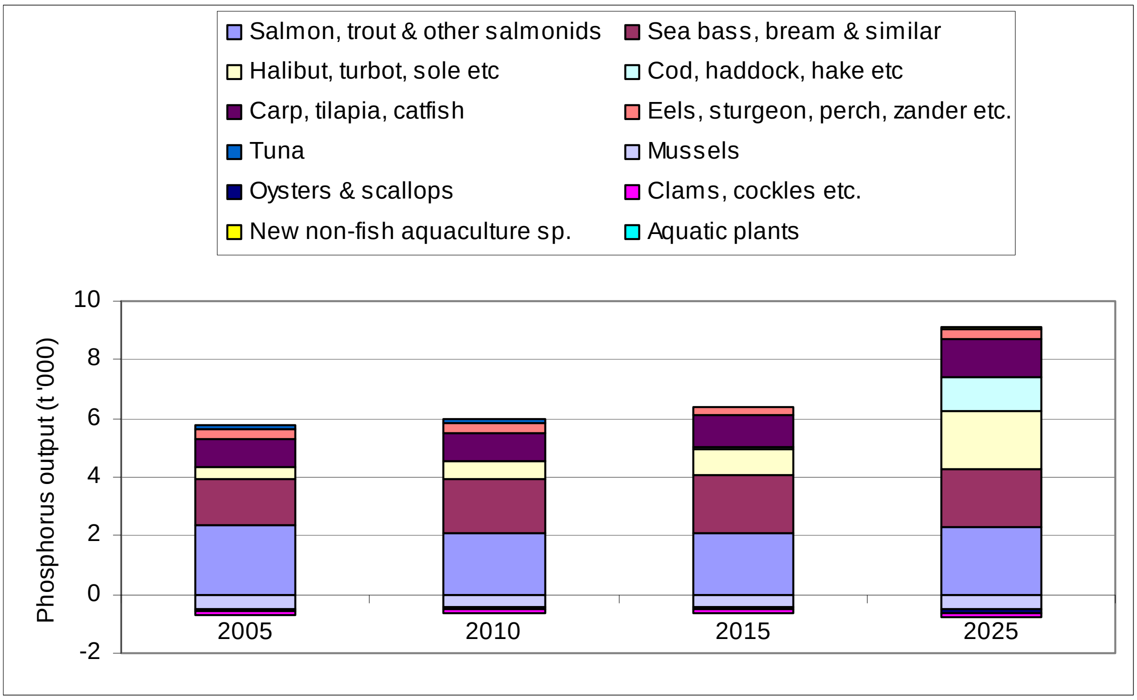


Figure 99: All scenarios – Carbon output

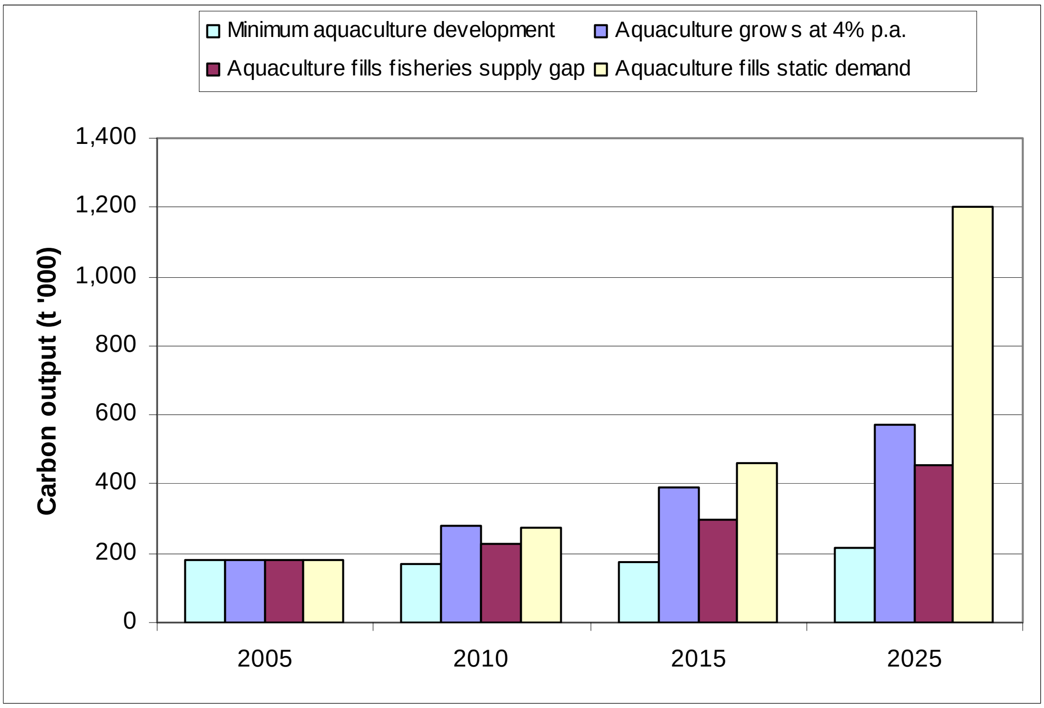
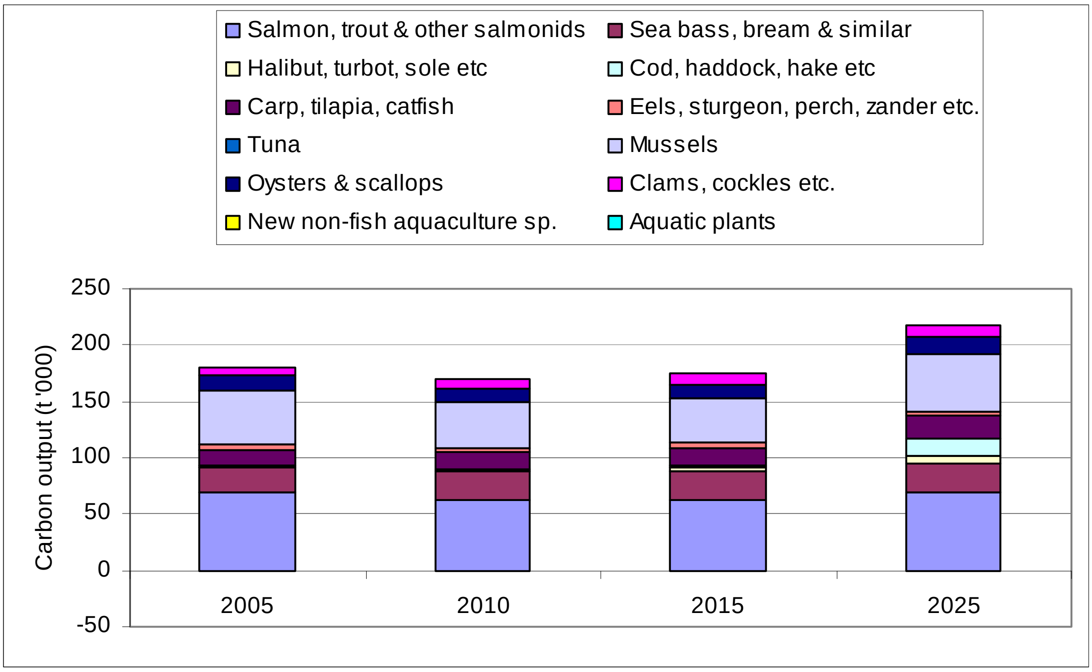


Figure 100: Baseline scenario – Carbon output.



The baseline scenarios suggest a 2.7 fold increase in production between 2005 and 2025, but a 4.1 fold increase in nitrogen, 6.3 fold increase in phosphorus and 3.2 fold increase in carbon output. This is due to an increased proportion of finfish in the aquaculture mix. Given existing concern over aquaculture waste output, it appears likely that regulators would wish to encourage this additional development to take place offshore, where the wastes are more easily dispersed and have lower impact, or produced in recirculated aquaculture systems where the waste streams can be captured and treated or utilised in a way that has lower environmental impact. These estimates do not account however for potential reduction in nutrient emissions due to improved diets or efficiency gains through better systems management or genetic improvements. These for instance might be reflected in improved feed conversion efficiencies. Alterations could also occur in waste nutrient profiles if fish meal is replaced to considerable extent with plant ingredients.

6.6 *Summary of scenario model results and implications for emerging systems*

6.6.1 Model development

The models presented above explore the potential for increased aquaculture production in EU Member States. They firstly identify potential market demand for fish and seafood products and compare this with supply from the capture fisheries sector. The shortfall in supply is then expected to be met through aquaculture and net imports from third countries. The implications of only part of the shortfall being met through aquaculture, or virtually all the shortfall being met through aquaculture are explored. The models are not intended to be predictive, but rather to indicate the development needed and associated implications of different options.

Table 28: Summary of main assumption scenarios used for modelling

Demand	Calculated as a function of population numbers multiplied by apparent average per capita fish and seafood consumption. Three main scenarios: (i) that per capita consumption does not change (ii) that per capita consumption continues to rise based on last 15 year trend (iii) that the per capita consumption falls again (inverse of growth rate) Price is not included as a factor at this level, as although clearly important, it is only one of a wide range of factors affecting overall fish consumption. Demand is not broken down by product group for the purpose of the model, but is a factor considered in the analysis. The first scenario is used as the demand baseline.
Capture fisheries supply	The status of different EU fish and shellfish stocks varies widely, and the capture supply scenarios do not attempt to break down supply by individual stocks. Three main capture supply scenarios are considered: (i) supplies are maintained at current levels (ii) supplies fall in line with recent trends at 2% per annum (iii) supplies fall in line with more catastrophic projections at 4% per annum. The second scenario is used for most of the models presented in the main report.
Balance of trade	The models assume that if there is a shortfall in supply from EU production, it will be met through imports. Net import calculations therefore depend only on the assumptions used for demand, EU capture and aquaculture production. They do not consider production trends outside Europe, prices, market preference or any other factors. In practice, the development of aquaculture in Europe will depend very much on its ability to compete effectively in both EU and export markets. For the purpose of policy development however, the potential deficit in production in relation to expected consumption is a useful indicator.
Aquaculture production	Four main aquaculture production scenarios are considered. Except for the first, these are target based: (i) Minimal development – current trend of decline continues for remainder of this decade, before reversing as the gap between production and demand rises (ii) To meet output targets derived from the EU 2002 policy objective of 4% annual increase in aquaculture production (iii) EU aquaculture develops to fill the gap left by capture fisheries declining at 2% per annum (iv) EU aquaculture develops to fill the entire gap between capture fisheries supply and expected demand. Within each scenario, 12 categories of aquaculture product are considered, and how these might develop in order to achieve the target production levels. Particular attention is given to the role of emerging aquaculture systems in achieving these goals.

Within the different production scenarios, growth rates for each product group were considered in 5-year blocks. The overall 20-year growth rates are compared in Table 29. The EU 4% growth target would now require an 8.4% per annum average growth rate to reach the same production by 2025 as would have been achieved by a 4% annual increase from 2000 onwards.

Table 29: 20 year average annual growth rates for different aquaculture product groups by scenario (2005 to 2025)

	Scenario 1 (minimal)	Scenario 2 (EU output target)	Scenario 3 (Compensate fisheries)	Scenario 4 (Meet all demand)
Salmon, trout & other salmonids	0.0%	7.4%	5.8%	16.9%
Sea bass, bream & similar	1.0%	7.7%	7.2%	23.9%
Halibut, turbot, sole etc	20.3%	27.8%	50.4%	130.0%
Cod, haddock, hake etc	5,462.5%	34,133.1%	14,721.3%	84,527.5%
Carp, tilapia, catfish	1.7%	26.4%	2.3%	39.3%
Eels, sturgeon, perch, zander etc.	0.3%	14.0%	43.1%	87.8%
Tuna	-5.0%	150.9%	132.2%	132.2%
Mussels	0.4%	2.5%	2.6%	7.4%
Oysters & scallops	0.4%	0.7%	0.7%	4.5%
Clams, cockles etc.	1.7%	0.5%	0.0%	2.3%
New non-fish aquaculture sp.	-0.3%	1,018.8%	1,727.5%	10,525.0%
Aquatic plants	-3.8%	231.3%	231.3%	146.9%
TOTAL	**0.9%**	**8.4%**	**6.1%**	**22.3%**

In this table, the product groups “cod, haddock, hake etc.” and “New non-fish aquaculture sp.” show very high percentage increases. This is an artefact of starting from very low production in 2005 (e.g. only 69 tonnes of cod). The resulting projection of 471,100 tonnes of production of these marine species by 2025 is high, but this growth rate was achieved by the salmon industry in Chile, and both the Norwegian and Chile marine cage aquaculture industries exceed 600,000 tonnes.

The scenarios assume that the growth rates in marine whitefish will be highest. This is a reflection that whitefish have historically formed the largest share of the fish market, so demand is high, but capture fisheries supply is declining. This should create opportunities for aquaculture, providing it can supply economically. Offshore aquaculture appears the most likely system to meet the volume demands projected. The technology is developing incrementally within the salmon, tuna and sea bass and sea bream industries with gradually larger cages moored in more exposed locations serviced by larger vessels etc. Newer marine species will borrow heavily from existing growout technology and could therefore be expected to scale-up faster than was the case with the more established species. There also remains the possibility of transformational change. This could come about through the development of a new offshore cage design that swings the production economics in favour of offshore farming. Competitive forces would then ensure rapid adoption, assuming appropriate regulatory measures are in place. The main centres of investment in offshore cage design at present are Norway and the USA, which suggests transformational development, if it occurs, is more likely to start outside the EU.

Good growth rates for (bluefin) tuna culture are also assumed in most scenarios if the life cycle can be closed and juveniles supplied from hatcheries. The grow-out sector is already in place, but is expected to be increasingly contrained through juvenile supply. A switch to formulated diets would also improve environmental sustainability and should be possible if juveniles are weaned onto dry diets at an early age.

Further development of recirculated systems for higher unit value species (both marine and freshwater) appears likely. This is assumed for species such as turbot, sole, eel, and perhaps perch and zander. Recirculated systems are also used for African catfish culture in Europe, which has low unit value, but can be cultured at very high densities. There is scope for substantial increases in production if the market were better developed. Several companies are also producing tilapia in freshwater recirculated systems, suggesting there is some optimism that economic production can be achieved and markets can be developed.

Except for the baseline model, all assume quite strong growth for salmonids, which are already the largest fin fish group cultured in Europe. Salmon has the best prospects if offshore farming is developed, but potential exists for freshwater trout and in some cases charr. This may be through greater industrialisation and use of recirculated water systems, or may be through functional diversification of fish farms and local product and label development. Elsewhere however, further contraction of traditional trout farms is expected due to increasingly restrictive environmental regulation, uncompetitive cost structures and failure to attract new entrants.

None of the scenarios assumes high growth rates for molluscs, since there is much less scope for substitution than between say whitefish species. Growth will depend on market development. Mussel farming is assumed to have the fastest growth rate since it is a lower unit value product and industrial scale farming operations are developing. More traditional shellfish bed style culture is less likely to expand due to growing pressures on coastal resources.

6.6.2 Model outputs

The model helps to answer questions such as "if the EU wished to eliminate its trade deficit with respect to seafood (by volume), as well as compensate for declining fisheries, how much extra area would be required and how many jobs would it create?" The key figures generated by the model are shown below.

Table 30: Summary of key indicators by 2025 for the four scenarios

	Scenario 1 (minimal)	Scenario 2 (EU target)	Scenario 3 (Compensate fisheries)	Scenario 4 (Meet all demand)
Aquaculture production (million tonnes)	1.48	3.37	2.80	6.88
Aquaculture value (€ billion)	3.64	11.01	9.69	27.40
Direct jobs	89,890	162,030	131,690	327,830
Land or water area required (M ha)	0.270	0.420	0.230	0.590
Water use (billion m^3)	3,429	6,975	6,048	13,108
Industrial energy used (M MJ)	181	527	419	1,091
Nitrogen output (t)	45,590	163,370	119,590	360,400
Phosphorus output (t)	8,330	30,940	25,100	74,060
Carbon output (t)	216,840	569,320	456,450	1,210,890

Note, Figures are rounded as appropriate

The model suggests that raising aquaculture output in line with earlier EU policy objectives would double the land and water area required. However, overall area usage would remain very small compared with agriculture (less than 0.5 million ha estimated, compared with over 6 million ha of terrestrial organic agriculture, which is only 4% of total agriculture)[37]. Of more concern would be increased output of nutrients (a 3.8 fold increase in nitrogen output for instance). However, this should be judged in the wider context. In comparison with the livestock sector for example, the additional

[37] Eurostat press release 80/2007 (12 June 2007)

nitrogen would be equivalent to increasing the European cattle population by around 0.7%[38]. More important would be how and where the nutrients are released. Offshore aquaculture would have very high waste dispersion characteristics, whilst recirculated systems provide greater means of control and removal for further processing or use.

The estimated direct usage of industrial energy (based on selected mix of systems) would triple if aquaculture develops to meet EU targets over the minimal development scenario. This increase of 346 million MJ is equivalent to the average annual energy usage of 4,600 European homes[39], or 10,500 people, which is around 1% of the annual European population growth. In terms of power generation it equates to a wind farm of about 15 turbines of 2.5 MW capacity each[40]. However, full lifecycle analysis (LCA) is needed to understand total energy consumption, as Grőnroos *et. al.* (2006) found feed production to be the major energy cost in Finnish trout farming.

Using constant multipliers, employment would more than double by 2025 if output matched the EU target growth rate of 4% per annum for aquaculture development. However, it is likely that price competition and market demand will result in the major increases in production volume through new marine fish production, especially in offshore systems that have much higher efficiencies. Employment per tonne of production however is greatest for small-scale artisanal and family-run farms, which might increasingly need to address niche markets to survive.

The scenarios outlined present a range of alternative interpretations and implications with varying degrees of likelihood of emergence. The spread and combination of determining factors is effectively impossible to predict with any certainty. However the impacts of the most likely scenarios have been identified and the wider implications of these for policy are discussed in the following concluding section.

6.6.3 Non-food aquaculture species

The models presented in this section have focused on fish as food. Aquaculture activities may also be carried out to produce fish for angling, ornamental purposes, or for the production of other biotechnology products including pharmaceuticals, fine chemicals and functional food components. These are not major activities within Europe, but can have considerable local significance.

The global trade in ornamental fish was worth US$ 0.9 billion (€0.68 billion) at wholesale values in 2000. This equates to at least US$3 billion (€2.28 billion) at retail values (FAO, 2007). Europe plays a large part in this trade, with imports of ornamental fish into EU-25 countries valued at around US$110 million (€85 million) in 2005[41]. Ornamental fish are produced to some degree in many European countries, however, by far the largest producer in the Czech Republic, with an export value of US$7.76 million (€6 million) in 2005[42]. Further expansion of this industry is anticipated, but unless there are major changes in the cost of transporting live fish, EU producers will continue to face substantial

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[38] An approximation based on a mean nitrogen output of around 100 kg per head per year for cattle (http://www.mfe.govt.nz/publications/climate/projected-balance-emissions-jun06/html/page11.html) and a European cattle population of approximately 130 million (http://cattle-today.com/)

[39] Calculations based on energy use per dwelling of 1.75 to 1.8 t oil equivalent per annum (http://themes.eea.europa.eu/Sectors_and_activities/households/indicators/energy/hh06households.pdf) converted to MJ using 1 toe = 42 GJ (42,000 MJ) (http://en.wikipedia.org/wiki/Ton_of_oil_equivalent).

[40] Typical turbine output is 2,628 MWhours/year per MW of installed capacity (http://www.westmill.coop/windfarmsites.php). Typical turbines are 2.5 MW capacity and 1 MWhour is equivalent to 3600 MJ.

[41] UN Comtrade data for classification HS2002/030110 Live ornamental fish (www.comtrade.un.org).

[42] Op cite.

competition from third countries with lower cost base. Successful ornamental production within the EU has focused on quality, or the production of higher value marine species.

Aquaculture is also providing stock for angling lakes throughout Europe. The European Anglers Alliance estimates the European leisure fishing sector to be worth at least €25 billion, of which €5 billion is in tackle sales[43]. This is almost ten times the value of food fish aquaculture production. An increasing number of aquaculture farms include leisure angling facilities, particularly in East and Central Europe, or the valliculture areas in Italy, where larger water bodies are forming the centre pieces for a variety of nature-based activities, include nature trails, angling and camping. In Scotland, 14.7 % of trout production is for restocking to "put-and-take" angling lakes, of which there were 287 in 2002[44]. Although unlikely to significantly increase total fish production, these initiatives greatly increase the value and employment multipliers for aquaculture, and for that reason should be taken into account in aquaculture policy development.

The potential for obtaining valuable fine chemicals, nutritionals and biologically active therapeutic compounds from marine organisms is continually under investigation. The major products at present are agar and carrageenan from seaweeds, but microalgae are also of interest for pigments, neurotoxins, polysaccharides, lipids, peptides and enzymes etc. Many other marine organisms are potential sources of future anti viral, anti-microbial or anti-cancer drugs. Already commercialised compounds include an antihelmintic insecticide from the red algae *Digenea simplex*; an antiviral (herpes) from the sponge Cryptotethya crypta, an anti tumoural compound from the sponge *Cryptotethya crypta*, and an antibiotic from marine fungi (*Cephalosporium sp.*)[45]. In some cases, once identified, a compound can be synthesized using chemical processes, or produced via bacterial fermentation (e.g. using genetic engineering approaches). In other cases, aquaculture of the species is the most appropriate solution. The high costs of product development, especially for pharmaceutical products, is likely to restrict rapid development in this area. Aquaculture for bioactive compounds will also be subject to the same competitive pressures as aquaculture for food products and would not necessarily develop in Europe even if the core development and primary market is here.

6.6.4 Export of aquaculture related goods and services

It should be noted that the models presented in this section do not take into account the value of aquaculture goods (e.g. feeds, medicines and equipment) or other services that are exported from Europe. Only goods and services sold within Europe contribute to measured turnover from European aquaculture production. There is little data available on the additional value of exports, but these may include for instance:

- Aquaculture equipment such as cages, nets moorings, tanks and water treatment equipment
- Aquaculture feeds, ingredients, pharmaceuticals, vaccines and diagnostic kits
- Information systems, software, monitoring and control equipment
- Analytical, consultancy, management and advisory services
- Contract research services
- Financial and insurance services
- Education and training

The greater the technological edge that Europe is able to maintain, the greater will be the prospects for, and potential value of these exports.

[43] http://www.eaa-europe.eu/docs/DEFINITION-EAA_Angling_Def_long_FINAL_EN.pdf
[44] Walker, 2002.
[45] European Science Foundation Marine Board, 2001.

7 Conclusions and Implications for EU policy

7.1 Policy implications of proposed scenarios

Some of the broad consequences and implications of the proposed developments in aquaculture are outlined below. These will have to be developed from current aquaculture related policy processes and are increasingly likely to link with existing or emerging policy areas in other sectors as the industry develops and expands.

7.1.1 Aquaculture policy

To ensure a strong aquaculture contribution to projected EU consumption demands, all of the scenarios propose a substantial growth in the European aquaculture sector between now and 2025, from around 2.3 to 7.5 fold. This requires a turnaround in the current sectoral trend for declining, if not negative, growth rates. It would be unrealistic to expect all sub-sectors to develop at the same rate, indeed some may continue to decline. It is more likely that major growth in volume will come from a smaller range of innovation-driven subsectors that reflect the earlier growth patterns of the salmon or sea bass and bream industries. However, existing EU policy on aquaculture has broader objectives than simple production targets, with commitment also to creating and sustaining employment, focusing on sustainability, product safety and quality, promoting animal health and welfare and ensuring an environmentally sound industry. In order to achieve this, it will be important to recognise enterprise diversity and especially the role for smaller-scale enterprises in generating rural employment and maintaining the diversity of specialist products. The capture of additional value through premium and niche marketing will be important strategies towards achieving these aims.

Whilst it is difficult to envisage substantial offshore aquaculture development other than through the actions of larger companies, land-based recirculation systems are potentially more scaleable, offering a greater range of business and marketing models. Such innovation among smaller businesses might be enabled through the formation of skill and infrastructure clusters.

7.1.2 Marine policy

The launch of the EU Green Paper on maritime policy in 2006 has placed greater focus on the future of marine aquaculture developments. Whilst aquaculture has relatively little specific coverage in this document, the prospect of moving aquaculture further from the coast is clearly noted with the acknowledgement that further research and development would be required to achieve this (EC, 2006). Interlinking with this initiative are the existing Water Framework Directive, covering river basins and estuaries, and the more recent Thematic Strategy on the Protection and Conservation of the Marine Environment, and the Thematic Strategy on the Sustainable use of Natural Resources. It is likely that these processes will encourage developments that minimise discharge of nutrients and other pollutants, or that harm biodiversity and fisheries conservation interests. It is perhaps too early to know what impact Integrated Multitrophic Aquaculture Systems might have on the development of marine policy in general or specific Integrated Coastal Zone Management Plans, as much will depend on the extent of integration considered, and the financial parameters which might define them.

There has been significant interest in developing synergies between aquaculture and other offshore developments, especially wind and wave power projects. The practicalities are highly challenging, but there could be benefits, not only in development cost, but also for staff security and facility servicing.

Various projects are studying marine aquaculture sustainability (e.g. the EU Consensus project, Scottish Executive High Level Indicators project, and Scottish Salmon Producers' Organisation Sustainability project). Indicators are required both for comparing aquaculture with alternative activities, and for benchmarking performance for future improvement.

7.1.3 Food policy and trade

The primary role of aquaculture is the supply of food, although it is also highly significant with respect to other policy drivers, as examined in subsequent sub-sections.

The significance of fish as food varies across the EU, ranging from 13% of protein consumption in Poland to 46% in Portugal (Table 31). Conservative values used in our models indicate a current EU-25 seafood market worth around €45 billion, rising to around €56 billion in 2025 (based on reaching EU aquaculture output production target). However, a recent study of the market for fresh and processed fish in 16 Western European countries (including Norway) calculated a total value of €69.4 billion in 2006[46].

Table 31: The importance of seafood in the diet of selected EU Member States, 2005

	Seafood as % of protein consumption	Protein consumption kg per capita	Seafood consumption kg per capita	Key species
Denmark	26%	89	23	
France	29%	116	33.7	Salmon, cod, haddock, Alaska Pollock, whiting, tuna, scallops, hake
Germany	17%	84,2	14.4	Alaska Pollock, herring, Atlantic and Pacific salmon, tuna
Italy	25%	100.8	25.0	Whitefish
Poland	13%	67.5	8.6	Herring, mackerel, salmon
Portugal	46%	124.0	56.9	Cod, hake
Spain	34%	130.2	44.7	Tuna, hake, salmon, cod, mackerel
United Kingdom*	21%	95.5	20	Salmon, cod, haddock, shrimp

Source: Adapted from Glitnir, 2007

National food security appears to be a lower priority as markets become more globalised, although there are important links with health policy, as seafood is generally recognised to be the healthiest of the meat protein sources, particularly with respect to the provision of essential omega 3 fatty acids. However, balance of trade remains a critical economic parameter and the seafood sector is large enough to have a significant impact. FAO Fishstat data suggests a trade deficit of US$8 billion (€ 6.7 billion) in fisheries products in 2004. This compares with an overall EU-25 trade surplus of €16.2 billion in 2005 and deficit of €8.2 billion in 2006[47]. In some respects however, the deficit in seafood trade is offset by the addition of value to imports. This can range up to 75% in the case of some products, supporting jobs and economic activity. The overall economic impact of imported seafood is therefore most likely positive when compared with an alternative of lower seafood consumption, providing the latter did not involve substitution with an alternative food with greater economic benefits.

[46] Research and Markets (2007)
[47] http://www.bloomberg.com/apps/news?pid=20601085&sid=ahXSwyIY_3Ko&refer=europe

EU food policy is not only concerned with quantities, but also quality and actively supports diversity in food production methods and the preservation and promotion of distinctive foods through the PDO, PGI and TSG[48] schemes. Three aquaculture products already have PGI designation while a fourth one has received PDO designation, so this could be extended further to help develop both home and premium export markets. Food policy is also concerned with the environment, animal welfare and food safety, all of which are key issues for aquaculture, affecting practices in most sub-sectors of the industry. A key concern of European producers, and perhaps increasingly for consumers, will be that aquaculture products imported into Europe will be produced to the same welfare and safety standards demanded of EU producers. The issue of food miles could also become more a more prominent feature of consumer purchasing behaviour, perhaps with greater impact than rising fuel prices alone. For the present however, a lower cost of production outside Europe may be expected to continue to encourage investment in overseas production for targeting at the European market.

7.1.4 Enterprise and innovation policy (including research)

It is important to differentiate between incremental innovation and transformational innovation. The former is critical to the successful development of an industry, but it is the latter that triggers the use of new approaches and sets off substantial growth. Incremental innovation is mostly achieved through the adoption of new technologies by the industry, and the advances made by supporting research and development. Transformational innovation may originate from within the industry, but often it comes through new entrants to the sector introducing a new technology or approach. Recent trends for close involvement of the industry in defining R&D priorities are welcome and particularly help to optimise incremental innovation. Providing scope for R&D in support of transformational innovation is potentially more challenging, but also important.

EU RTD programmes have been particularly successful in creating collaborative approaches to RTD and the development of strong consortia with a broader and deeper range of skills and resources to bring to bear on an issue. However, there are questions about how these consortia are formed, the appropriate scale (funding and membership) and degree of turnover (research topics and members). There will clearly be continual tensions between the virtues of top-down planning and allowing for bottom-up initiatives.

Considerably less attention has been given to the issue of technology transfer as a strategic objective. All RTD projects are now expected to either have a mechanism for commercialising or disseminating their results. Much technology transfer is through commercial trade (equipment, feeds, pharmaceuticals etc.) whilst trade journals and educational institutions also play a significant role. Nevertheless, this can still leave a gap that has previously been addressed through government extension services. There would appear to be potential benefits in developing new and more targeted initiatives in this space, probably involving producer associations and other groups able to collaborate on achieving specific subsectoral strategies.

7.1.5 Social policy

The clear priorities at EU level are set out in the Lisbon Strategy. The agenda focuses on providing jobs and equal opportunities, and on ensuring economic growth where the benefits reach everyone in society. The target of more jobs suggests that promotion of smaller enterprises might be preferred to larger enterprises with respect to aquaculture. However, this must be balanced against international

[48] "Protected Designation of Origin", "Protected Geographical Indication" and "Traditional Speciality Guaranteed" respectively.

competitiveness. Larger enterprises are generally able to develop more efficient management structures and invest in greater levels of automation.

The quality of employment is also a key concern. Establishing mechanisms for continuing education and training, and enabling a culture within industry that values personal advancement and initiatives would clearly be desirable, but often proves difficult for companies operating in a competitive environment. Aquaculture is probably not a special case in this regard, and generic policy measures might be expected to have some influence. Aquaculture is more distinctive in that most activity is conducted in rural and coastal areas where alternative employment opportunities are often limited. Greater emphasis could be placed on the role of aquaculture in local development opportunities, which allows for local added value to be identified and realised.

7.2 Discussion

7.2.1 Patterns of demand, processing and value addition

Seafood is a far more complex market than other meats due to the wide variety of species and meat types as well as wider variety in sourcing, uniquely including capture as well as a full range of farming methods. A simple analysis suggests that whitefish comprise the larger proportion of seafood supplies, and therefore predicted growth in demand due to population expansion will mean demand for whitefish increasing more than other types in terms of total quantities (at least at the global level). The situation is exacerbated by whitefish stocks being under the most pressure and therefore most vulnerable to collapse.

Closer examination shows that much of the whitefish volume is relatively low-value, and that this is not a sector currently addressed by European aquaculture. A prospective analysis based on expansion of existing supply patterns suggests only modest growth in current aquaculture species will be required, but that major opportunities will emerge for aquaculture-produced low-value whitefish. Whether this is possible in Europe is discussed further later in this section.

Recent trend data indicates apparent consumption of white fish is falling in the EU and Norway. This is compensated (although not entirely), by increasing apparent consumption of salmonids, crustaceans and molluscs – all sectors serviced by aquaculture. Markets appear to be adapting to changes in supply with substitution occurring as price differentials are either eroded or reversed. This suggests that much of the overall future supply gap could be fulfilled by expansion of existing aquaculture species, with volumes primarily determined by the lower price levels that can be achieved.

A combined analysis would suggest that the greatest opportunities for volume expansion will exist for lower-value whitefish, but that there is ample opportunity for other species to increase market share. Account must also be taken of the increasing sophistication of the food market generally and seafood market in particular. In most of Europe, there is an increasing variety of value-added seafood products. The processing sector has increasingly exploited the potential for adding value to fish raw material to appeal to varied target groups. This has also provided a route for lower-value species to gain greater market share. For such products, little marketing focus is placed on the original source of the raw material. White fish is likely to retain a dominant position, subject to price constraints, largely because of the versatility of the raw material. A raw material capable of transformation into a variety of different value-added products enables creation and incorporation of additional attributes such as the desire for convenience in pre and post-purchase handling and preparation. With a more homogeneous raw material base processing costs can be driven down and the wide range of products possible enables increased profitability. Many of the non-white fish species and molluscs do not have this versatility and have more finite constraints on their acceptance. Whitefish based products span a very wide range of price-points with premium ranges expanding. However, the main volume is in everyday value products where price is critical.

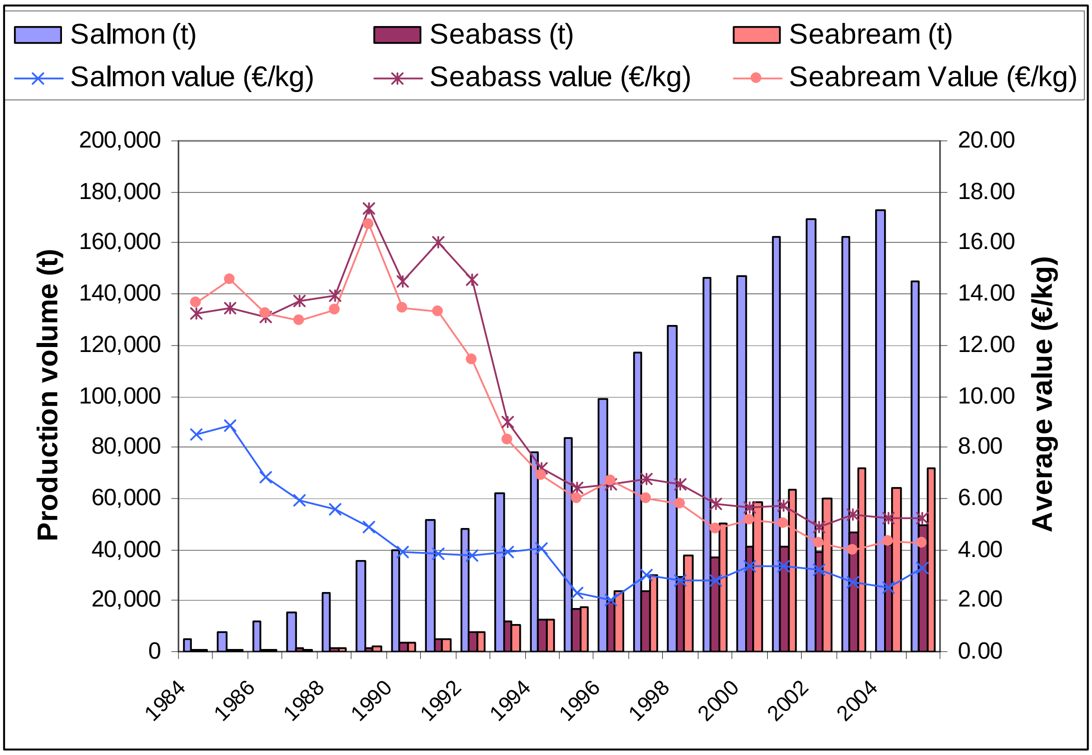
In addition to format, value addition involves positioning with respect to quality. This is a more complex concept involving both subjective sensory aspects as well as intangible values. The latter are particularly important in premium products. Increasing consumer awareness and concern with respect to environmental, health and food safety issues is therefore encouraging differentiation and value addition based on material sourcing e.g. through the use of organic, welfare and eco-label certification schemes. The health benefits of fish are also an important component of the quality offering. However there are countermanding signals in the market, for example the benefits of omega 3 set against the problems of contaminants in salmon. Health scares associated with the food industry have typically been short lived, with the exception of BSE and the resultant export ban for nearly 10 years, but their impact remains difficult to assess. Periodic reminders such as the recent outbreaks of bird flu in the EU reinforce consumers about food scares and may invoke negative responses. However these need not necessarily work to the disadvantage of fish, as witnessed with rising demand during the UK outbreak of avian flu in 2007. Knowledge of consumers' longer term responses to food scares is not clearly understood. Some opine that overexposure to successive food scares tends to encourage more risk averse behaviour. Others still may become yet more frantic in ensuring alleviation of their perceived risks through traceability, verification through certification, ensuring compliance with environmental criteria and husbandry practices, trusted market channels and other behaviours.

7.2.2 Positioning of aquaculture produce in the market

An important issue for aquaculture, of all types, will be to build public confidence in its products. In addition to the food scare issues discussed above, farmed seafood is often regarded as inferior to capture seafood, particularly in coastal countries used to plentiful capture fisheries supplies. Nevertheless, with increased publicity concerning declining stocks and biodiversity, aquaculture produce is becoming more widely accepted. Examples of aquaculture produce achieving a premium over the captured product are rare, but examples such as Shetland nocatch cod suggest opportunities are there to be exploited. Attributes such as environmental and social benefit for instance could be given more attention by producers. More specifically, if environmental externalities are increasingly to be drawn into policy, concepts of value per unit of environmental capacity may also gain strength.

Most of the growth in European aquaculture over the last 30 years has depended on the exploitation of new technologies (particularly for marine fish farming) and a strategy of targeting high value products that justified relatively high initial production costs. This approach was exemplified by the Atlantic salmon sector in its early expansion phase, following which significant production increases and market expansion settled the product in the lower price ranges.

Figure 101: EU-25 salmon, seabass and seabream aquaculture production and average unit value



Source: Developed from FAO Fishstat database, 2007 (Conversion from US$ to € values using average annual inter-bank exchange rate values)

Similar developments have been seen in seabass and seabream. By contrast most freshwater species, with the exception of sturgeon and eels, have been lower priced. This broad pattern of new species being launched at initially high prices then followed by a relatively rapid price decline is likely to be maintained. Although the 'honeymoon period' of higher prices and enhanced profitability is liable to be increasingly short-lived as more species are launched. Each successive new entrant has to compete with a yet wider array of alternative products at price levels commonly depressed by their earlier cycle of rapid expansion. Given an increased choice, the propensity for prospective consumers to purchase at prices higher relative to alternative options is diminished.

As the number of species available from aquaculture increases it is less likely that each one will command a discrete position within the market. Whilst it seems reasonable to expect that consumers will continue to harbour preferences for particular species, as reflected in the price differentials for wild captured supplies, so too is it likely that the tendency to commoditisation of fish, again evident in the wider market for fish will embrace farmed supplies too. This increasing difficulty in identifying a unique species proposition in the market tends to focus emphasis upon price and thus cost reduction to maintain profitability. Indeed it may be conjectured that because prevailing (pre-launch) market prices play some role in R&D decisions about which species to farm and launch, and that these values in turn reflect some engrained contexture of consumer preference for similar attribute combinations, there may be a greater inherent tendency for farmed products to be perceived as more similar, a more uniform commodity, than the natural greater diversity of product available from capture fisheries. If so, this will accelerate the need for aquaculture producers to consider alternative routes to maintain profitability other than simple species diversity. Strategic considerations might for instance include:

- Relative pricing positions of fish groups vis a vis other competing products
- Price trends in capture supplies and dominance of their influence upon the market
- Aquaculture product prices liable to be heavily influenced by productivity gains enabling cost reductions.

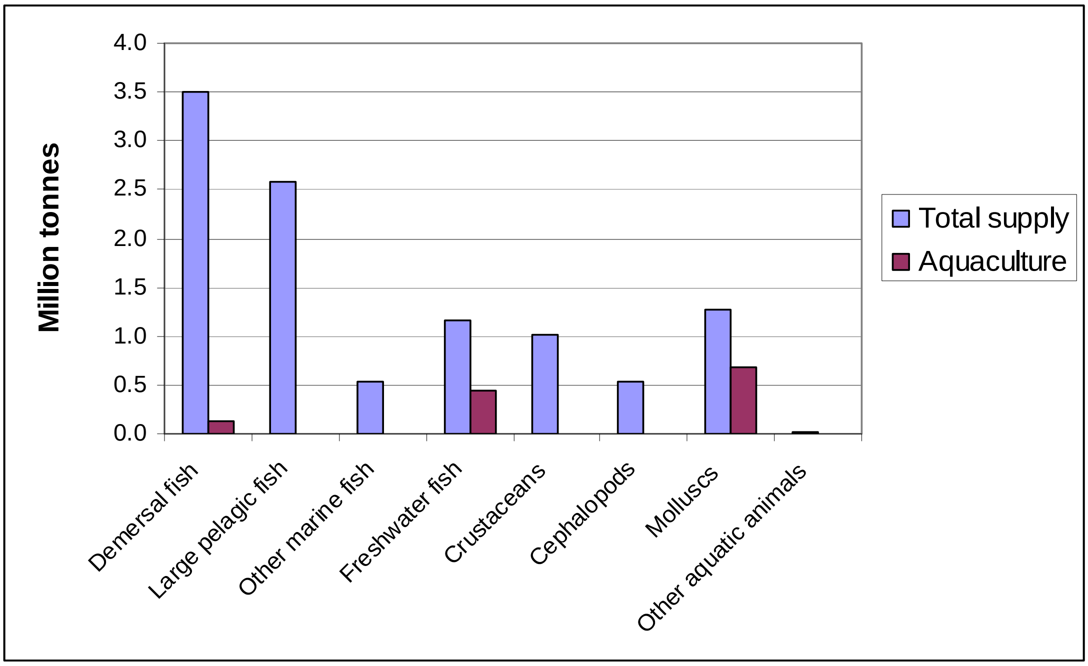
- Attempts to position products at artificially high price points liable to be successful only temporarily as most producers have similar access to technical innovation and entry barriers thus making it difficult to sustain any product advantage.
- Fish must compete with other established protein sources (chicken etc) which have witnessed success in productivity gains.
- Some respite from intensive food production trends possible in niche markets, but even in food-scared markets and other enviro-driven factors, consumers tend to be premium averse for every-day purchase decisions.
- Positioning of products with high price points based on evermore esoteric attribute advantages is vulnerable to ennui of risk aversion, and other demands on disposable income.

7.2.3 Future expansion of the European aquaculture sector

In 2002, the Commission set a target for aquaculture production to increase by 4% per year. Available statistics to 2005 (assuming they are accurate) suggest that this is not being achieved, with a negative growth rate recorded in 2005. The target itself appears reasonable in light of available projections for demand and supply, especially from the capture fisheries sector. It would more or less keep domestic (EU-25 better than scenario 3) production at constant levels if capture fisheries continues to decline at up to 2% per annum. If capture fisheries are sustained at current levels, a 4% per annum growth in aquaculture could eliminate Europe's trade deficit in seafood products if consumption also remains stable. However, if achieved, the target would lead to an almost threefold increase in aquaculture production by 2025. With growing pressures to limit or reduce exploitation of inland and coastal waters in most EU-25 countries, this looks unlikely unless new aquaculture technologies are adopted, most likely involving offshore systems or land based using recirculated aquaculture systems. At present, the primary obstacle to this development is economic, although regulatory and other barriers exist, especially for offshore farming. On present trends it appears likely that investors will be attracted to lower-cost conventional systems in Africa and perhaps South America, targeting the European market.

Figure 102 shows the total supply (production plus net imports) of major seafood groups compared with EU-25 aquaculture production in 2005. This illustrates the relative vulnerabilities if capture fisheries declines, or imports constrained. Aquaculture makes the greatest contribution at present to freshwater fish supplies (which include salmon) and to molluscs. It makes only a very small contribution to marine whitefish or pelagic supplies, and no contribution to cephalopods, although these are all groups that are expected to be targeted for aquaculture development in the future. Tropical aquaculture provide a substantial share of global shrimp supplies, and some other crustaceans, but is limited to small scale crayfish farming in Europe, with less sign that this will change in the foreseeable future.

Figure 102: EU-25 aquaculture production compared to total apparent seafood consumption 2005



Source: Developed from Eurostat and FAO Fishstat databases, 2007

There is undoubtedly room for some substitution within and between these groups, but demand for core species such as cod and tuna can be expected to remain high. This again highlights the need for technological breakthroughs in the marine fish farming sector, especially with respect to juvenile production.

Currently marine white fish aquaculture is dominated by two species in Europe; sea bass and gilthead sea bream. There is growing pressure to substitute some of the lower-value marine whitefish with cultured freshwater species. The leading freshwater species (excluding salmon and trout) is carp, but there is limited scope for increasing carp aquaculture along traditional lines, although it could be a candidate for recirculated intensive systems. However, species such as tilapia and catfish offer a more versatile fillet and shorter production cycles. At present, these species are more cheaply produced in tropical pond and cage systems. Substituting these species for traditional marine fish in products such as fish fingers is more challenging though due to taste and especially texture differences. Sea bass and sea bream also suffer with respect to processing flexibility and so far, production costs also limit market expansion. Cod is a more flexible product and in the long-term there is scope to bring production costs in line with those of salmon. A number of advances have already been made and the prospects for substantially increasing production are looking ever more promising. In 2003, the first breeding programmes for Atlantic cod were initiated resulting in around 200 viable families by 2005 in Norway alone. The Icelandic firm Icecod Ltd. have also produced many viable families and Canada is also carrying out work in this field. Advances have also been made in reducing spinal deformities through improved culture and grading methods, however much work is still needed in preventing early maturation, nutrition, disease and larval survival. Norwegian juvenile production has increased from 1m in 2001 to 5m in 2004 and the aim is to produce 100,000 t of cod every year from 2010 to 2015. However setbacks are an integral part of R&D, as has been borne by the experience of one of the larger producers which, in 2007, has been reported as losing all its planned production due to an outbreak of disease. Meanwhile Iceland is hoping to produce 7,000 t in 2007, an increase from 600 t in 2004. (Björnsson *et. al.*, 2005). However these impressive aspirations, if met, would still not match the total capture production of EU-25 and Norway in 1975 which was over 1.3m t (declining to less than 0.4m t in 2004).

In projecting future developments it is important to note also the export potential for higher-value species. Virtually the entire production from the bluefin tuna fattening industry was for export to Japan (6,546 tonnes worth €80m in 2004 according to FAO statistics). The balance of trade for trout products (Exports from EU-25 to rest of the world, minus imports to EU-25 countries from the rest of the world) was over 3,000 tonnes worth approximately €10.45M in 2005[49]. Where Europe has competitive advantage by virtue of natural resources and well developed service sector, there are good prospects for expansion beyond domestic market requirements. Markets for salmon for instance are growing rapidly in parts of Asia[50] but EU production is modest in comparison with Norway and Chile, and mostly in Norwegian ownership. This left Europe with a deficit in salmon products of approximately €1.45 billion (412,000 tonnes) in 2005[51]. Competitiveness is therefore critical, and it remains to be seen whether EU countries can compete as the marine whitefish industry expands. It is less likely that large export industries will develop on the basis of recirculated systems (although these will probably be involved in hatchery and nursery phases of some export species). This is because part of their competitive advantage is likely to be their versatility with respect to location and potential for siting close to target markets.

Overall there are good prospects for steady expansion of European aquaculture based on further species and product diversification. For substantial volume expansion in line to upper demand projections there will be a need for a breakthrough in low-cost whitefish production.

7.3 Conclusions

The EU has an active and high quality science and technology base for aquaculture, and processes of knowledge exchange and building are improving; links between industry and research centres are still not strong enough to create a genuinely objective-led approach to sector development.

Particularly through the most recent expansion, EU territories and economies have considerable potential for upgrading investment, technology application, production and economic output, and it would be appropriate to define medium to longer term horizons for achieving these. Domestic demand associated with rising average incomes, changing food preferences, and more competition for traditional aquatic food supplies will provide a strong potential for growth. Export of products and services will also have a strong potential. Both require a sound science and technology base. Fish is a healthy product able to compete favourably with other substitutes and for which high prices can be commanded. Issues of variations and differentiation within the market create further niche and commodity opportunities for a diverse basis to supply.

Though the size of the domestic industry has grown significantly in the last two decades, and is likely to expand further, margins on the increased turnover and on the associated supply and service sectors have not been sufficient to create a major technology incentive of the scale found in other technically driven sectors such as energy, ICT, health care and pharmaceuticals.

The EU market role as a higher income consumer of global aquatic products gives it a particular position in defining product standards and quality attributes, which in turn creates technology drivers in supplying countries. Opportunities to ensure moves towards compliance with market standards in developing countries vary, but there is a strong regional argument for ensuring EU expertise through partnerships, commercial ownership or joint initiatives across the global supply networks.

[49] Calculated from UN Comtrade data using HS2002 codes 30191, 30211 and 30321.

[50] See http://www.infofish.org/marketreports/salmon0507.html

[51] Calculated from UN Comtrade data using HS2002 codes 30212, 30322, 30541 and 160411 which include some Pacific salmon products

Related to this, market and other commercial information, and a clear sense of the competitive advantages achievable through different policy environments, agroecological conditions, technology application, enterprise behaviour and technical skill, needs to be developed further, so that EU States can be intelligently positioned for domestic supply, export of product and services, productive investment and sustainable high returns on its natural resources.

Drivers associated with energy, carbon footprint, resource use and environmental protection are likely to dominate supply options and market sourcing decisions, closely matched with concerns for food safety and for ethical/animal welfare standards. Current and emerging technologies will be critical in meeting demands, and will confer competitive advantages on producers, market intermediaries and retailers alike. Arguably one of the biggest drivers at EU level is the ability of food retailers to establish an even more pre-eminent position in global markets. There is a need for a clear understanding of the drivers in carbon footprints – possibly moving away from cruder food miles debates to more comprehensive life cycle assessments that incorporate how food is produced, distributed, purchased and prepared. This has implications for models of local small scale aquaculture production.

There remains a need for holistic technology perspectives for the aquaculture sector, in which the overall efficiency of performance – judged by key criteria linked to profitability, environmental risk and social acceptability, can be defined and targeted. Simple measures such as energy efficiency, food conversion or volumetric productivity will not in themselves be sufficient, and policy makers, industry and technology developers will require to share and develop perspectives to ensure better overall technology performance targets. From this in turn could be derived more effective sectoral goals and criteria for R&D investment.

A number of global perspectives will also be expected to connect with this theme – examples include the ''ecosystem approach to aquaculture'' currently being explored as a policy tool, perspectives on ecosystem-linked economic risk, concepts of corporate social responsibility and technology partnerships bridging higher and lower income countries; expansion of global rights to safe food, and changing global security and trading relationships. It is beyond the scope of this review to comment on the potential scenarios across this wider field, but important to note that a well developed sectoral technology perspective will be essential, not just theoretically, but as a shared resource amongst EU stakeholders associated with the sector.

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Abstract

This report is based on the outcome of the study on "Prospective analysis of the aquaculture sector in the EU", launched and coordinated by the JRC (IPTS) and carried out by the University of Stirling. The report consists of two parts:
1) "Prospective analysis of the aquaculture sector in the EU - Part 1: Synthesis report", and
2) "Prospective analysis of the aquaculture sector in the EU - Part 2: Characterisation of emerging aquaculture systems."
This first report sets out the context for the future role of aquaculture in the EU, and the potential directions to be taken within the sector. It builds from materials reported in Part 2, and is structured by the outcomes of a review/expert panel meeting carried out in Sevilla, in November 2006 in which a process and system of synthesis was agreed. It follows a format in which we:
- Project potential future demand for aquaculture-derived product, recognising domestic supply and international trade features, emerging consumer trends, and expected price positioning commensurate with sector production costs.
- Develop further detail with respect to species, subsectors, systems, locations, and their interactions.
- Set out issues and discussions on implications for future policy.
- Develop conclusions.
These projections and details were further developed through a process of discussion and comment with the expert panel during the period March-August 2007.
The study was conducted between January 2006 and November 2007, the data collection taking place in the early stages followed by the analysis in the later stages.

The mission of the JRC is to provide customer-driven scientific and technical support for the conception, development, implementation and monitoring of EU policies. As a service of the European Commission, the JRC functions as a reference centre of science and technology for the Union. Close to the policy-making process, it serves the common interest of the Member States, while being independent of special interests, whether private or national.

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