Towards Sustainable Aquaculture in Europe

consensus
SUSTAINABLE AQUACULTURE IN EUROPE

CONSENSUS: a Multi-stakeholder Platform for Sustainable Aquaculture

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CONSENSUS is an initiative that works towards sustainable European aquaculture by building sustainable aquaculture protocols that are based on low environmental impact, high competitiveness and ethical responsibility with regard to biodiversity and animal welfare.

CONSENSUS is steered by the principal European stakeholders - the European Consumers' Organisation (BEUC), the European Bureau for Conservation and Development (EBCD), the Federation of European Aquaculture Producers (FEAP), the European Mollusc Producers Association (AEPM/EMPA), the European Feed Manufacturers Federation (FEFAC) and the European Aquaculture Society (EAS).

SIXTH FRAMEWORK PROGRAMME

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CONSENSUS is at www.euraquaculture.info

Towards Sustainable Aquaculture in Europe

Commissioner's Foreword

"The CONSENSUS initiative is making progress on two important issues related to the European aquaculture sector. The first is the involvement of stakeholders in the identification of desired trends and sustainability indicators to measure progress towards those objectives. The second is the provision of science-based information to consumers, through their representative associations across Europe. Research has been a strong driver for aquaculture development over the last two decades, and the Commission supports CONSENSUS, as we encourage the sector to continue to move further along the path towards sustainable aquaculture in Europe."

European Commissioner for Fisheries and Maritime Affairs, Joe Borg

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An introductory message from the Marine Conservation Society

Due to the rising demand for fish and shellfish, aquaculture is predicted to have an increasingly important role in providing a protein source for future generations. It is therefore essential that consumers are well informed about the role aquaculture plays both in providing a continuing source of fish and in the interaction it has with the local and wider environment. Historically there has been a lack of concise yet comprehensive information aimed at the European consumer specifically about aquaculture. Considering the complex nature and diversity of aquaculture production within Europe it is important that information relating to aquaculture practices is well informed, up to date and well balanced.

As an independent organisation not involved in the CONSENSUS project development MCS can see the value this document plays in providing important information for the European consumer to allow them to make informed choices and influence the market. In our own aquaculture work, the MCS Principles and Criteria for Sustainable Fish Farming, we worked in conjunction with a number of key stakeholders via a consultation process, to fully define what we believe to be best environmental practice for UK marine finfish production. This CONSENSUS project document reflects the shared aim that we have for improving the overall environmental performance of the aquaculture industry and empowering consumers to drive its long term environmental sustainability.

The Marine Conservation Society (MCS) is the UK charity dedicated to caring for our seas, shores and wildlife. MCS provides information to consumers about the sustainability of the seafood choices they make from both wild and farmed sources via our website www.fishonline.org, where over 150 species of fish and shellfish are listed with specific advice for each. The Society has also developed our own Principles and Criteria for Sustainable Fish Farming that can be accessed at www.mcsuk.org

MCS Marine Conservation Society

If we can farm the land, we can farm the waters

Fish farming and shellfish cultivation in Europe have a long history. From the storage of oysters in tidal pools in Italy in Roman times and the creation of managed ponds for carp production in Hungary in the early medieval period, to the farming of a broad range of marine species in recent decades, aquaculture has now come of age.

This document offers science-based information on the many efforts to further increase the sustainability of European aquaculture. The future of this growing sector will only be secure if all stakeholders in the supply chain, from producers and processors to transporters and retailers, adopt a responsible attitude towards the sustainability of the sector as a whole. One part of the industry cannot achieve this alone.

Like many sectors that deal with our food supply, the European aquaculture sector faces many questions. Food security, to name one example, is an issue of increasing importance. Another one will involve genetic modification. The Federation of European Aquaculture Producers (which represents more than 80 percent of European finfish production) has a clear policy of not using GM organisms until more knowledge is acquired, so we are not likely to see GM fish being used in the near future. However, the replacement of fish meal by vegetable proteins as a strategy to ensure feed sustainability could well mean that it will be increasingly difficult to use certified non-GMO aquaculture feeds.

While the European aquaculture sector is very diverse, it remains but a small part of global aquaculture production. Around two thirds of European demand for seafood is currently imported; approximately one half of seafood sold in Europe is farmed. It follows that sustainable aquaculture production in Europe will probably not be able to fully satisfy European demand for farmed seafood products. In the future it will therefore also be necessary to demonstrate the sustainability of aquaculture in other parts of the world, even though the criteria for measurement will probably not be universal.

I very much hope that readers will find the information in this document helpful and that it will contribute towards the development of their thinking on aquaculture. One of the key messages is that European research has strongly driven developments in the sector in Europe over recent years and is underpinning both policy and legislation. Reference material supporting the information presented here is provided on the CONSENSUS web site.

As we are learning to farm the land in a sustainable way, so too are we moving ever more closely towards sustainably farming our seas and inland waters. Aquaculture does have advantages for discerning consumers in terms of sustainability, safety, affordability, traceability and biodiversity. I am pleased to highlight these through this collection of science-based facts.

John Godfrey OBE, FRSH
Chair of the CONSENSUS Steering Committee
Representing the European Consumers' Organisation (BEUC) within the initiative

Farming replacing hunting

When it comes to seafood, consumers face a paradox.

Health researchers agree that ***people should eat more seafood*** *– and this is confirmed by advice from our doctors and health institutes.*

However, conservation organisations are telling us to make sustainable choices in the seafood that we eat. With only a proportion of the total seafood available being currently certified as sustainable, this has the impact of reducing the supply available to meet a growing demand.

If we can farm the land, why can't we farm the sea and inland waters? CONSENSUS partners are convinced that aquaculture can work in harmony with the environment to create a sustainable source of seafood to satisfy increasing demand.

Aquaculture has unique advantages for the discerning consumer:

- *Sustainability: aquaculture is an increasingly sustainable complement to the traditional fishing industry.*
- *Safety: seafood produced by aquaculture lends itself far more to quality control than product harvested from the wild.*
- *Affordability: seafood produced by aquaculture is generally more affordable than fish caught in the wild.*
- *Traceability: cultured products can be traced back right to the egg and to the parent fish.*
- *Biodiversity: aquaculture can also be used to restock depleted fisheries for a wide variety of species.*

We are more aware now than ever before of the benefits of eating seafood, and information and advertisements that portray the benefits of omega-3 fatty acids and the other nutrients contained in seafood for our health and wellbeing are abundant. Our doctors and nutritionists also confirm this need. Health supplements containing fish oils and functional foods, such as enriched milks and margarines containing omega-3 fatty acids, are widely available, although there seems to be agreement that the best source of omega-3 is seafood.

> "In themselves, omega-3 fatty acids are not enough – you need to eat fish. Seafood is rich in antioxidants, fat-soluble and water-soluble vitamins, easily digestible proteins with special amino acid composition, minerals, trace elements and fat of the healthy, polyunsaturated type. We have carried out a clinical study that shows the uptake of omega-3 is three to four times greater from salmon fillet than from fish oil."
>
> ***Professor Edel Elvevoll, University of Tromsø, Norway.***

While demand is rising, supplies from wild fisheries are either static or falling. How can we bridge the gap?

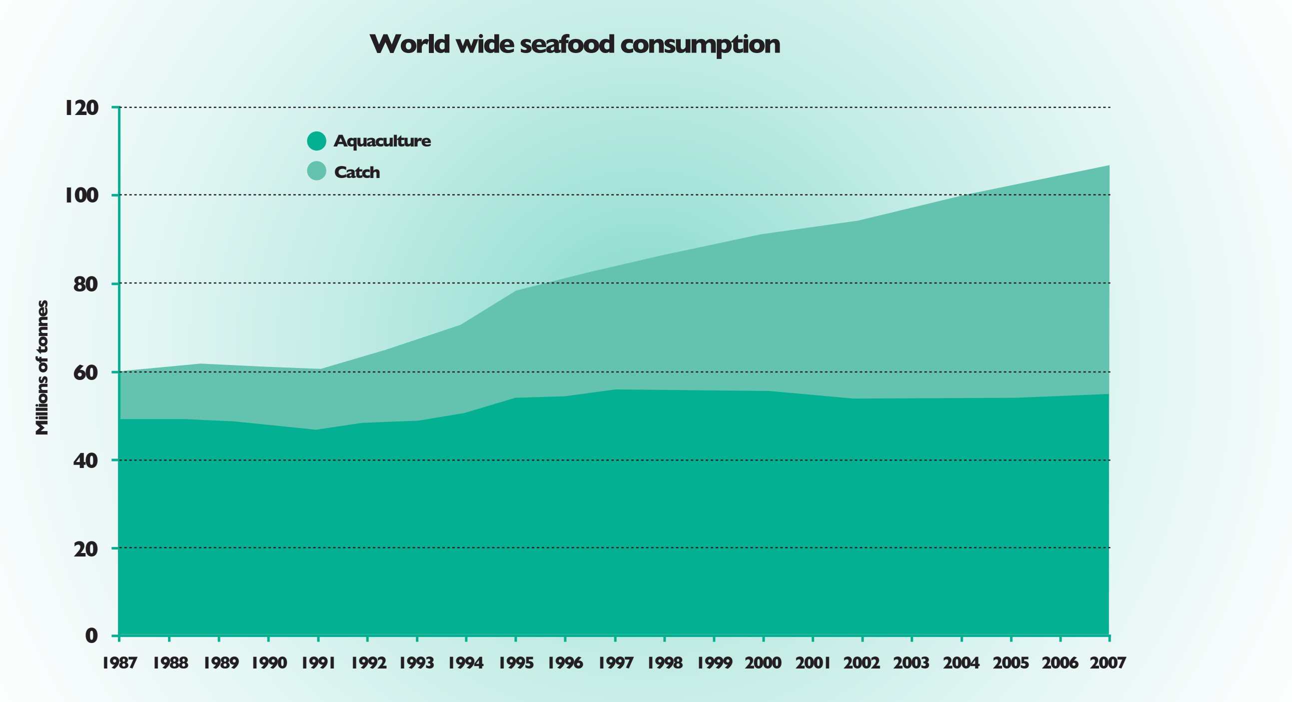


Figure 1:The share of worldwide seafood consumption coming from aquaculture and capture fisheries. Courtesy Kontali Analyse AS.

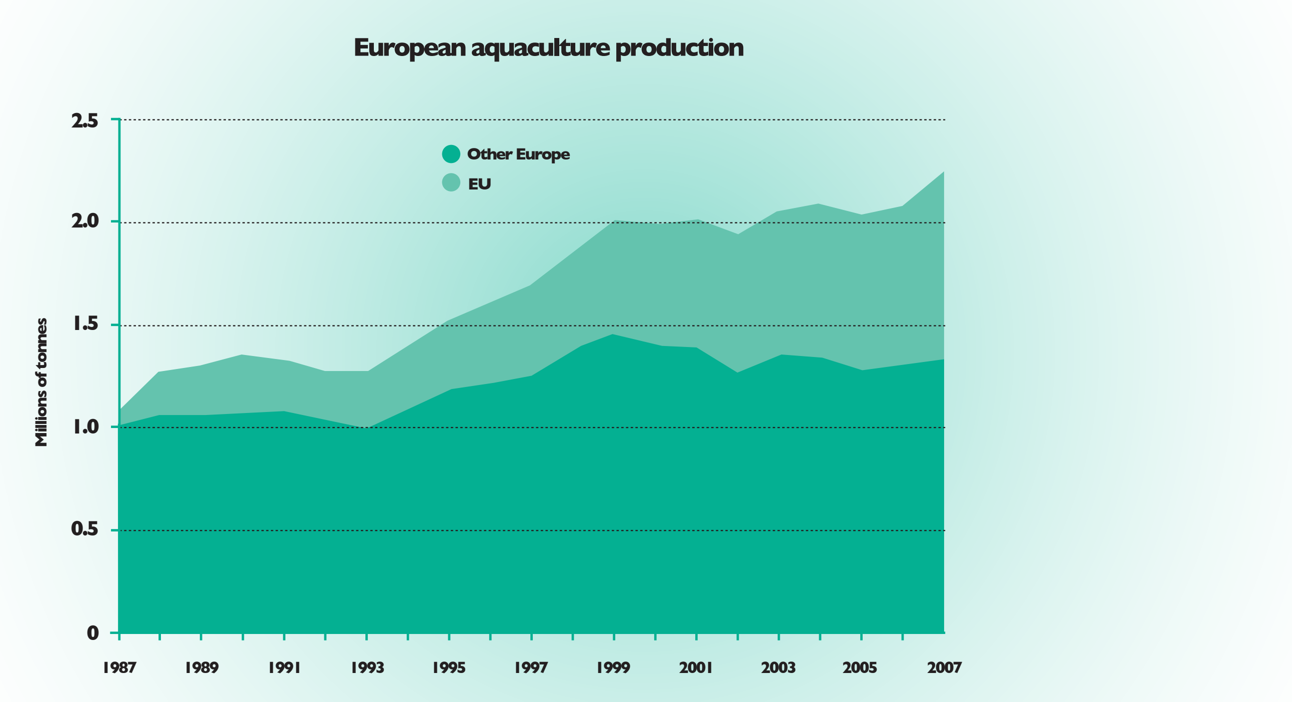


Figure 2:Aquaculture production in Europe. Courtesy of Kontali Analyse AS.

"We must plant the sea and herd its animals using the sea as farmers instead of hunters. That is what civilization is all about - farming replacing hunting."

Jacques Yves Cousteau (filmmaker, scientist, marine conservationist)

On a global level, farmed fish and shellfish production is growing more rapidly than any other food sector. While some of the products in demand (tropical species) cannot be produced in European waters, a significant proportion of the demand for fish and shellfish products can be produced in Europe.

'Aquaculture' may be a recent addition to our vocabulary, but the farming of fish and the cultivation of shellfish dates back millennia – from old Chinese civilisations to the Roman Empire. What is new is the level of production now demanded by a growing world population and the challenge this presents to farmers who want to conduct their activity in a sustainable way.

This document demonstrates for consumers how European aquaculture is addressing sustainability issues through scientific research and how the sector is continuing to improve its production practices in the light of that research.

Aquaculture produces safe, high-quality food

Just as with wild-caught fish, farmed seafood represents an excellent source of nutrients important for human health. There is hard evidence that regular consumption of fish lowers the risk of coronary heart diseases because of high concentrations of omega-3 poly unsaturated fatty acids. Other important nutrients in farmed fish are vitamins A and D for maintaining healthy bones, eyes and skin. Farmed fish is also a rich source for iodine, important for the proper functioning of the thyroid gland, and selenium, which is an important anti-oxidant.

Because farmed fish and shellfish are produced under controlled conditions, it is possible to maintain the highest quality standards from the egg to the plate. In the same way that business processes may be certified to meet standards (e.g. ISO), aquaculture production also has certification schemes. They are increasingly supported by various codes (of conduct and of good practice), developed at national and European levels.

Production of fish and shellfish on farms allows for consistent and even enhanced levels of the elements in seafood that do us good. For example, the level and balance of omega fatty acids, vitamins and minerals such as iodine and selenium can all be influenced through specially designed fish feeds.

What are the health benefits of seafood?

Much of the importance of fish in health has come from research into long-chain polyunsaturated fatty acids (PUFA) of the n-3 family. Other abbreviations used are omega-3 and n-3 fats. Fish is a rich source of two important PUFA: eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). PUFA are present in both wild and farmed fish. DHA and EPA are found in abundance in the flesh of oil-rich fish but they are also present in lean fish.

The effect of PUFA on coronary heart disease has been extensively studied. The human body cannot make PUFA. There is strong evidence from many scientific studies that PUFAs from fish play a major role in protection against heart disease[1]. PUFAs may also help prevent other illnesses, such as arthritis, Alzheimer's disease, some types of cancer and asthma. Extensive research to confirm these relationships is ongoing.

How much seafood should we eat?

Different values exist in the scientific literature for what is the "ideal" daily or weekly intake of EPA and DHA for human health. Government advice varies considerably between countries. However, as a general rule, a healthy diet is generally assumed to include 1-2 fish per week, especially fatty fish.

The International Society for the Study of Fatty Acids and Lipids (ISSFAL) suggests an uptake of 500 mg of EPA + DHA per day or 3.5 g per week provides enhanced cardiac health in adults.

[1] Simopoulos, A.P. "Essential Fatty Acids in Health and Chronic Disease". Am J Clin Nutr 2000; 71 (suppl): 5065-95.

In its 2004 report "Advice on Fish Consumption – Benefits and Risks", the UK Scientific Advisory Committee on Nutrition (SACN) concluded that the majority of the UK population does not consume enough fish, particularly oily fish, and should be encouraged to increase consumption. The Inter-Committee Subgroup endorsed the Committee on Medical Aspects of Food Policy (COMA) 1994 population guideline recommendation that people should eat at least two portions of fish a week, of which one should be oily. Consumption of this amount would probably confer significant public health benefits to the UK population in terms of reducing cardiovascular disease (CVD) risk and may also have beneficial effects on foetal development.

Current advice from the UK Food Standards Agency suggests a weekly intake of up to four 140g portions of oily fish for men, boys and women over reproductive age, with the caveat that girls and women of reproductive age should only consume two portions of oily fish per week[2].

[2] See http://www.foodstandards.gov.uk/

How rich is farmed finfish?

PUFA (Omega-3)

Scientific name	Rainbow trout		Coho salmon		Atlantic salmon	
Latin name	*Oncorhynchus mykiss* (Walbaum)		*Oncorhynchus kisutch* (Walbaum)		*Salmo salar* L.	
	wild	farmed	wild	farmed	wild	farmed
Fat	3.46 ± 0.226	5.4 ± 0.306	5.93 ± 0.1616	7.67 ± 0.696	6.34 ± 1.772	10.85
Fatty acids						
18:3 n-3	0.119	0.058	0.157	0.075	0.295	0.094
20:5 n-3	0.167	0.260	0.429	0.385	0.321	0.618
22:6 n-3	0.420	0.668	0.656	0.821	1.115	1.293
22:5 n-3	0.106	0.000	0.232	NA	0.287	NA
18:2 n-6	0.239	0.710	0.206	0.349	0.172	0.586
PUFA	1.237	1.805	1.992	1.861	2.539	3.931
Sum of LC n-3 PUFA	0.693	0.928	1.327	1.206	1.723	1.911

ND: Data not available
[1] Data from different databases may differ.

*Figure 3: Total fat and fatty acid content (g/100g wet weight) of wild and farmed rainbow trout (*Oncorhynchus mykiss*), Atlantic salmon (*Salmo salar L.*) and coho salmon (*Oncorhynchus kisutch* (Walbaum)) "http://www.nal.usda.gov/fnic/foodcomp/"http://www.nal.usda.gov/fnic/foodcomp/*
Source: The EFSA Journal (2005) 236, 1 - 118

Farmed finfish is an excellent source of PUFA. However, different fish species vary widely in their flesh lipid content (0.7-25% lipid by wet weight) and, consequently, in their concentrations of PUFA. Farmed Atlantic salmon, cultured on diets based largely on marine raw materials (fishmeal and fish oil), contain around 1.6-2.5g EPA + DHA per 100g of flesh. However, for reasons of sustainability, many farmed salmon feed formulations now contain appreciable levels of plant-derived meals and oils and this would tend to reduce the levels of EPA and DHA in their flesh. By comparison with salmon, rainbow trout, European sea bass, gilthead sea bream and Atlantic cod, cultured on largely marine raw materials would provide around 1.0, 1.0, 1.2g and 0.3g EPA + DHA per 100g flesh, respectively.

Often, farmed fish are perceived as being of poorer quality in terms of their ability to deliver PUFA to human consumers. However, for the 5 species mentioned above, this is not the case as the farmed product generally has a higher lipid concentration than the wild product. Consumption of two portions of farmed fish per week can provide the majority, if not all, of this requirement.

Proteins

The protein content in fish varies between 15 and 23%. The amount of connective tissue in fish muscle is quite low and softens and dissolves more readily when heated compared to the connective tissue of land animals. The connective tissue is easily broken down by digestive enzymes making it very easy for the body to digest.

Vitamins A and D

Fish is well known as a source of fat soluble vitamins A and D. Vitamin A in fish is of a type that is easily absorbed by the body. Vitamin A is important in the eye for transmission of light stimuli to the brain. It promotes growth and health of all cells and is particularly important for endothelial cells.

Vitamin D is needed for healthy bones as it helps to absorb calcium in the body. A low level of vitamin D can lead to osteoporosis (brittle bone disease) or osteomalacia (softening of the bones). Fatty seafood such as mackerel, herring, salmon and trout are all rich in vitamin A and D.

Iodine

Fish contains more iodine than any other food in a normal diet. Eating one or two fish-based meals every week provides enough to meet the Recommended Daily Intake for adults. It is important for hormone development. A person who doesn't have enough iodine in his diet may develop an enlarged thyroid gland (goitre) or other iodine deficiency disorders.

Selenium

Fish is also an excellent source of selenium. The amount of selenium in fish varies between 0.02 and 0.06mg per 100g fish flesh. Selenium is incorporated into a number of enzymes in the body, such as glutathione peroxidase. This enzyme plays an important role in protecting cell membrane from damage by free radicals, which are linked with increased risk of heart disease and cancer. Gluthathione peroxidase makes free radicals harmless and helps to protect against heart disease and certain cancers.

Safe seafood products

Because it is a controlled food production process, fish farming can include safeguards to protect its product from contamination. Ironically, the main source of contaminants in farmed fish (such as trace amounts of dioxins, PCBs and mercury) is fish feed composed of wild fish. However, because this food can be sampled and analysed prior to feeding, maximum limits of contaminants in fishmeal and fish oil used in aquaculture have been established by international law.

Data from the official controls of the fish feed ingredients and analysis of the farmed fish itself are available for consumers, authorities and industry alike.

Strategies to minimise contamination of farmed fish by way of feed derived from the wild are in place and can include; careful selection of the fish oil source, purification of fish oil prior to its inclusion in fish feed, and partial replacement of fish oil by vegetable oils.

A number of factors have combined to make us more aware than ever of the safety of food. Firstly, increasingly accurate measuring techniques allow us to detect even the lowest levels of contaminants. Secondly, increasing media focus on food safety has highlighted issues such as BSE, dioxins and salmonella, and 'food scares' have become regular features of news broadcasts. For food to be acceptable, it must be proven to be safe to eat.

Food safety standards have been developed giving clinically proven safe levels of food constituents that may at higher levels provide a risk to health.

Contaminants and health risks

Contaminants in fish derive predominantly from their diet. Whilst it is not possible to control the diet of wild fish, the levels of contaminants and some nutrients in farmed fish may be modified by altering their feed.

> Strict EU regulations (e.g. Directive2002/32/EC) and controls by food safety authorities ensure that contaminants are kept well below dangerous levels in farmed fish. Emerging technologies allow fish feed producers to purify fish meal and oil before it is incorporated in the feed.

The retention of dietary mercury by fish is dependent on dietary concentration and the duration of exposure to the contaminant. Methylmercury (the toxic form of mercury in fish) is present in higher amounts in large predatory fish such as swordfish and tuna. High consumers of such top predatory species, such as pike or tuna (especially fresh or frozen bluefin or albacore tuna), may exceed the provisionally tolerable weekly intake (PTWI) of methylmercury.

The greatest susceptibility to the critical contaminants (methylmercury and the dioxin-like compounds) occurs during early human development. For a developing human foetus, this means that the risk comes from the amount of these compounds in the mother's body.

Furthermore, EU maximum limits exist for a range of contaminants in food such as dioxins, dioxin-like PCBs, mercury, lead, cadmium and polyaromatic hydrocarbons (the maximum level is for one PAH, BaP). These limits include food of farm origin and other foods such as fish from capture fisheries.

Monitoring programmes exist to document the levels of contaminants in wild and farmed fish to fulfil a need for independent data for consumers, food authorities, fisheries authorities, industry and markets.

Photo: Courtesy of Vidar Vassvik

The European Food Safety Authority (EFSA)

assesses health risks of wild and farmed fish

The European Food Safety Authority (EFSA) is the keystone of European Union (EU) risk assessment regarding food and feed safety. In close collaboration with national authorities and in open consultation with its stakeholders, EFSA provides independent scientific advice and clear communication on existing and emerging risks.

In December 2004, EFSA was requested by the European Parliament to conduct a scientific assessment of health risk related to human consumption of wild and farmed fish. EFSA's opinion (EFSA Journal (2005) 236, 1-118) focused on eight finfish species which are widely available in the EU and likely to be consumed most frequently: salmon, herring, anchovies, tuna, mackerel, pilchards, rainbow trout and carp. Of these, salmon, rainbow trout and carp are predominantly or exclusively farmed. Currently, about two-thirds of fish consumed in the EU is caught from the wild.

According to EFSA, the highest levels of methylmercury are found in tuna, which is mostly caught from the wild. Highest levels of PCDD/F and DL-PCBs are found in herring, which are caught from the wild, and salmon, which are mostly farmed.

Overall EFSA concluded that, with respect to consumer safety, farmed fish is not less safe than wild fish.

Traceability

As in land farming, fish farming benefits from traceability technologies to monitor and follow the production cycle through its entirety. While traceability itself is not a guarantee of safety, it is essential in pinpointing problems, should they occur, throughout the whole production chain. This is not just limited to producers, but encompasses their suppliers, processors and distributors. Such "full chain traceability" is most effective when all links in the chain have the same principles and use the same (or at least compatible) tools.

In 2002, an EU-funded concerted action initiative called "TraceFish" (www.tracefish.org) produced three consensus-based standards for the recording and exchange of traceability information in the seafood chains.

One of these is a standard for farmed fish. The basic element in the system is a unique identification number to be placed on each lot of products in such a way that traceability can be transmitted electronically. The system is voluntary.

Traceability tools are being continuously improved and are major monitoring components of various labelling and certification schemes for aquaculture products.

An example of this is the TRACE initiative (www.trace.eu) that is using 5 case studies in food to improve traceability parameters and measure food authenticity. This last point has specific interest for fish products and TRACE is developing generic low cost analytical tools for use in the traceability infrastructure that verify geographical origin, production origin and species origin.

Affordable seafood products

As fish species become scarcer in the oceans, they will become less affordable to consumers.

All of the approximately thirty species of fish in European aquaculture production have shown a decrease in farm gate price as their production volume has increased, while improvements in production techniques have resulted in ever-increasing quality.

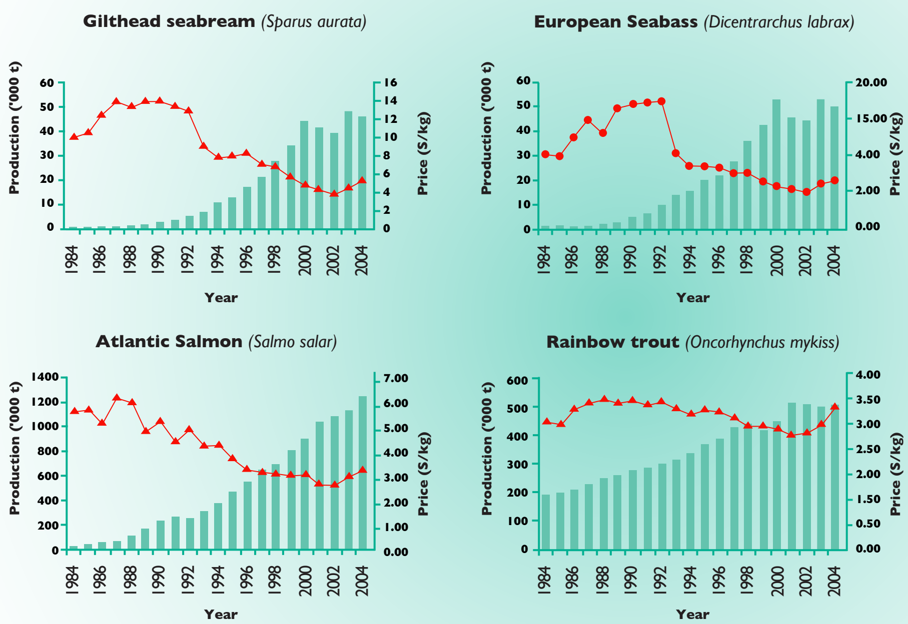


Figure 5: EU production and price trends – for several aquaculture species produced in Europe. Data from FAO FishStat 2006. Note prices in US Dollars.

Atlantic salmon and rainbow trout are almost exclusively farmed.They are now comparable in price to land farmed produce such as chicken and pork.

The availability of 'new' farmed species (sea bass, sea bream, cod, sole, scallops, octopus etc.) has the potential to provide this increase in affordability to all consumers.

Quality of life of aquatic animals

Health

Infectious diseases are encountered in all food production. Fish and shellfish may be more under threat from disease than land animals or plants because germs survive longer and can spread more effectively in water. The rapid identification and treatment of bacterial and viral infection is therefore crucial in aquaculture. While best management practice remains the preferred option for producers, the use of therapeutic agents may sometimes be necessary.

National and international regulations have been implemented to approve veterinary medicines that do not compromise food safety. An example of this is the so-called 'withdrawal period', defined as the minimum time to elapse between termination of the treatment and harvest of the animal. Withdrawal periods are specific for each drug and each utilisation of that drug, for example to treat bacterial disease.

It is important to note that the use of veterinary medicines such as antibiotics has greatly decreased in many types of aquaculture. For example, in Norway the use of antibiotics in salmon and trout farming has been negligible for the last 10 years due to the use of better vaccines. In 2004, Norway produced 23 times more salmon and trout than in 1985; in the same period, the use of antibiotics dropped by a factor of 25.

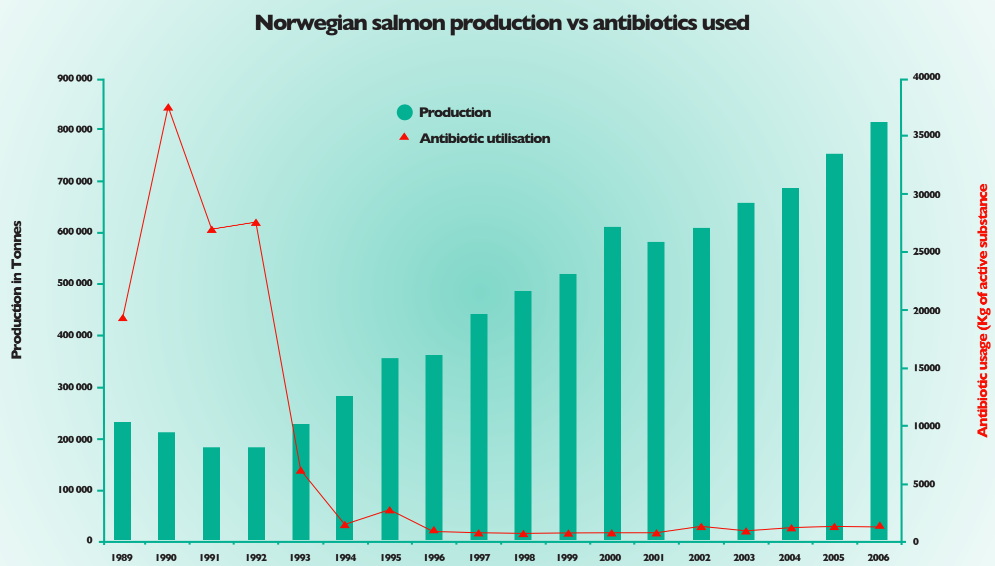


Figure 6: Antibiotics used in Norwegian farming of trout and salmon 1980-2004.

The principal challenges in aquaculture are now related to viruses and parasites. For example, "sea lice" threaten farmed salmon in temperate waters. However, non-medicinal and environmentally friendly lice treatments are being developed. In Norway, for example, wrasse, another fish, is used to eat the lice from infected salmon.

With the adoption of tighter laws and regulations, and with the difficulties of drug companies registering new treatments for aquaculture, the availability of medicines to treat aquaculture species becomes increasingly unsure. More and more, research is therefore turning towards prophylaxis as a solution.

Parasites are common in wild fish, too

Parasites are not unique to farmed fish, but in the wild they obviously go untreated. Parasites fall into two main groups – ectoparasites, which affect the skin and external organs, and endoparasites, which invade the body and attack the musculature and internal organs.

Ectoparasites include several types of sea lice, crablike creatures that eat the skin and flesh of the fish. If left untreated, they will cause considerable suffering to the fish and open wounds on the skin of the fish that may become sites for disease.

Endoparasites include nematode worms that enter the body of the fish through the mouth, infest the gut and can then burrow into the flesh of the fish. As well as reducing the fish's ability to regulate the amount of salt in its body by perforating the gut membrane, they also reduce the saleability of the flesh, since fish infested with nematode parasites are not saleable for human consumption.

As on land-based farms, when animals are held at higher densities parasites can infect a stock relatively rapidly. Because unhealthy fish mean substantial loss to the farmer, however, it is uncommon in modern fish farms to find harmful burdens of parasites. Outbreaks are controlled by modern farming practices and the use of medicines that authorities have deemed safe to the fish, to consumers and to the environment.

Medicine and chemical residues are tightly regulated

At international level, The Codex Committee on Residues of Veterinary Drugs in Foods is responsible for setting acceptable limits to concentrations of drug residues in foods for human consumption, including farmed fish. Acceptable concentrations are expressed as Maximum Residue Limits (MRL) and are based on careful toxicological evaluation of the substance and information on consumption patterns. Consumption of food with drug residues below the MRL should not, with large safety margins, bring negative health effects to the consumer. Products containing illegal drugs or legal therapeutics in concentrations above the MRL cannot be sold for human consumption.

Medicine and chemical residues in fish are also covered by EC legislation. According to Directive 96/23/EC, all EU member countries have to carry out extensive surveillance for a number of foreign substances in all species produced for food. The Directive represents an important and standardised means of drug residue control in Europe.

In October 2006, the EC issued Directive 2006/88/EC to improve the health of fish and shellfish farmed in the EU. Among other things, it sets criteria for the authorization of aquaculture production businesses and processing establishments. The Directive also facilitates enhanced disease prevention and control throughout the production chain. The new Directive will be implemented by member states from 1st August 2008 onwards.

Science may provide the key to control sea lice – research in progress

Sea lice are often cited as a major problem in the intensive farming of Atlantic salmon, as well as a threat to wild salmon populations. Monitoring of sea lice infestation and new research initiatives are helping to address the issue.

Monitoring: Lusedata

www.lusedata.no is a monitoring programme of sea lice in salmon farms around Norway. The website (in Norwegian) provides monthly data for all coastal areas on the water temperature, the numbers of adult female lice, the percentage of farms that treated for lice over the last month, the percentage of farms using cleaner fish and a long-term (3-year) graph of mobile lice and adult females - all as reported by fish farmers in those areas, under Norwegian legislation.

Research: Chemical cues

The most well-known semiochemicals are pheromones, often referred to as 'sex hormones', which regulate many essential aspects of behaviour, including mating. Sea lice use a combination of cues to locate and identify their fish hosts and then attach themselves and feed on the host before they can reproduce. These cues include kairomones – a semiochemical cue released by the host fish.

Researchers at Aberdeen University have identified chemicals produced by salmon that attract sea lice. "Unattractive chemicals", isolated from turbot, have also been identified and these are effective in repelling sea lice.

If attractive and non-attractive semiochemicals can be successfully deployed in fish farms (in traps or other devices), they could reduce the rate of infections in farmed salmon. Such techniques are well established in terrestrial agriculture and could form part of an integrated sea lice control programme, which would be less dependent on chemical treatments and more cost-effective to implement.

Research: Enhanced immunity

Stimulating the immune system in fish significantly increases their ability to resist louse infection. New research being carried out at Akvaforsk in Norway (www.akvaforsk.no/english) shows that the addition of β1.3/1.6-glucan (a naturally derived polysaccharide or sugar) in fish feed decreases the number of lice per fish by 28 percent. One of the major salmon producers, Marine Harvest in Scotland, reported a 20 percent infection reduction when salmon were fed glucan-containing feed in the period prior to being treated (chemically) for lice.

These new approaches have advantages compared to current medical treatments, which carry the potential for resistance and can have negative environmental effects.

Welfare of farmed fish

Farmed fish are contained - in ponds, tanks or cages - as with all farmed animals. Just as in land-based farming, farm managers increasingly choose stocking densities and handling practices that optimize growth and health status while avoiding unnecessary suffering.

Questions are sometimes raised about welfare aspects of aquaculture production. Usually, such questions focus on three issues: stocking densities, the possibility to have 'free-range' aquaculture and the way farmed fish is slaughtered at harvest.

There are many definitions of animal welfare. One definition is based upon the Farm Animal Welfare Council's "five freedoms":

- Freedom from thirst, hunger and malnutrition
- Freedom from discomfort due to environment
- Freedom from pain, injury and disease
- Freedom to express normal behaviour for the species
- Freedom from fear and distress.

Scientific studies have identified operating indicators of fish welfare so that producers are able to measure the welfare status of their stock. The Freedom Food certification scheme of the RSPCA in the UK is a very good example of a welfare standard that has been built by on-farm dialogue with producers and which is now available for salmonid species.

Stocking Density

Many species of fish, such as herring and mackerel, live in large shoals in the wild and are therefore used to very high densities. Keeping such fish in high densities on a farm will only become a problem if the water quality deteriorates, or if the fish are deprived of oxygen or exposed to disease. Fish farmers do their best to prevent such conditions since they will reduce production.

Fish farms holding fish at high stocking densities carefully monitor the oxygen in the water and maintain it at the optimum level for fish growth. Every effort is made to ensure that fish are kept in a healthy condition and that disease is prevented wherever possible, or identified and treated should it occur.

Stocking density has often been proposed as an indicator to measure welfare and there is considerable debate about its value. Also, since the 1980's the volume of cages used for salmon culture in Northern Europe has increased considerably – in some cases more than 200 times, reducing densities and enhancing the ability for the fish to show natural behaviour. However, as land animals that are kept within fences, some limits on behaviour are necessary in farmed fish production.

Free-range aquaculture

"Freerange" aquaculture exists in several forms – for example in "ranching" of salmon and lobster, in "organic" salmon production and in shellfish farming.

Photo: Juvenile lobsters reared for restocking Copyright: The AquaReg Lobster Project www.aquareg.com

"Ranching" – is an aquaculture technique whereby fish and shellfish are bred in captivity and then released into the wild to complete their life cycle before being harvested at some time in the future. Ranching has effectively been applied to Atlantic and Pacific salmon production, whereby juvenile fish have been reared from wild-caught eggs and sperm, raised in hatcheries and then released into specific rivers as smolt, allowed to migrate to sea and recaptured on their return to their river of origin.

Lobster ranching has also been tried on a number of commercial lobster beds in the past, with juvenile lobsters being raised in shore-based hatcheries and then placed on the seabed in sheltered rocky habitats where their chance of survival is thought to warrant the expense of production.

"Organic" salmon farming is conducted according to agreed codes of organic production. Rearing takes place in large, open water floating pens where conditions are as close to the open ocean as possible. Stocking densities are reduced to allow the fish to grow and develop in as natural a way as possible and the only feed used comes from sustainable fisheries. Because of lower stocking densities and open water conditions, the fish tend to be less prone to disease and therefore the use of medicines can be kept to a minimum. Increased production cost for "organic" fish is recouped with higher prices on the marketplace.

Shellfish farming, such as the laying of oysters and mussels directly on the seabed or the hanging of mussels on suspended ropes, can be said to be "free range" in so far as it is allowing the shellfish to grow in identical conditions to those they would encounter in the wild.

Slaughter methods

Recent studies suggest that fish, like warm-blooded animals, can experience fear and pain, leading to justifiable concern that codes of practice for the welfare of warm-blooded farm animals should be extended to cover farmed fish.

Accordingly, a four-step process for the humane slaughter of farmed fish has been developed similar to the European Directive covering warm-blooded animals. It covers transport and live storage, restraining, stunning and slaughter.

The process decrees that, to spare fish avoidable trauma, stunning prior to slaughter should induce immediate (within one second) and permanent loss of consciousness or, where loss of consciousness is not immediate, it should be without any avoidable excitement, pain or suffering.

Photo: Electrical stunning of Atlantic Salmon in Tasmania. Systems identical to this are currently being installed in Norway, so that all farms are equipped by July 2008. Photo courtesy of Bruce Goodrick.

Farmers currently employ any of three ways to reach this goal: electrical stunning (passing a current through the animal); mechanical stunning (a captive needle destroys the brain) or chemical stunning (adding a food-grade substance like eugenol, based on clove oil, to the water in which the fish are held.)

EU initiatives address welfare issues

Fish Welfare

Fish welfare net is a portal dedicated to research into fish welfare and serves as a source and reference point for information on fish welfare-related research initiatives. The site aims to increase awareness of emerging fish welfare concerns, and is able to rapidly disseminate new research findings. **www.fishwelfare.net**

Benefish

The EU project Benefish (Evaluation and Modelling of BENEfits and Costs of FISH Welfare Interventions in European Aquaculture) explores the benefits and costs of welfare measures in aquaculture production systems, having defined a widely-applicable set of operational welfare actions and indicators that can be connected to measurable consequences in production and extended to effects on value chain and changes in consumer perception. **www.benefish.eu**

Wealth

The WEALTH initiative, also funded by the EU, focuses on how different environmental factors and husbandry condition in various farming systems result in physiological stress, and on the subsequent consequences for behaviour, growth performance, disease resistance and general welfare in fish farming. WEALTH has developed and tested new welfare indicators and applied these together with established indicators in various experiments in both tanks and sea cages. Recommendations for industry good practice are also provided. **www.wealth.imr.no**

Species protection and conservation

Fish farming can contribute to the protection and restoration of endangered fish populations living in the wild through the efficient provision of juveniles for release or stocking.

An increasing number of fish are finding their way onto the CITES[3] lists of endangered species. The production of juvenile fish and shellfish in hatcheries is far more efficient (in terms of survival) than in the wild. These juveniles may not only be grown on as food, but also for the conservation and restoration of fish populations (through release or restocking) and the provision of fish for angling.

This technique, also known as "stock enhancement" or "enhancement aquaculture" has an economic advantage in that production costs are much lower, and has proven to be successful for a variety of marine fish species, mainly in Norway, Japan and the USA.

Photo: Juvenile sturgeon for restocking. Source Aquaculture Europe Vol 32 (3). September 2007. Courtesy M. Chebanov.

Sturgeons are among the world's most valuable wildlife resources and can be found in large river systems, lakes, coastal waters and inner seas throughout the northern hemisphere. For people around the world, caviar, i.e. unfertilized sturgeon roe, is a delicacy. Sturgeons are also a major source of income and employment, as well as an important element of the local food supply. Current trends in illegal harvest and trade put all these benefits at risk. Since 1998, international trade in all species of sturgeons has been regulated under CITES owing to concerns over the impact of unsustainable harvesting of and illegal trade in sturgeon populations in the wild.

[3] CITES (the Convention on International Trade in Endangered Species of Wild Fauna and Flora). www.cites.org

The Ramsar Declaration on Global Sturgeon Conservation recognises the importance of aquaculture in the preservation of sturgeon species, specifically mentioning the importance of captive broodstock programmes to prevent loss of genetic variety; the monitoring of stocked juvenile fish to assess the cost-effectiveness of stocking strategies; the cultivation of sturgeon for meat and caviar products – especially with due involvement of the low-income local fishing community who need alternative livelihoods; and the need for internationally agreed standards on culture technology and general husbandry, adequate nutrition, disease prevention and product quality control.

More information is available at www.wscs.info – the site of the World Sturgeon Conservation Society.

Different trout species have been restocked in Europe's rivers for decades. Prior to the Second World War, the UK production of trout juveniles was exclusively to stock rivers in England and Scotland to support natural populations and for recreational fishing. It was only in the 1950s that technology was introduced to produce fish for the table. This is the case across much of Europe, where trout remains the top aquaculture production species within European Member States, and where restocking accounts for a significant proportion of total trout fry production.

Photo showing 2007 re-population in the river Nivelle in the Basque region of France. Photo courtesy of Dr. Jacques Dumas, INRA.

Quality of life for the planet

Environment – need for high quality water and other resources

Clean water is the primary pre-requisite to successful aquaculture. A clean environment is therefore critical for its commercial success. Any environmental impact that would compromise the quality of the water used on fish farms must be monitored and minimised through appropriate siting (choice of locations) of farms and production processes.

In recent years, the development of aquaculture has raised some associated environmental concerns. Like any farming operation on land, fish farm cages produce waste materials. These fall into three categories – uneaten feed, fish faeces and dead fish. Most of the environmental impacts of aquaculture can be managed and minimised through understanding of the processes involved, responsible management and the effective siting of farms.

Uneaten feed – Should uneaten feed reach the bottom of a cage, processes that break it down can reduce the amount of oxygen in the sediment. In severe cases, oxygen levels in the water above may also decrease, creating "anoxic" conditions in which only a few animal species can survive. Should the feed contain antibiotics used to treat the farmed fish above, bacteria in the sediment and the natural breakdown of waste material might be affected.

In practice, fish farmers do everything they can to prevent such a situation, since the cost of fish feed amounts up to 40 percent of the total production cost. Feed reaching the sediment is lost, and it is in the farmer's interest to minimise such waste. On well-managed farms, feeding is carefully regulated to ensure that the maximum amount of food is taken up directly by the fish and farmers aim to ensure that less than 5 percent of the feed is wasted. To improve uptake by fish, feed pellets are manufactured to either float or to sink slowly through the water.

Fish faeces – Unlike land animals, fish do not generally produce compact solid faecal material and more often excrete a loose cloud of faecal material that is easily dispersed by water currents. In still conditions, however, faecal material can build up beneath fish cages. It is, however, not in the farmer's interest to let this happen, since the build-up of faecal material can lead to anoxic conditions which affect the fish above. Fish farmers wanting to ensure the health of their fish will frequently check the bottom below their fish cages to ensure that faecal material is not building up. In addition, in many EU Member States, the government employs diving teams to carry out inspections. If faecal build-up is observed, farmers will be advised to move their cages, allowing the bottom to recuperate for a short period, however full recovery typically takes between three to ten years. In recent years, improved feed formulations have also been introduced that fish digest more efficiently, producing less waste.

Fish farmers generally avoid overly sheltered and stagnant sites, preferring areas that contain a healthy flow of water through the cages. Such flows disperse fish faeces so it can enter the natural food chain.

Dead fish – Dead fish are a loss to the farmer and a potential health hazard to the stock as well as a source of pollution. Fish farmers will, at all times, endeavour to minimise the number of dead fish on their farms and to remove such mortalities where they occur.

Fish farms are required to report significant fish deaths when they occur and are inspected by state agencies at least twice a year.

Ocean sensor technology

Photos courtesy of the AKVA Group (www.akvagroup.com)

Ocean sensor technologies help fish farmers reduce feed costs and feed impacts

As fish farm units (cages) get bigger, producers are using various techniques and equipment to better manage their stocks. Accurate measurements of the water flow rates, oxygen concentration, salinity and temperature at different depths throughout the cage allow computer-assisted feeding machines to deliver the right amount of feed in the right place at the right time.

Feeding cameras are positioned at depth below the feeding areas and point towards the surface. They can be linked up to a monitor or remote video, so that the feeding efficiency can be observed in real time.

Furthermore, a feed detector suspended in the cage will record the uneaten feed that falls to the bottom of the cage. By reducing the uneaten feed, an increase in the food conversion ratio can be achieved.

This is a significant development, compared to the hand-feeding "by eye" carried out on fish farms some years ago. It not only leads to a saving in feed costs for the producer, but it also lowers the environmental impact of uneaten feed on the sea floor area below the production cages.

Shellfish cultivation

Shellfish such as oysters, mussels and clams are filter feeders and take their food directly from the water in which they live. This means that they do not require supplementary food and, if anything, actually improve the quality and clarity of the water. **Shellfish farming can only provide the best quality products if practiced in pristine environments with the highest water quality**.

Environmental problems can arise on shellfish farms where the animals are held at overly high densities, leading to depletion of food in the water and build-up of faeces below the holding areas. Both effects will harm the outcome for the farmer and hence shellfish farms are generally sited where water exchange is high and the stock is kept at densities that are compatible with the level of water exchange. In many cases, stocking densities on farms are lower than those of clusters of shellfish (e.g. mussels) that occur on natural beds.

Shellfish farms have been thought to disturb wildlife habitats by taking up space on a beach where wading birds feed. It has been shown, however, that wading birds and oyster farms can exist side by side. The fallen oyster or mussel can have a positive impact on a bird's feeding pattern.

Other potential impacts include the importation of parasites, pests and diseases onto the shellfish farm which would then spread to other areas. The microscopic oyster parasite *Bonamia ostrea*, for example, gradually spread through Europe with the spread of oyster farming. Oyster farmers have responded by significantly reducing the density at which their shellfish are farmed.

Some people complain of "visual pollution" caused by large numbers of floating barrels or shellfish trestles in otherwise unspoilt areas. Low-profile and dark-coloured floats have recently been developed to minimise the visual impact.

Pond fish farming

Fish pond systems represent the oldest fish farming activity in Europe, at least dating back to medieval times. Ponds were built in areas where water supply was available and the soil was not suitable for agriculture. The wetlands of Central and Eastern Europe are good examples of this. The total European production from pond farming is approximately 475,000 tonnes. About half of this production is cyprinid fish, such as common carp, silver carp and bighead carp. The main producer countries are the Russian Federation, Poland, Czech Republic, Germany, Ukraine and Hungary.

Typical fish ponds are earthen enclosures in which the fish live in a natural-like environment, feeding on the natural food growing in the pond itself from sunlight and nutrients available in the pond water.

In order to reach higher yields, farmers today introduce nutrients into the pond such as organic manure. This is accompanied by stocking of fingerlings and by water being flushed through the pond. Fish pond production, however, remains 'extensive' or 'semi-intensive' (with supplementary feeding) in most countries, where semi-static freshwater systems play an important role in aquaculture. Chemicals and therapeutics are not usually used in such ponds. Hence the main environmental issue is the use of organic fertilisers, which may cause eutrophication in the surrounding natural waters. The use of organic fertilisers is regulated at national levels.

Extensive fish ponds are usually surrounded by reed belts and natural vegetation, thus providing important habitats for flora and fauna. They play a growing role in rural tourism. Many pond fish farms have been turned into multifunctional fish farms, where various other services are provided for recreation, maintenance of biodiversity and improvement of water management.

In areas where water is scarce, some farm systems recirculate, treat and re-use their water. Such systems are generally self-contained and therefore pose little threat to the environment. Solid waste material produced in such systems is rich in organic compounds and often used as a fertilizer elsewhere. Alternatively, new hydroponic systems have been developed to grow vegetables and other food crops in the nutrient-enriched water. There is much interest in these systems, but their economic viability remains challenging.

The special case of multifunctional fish farms

Multifunctional farms are farms where the various elements are systematically integrated into the farming practice and where an increasing ratio of income derives from various non-fish farming activities. Such farms are becoming more widespread. Usually the first step towards multi-functionality is to convert some usually small size ponds of the farm into angling ponds and to start to provide services for anglers. This is followed by the provision of other types of services like shops, restaurants and hotel services. Nowadays, pond fish farms offer a wide range of various services - not only for specific customers like anglers, hunters and tourists but also for the society as a whole through the maintenance of biodiversity, the improvement of water management and the maintenance of traditional culture and lifestyle.

The Aranyponty fish farm in Hungary **www.aranyponty.hu** is a good example of a multifunctional fish farm.

Photo As well as being a farm that produces fish for food, Aranyponty - in Magyar, the Golden Carp - communicates the importance of managing Europe's wetland heritage to society, by diverse social and educational activities. Fish ponds such as these are also exceptional sites for the observation of flora and fauna. Photos courtesy of Levai Ferenc, Aranyponty.

Trout farming in flow-through systems

The most widely-practiced form of inland aquaculture in Europe is trout farming. Water is taken from the river, circulated through the farm and treated before being released downstream. All water in the farm is renewed at least once per day. Where more than one farm exists on the same river, it is in everyone's interests that the quality of the outflowing water from one farm is good, as this then becomes the inflowing water for the next farm. Other water sources include spring water or drilled and pumped ground water. In some countries, heated industrial water sources (such as electricity generating plants) are used to increase the water temperature (by heat exchange) used in the farm, thereby saving energy costs to heat the water. Geothermal water also provides naturally warmed water, thus allowing the farming of new fresh water species (especially eel, sturgeon, perch and tilapia) with low environmental impact.

Recirculation Aquaculture Systems

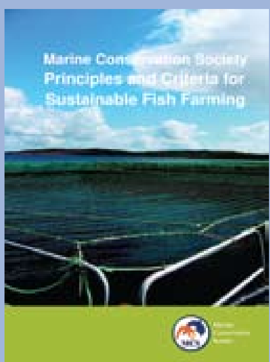
Recirculation Aquaculture Systems (RAS) are land-based systems in which water is re-used after mechanical and biological treatment so as to reduce the needs for water and energy and the emission of nutrients to the environment. These systems present several advantages such as: water and energy saving, a rigorous control of water quality, low environmental impacts, high biosecurity levels and an easier control of waste production as compared to other production systems. The main disadvantages are high capital costs, high operational costs, requirements for very careful management (and thus highly skilled labour forces) and difficulties in treating disease. RAS is still a small fraction of Europe's aquaculture production and has its main relevance in The Netherlands and Denmark. The main species produced in RAS are catfish and eel but other species are already being produced using this type of technology such as turbot, sea bass, pikeperch, tilapia and sole.

Producers and conservationists working together

The Federation of European Aquaculture Producers (FEAP) and the **World Conservation Union** (IUCN) are working together to address the environmental impact of aquaculture. With the input of other stakeholders, working groups are developing guidelines for the sustainable development of aquaculture in the Mediterranean.

Work to date has led to the publication of guidelines on the interactions between aquaculture and the environment (pictured left) and further publications are in preparation. These address the siting of aquaculture installations, traceability issues.

More information at www.iucn.org/places/medoffice/en/en_fishery.html



In the UK, the **Marine Conservation Society** (MCS) has also made a wide consultation of professional and other stakeholders to prepare principles and indicators of sustainable fish farming, with a focus on UK marine aquaculture.

The core principles are the responsible siting of fish farms; the use of sustainable sources of feed; minimising the effects of marine pollutants; minimising the wider ecosystem effects; optimal welfare standards and environmental management and continuous improvement through research.

See www.fishonline.org

Other environmental impacts of fish farming – the case of escaped fish

It is inevitable that fish farmed in net pens in either fresh or salt water will sometimes escape into the wild. In some cases, there will be a small but steady release of fish. Sometimes, large numbers will escape due to severe damage to the net pen by way of storms, predator attacks or vandalism.

There has been vigorous debate on the potential impact of escaped farmed fish, in particular salmon, on wild populations. On the one hand, it has been suggested that escaped farmed salmon could compete for living space, breeding partners and food resources, spread disease, or interbreed with wild fish, causing "genetic pollution" and thereby weakening the wild strain and reducing its ability to survive . On the other hand, scientists have argued that farmed salmon, which are bred for fast growth in perfect conditions, are less able to compete for food, territory and mate in the wild than their wild colleagues. Therefore, a limited escape of farmed fish would be unlikely to have a serious effect on wild fish populations. Only if very large numbers of fish escape into a small area, would interbreeding occur and the fitness of the local population potentially be reduced.

In its Aquaculture Europe 2005 conference, the European Aquaculture Society invited the North Atlantic Salmon Conservation Organisation (NASCO) to hold a special workshop on the interactions between wild and farmed salmon. The summary report of this event "Wild and Farmed Salmon – Working Together" drew the following main conclusions:

Through the use of single bay management, single generation sites and synchronised fallowing, real progress is being made in relation to minimising impacts of diseases and parasites, which are key issues for wild fish interests. The development of third-party audited containment management systems may represent a significant step forward.

The liaison group should look more at the possibilities of rearing all-female triploid salmon, which could eliminate genetic interaction with the wild stocks, but which need to be balanced by the production cost of these fish, as well as consumer resistance to what could be seen as genetic manipulation.

Restoration programmes can benefit from fish farmers' expertise, but habitat protection and restoration have equal or greater importance in species restoration than stocking programmes alone.

> "….today we have heard about some very positive examples of wild and farmed salmon interests working together. I believe that further development of this working relationship in the future should lead to mutual benefits and attainment of the shared goals of healthy wild salmon stocks and a sustainable salmon farming industry."

Concluding comments by Ken Wheelan, NASCO President, at the AE2005 Workshop "Wild and Farmed Salmon – Working Together"

In spite of all the debate, it has been difficult thus far to reach a firm conclusion.

What's clear is that the aquaculture industry is working towards minimising the number of escapes with increasing efficiency through improved cage technology, management, maintenance, legal requirements for monitoring and reporting and codes of practice for recapture of escapees.

To this end, the Norwegian Directorate of Fisheries[4] has recently updated and extended its 2007 "Vision No Escapees" Action Plan to achieve a level of escapees from fish farms as close to zero as practicable.

[4] www.fiskeridir.no/fiskeridir/english

Sustainable feed resources

Fish farming is very efficient in terms of the conversion of protein, which means an important ecological advantage in light of the sustainability of fish feed resources.

One of the most-frequently cited issues with the sustainable development of aquaculture is the capture of other fish as raw material to be used as fish feed in the form of fish meal and fish oil. It is seen as an issue because a food production sector is in part relying on a capture fishery for the supply of raw materials for the production of aquaculture feed.

Typically, these other fish species are small, oil-rich, bony pelagic fish that are not normally used for direct human consumption. Two decades ago, the majority of fish meal and oil was used to make feeds for land animal production. At present, over 50 percent of fishmeal and over 80 percent of fish oil is used for aquaculture.

If aquaculture is to fill the gap in demand for seafood, this raises important sustainability issues as to the availability of sufficient feed supply. This is particularly relevant given the fact that fishmeal and fish oil production has been, and is likely to remain, relatively constant at around 6 million and 0.9 million tonnes per year, respectively.

However, as the demand for fishmeal and fish oil in aquaculture has increased, so the price has risen. This has driven both terrestrial agriculture and aquaculture to seek nutritional alternatives to fishmeal and fish oil. This is an on-going process and estimates made by the International Fishmeal & Fish oil Organisation (IFFO) show that the growth of aquaculture and the substitution of fishmeal and fish oil can continue together. The IFFO has started to produce datasheets on fisheries for fish meal and fish oil and these are available at the IFFO web site[5].

Conversion of caught wild fish to farmed fish

It has been noted that certain types of fish, particularly salmon, are net consumers, requiring in the region of 3 kg of wild fish as feed to produce 1 kg of farmed fish. While it is true that growing high-quality salmon requires considerable amounts of fishmeal and oil, improved technology in fishmeal and oil production as well as better feeding practices on farms have reduced the ratio over time.

Salmon are an exception, because their diets require large amounts of fish oil. For aquaculture overall, the ratio is now well below one: less fish is used for feed than is produced at farms. For carnivorous species, the ratio is still decreasing and expected to reach 1.0 around 2012 (IFFO).

These figures do not include recent gains thanks to the recovery of meal and oil from aquaculture waste. Increasingly in Europe, waste from aquaculture is collected and processed, redirecting around 50 percent of the harvested weight to valuable products.

[5] www.iffo.net

It should also be noted that wild carnivorous fish also need food. It is estimated that it takes 10 kg of forage fish to produce 1 kg of salmon caught in the wild[6]. If by-catch values are added to the equation, another 5 kg of forage fish has to be added. Hence, even a 3 to 1 ratio for farmed salmon would be significantly better than a 10-15 to 1 ratio of salmon caught in the wild.

Efficiency of food conversion in farmed fish

The 'food conversion ratio' (FCR) is defined as the weight of food that is required to produce one kilogram of fish. In the early days of aquaculture, farmed fish were fed with whole 'trash' fish and FCRs were more than 20 to 1. Through the years, the ratio has dramatically declined. With the advent of dry, pelletised feeds and modern extrusion technologies, FCR levels are now almost 1 to 1. Certain trout and salmon farms achieve an FCR of less than 1:1, making them far more efficient converters of marine protein than their wild counterparts.

As fish feeds represent an increasingly high share of total production cost, fish farmers have every interest in using feeds as effectively as possible, thereby also reducing the potential environmental impacts of non-consumed feeds. Overfeeding or underfeeding would increase the FCR. Therefore, many farms are equipped with underwater surveillance and monitoring systems as well as devices controlling the supply and delivery of feed.

[6] Forster J. (1999) Aquaculture chickens, salmon: a case study. World Aquaculture Magazine, 30:(3), 33, 35–38, 40, 69–70.

The main ingredients of feed

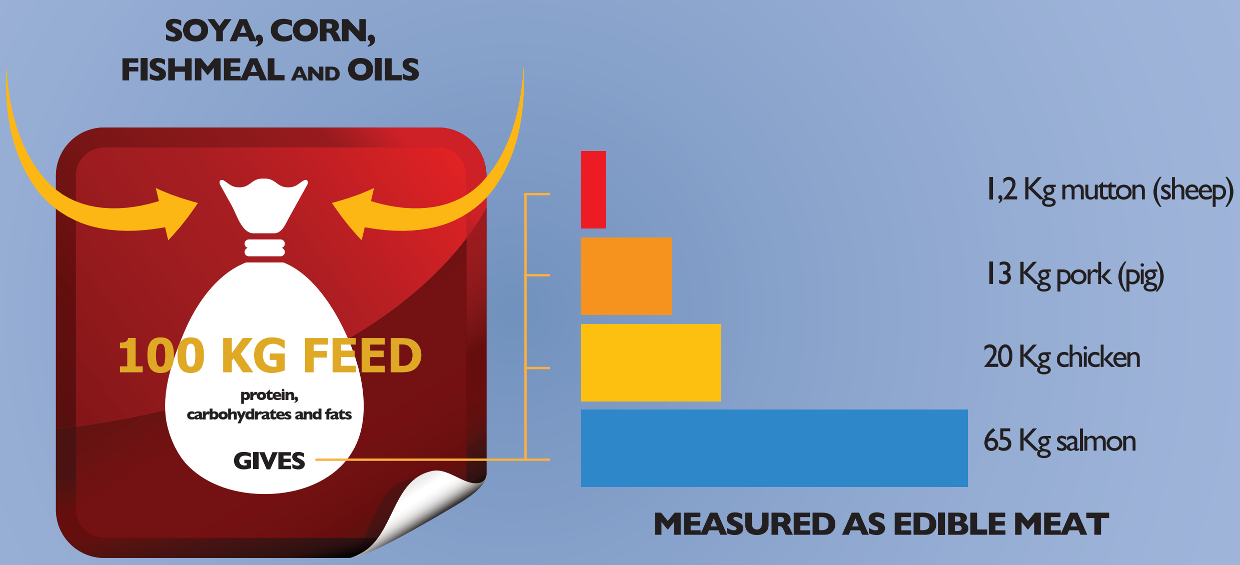


Figure 7: Comparative protein efficiency of fish, compared to land animals in converting 100 Kg of feed into 'meat'.

The main ingredients of feeds for farmed carnivorous fish species are fish meal and fish oil, at levels of about 25 percent and 30 percent, respectively. These two ingredients supply essential amino acids and fatty acids required by the fish for normal growth. More recently, small quantities of fish meal and fish oil (3-5 percent and 1-3 percent, respectively) have been included in feeds for omnivorous and herbivorous fish.

Manufactured fish feeds account for 35 percent of the fish meal and 55 percent of the fish oil produced annually. Most of the rest is used in manufactured feeds for terrestrial farm animals and poultry.

Carnivorous fish convert these manufactured feeds to edible flesh with maximum efficiency.
Farmed salmon convert approximately 1.2 kg of feed into 1 kg of fish.
Poultry convert between 3 and 5 kg of feed into 1 kg of flesh.
Pigs convert approximately 8 kg of feed into 1 kg of flesh.

Replacement of marine protein sources by (terrestrial) plant protein

For various reasons, fishmeal and oil are gradually being replaced by plant proteins in feed that is used in fish farms. Plant proteins can be less costly and they are free of potential contaminants like dioxin, PCB or mercury.

However, fishmeal is an important ingredient in fish feed and can only to a limited extent be replaced by vegetable proteins without reducing feed efficiency and growth. After all, carnivorous or 'piscivorous' fish naturally feed on other fish. The fatty acid composition in the flesh from farmed fish will also reflect the feed composition and inclusion of vegetable oil will reduce the level of omega-3 fatty acids.

Although the introduction of plant protein into the feed can be seen as a way of reducing the sector's dependence on fish meal and fish oil, some have questioned the trend because:

- carnivorous fish do not naturally feed on plants;
- plant proteins may have anti-nutritional effects on fish;
- there is a maximum level of replacement, after which the texture and eating quality of the fish is compromised;
- some plant proteins could be derived from GMOs.

Generally speaking, though, marine plants have enormous potential to act as fish feed ingredients. Initial research has confirmed this potential and our knowledge in this area is starting to build.

Decontamination of fish meal and fish oil

Fishmeal and fish oil are produced from fish that may contain contaminants. Various research projects are ongoing to look into the feasibility of de-contaminating fish meal and fish oil. One such project is carried out at the Fiskeriforskning Institute in Norway.

Fish stocks of concern in the northern European industry are sprat and herring from the Baltic Sea, and herring, sprat, sand eel and blue whiting in the North Sea. The differences in dioxin and PCB levels reflect the general pollution levels in the respective fishing areas and will disfavour the North European fishmeal and oil producers in the world market. This is already the case in aquaculture, where most fishmeal is sourced from the southern hemisphere.

The main objective of the project is to develop a new oil extraction process to reduce the persistent organic pollutants level in fishmeal. The research will aim to identity optimal processing conditions with respect to both decontamination efficiency and preservation of fishmeal and oil quality. The new oil extraction process is expected to have several advantages compared to a standard hexane extraction process. This will include the possibility of easy integration in an existing fishmeal processing line, use of a safe and non-flammable extraction medium and lower investment and operation costs.

Do farmed fish contain artificial colouring?

The natural red/orange colour of salmon results from carotenoid pigments, largely astaxanthin in the flesh. Astaxanthin is a potent antioxidant that stimulates the development of healthy fish nervous systems and that enhances the fish's fertility and growth rate. Wild salmon get these carotenoids from feeding on small crustaceans, such as prawns and shrimp. Astaxanthin does not naturally occur in fish feeds and thus must be added. The astaxanthin which is added to feed is identical to the natural pigment.

EU initiatives address sustainable feed resources

FORM

FORM is a Thematic Network on Fish Oil and Meal Replacement, bringing together five EU-funded research programmes. The forum participants are five of the leading European institutes in fish nutrition. www.formnetwork.net

AquaMAX

AquaMAX is an Integrated Research Project that brings together a wide spectrum of expertise to develop feeds based on sustainable alternatives to fish meal and fish oil to produce healthy and minimally contaminated fish that are highly nutritious, health-beneficial and acceptable to consumers. To be able to detect very low levels of contaminants in feeds to ensure farmed fish are as low in contaminants as possible, analytical methodology will be advanced. The feeds developed will be tested on Atlantic salmon, rainbow trout, sea bream and carp.

The health benefits of the fish produced on the new diets will be tested in pregnant women and special emphasis will be placed on predictors of disease and on the development of immune competence in infancy. AquaMAX will also measure consumer perception and acceptance of fish farmed on conventional and new diets, by conducting taste panel trials and sensory evaluations of the final products. www.aquamaxip.eu

New research on marine vegetable protein from microalgae - PUFAfeed

The main aim of the PUFAfeed project was the production of microalgae that are rich in poly-unsaturated fatty acids for their incorporation into fish feeds as an alternative resource to fish oil. This would help to supply the aquaculture industry with feeds of constant and good quality that are free of toxins or genetically modified materials.

The PUFAfeed project has proven the technical feasibility to produce and include biomass from cultivated marine microorganisms with high levels of omega-3 fatty acids in feed for salmon and sea bream. Further research on finding novel strains and improved production methods may result in applications of cultivated marine organisms that are also economically feasible, and give rise to a more sustainable aquaculture sector.

Food miles

In recent years, there has been increasing emphasis on energy resources needed to ship in food from afar. Although the relationship between transport and overall sustainability can be complex, it can be said that where food supply chains are otherwise identical, reducing food transport improves sustainability.

Therefore, generally speaking, European aquaculture production could be seen as more efficient in terms of "food miles" than imports of the same species from countries far away.

However, there is a food mile issue with the use of fish meal and fish oil produced in the southern hemisphere and used in Europe, although this is itself a trade-off of not using fish meal produced in Europe due to issues of species in recovery (e.g. sandeel and capelin) and contamination of fish meal and oil (e.g. Baltic herring).

However, as stated before, comparisons can be complex, involving differences between food supply systems that often involve trade-offs between a diverse variety of environmental, social and economic factors. The impact of food transport can be offset to some extent if food imported to an area has been produced more sustainably than the food available locally. For example, a case study showed that it can be more sustainable (at least in energy efficiency terms) to import tomatoes from Spain than to produce them in heated greenhouses in the UK outside the summer months.

In the case of fishmeal and fish oil, the world's largest producers of fishmeal and fish oil are in South America. There, fishmeal and fish oil are mass-produced very efficiently and shipped overseas (already with a reduced water content in the case of fishmeal) to Europe to be used as feed in aquaculture. Surely, this has to compare favourably to using airplanes to import fresh fish from Asia or South America.

Bridging the gap – through governance

The European Commission has established several programs to ensure that fish farming in the European Union is sustainable and assures the availability to European consumers of farmed fish that is healthy, safe and of good quality. European fish farming also provides long-term secure employment in an environmentally sound and profitable European-based industry. Programs for the tracing and the identification of the origin of fish have become obligatory within the European Union. Farmed fish can be traced throughout its entire life cycle. This provides excellent guarantees to consumers that the healthiness, safety and sustainability of European farmed fish is optimally monitored and constantly controlled for, until it reaches the consumer's plate.

As wild fisheries continue to remain static or even to decline, and as demand and seafood consumption continues to increase, the only future scenario is that more farmed fish and shellfish will be consumed. Aquaculture producers, processors and distributors therefore have a responsibility to prove to consumers that their products are tasty, healthy and safe to eat.

In 1999, the ***Federation of European Aquaculture Producers*** (FEAP) developed a Code of Conduct for European aquaculture that set out clear recommendations for its members (80 percent of European fish farmers) on sustainable production and food safety. This self-regulation was seen as a model for fish farmers in other regions of the world. FEAP has also coordinated the ***AquaMedia*** initiative (www.aquamedia.org), designed to provide clear information to consumers on many aspects of European aquaculture.

In 2002, the ***European Commission*** proposed to the European Parliament a strategy for sustainable aquaculture in Europe. The strategy[7] provided specific objectives for the aquaculture sector, aiming to

- Create long-term secure employment, in particular in fishing-dependent areas;
- Assure the availability to consumers of products that are healthy, safe and of good quality, as well as promote high animal health and welfare standards;
- Ensure an environmentally sound industry.

An extensive consultation in 2007, culminating in a European conference in November 2007, has identified the need to update this strategy, and the Commission has started preparing a new Communication for publication in 2008.

Today, several Member States have expanded the European Code of Conduct with specific Codes of Good Practice that ensure sustainable aquaculture production. Others are in preparation and all Member States wishing to benefit from EC Structural Funds under the European Fisheries Fund have submitted "Operating Programmes for Fisheries 2007-2013" that in many cases contain sustainable aquaculture development plans. The current, updated FEAP Code of Conduct includes many of the indicators developed by the CONSENSUS initiative that can be implemented on the farm.

[7] COM (2002) 511 final

Over the last 15 years, considerable efforts in research and development have accompanied dramatic production growth in the aquaculture sector. This research generally focused on areas such as production techniques, feed development and knowledge of fish diseases and their treatment. This is what was called the "farm to fork" approach – where the emphasis was on selling the fish that farmers had produced.

Current research is significantly more consumer-focused and orientated towards identifying consumer needs and meeting those through production and processing technologies. This is now called the "fork to farm" approach – where the emphasis is on producing the fish that consumers want.

This "fork to farm" concept drove the European Union research framework programme from 2002 onwards. This framework programme also placed considerable emphasis on the role of scientific knowledge in developing and supporting policy in aquaculture.

The CONSENSUS initiative was funded by the European Union as part of its key action "Food Quality and Safety". With its stakeholder representation of consumers, aquaculture producers, environmental and other non-governmental organisations, CONSENSUS is building ***sustainable aquaculture protocols*** based on low environmental impact, high competitiveness and ethical responsibility with regard to biodiversity and animal welfare.

These protocols are complementary to European industry codes described above. Future impacts – and a longer-term objective of CONSENSUS – are based on the establishment of a European Sustainability Standard recognised by industry and by consumers.

An alternative scenario is that the gap between demand and supply will not be filled by European production, but by imports from third countries – a trend that is already being observed. At the end of the day, European consumers will choose whether to buy European aquaculture products, or not.

Readers Notes

CONSENSUS Partners

European Aquaculture Society

Federation of European Aquaculture Producers

European Mollusc Producers Association

The European Feed Manufacturers' Federation

The European Consumers Organisation BEUC

European Bureau for Conservation Development

Test Achats / Test-Aankoop (Belgium)

Danish Institute for Fisheries Research (Denmark)

Ghent University (Belgium)

Stirling University Institute of Aquaculture (UK)

University of Glasgow (UK)

Aquaculture Technology and Training Network (Ireland)

French National Institute for Agricultural Research (France)

The National Committee for Research Ethics in Science and Technology (Norway)

BVD Consultants SA (Belgium)

Research Institute for Fisheries, Aquaculture and Irrigation (Hungary)

Wageningen University and Research (The Netherlands)

Association of Scottish Shellfish Growers (UK)

Technical University of Catalonia (Spain)

Norwegian Institute of Fisheries and Aquaculture Research (Norway)

Marine Institute (Ireland)

consensus
SUSTAINABLE AQUACULTURE IN EUROPE

European Aquaculture Society
Slijkensesteenweg 4,
B-8400 Oostende,
Belgium

T: +32 59323859
F: +32 59321005