4 A bright future for fish farming

> It is highly unlikely that wild capture fisheries will be able to produce higher yields in future. For aquaculture the opposite is the case. No other food production sector has grown as fast over the past 20 years. Abuses such as antibiotics in fish feed and the over-fertilization of marine waters, however, have brought the industry into disrepute. It must now prove that large-scale fish farming is possible without placing unacceptable demands on the environment.

Aquaculture – protein provider for the world

> During the 1970s aquaculture was a relatively insignificant industry, but today it is almost as productive as the ocean fishing sector. About 600 aquatic species are now raised in captivity, with different species being preferred for different regions. Experts predict that the importance of fish farming will increase even more in the future, because it has clear advantages over beef and pork production.

Fish for 9 billion people

The global population is growing at a breathtaking pace. In 1950 the world had a total of 2.5 billion people, a figure that had burgeoned to 7 billion by 2012. According to United Nations estimates, this number could exceed the 9 billion mark by mid-century. As populations increase, so too does the need for food. Fish is a widespread, affordable and healthy source of valuable protein. There is no question, therefore, that the global demand for fish will intensify in future.

When we consider that the amount of wild-captured fish has not increased in recent years, only one alternative remains: fish farming, or aquaculture, must fill the gap. Is it capable of doing so? This is the question many scientists around the world are trying to answer.

4.1 > No other food production sector has achieved such high growth rates as aquaculture in the past 40 years.

Average annual production increase (1970 to 2008)	
Plant Food Commodities	
Cereals	2.1 %
Pulses	1.1 %
Roots and tubers	0.9 %
Vegetables and melons	3.4 %
Animal food commodities	
Beef and buffalo	1.3 %
Eggs	3.2 %
Milk	1.5 %
Poultry	5.0 %
Sheep and goats	1.8 %
Fish	8.4 %

For many years aquaculture played a relatively minor role in global fish production, but its significance has increased dramatically over the past 20 years, spurred by the demand from Asia's fast-growing populations. Today, aquaculture makes a major contribution to human nutrition. For example, it provides a large proportion of the animal protein consumed in China, Bangladesh and Indonesia. Global production of fish, mussels and crab in 2010 was almost 60 million tonnes, a figure which includes production in marine waters, brackish water and freshwater. Aquaculture production is now about three quarters of that from ocean fish and seafood caught in the wild. In 2011 this amounted to 78.9 million tonnes.

No other food industry has shown such growth as aquaculture in recent decades. Between 1970 and 2008 annual production worldwide increased by an average of 8.4 per cent; much more than poultry farming and egg production, which have the second highest growth rates after aquaculture.

Asia – the cradle of fish farming

Aquaculture is not equally important in all countries and all regions. For instance, central Europe in general prefers its fish to be caught in the wild. In China on the other hand, fish farming is widespread and has enjoyed a millennia long tradition, since carp were first domesticated. China is still the undisputed leader in aquaculture production. Since 1970 it has recorded annual growth rates in aquaculture production of an average 10 per cent, although recently these have slowed to about 6 per cent. Today 61 per cent of global production comes from China, with

Asia as a whole supplying a massive 89 per cent. This figure includes both fish farming inland (in freshwater) and in coastal areas.

The proportion generated in the other world regions is therefore small. Europe and America produced approximately 2.5 million tonnes each in 2010, Africa a little below 1.3 million tonnes and Oceania less than 200,000 tonnes.

For a long time aquaculture in many Asian countries has mainly provided food for local populations. Nations such as Thailand and Vietnam traditionally farm fish in the flooded rice fields; many people catch their lunch or evening meal from the neighbouring rice paddy. This widespread peasant practice, never captured in actual numbers, makes it difficult to estimate the actual extent of aquaculture production. For this reason experts assume that some Asian states produce totals even greater than those quoted in the statistics.

What is certain, however, is that aquaculture has not developed equally in all Asian states. The 10 largest producers alone generate 53 million tonnes, a massive 86 per cent of global aquaculture production, with the remaining Asian states producing only about 1.5 million tonnes. These countries still use only small amounts of farmed fish for their own consumption needs.

Modest growth in America and Europe

Between 1970 and 2000 aquaculture production in America and Europe grew by 4 to 5 per cent per annum. Since then it has increased by a moderate 1 to 2 per cent a year. Chile is the most important producer in America, since major salmon farms were established there over the last 20 years. In 2010 Chile supplied a good 700,000 tonnes of farmed fish, mainly salmon. The second largest producer on the American continent is the USA with slightly under 500,000 tonnes of fish.

Norway is the most important aquaculture nation in Europe, with about 1 million tonnes of farmed fish, followed by Spain with a good 250,000 tonnes; France takes third place with 220,000 tonnes. The main aquatic products farmed in Europe are salmon, rainbow trout, eel and carp.

World	Tonnes	Percentage
China	36,734,215	61.35
India	4,648,851	7.76
Vietnam	2,671,800	4.46
Indonesia	2,304,824	3.85
Bangladesh	1,308,515	2.19
Thailand	1,286,122	2.15
Norway	1,008,010	1.68
Egypt	919,585	1.54
Myanmar	850,697	1.42
Philippines	744,695	1.24
Others	7,395,281	12.35
Total	59,872,600	100.00

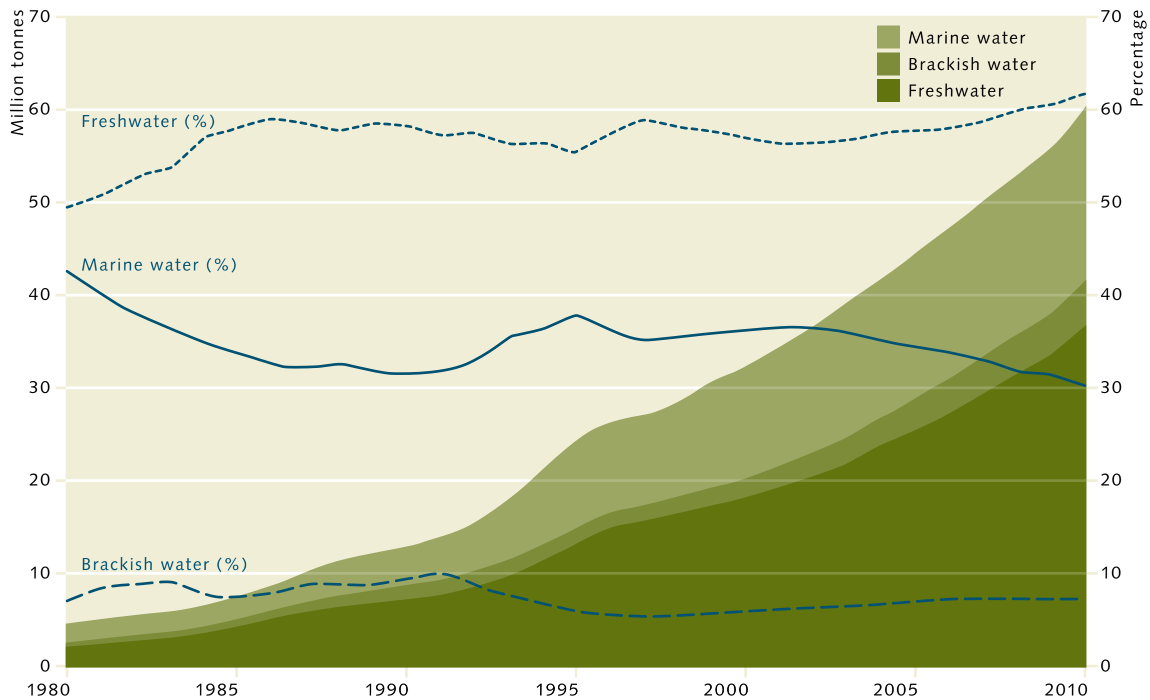
4.2 > Asia dominates world aquaculture. The total output of the top ten producer countries worldwide is shown. The amounts of farmed algae and aquaculture products not used as food are not included

Aquaculture – a prospect for Africa?

Developments in Africa are of paramount interest. Although aquaculture production was barely 1.3 million tonnes in 2010, experts nonetheless expect to see fish farming become further established in Africa. It would enable the – relatively easy – generation of large amounts of valuable protein for the growing population.

Egypt is the trailblazer here, with large numbers of finfish (tilapias, mullets and catfish) being farmed in the Nile Delta. Aquaculture is also expected to grow wherever fish is a traditional food, but where insufficient wild fish will be available to meet the growing demand.

The lack of wild fish, particularly in urban centres, is forcing a change in thinking. Take Lagos, the capital of Nigeria, on the Gulf of Guinea as an example. The people living around the Lagos Lagoon have always farmed catfish for their own use, but now the early stages of commercial aquaculture are becoming evident, and further expansion is expected. Similar developments are being



4.3 > Marine water, brackish water and freshwater – aquaculture production has shown strong growth in all areas over the past 30 years.

seen in Accra, the capital of Ghana, and Lusaka, the capital of Zambia. Small and medium-sized businesses are also becoming involved in Zambia and Uganda, with the aim of operating commercial aquaculture on a large scale. Experts are praising these approaches, because they believe this is the only way of making enough fish available to supply local markets.

Furthermore, there is great interest in the large-scale expansion of fish farming in countries such as South Africa. For about 5 years now a national aquaculture association has been involved in setting up aquaculture operations. Some of the technology applied will be exported to other African nations, although in some countries the importation of the facilities is still complicated by exorbitantly high duties.

In many other regions of Africa, however, an aquaculture industry is still a long way off. For this reason non-governmental organizations (**NGOs**) have been trying for some years to encourage aquaculture among individual communities.

With the exception of a few nations, aquaculture in Africa is still at an embryonic stage, and its potential is far from being exploited. It will take at least 10 years before any appreciable production increases are seen. Unfortunately, even if strong expansion should occur, aquaculture is unlikely to be able to keep pace with the needs of the fast-growing population.

From salmon to pangasius – aquaculture products

About 600 species are raised worldwide by aquaculture. Depending on local traditions and preferences, different species are in high demand in different regions of the world. The species raised include fish, crabs, mussels, amphibians (frogs), aquatic reptiles, sea cucumbers, jellyfish and sea squirts (fleshy organisms which live on the sea floor and filter the water). China farms mussels and carp in particular, and in terms of the latter, has done so for several thousand years. The carp is also a popular farmed fish throughout the rest of Asia. Finfish are found here, too, along with catfish and shrimps, and prawns which are exported all over the world. For some years now a popular Asian export fish has been the pangasius, of which there are several different species. These catfish are white-fleshed, neutral-tasting and almost bone-free. At first it was necessary to catch juvenile fish in the wild for breeding purposes, but in the early 1990s a French-Vietnamese project succeeded in breeding two types of pangasius in captivity. Only then was it possible to breed the fish in large numbers, allowing its export on a grand scale. Today the export of pangasius is a global winner.

In Europe, however, the farming of mainly salmonids is preferred, including salmon and trout along with turbot and mussels. Only small numbers of carp and other finfish are bred in captivity. In the past 10 years production of sea bass, common dentex and gilthead seabream has expanded, particularly in Greece, Italy and Turkey, mostly in net cages in coastal bays.

Salmonids are also the dominant group of farmed fish in South America, mainly in Chile, followed in equal parts by shrimps, prawns and mussels. Shrimps and prawns, catfish, mussels and salmonids are farmed in North America, mainly in Canada. Tilapia, catfish and other finfish are of particular interest in Africa, while shrimps and prawns predominate in Oceania.

Algae for Asia

The cultivation of algae is less widespread than that of aquatic animals. It is only practised in about 30 countries throughout the world, predominantly in Asia. In most cases cultivation is of large algae such as kombu *(Laminaria japonica)*, a Japanese seaweed which is several metres long. It is now farmed mainly in marine water and brackish water along the coast of China. Kombu is often used as a soup ingredient. Although the 19 million tonnes of algae produced in 2010 was much less than farmed aquatic animals, nonetheless its growth rate has been similarly strong in recent years – an average of 9.5 per cent per annum during the 1990s and 7.4 per cent in the past decade. In 1990 global algae production was 3.8 million tonnes. The most

Aquaculture production (Million tonnes)

Species group	2003	2008
Carps	15.04	19.72
Catfish	1.03	2.78
Tilapias	1.59	2.80
Eels	0.32	0.48
Salmonids	1.85	2.26
Other finfish	4.40	5.79
Bivalves	11.06	12.65
Gastropods	0.21	0.37
Crabs and lobsters	0.49	0.76
Shrimps and prawns	2.59	4.35
Other invertebrates	0.12	0.31

4.4 > In terms of aquaculture production, carp is the most important fish worldwide.

	Milk	Carp	Eggs	Chicken	Pork	Beef
Feed conversion (kg of feed/kg live weight)	0.7	1.5	3.8	2.3	5.9	12.7
Feed conversion (kg of feed/kg edible weight)	0.7	2.3	4.2	4.2	10.7	31.7
Protein content (% of edible weight)	3.5	18	13	20	14	15
Protein conversion efficiency (%)	40	30	30	25	13	5

4.5 > Fish can convert feed into body mass much more efficiently than birds or mammals. They provide a great deal more mass per kilogram of feed.

important regions are China (58.4 per cent of global production), Indonesia (20.6 per cent) and the Philippines (9.5 per cent). Most of the algae produced worldwide is used in the cosmetics, chemical and food industries. Only a small proportion is used for human consumption, as a base for soups. The tropical algae *Eucheuma* and *Kappaphycus*, harvested throughout the Indo-Pacific region between the island of Zanzibar and the Philippines, are also of significance. They offer many fishermen an additional income and are utilized in the chemical, health and biological industries as a bacterial growth medium.

The strengths and weaknesses of aquaculture

Aquaculture has come in for some hefty criticism in recent years. For various reasons it still attracts controversy. Food, faecal and metabolic wastes from intensive fish farms can lead to the **eutrophication (over-fertilization)** of water in rivers and coastal bays. There have also been complaints that fish farmed under intensive conditions for maximum yields are more susceptible to disease than their relatives in the wild. Tremendous amounts of antibiotics and other medications are used to fight disease, particularly in relation to shrimp on farms in South East Asia – with unforeseeable consequences for surrounding ecosystems and consumer health. In some cases these points are valid, but they should not detract from the fact that aquaculture can be a very efficient and sustainable method of supplying humans with animal proteins – and counteracting over-fishing.

The farming of the classic common carp or mirror carp provides a positive example of environmentally-sound aquaculture. Carp are bottom feeders, generally eating small aquatic animals, plants, dead plant matter and waste

4.6 > In Belize, in Central America, the construction of huge aquaculture facilities has involved the destruction of large tracts of land and mangroves. The effluent is discharged to the sea without any prior treatment. Such operations have brought the sector into disrepute.

material which gather on the pond floor. They also sieve the water to extract suspended solids, thus helping to keep the water clean. Carp ponds often have very clear water. Intensive mussel farming also helps to keep the water clean. Mussels filter large amounts of water, sieving out tiny particles of food, thus counteracting the over-fertilization of water and **algal blooms.**

Although the nutrient-rich effluents from aquaculture facilities can lead to problems in rivers or coastal areas, nonetheless many fish farms are more environmentally-friendly than, for instance, the intensive farming of pigs or cattle. The latter emit large quantities of nitrogen and phosphorus from the slurry and manure used to fertilize the land. Aquaculture produces far lower emissions of nitrogen and phosphorus and can roughly be compared with those from the much less problematic farming of poultry. This is made abundantly clear by the example of the Mekong Delta. Only about 1 to 2 per cent of nutrient inflows into the delta come from pangasius aquaculture. The majority comes from agriculture, the production of vegetables and fruit as well as from untreated municipal sewage and industrial effluent. Aquaculture also scores well when compared to livestock breeding because fish and other aquatic organisms need less nourishment to build body mass than land animals. Therefore a lot less feed is required to produce 1 kilogram of carp than to produce 1 kilogram of chicken, beef or pork. One reason for this is that fish are cold-blooded creatures, meaning that their body temperature is approximately the same as that of their surroundings. They therefore need far less energy to produce heat than warm-blooded mammals or birds. Also, it takes greater expenditure of energy to move on land than in the water. As water is denser than air, it provides buoyant lift to the body, meaning that fish are supported without the development of heavy skeletal mass. Many marine animals such as mussels, snails and sea cucumbers also manage without an internal skeleton. This saves them the energy they would otherwise use to build bones. Fish have another energy advantage, too: they are capable of releasing into the water (as ammonium, a simple chemical compound) any surplus nitrogen they may have absorbed with their food. In contrast, land-based animals have to use energy to convert nitrogen into urea or uric acid. Only in this chemical form are they able to excrete the nitrogen with their faeces or urine.

Commodity	Nitrogen emissions (kg/tonne protein produced)	Phosphorus emissions (kg/tonne protein produced)
Beef	1200	180
Pork	800	120
Chicken	300	40
Fish (average)	360	102
Bivalves	–27	–29
Carps	471	148
Catfish	415	122
Other finfish	474	153
Salmonids	284	71
Shrimps and prawns	309	78
Tilapia	593	172

4.7 > Aquaculture emits much less nitrogen and phosphorus per tonne of produced protein than livestock farming. Farmed mussels even lower nitrogen and phosphorus levels as they filter the water. However, this also means that mussels from highly polluted waters can themselves contain high nitogen and phosphor levels.

Fish for all?

In an international collaboration scientists have investigated whether aquaculture and commercial fishing will be capable of meeting the global demand for fish in 2050. They are optimistic, believing that yes, they can. However, this would depend upon the world's fish stocks being managed sustainably in the long term. Also, the fish used as feed in aquaculture in the form of fishmeal and fish oil must be utilized more efficiently. Scientists have also queried the predicted direct impact of climate change and ocean warming on potential marine fisheries procduction. They have concluded that the amount of wild marine fish available for fisheries worldwide will probably be redistributed due to climate change and predict a slight 6 per cent overall increase on marine fisheries potential.

Towards more eco-friendly aquaculture

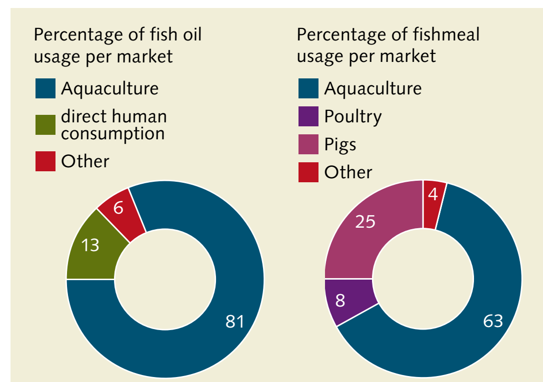
> Aquaculture is expected to satisfy the growing world population's demand for fish – and at the same time protect ocean fish stocks. Hopes are pinned on farming as an alternative to over-fishing. But the use of copious amounts of feed derived from wild fish, the destruction of mangrove forests and the use of antibiotics have given fish farming a bad name. Current research and development projects, however, show that environmentally-sound aquaculture systems are possible.

What do farmed fish eat?

The impact of aquaculture on the environment depends on several factors. It makes a difference whether the fish are farmed inland in freshwater, or along coastal areas. Intensive fish farms in coastal waters can pollute entire bays with uneaten food and fish faeces. Large areas of land are sacrificed to set up ponds, for example. An accumulation of effluent from aquaculture facilities can cause over-fertilization if it contains excess nutrients. Moreover it can contain residues of veterinary drugs. Feed is another important factor to consider when carrying out an environmental audit for an aquaculture operation. First of all, it is crucial to ascertain if any feeding at all is required, and if so, what kind of feed should be given to the aquatic animals. The aquaculture industry differentiates between natural feed and artificial feed.

- Natural feed includes the organisms that fish find and exploit in their surroundings. For example, mussels extract nutrients from the water without needing extra food. Carp feed on mosquito larvae, small mussels and zooplankton.

- Artificial feed (mostly in pelletized form) is processed in factories by feed manufacturers. The pellets are made of grain, fishmeal and fish oil. They contain all the nutrients which the species of farmed fish requires, and also a high proportion of protein and fat. Pellets are used for intensive fish farming – by companies which breed and sell fish on a grand scale. Salmon, tilapia, sea bass and some shrimps and lobster are fed with diets that contain fishmeal and fish oil from marine origin.

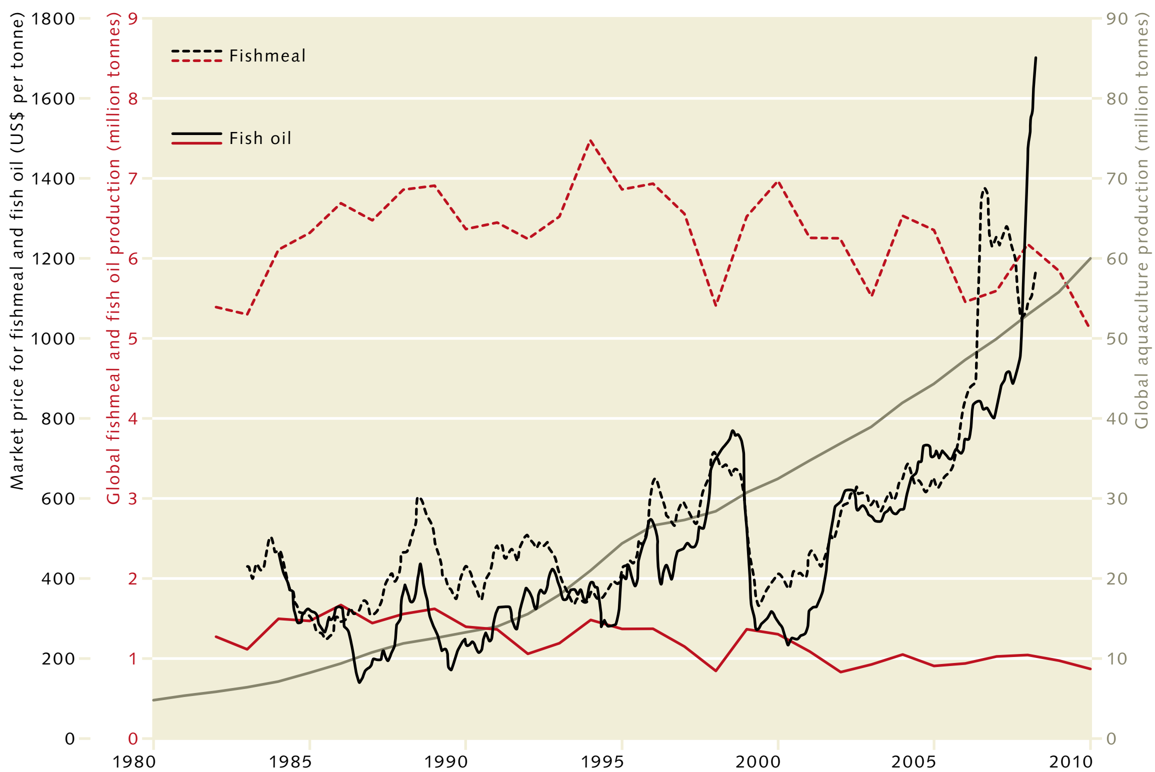


4.8 > Today fishmeal and fish oil are predominantly used in aquaculture. They are extracted mainly from anchovies and sardines.

Small aquaculture operators in particular tend to use feed which either grows or can be sourced locally at affordable prices. This includes plants, crop residues and fish waste.

The most controversial types of feed are those which contain a high proportion of fish. The problem is that the farming of some species requires the use of wild fish as feed – in most cases small pelagic fish, particularly anchovies, sardines and herring. Salmonid farming utilizes relatively large amounts of fish-based feed. Fishmeal and fish oil are produced in large industrial facilities, which involves grinding and boiling the whole fish. Centrifuges are then used to separate, dewater and dry the resultant mass.

In light of the fact that many wild fish stocks have been reduced to critical levels, it seems nonsensical to use them as fish feed, especially if the volume of wild fish produces a lower weight of farmed fish, as expressed by the "Fish In – Fish Out" (FIFO) ratio. For this reason critics are urging people to eat the wild fish directly, instead of using it as feed. However, so far there has been limited demand



4.9 > Although the output of aquaculture has increased greatly over the past 30 years, the sector's consumption of fishmeal and fish oil is at about the same level as in the 1980s. Greater use of plant-based nutrients is one reason; more efficient utilization of fishmeal and fish oils is another. The price of fishmeal and fish oils has multiplied, mainly due to rising demand in China.

around the world for small pelagic fish as food. Markets would first need to be developed. The fishmeal industry points out that the use of fishmeal and fish oil is justified because the fish utilized are from stocks that are in good state as a result of good fisheries management. But it is fair to say that not all these fish stocks are in fact managed sustainably.

Fishmeal and fish oil – expensive commodities

Not only salmon and eels, but many other farmed aquatic animals are currently being fed with fish caught in the wild – particularly with pellets processed from fishmeal and fish oil. Fishmeal and fish oil have been used in the farming of both poultry and pigs for decades. However, rising prices have reduced the proportion of these commodities in their feed. Aquaculture is by far the largest consumer, accounting for about 60 per cent of fishmeal and 81 per cent of fish oil. Fish oil is mainly used in the breeding of salmonids. Norway has greatly expanded its salmon farming facilities and is now the largest importer of fish oil. The amount consumed in food supplements and medicinal products for human use is 13 per cent.

Fishmeal and fish oil are extracted mainly from anchovies and sardines, which are found in large numbers off South America. China, Morocco, Norway, Japan and other nations also produce these commodities for their own consumption and for export. Among others, blue whiting, sand eels, capelin and sundry waste from fish processing are used in these countries. While Norway imports the most fish oil, China, Japan and Taiwan are the largest importers of fishmeal. Yet despite the strong growth in aquaculture of recent decades, the production of fishmeal and fish oil today is almost the same as it was in the early 1970s. There are several reasons for such growth combined with virtually constant inputs. First, the price for fishmeal has increased considerably in recent years as a result of strong demand in the importing countries, especially China. For this reason aquaculture producers are more interested in using feed substitutes – from crops for

How much fish does a fish need?

Aquaculture operators aim to raise as many fish as they can with as little feed as possible. Large predators such as salmon, however, require comparatively large amounts of feed to produce body mass. The FIFO ratio is the measurement of the amount they need. It indicates how much wild fish must be used as animal feed in order to produce an equivalent weight unit of farmed fish. If 1 kilogram of wild fish is used to produce the feeds of 1 kilogram of farmed fish, the FIFO ratio is 1 (1 kilogram/1 kilogram = 1). Any value more than 1 means that more than 1 kilogram of wild fish is required to produce 1 kilogram of farmed fish. In the mid-1990s the FIFO ratio for salmon was 7.5, while today the figure is between 3 and 0.5. Our increased knowledge of efficient feeding and improved feed formulations has contributed to this development.

Improved feeding efficiency as expressed by the FIFO ratio saves fishmeal and enables more farmed fish to be produced with less fish in feeds. Studies have shown that this technological adaptation from aquaculture industry is vital if we are to meet current and even larger per capita consumption rates. For example, if the current global consumption rate of fish of 17 kilogram per capita and year is to be maintained by 2050, aquaculture would have to reduce its FIFO ratio from approximately 0.6 in 2008 to 0.3 units of marine fish to produce a unit of farmed fish. The most recent assessments and projections indicate that this value is achievable if aquaculture continues to improve its efficiency at the current pace.

This seems to be possible – not only by optimizing feedstuffs, but also by breeding fish species which are less demanding. Catfish already achieve a ratio of 0.5, tilapia of 0.4 and milkfish, a popular fish group in Asia, a ratio of 0.2, which would mean that 5 units of cultivated milkfish are produced using one unit of marine fish.

instance. Second, the FIFO ratio of many fish species has been reduced by the use of improved feeds or improved feeding regimes.

Rapeseed in place of fishmeal?

Scientists are working hard to reduce both the amount of additional feed used in aquaculture and in particular the FIFO ratio. One approach is to develop crop-based feedstuffs which are rich in protein. The problem is that fishmeal contains a high percentage of protein, about 60 per cent, which is essential to build muscle mass. Rapeseed *(canola),* however, contains only 20 to 25 per cent. For this reason the researchers are trying to produce protein extracts, varying the amount of different proteins to ensure the feed is very easily digested and converted to body mass. Rapeseed is showing particular promise. This crop is utilized extensively for bioethanol (biodiesel) production: the large amounts of plant waste which accumulate would be suitable feedstock for aquaculture.

Protein can also be extracted from potatoes. Trials have been carried out using various different combinations of potato protein. Up to 50 per cent of fishmeal could be saved without any negative impact on the growth of the farmed fish. Alternative feedstuffs can also achieve the opposite result, however. So-called anti-nutrients can have a disastrous effect. These are substances which are poorly utilized by the fish and can induce metabolic disorders.

Scientists are convinced that feeding farmed fish with a combination of different ingredients is the most efficient approach. This would further reduce the use of expensive fishmeal and lower the FIFO ratio. It would make little sense to dispense with fishmeal and fish oil completely, however. Both provide essential omega-3 fatty acids which come from plankton. Fish cannot produce these themselves but ingest them with their food. If they are fed only plant-based feedstuffs, the farmed fish will lack these essential fatty acids, thus defeating the object. Such omega-3 fatty acids are one of the main reasons that consumers choose to eat fish.

More economical and environmentally-responsible feeding regimes require the following measures:

- the use of nutrients from local regions, to avoid long transportation routes;
- the improvement of processing and manufacturing methods to make the feed more nourishing and digestible, and reduce the content of anti-nutrients;
- the targeted and sparing use of fishmeal in combination with other alternative inputs;
- the increased farming of undemanding fish species which need fewer proteins and fats;
- the increased farming of fish species which are bred without fishmeal;
- the further development of high quality proteins and fats from plants and microorganisms.

The impact of aquaculture on marine habitats

If aquaculture is operated indiscriminately, environmental damage is often the consequence, especially in coastal areas. This can occur with mussel farming or fish farming in cages, where there is direct contact between the aquatic animals and the surrounding waters. In the past, farmed fish such as European Atlantic salmon in North America often escaped from their cages. In time they transferred diseases to the wild populations on the US coast. If the alien species feel at home in their new environment they can breed prolifically and in some cases completely crowd out indigenous species. Cultivation of the Pacific oyster was abandoned some decades ago by mussel farmers in Holland and off the North Sea island of Sylt. The species has become a problem, spreading over the entire mudflat area of the Wadden Sea – a shallow coastal sea bordering the North Sea – and overrunning the blue mussel, the staple food of the eider duck and the oystercatcher. The banks of mussels have now become inaccessible to the birds. "Invasive alien species" is the term given by experts to these non-native species. Regulations in Europe now govern the introduction of new species, prescribing a long period of quarantine. Many areas of Asia, however, do not take the problem of invasive alien species nearly so seriously. For this reason experts are calling for in-depth case-by-case assessments of the potential of species becoming prevalent in a new habitat and changing the ecosystem. Another problem can be the removal of juvenile fish or fish larvae from their natural habitat. The European eel, for example, migrates from the rivers of Europe to spawn in the Sargasso Sea in the western Atlantic. As this species cannot be bred in captivity, juvenile eels must be caught in the wild for breeding purposes. The practice places extra pressure on wild eel stocks. Happily, however, increased public pressure has virtually put a stop to mangrove clearances for new fish farms in the major river estuaries of South East Asia. The mangroves also proved to be unsuitable for the industry. Like the Wadden Sea mudflats, the sediment in mangrove forests contains nitrogen compounds, in particular toxic hydrogen sulphide. For several reasons this environment proved to be inappropriate for farming. According to development aid agencies, aquaculture facilities based on brackish water are no longer being established in the mangroves in Thailand, but in areas further inland.

4.10 > The Pacific oyster has colonized the entire Wadden Sea. It overruns the banks of blue mussels that are a vital source of food for seabirds such as eider ducks. It was originally introduced by mussel farmers in Holland and on the North Sea island of Sylt.

Effluent to feed plants

The excrement from fish farms can be used to sustain other organisms. For instance, the excretions from shrimps serve as food for large marine algae. Haddock feed on faeces particles and shrimp shells. This integrated multi-trophic aquaculture (IMTA) is now found in many different countries. It is operated mainly in breeding facilities along coastal areas.

Another type of integrated feeding used in inland breeding facilities is the aquaponic process. Effluent is used to fertilize crop plants; uneaten food, faeces and fish excreta provide the plants with nutrients. The plants in turn clean the water, thus closing the loop. Bacteria are often a part of the system which converts the food, faeces and excreta into chemical compounds that the plants can utilize. When animals and plants are combined with skill, such aquaponic facilities can be quite self-sufficient: operators neither have to feed the fish nor process the water. Tilapia, flowers and vegetables, among others, are farmed in aquaponic facilities. To date such facilities have seldom been operated on an industrial scale. The technology still needs optimization.

4.11 > Impressive aquaculture: fish and vegetables are produced together in this facility in the USA. Fish excrements provide nutrients for the plants. The plants purify the water. Such a closed-loop system is called "aquaponic".

The life cycle assessment

Aquaculture has drawn huge criticism in recent decades, not only for its feeding of fishmeal and fish oil. The use of antibiotics in breeding has also been condemned. Fish farmed in intensive systems to provide maximum yields are more susceptible to disease than their relatives in the wild. For this reason antibiotics and other drugs are widely used, especially in South East Asia. Already there are signs that these are no longer effective. In 2011 almost the entire shrimp production in Mozambique was destroyed by a viral disease. In 2012 the infection broke out on breeding farms along the coast of Madagascar. Experts blame the mass production of shrimps on factory farms. The antibiotics can in turn find their way through the food chain into the human body, potentially impacting on consumer health.

The antibiotics used in aquaculture and on other fattening farms – and also from hospital effluent – have in recent years led to the spread of multi-resistant pathogens, against which most established antibiotics are ineffective. Only special or newly-developed agents can help against multidrug-resistant infections. It is imperative therefore that the use of antibiotics in food production is strictly monitored and restricted.

The effluent from aquaculture operations is polluting rivers and coastal waters in other areas. However, the situation varies from region to region. In Norway, for example, production methods have improved as salmon farming has intensified and professionalized. Pollution with organic wastes (excreta) has reduced as a result of improved feeding techniques. And thanks to modern vaccines the use of antibiotics has almost completely been abandoned.

In order to better assess the adverse effects of aquaculture, experts now call for a comprehensive life cycle assessment (LCA). This is a methodology for evaluating the environmental performance of a product over its full life cycle – LCAs have in the meantime become established in industry in general. They analyse all the environmental effects of a product – from raw material extraction, to production, transportation, utilization and, finally, recycling.

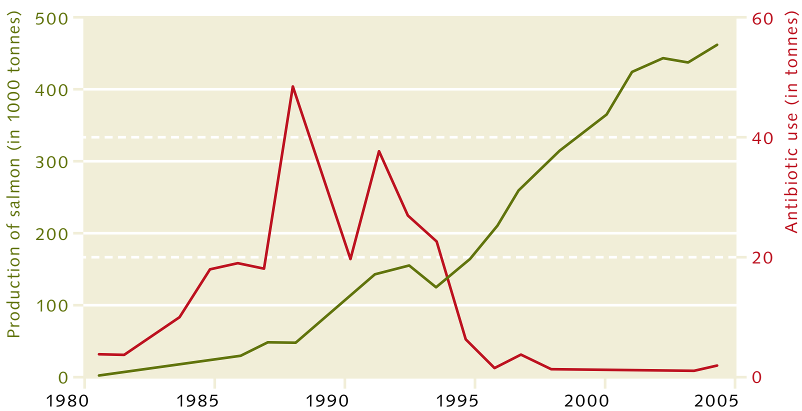
Among other aspects of aquaculture operation, eutrophication (over-fertilization) needs to be taken into account, along with nutrient inputs, such as faeces-enriched effluent discharged untreated into the water from the breeding ponds. The LCA also reflects the environmental pollution created by energy generation for an aquaculture operation: the cleaner the energy production, the better the result. The amount of wild fish used for feeding is also recorded, while land consumption is another important aspect. This includes the amount of land for the facility itself, and the amount used to grow the feedstuffs to meet operation needs. Critics of such life cycle assessments for aquaculture point out that it is difficult to compare the methods of production – carp pond and high-tech plant are two very different types of settings. Initial studies show, however, that such LCAs do indeed make sense for individual production methods.

A comprehensive analysis must also take into account the intensity of farm operations. Production can be broadly divided into three types:

- Extensive: natural bodies of water, such as ponds, are used for breeding, with little or no additional feedstuffs. Finfish, mussels, algae and some types of shrimps and prawns are produced by this method.
- Semi-intensive: natural bodies of water are used. Locally-sourced feedstuffs are fed to the fish. Typical species are finfish in Asia.
- Intensive: mainly operated in efficient, artificial pond systems or cages. The fish – e.g. eels from China – are fed with pellets.

According to a recent life cycle assessment of the different aquaculture systems (pond, breeding cages in coastal areas, mussels on the sea floor or suspended on a frame) and aquatic animal species throughout the world, intensive carp breeding in China is the most unsustainable. The ponds are heavily fertilized to speed up growth of the aquatic plants eaten by the carp. The effluent is often discharged without treatment, leading to eutrophication of

Sustainability certificates
Sustainability certificates are usually agreed between dealers, suppliers and producers. Environmental foundations are often involved. Such seals of approval verify that all parties concerned undertake to uphold binding social, environmental or sustainability standards. How far the specifications go depends on individual agreements. The aims are, among other things, to protect species, the environment and the water in the cultivated areas, as well as to improve social security for the employees. This includes a ban on child labour, the right to freedom of assembly as well as the right to health insurance and social insurance.



4.12 > The example of Norway shows that the intensification and professionalization of production can lead to improvements. Despite increasing numbers of salmon, the use of antibiotics in the Norwegian salmon farming industry has declined.

the rivers in many places. Conversely, in Europe carp farming is considered very environmentally-friendly, as the aquatic animals are bred under extensive production methods. This is mainly due to the fact that, unlike in China, the demand for carp is comparatively low.

The results for eel and shrimp farming in ponds are poor. As far as cage production along coastal areas is concerned, finfish are problematic. They involve a very high level of energy use, partially because of the frequent supply trips in boats. They also perform badly in terms of carbon dioxide emissions and acidification of the seas.

Improvement in sight

Europe imports large numbers of shrimp and fish from Asia in response to customer demand in countries such as Germany and France for affordable products. Cheap, however, can be synonymous with intensive, industrial, and often environmentally-damaging factory farms, which European consumers would prefer to be situated in someone else's back yard. Scientists claim that this is just outsourcing the problems from Europe to Asia, and the situation will not improve until attitudes change. The signs are promising, with many consumers now mindful of food safety and sustainability certificates. The certification of wild capture fisheries is already well established. Aware that such eco-labelling on product packaging can impact on purchasing decisions, the trade is now putting pressure on suppliers in the aquaculture industry, demanding fish from sustainable production. In the coming months farmed fish will appear on European shelves bearing the new "Aquaculture Stewardship Council" (ASC) label co-founded by the World Wide Fund For Nature (WWF), various food trading initiatives and fisheries. The "Marine Stewardship Council" (MSC) standard, the equivalent for ocean fish, has been around for many years.

There is no question that fish farming sustainability is gaining momentum or that the topic is being debated at the highest levels. Two years ago the Food and Agriculture Organization of the United Nations (FAO) published guidelines setting out clear standards for the certification of aquaculture operations. It is expected that traders will in future measure their producers against these guidelines. Certificates and voluntary commitments by the trade are already in existence, but consumers are unaware of them as they are only relevant for direct contacts between traders and suppliers. The same objectives, however, apply. For instance, trade cooperation agreements have been adopted for the distribution of pangasius from certified aquaculture operations along the Mekong Delta. Some major and international supermarket chains have also concluded individual agreements with producers.

For about 10 years now development aid agencies and non-governmental organizations in Asia have been trying to set up sustainable aquaculture operations. Converting a vast number of small operations is proving a challenge. For this reason efforts are being made to include as many farmers as possible in cooperation projects with the aim of improving production within an entire region. In some cases the solutions are extremely pragmatic. For example, extra ponds act as a buffer to protect rivers from the inflow of nutrients from farming ponds. The nutrients and suspended matter then settle as sludge for later use as fertilizer. In some regions of Vietnam there is now a brisk trade in sludge.

Experts also see a growing awareness in China for products from sustainable aquaculture, especially among the burgeoning middle class. National seals of sustainability are thus being promoted aggressively. Although this trend is promising, it will nonetheless take years for environmentally-sound aquaculture to finally become established.

Conclusion

The future of farmed fish

Driven mainly by massive population growth, urbanization and increasing wealth in Asia, aquaculture has grown by a good 8 per cent per annum over the past 20 years – faster than any other food sector. Today about 60 million tonnes of fish, mussels, crab and other aquatic organisms are farmed around the world each year. This is almost equal to the amount of ocean fish and seafood captured in the wild, which totalled 78.9 million tonnes in 2011. Asia, particularly China, is the most important aquaculture region, currently supplying 89 per cent of global production. Aquaculture will continue to grow strongly and thus make a significant contribution to providing the global population with valuable protein.

An advantage of aquaculture is that much fewer feedstuffs are needed to farm fish and seafood than beef and pigs. It takes 15 times as much feed to produce 1 kilogram of beef as to produce 1 kilogram of carp. Aquaculture is thus a resource-efficient method per se of producing protein-rich food from animals. Current studies investigating likely developments to 2050 indicate that aquaculture is capable of satisfying the world population's growing need for fish.

This ongoing growth, however, must not come at the cost of the environment or the climate. It is problematic that aquaculture still requires large amounts of wild fish, which is processed into fishmeal and fish oil and used as feed. Although the volumes of these commodities have been stagnating for years, in some cases they still make use of fish stocks which are not managed in a sustainable manner. Aquaculture can thus still be a contributor to the problem of over-fishing. Efforts are now being made to reduce the amount of fishmeal and fish oil used in fish farming, not least because prices have soared as a result of high demand in China. Many research groups are developing alternative types of fatty, protein-rich feed from potatoes and rapeseed. In many cases aquaculture production is still not sustainable. Facilities require too much energy and generate nutrient-rich effluent which is often channelled into rivers and coastal waters in an untreated state. The waters then become over-fertilized, causing algal bloom and oxygen-deprived dead zones.

Scientists are now developing methods to analyse the full life cycle of aquaculture facilities – life cycle assessments. For some time now the industry has been testing products for their environmental compatibility, embracing all aspects from the extraction of the raw materials through to recycling. The intensive rearing of carp and shrimps in ponds is considered very harmful. It scores extremely poorly in the life cycle assessment because it uses too much feed, produces nutrient-rich effluent, and consumes large amounts of energy. Yet in recent years environmental awareness has also become more widespread in the aquaculture sector. A change of thinking is evident, particularly in the industrialized nations which import large volumes of fish from Asia. Increasingly traders and customers are demanding goods which comply with environmental standards. For some years there have been sustainability certificates for marine capture fisheries, and products bearing this label are very much in demand. Soon the "Aquaculture Stewardship Council" certificate, a seal of approval for aquaculture operations, will be appearing on European markets. Traders and producers wishing to have this certificate must undertake to protect species, the environment and the water in farmed areas, and comply with a high level of social standards. We have an opportunity to gear the further expansion of aquaculture towards sustainability. Current environmental problems, over-fishing and climate change make this a matter of urgency.

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