The Economist

Special report:

Fish farming

The promise of a blue revolution

How aquaculture might meet most of the world's demand for fish without ruining the environment

Aug 7th 2003 | From the print edition

FISH farming has a bad reputation. Its supporters argue that it promises to meet the growing shortfall as the world's wild fisheries become more and more exhausted. But its critics have the louder voice. They argue that farmed fish is fatty, dyed, polluting and stuffed with antibiotics. Moreover, they say that it is unsustainable. When a carnivorous fish—such as the salmon—is reared on a farm, it too must be fed with fish. And these fish must be caught in the wild, thus putting even more pressure on marine life, not less.

The critics portray fish farming as an alarming environmental and health hazard, not a potential source of food for the world's rich and poor alike. But they glide quickly over the fact that modern aquaculture is at an early stage of development. Commercial agriculture has developed over centuries; large-scale commercial aquaculture is little more than 30 years old. New technologies, new breeds and newly domesticated species of fish offer great hope for the future. They promise a blue revolution in this century to match the green revolution of the last.

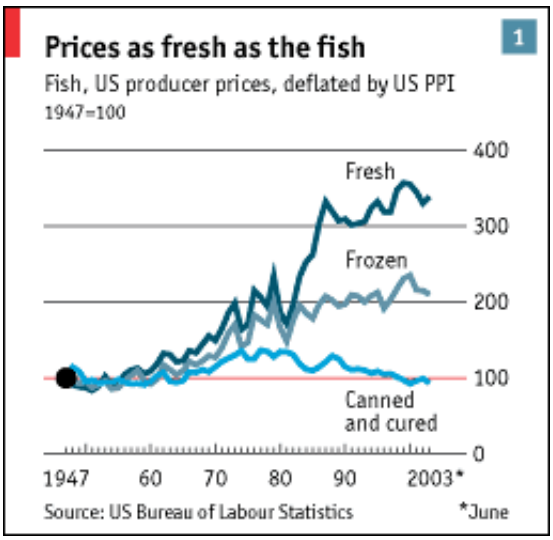
On land, human beings may be committed agriculturists, but in the sea they remain largely hunter-gatherers—albeit hunter-gatherers with industrialised fleets equipped with satellite and radar. In 2000, the world landed 95m tonnes of wild fish, with a first-sale value of $81 billion, according to the Food and Agriculture Organisation (FAO). Although this appears to be the highest catch of fish ever recorded, the figure is almost certainly wrong.

In the past year, it has become clear that statistics from China, the world's largest supplier of fish, have been inaccurate for at least a decade. Many now believe that the global catch has actually been in decline since the mid-1980s. This should come as no surprise: some 75% of global fish stocks are depleted in some way.

As people get richer, they eat more fish. Average consumption per person has almost doubled in under half a century. And fish has certainly become more expensive (see chart 1) as demand has increased and supply declined. There are still not enough farmed fish to stem this price rise. Some products, such as wild salmon and blue-fin tuna, are now luxuries. Nikolas Wada, a researcher with the International Food Policy Research Institute, says that the rise in seafood prices is even more remarkable when set in the context of prices for other animal products—such as beef, chicken, pork and milk—which have plummeted in real terms over the past 30 years.

The reason that people have been able to continue to eat more fish in spite of the over-exploitation of wild fisheries is because aquaculture production has been booming. In 2000, the industry produced 36m tonnes of fish and shellfish. Since 1990 the industry has been growing at an average compound rate of around 10% a year. It is probably the world's fastest growing form of food production. (By comparison, farmed meat production grew by 2.8%.) Already, around half of the fresh and frozen seafood consumed by Americans is farmed. Some people believe that, by 2030, aquaculture will supply most of the fish people eat.

The problem with some of these global figures is that nobody is sure how inaccurate China's statistics are. The country is without a doubt the world's largest producer of farmed fish and has seen strong growth in recent years (see chart 2). Official figures put its contribution at over 70% of the world's farmed fish and aquatic plants. But if China's production figures are out by only a little, many global predictions are out by a lot. Without China's contribution, aquaculture's growth since 1990 would have been less than 5% per year.



Nevertheless, there is still plenty of cause for optimism. On land, the green revolution allowed dramatic increases in crop production, with increased mechanisation, and improved pest control and soil fertility through the addition of herbicides, pesticides and nitrogen-based fertilisers. In the water, similar kinds of things are happening too. The stage is being set for an aquacultural revolution.

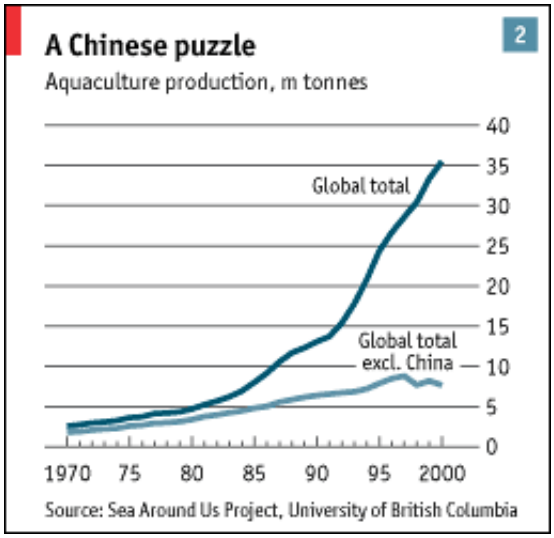
Blue is the colour

Traditional aquaculture, of the kind that the Chinese invented many thousands of years ago, is a low-tech affair involving no more than a pond, some rotting vegetables and a few freshwater fish that are not too fussy about the quality of water they live in or the proximity of their neighbours.

There is still plenty of it about. Jiansan Jia, an aquaculture expert at the FAO, says that 80% of the fish produced by aquaculture are herbivorous or omnivorous, mostly produced in low-intensity systems for local consumption. Such fish do a great deal to alleviate nutritional deficiencies and poverty in rural areas, and may yet become a big contributor to local food supplies in most developing countries.

However modern aquaculture, the kind that began with salmon about three decades ago, is a different matter. It involves technically specialised conditions and a great deal of knowledge about the habits and life cycle of each fish species.

It can take years of research to domesticate a new species. Stocking densities, water quality, breeding conditions, animal behaviour, health and precise nutritional requirements have all to be worked out in detail to domesticate wild fish such as the salmon, sea bass, flounder, halibut, sole, hake, haddock and sea bream. And it is scientific and technical knowledge that is driving competitiveness in the industry, by improving fish health and nutrition, and by reducing stress, disease and the use of antibiotics and vaccines.



Mirroring developments in the green revolution, the blue revolution has seen companies breeding fish to improve traits such as their growth rate, conversion of feed into flesh, resistance to disease, tolerance of cold and poor water, and fertility. Breeding tilapia (a freshwater, plant-eating fish popular in America) has produced a strain that is hardier and grows 60% faster than the wild variety.

This is only the beginning. There is already much talk of using genetic modification (GM) in fish farming. Scientists are tinkering with a salmon that carries a gene inducing the production of a growth hormone, which make the fish grow bigger and faster. This project, though, is even more controversial than farming GM crops because of concerns about what might happen if fish escape. No GM fish are being farmed for food at present.

Aquaculture has brought two crucial changes to the seafood industry: consistency of supply and lower prices. Dennis Overton, the managing director of Aquascot, a fish-farming operation in the Scottish Highlands, says that aquaculture has led to an increase in demand for fish. Before salmon were farmed, supermarkets found the unpredictable supply made it difficult to sell. Now salmon can be sold in the same way as beef or lamb, and this, he says, has had a huge impact on sales.

The market is growing fastest in North America—by 12-13% a year in recent years. Salmon is now

the third most popular seafood in America. A decade ago, Costco, a big retailer, did not even stock fresh fish. Now it sells 15,000 tonnes of farmed salmon fillets a year. The same story applies to shrimp, now America's most popular seafood.

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Scottish Quality Salmon, which represents the salmon-farming industry in Britain, says that in the early 1980s farmers received £11 a kilo ($10 a pound), but increased production and Norwegian dumping drove this down to £3 a kilo in the early 1990s. In 2002, the equivalent price was £1.90. Not all these improvements have been passed on to consumers, however. The retail price of salmon has not changed in Britain in the past decade.

For the future, says Richard Slaski of the Federation of Scottish Aquaculture Producers, it is halibut and cod that are causing a "huge wave of interest in northern and western Europe". Cod is (literally) the great white hope of European producers who are facing tough competition from cheap salmon production in Chile. Intensive research efforts are under way in France, Norway and Scotland to farm cod with complete predictability. It is a difficult business. Unlike salmon, cod fry do not have large yolks that they can live off in the early days of their lives. They must be fed, and fed correctly, almost as soon as they have been hatched.

Mr Overton says that Aquascot will breed cod to order from customers, rather than breeding lots of it in the hope of finding a market. But not everyone is thinking this way. "Our colleagues in Norway say they are going to produce thousands of tonnes," says Mr Slaski, although "they have not addressed the issue of where they are going to sell it." However, given that catches of wild cod have dropped by two-thirds in the past three decades, there is a clear gap in the market.

Cleaning up

It is pollution not revolution that most folk associate with aquaculture. And indeed, broadly speaking, modern intensive fish farming does harm the environment, although the extent varies enormously. But so does agriculture, and that has not detracted much from beef sales. The issue, of course, is whether society is willing to pay the price.

Waste from fish farms—such as uneaten food and dead fish—can accumulate and destroy parts of the sea. The overuse of antibiotics can threaten both marine and human health. And fish may transmit diseases such as sea lice to wild stock, or breed with wild fish causing "genetic pollution". In the past decade, 1m non-native Atlantic salmon have escaped from fish farms and established themselves in streams in the north west of America. There are some fjords in Norway where 90% of

the fish have escaped from farms.

Shrimp aquaculture also causes serious environmental problems—especially in countries with poor environmental regulations. These problems include the destruction of wetlands and mangroves, the dispersion of chemicals and nutrients, and the salinisation of the soil. A recent study by the Environmental Justice Foundation says that, in the Cau Mau province of Vietnam, the world's fifth-largest producer of farmed shrimp, the Mekong Delta's mangrove cover is 30% of what it was in 1975. Shrimp aquaculture is easily the main cause. Elsewhere, though, aquaculture has probably contributed to the loss of less than 10% of the world's mangroves: the rest is due to causes such as rice production, grazing, urban development and tourism.

The good news is that well-regulated countries have done something about the industry's poor environmental performance. One result has been feed formulations that are more digestible and that leach less waste into the environment. The EWOS group, one of the largest feed suppliers to the salmon-farming industry, is spending more than €10m ($16m) a year on improving nutrition, feed development and fish health. Kjell Bjordal, its chief executive, says that one measure of the release of waste—the nitrogen loading of the water—has declined sharply. In 1972, it was 180kg per 1,000kg of Norwegian salmon produced; today, new feeding technologies have brought it down to 30kg. The amount of feed used for growing salmon is 44% of what it was in 1972.

Mr Slaski says that the use of antibiotics in Norwegian aquaculture is less than 0.5% of what it was ten years ago. Vaccines have brought about great reductions in the use of antibiotics and other chemicals. Even shrimp farming need not be an environmental nightmare, agrees Jason Clay, an aquaculture expert at the World Wildlife Fund in Washington, DC. And in Florida, Ocean Boy Farms claims to be able to produce a marine shrimp that does not pollute the environment. Their inland shrimp farm uses another fish, the tilapia, to mop up the shrimps' waste. A similar technique is being tried by a farm at Mikhmoret, Israel. Such land-based, integrated farming techniques offer great promise but with minimal environmental cost.

Making a meal of it

Aquaculture's critics say that, despite all this effort, the industry has a fatal weakness. The problem was outlined several years ago by scientists who calculated that several kilos of wild caught fish were needed to feed every kilo of farmed salmon or other carnivorous fish such as eel or striped bass. This, it is argued, means that modern aquaculture is increasing, not reducing, the pressure on marine animals. Dan Barlow, of Friends of the Earth in Scotland, says it is even worse for cod. The sand eels that are caught in the North Sea for the farmed cod are supporting the marine food chain there. “You are robbing Peter to pay Paul,” he says, and wild cod will never recover.

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Yet despite the growing popularity of farmed carnivorous fish, there has been no corresponding boom in catches of the food they eat. The world's catch of “industrial” fish—mostly anchovies, sardines and menhaden—that is used to make fishmeal has remained resolutely stable at 30m tonnes for decades. The reason for this mystery is that in the past fishmeal was used to feed animals such as poultry and pigs, but this has been cut back. Many argue that using fishmeal to feed fish is, in fact, more efficient than using it to feed terrestrial animals. Today, fish farms use about 40% of the world's supply of fish oil, and 31% of its fishmeal. Many, including the FAO, predict a worldwide shortage of fish oil within the decade.

Technology may help to avert it. Mr Bjordal says the fishmeal content of fish feed has been reduced from 70% in 1972 to 35% today. He believes his firm can cut the use of marine resources in half again without reducing the amounts of a key fish oil—omega-3—which is the main reason why fish is seen as a healthy food. Replacement feedstuffs such as soya, rapeseed oil and corn gluten are being developed. Chinese researchers are working on a yeast-based protein supplement that could be a substitute for more than half the fishmeal.

How fast this resource runs out depends a great deal on what China does. It is now the world's largest importer of fishmeal and, if that continues, the FAO dryly observes, it will have “a serious impact on the rate with which the requirements for marine resources may potentially equal supply.”

The most serious concern if fishmeal were to run out, argues Mr Wada, would be the diversion of low-value fish from the mouths of people in developing countries into the mouths of well-fed fish in the developed world. However, if the price of fishmeal rises, a way might be found to harvest unexploited stocks of hard-to-catch industrial species such as krill. This would, though, reduce the amount of food available for large fish and marine animals. Alternatively, more use could be made of what is known as “bycatch”. This is marine collateral damage: the fish that are accidentally caught, killed and then thrown back in the water when other fish are the target. Bycatch amounts to tens of millions of tonnes of fish every year.

Aquaculture has one important advantage over open-access fisheries: it can be more easily governed. Environmental pressure can, and does, force the industry to change. The same cannot be said of the open seas, where nations compete furiously for a dwindling supply of wild fish, and politicians routinely ignore scientific advice. While fishermen can work only on improving the efficiency with which they capture the few remaining fish, aquaculture can work at lowering its costs of production and increasing its profits. As it does so, it may start to undercut the costs of open-seas fishing to the point where the government subsidies given to ocean fisheries become patently ridiculous. In this way, farming might one day relieve the pressure on wild fisheries.

Certify them

If the past history of agriculture is any guide, aquaculture will surely find a way to meet the world's demand for fish. The big question is: will this be done in a way that pollutes the marine environment unacceptably? As consumers become more aware of the sources and the means of production, they may insist that intensive, modern aquaculture should grow in environmentally sustainable ways.

The problem is that good independent information about the environmental friendliness of farmed fish is sorely lacking. Standards vary widely among countries, and raising standards in one place may drive the industry (and its pollution) somewhere else with weaker rules. An internationally recognised certification scheme, along the lines of dolphin-friendly tuna, is urgently needed to alert consumers to the sustainability (or otherwise) of the farmed fish that they are eating. Only in this way can consumers hope to find out whether the products of modern aquaculture are doing more harm than they prevent. And only then will it be clear how green is the blue revolution.

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