SUSTAINABLE FISH FARMING SAVES THE ENVIRONMENT

Green to the bone

We are already consuming more farmed than wild-caught fish, and that level of consumption is set to go on soaring. Whether the environment can cope largely depends on new fish-farming technology and improvements to fish, feeds and vaccinations. 'A farmed trout grows to ten times the weight of a wild trout in the same time.'

TEXT ARNO VAN 'T HOOG **PHOTO** GETTY IMAGES **INFOGRAPHIC** STEFFIE PADMOS

The hundred metre-long hall of Kingfish Zeeland on the former island of Noord-Beveland in the Netherlands resounds with the humming of pumps and murmur of air bubbles and running water. The sound is only dampened in the small room where the air is warm and humid and a round tub one metre high and two metres across teems with thousands of miniscule fish larvae the size of rice grains. The landscape outside is typically Dutch, with fields of potatoes and sugar beets and the Zeeland bridge, which punctuates the flatness. Indoors swim young sub-tropical yellowtail kingfish – a fish which does not have a Dutch name but is known to some here as amberjack or as the hiramasa served in a sushi bar.

'These larvae are now three weeks old,' says Sander Ruizeveld de Winter, the hatchery manager responsible for raising the fish larvae. 'They get fresh fairy shrimps which I breed myself every morning. Next week they will be put on dried food, and that's always a tense moment, seeing whether the larvae will eat it. Meanwhile I have to watch out that the larger larvae don't eat the smaller ones. For that reason we are going to >

> ‘The challenge is not to fall into the same traps as the livestock industry’

sort them soon with a fine sieve. Actually, I have been pleasantly surprised by the way things have gone up to now. To my knowledge this is only the second time anyone has succeeded in breeding yellowtail in Europe.’
As soon as the yellowtails are a couple of centimetres long, Bram Rohaan takes over. Rohaan is production manager, and, like his colleague Ruizeveld de Winter, a Wageningen graduate. As is Kees Kloet, co-founder and operational director of Kingfish Zeeland.

LIKE A RUGBY BALL

The warehouse houses tall tanks with a diameter of four and a half metres. In one of the tanks, 90 silvery grey fish swim in slow circles. Their heads are pointed like rugby balls and their streamlined bodies taper off into a crescent-moon-shaped yellow tail. At 70 centimetres and 15 kilos, these fish are still relatively young, explains Rohaan. Yellowtail kingfish *(Seriola Ialandi)* can live for 30 years and grow to 40 kilos and nearly 2 metres in length. ‘They really do grow incredibly fast. These parent fish are now four years old. If we gradually increase the temperature and daylight hours, they think it is summer and they spontaneously start spawning – and that can go on for months on end. Once fertilized, the eggs float to the surface and we can collect them easily.’
Much of the technology at this company is for the purpose of maintaining water quality and purifying water. Yellowtails eat protein-rich food and the waste products – ammonium and phosphate – get into the water. So the shed is full of big water pipes leading to water filters, deaerators, protein skimmers and bio filters. This is high-tech fish farming in a ‘recirculation system’ in which water is continuously recycled, while it is refreshed daily with a small proportion of clean water from the Eastern Scheldt estuary. This high-tech approach differs from conventional fish farming in ponds or net cages in open water, through which waste products enter the environment.
Farming fish in net cages is cheaper at present but in the end, land-based fish farming in a recirculation system is the way ahead, says Wageningen professor of Aquaculture and Fisheries Johan Verreth. ‘Closed systems provide more scope for intensive fish farming, which is what we need to meet the growing demand for fish. And it offers better prospects of doing so in a way that is ethically sound.’
The point is that global fish consumption is set to grow uncontrollably in the coming years, says Verreth, whose research includes studying the composition of fish feed and water purification in aquaculture. ‘Globally, people already eat more farmed than wild-caught fish. If we take world population growth into account, and the growing middle class in developing countries, fish farming production needs to double in the next 15 years. Everyone believes we can manage that, but to manage it in an ethical, sustainable manner really does pose a massive challenge.’
According to Verreth, the prospect of such growth raises a host of questions about feed consumption, water pollution and fish diseases. The manufacture of fish feed, for instance, involves processing large quantities of anchovies, herrings and sardines into fishmeal and fish oil. Fish oil is a key ingredient of fish feed, and depends on fisheries. With global fish catches already at their limit, fish oil is set to become an increasingly scarce resource, especially if aquaculture expands.

AVOIDING TRAPS

There is more to sustainable fish farming than technology and the environment, says Verreth. ‘You must also keep an eye on its place in the landscape and on socio-economic issues: accessibility and pricing of fish, and the labour conditions of people working in the industry. Aquaculture is farming in water. The challenge is not to fall into the same traps the intensive livestock farming industry has done. Because it is a new field, you can try to take all kinds of precautions and make the right decisions.’
One of the concerns is animal welfare. The issues in aquaculture are not really any different to those in livestock farming, says researcher Hans van de Vis of Wageningen Livestock Research. ‘It is important that the farming system is appropriate for the animal. You must look, for example, at its natural habitat, to identify the essential elements for the animal’s wellbeing. Of course, in the farm context, you can’t just randomly plant vegetation in a fish tank. You need to check which structures fit well and don’t hamper the flow of water, for instance.’
Together with Nijmegen researchers, Van de Vis studied zebra fish and demonstrated that they are far more resilient if they grow up in a tank with natural elements such as a sandy bottom and plants. They cope better with change and stress than members of their species raised in a bare aquarium. ‘That demonstrates the importance of meeting a fish’s natural needs. The diurnal rhythms and degree of light in the tanks should also match the fish’s needs, as should the temperature, oxygenation, acidity, and levels of waste products such as ammonia in the water.’
But techniques and measurements don’t solve everything, says Van de Vis. ‘It is important, too, to look at animal-based criteria: what does the animal “tell you” about the quality of the farming system. If a fish reacts strongly to, say, a net in the tank and takes a long time to recover from the stress, that is a signal that the farming system is not optimal.’ The same issues crop up at the end of the farming cycle, and during slaughter, says Van de Vis. ‘What conditions can you create so as to avoid unnecessary suffering? This applies to methods >

FISH FARMING

Global fish consumption is growing steadily, and farmed fish accounts for most of it. A new trend is farming fish in closed land-based systems: an innovative sector in which a lot of research is going on.

The growth in global fish consumption

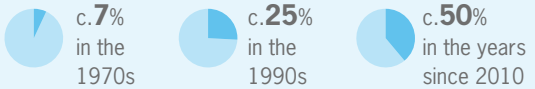
Fish consumption per person per year:

c. **10** kg in the 1960s

c. **14.5** kg in the 1990s

c. **20** kg in 2013

The percentage coming from fish farms:

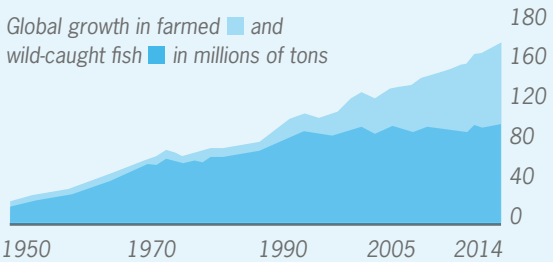


c.**7**% in the 1970s

c.**25**% in the 1990s

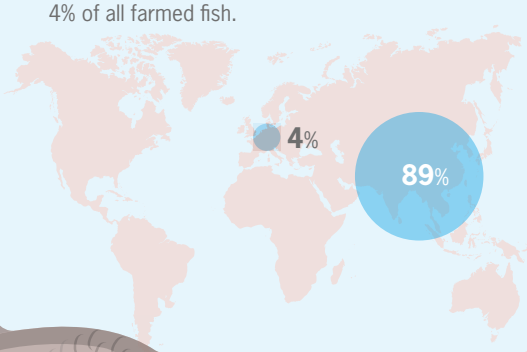
c.**50**% in the years since 2010

Growth in global fish production



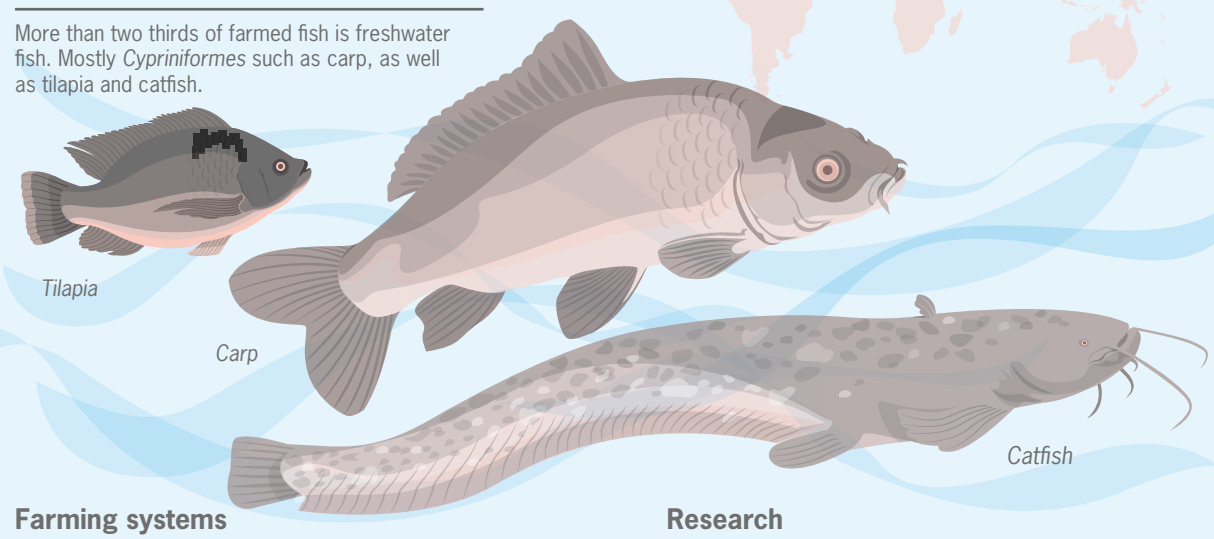
Location

By far the biggest volumes of farmed fish (89%) come from Asia (60% from China). Europe produces about 4% of all farmed fish.

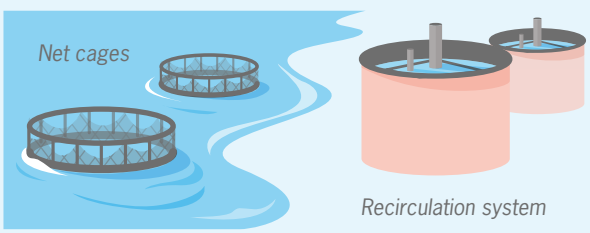


Freshwater fish

More than two thirds of farmed fish is freshwater fish. Mostly *Cypriniformes* such as carp, as well as tilapia and catfish.



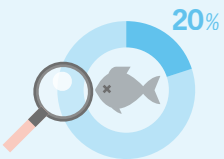
Farming systems



There is a long-standing tradition of farming fish in net cages in open water. The new trend is to use closed recirculation systems. Research on sustainable fish farming focuses on issues such as feed consumption, water pollution and fish diseases.

Research

European aquaculture loses c. 20 percent of its production value to diseases. A lot of research is going on to find ways of preventing this, through vaccination for instance.



Large quantities of anchovies, herring and sardines are processed into fish meal and fish oil, requiring catches of wild fish. Research topics include plant-based fish food.

Tilapia eggs in a hatching tray at a tilapia hatchery.

of transport, maintenance, anaesthetizing and slaughter. The conditions must be adapted to the species. Putting fish in a stunning device shows up the differences. While catfish can breathe in the air and do not suffer much from being lifted out of the water, salmon can't cope with it at all. These are big differences, and they dictate how you should handle a fish.'

CARP ARE CHAMPIONS

Compared with livestock, fish farming is a very small sector in the Netherlands. The chief farmed fish is eel, with some catfish and some pike-perch, as well as sturgeon for caviar. Globally too, the emphasis lies on freshwater fish-farming, which accounts for more than two thirds of farmed fish. Species such as tilapia and catfish are very popular, but the carp family are the champions of aquaculture. Worldwide, four million tons of common carp are produced by fish farms, far more than the global production of farmed salmon. Much farmed freshwater fish comes from Asia, often from small farming systems that are compatible with local customs and traditions. This diversity and the small scale make it harder to do research than it is in the livestock sector, says Verreth. 'Altogether, we are talking about 600 farmed fish species, as opposed to 15 species of animals in livestock farming. All those fish species make their own demands on the farming system and the water quality.'

The most advanced industry when it comes to research and technology is salmon farming, says Verreth. 'There are already pioneers in Denmark and Norway who are experimenting with land-based closed seawater systems. Another innovation is a closed system at sea: floating tanks in which the fish droppings are collected so they don't get into the sea.'

RESISTANCE TO SEA LICE

The salmon sector has made the most progress with selective breeding too. Farms started collecting wild Atlantic salmon from several Scandinavian rivers back in the 1970s, with a view to improving them by means of selection. The main breeding objectives were faster growth and efficient feed utilization, but steps have also been taken recently towards improving resistance to infectious diseases and parasites such as sea lice. Commercial lines were developed by companies such as Salmobreed in Norway, Marine Harvest in Scotland and Hendrix Genetics in the Netherlands. Today salmon farmers can choose from a catalogue offering five or six lines with specific characteristics such as improved rate of growth, resistance to disease and fillet colour. Forty years of selective breeding have led to remarkable improvements, says Kaspar Jansen, a PhD student supervised by Hans Komen, professor in the Breeding and Genetics chair group. At his inauguration in June, Komen called for breeding for healthier, more efficient fish which could be fed on plant-based feed. Nowadays a commercial salmon reaches three times the weight of its wild counterpart in one year, Jansen calculated in a study published recently. The difference is even greater in rainbow trout. 'A farmed trout grows to ten times the weight in the same amount of time,' says Jansen. 'By comparing the growth data on wild and farmed trout, I arrive at an estimated genetic improvement of 900 percent.'

ASSESSING BREEDING VALUE

Jansen is trying to gauge the economic value of these kinds of improvements more precisely. This entails questions such as how exactly an improved growth rate or resistance to disease contribute to a fish farmer's profit margin. 'I try to describe the relation between breeding and the costs and benefits for fish farmers. Fast growth stimulates profitability, and efficient feed utilization cuts costs. Reducing disease or infection with sea lice has economic value too: roughly 5 to 15 percent of fish die prematurely due to a combination of factors.'

The key point when combining so many useful characteristics, says Jansen, is for breeders to find a balance. 'You can't score a maximum improvement on all the breeding objectives, so you have to balance them out when you select. Once you know all those economic values precisely, you are better

> ‘Fish farming production needs to double in the next 15 years’

placed to choose the right balance of breeding objectives. Maybe in the end, accelerated growth will bring fewer benefits than resistance to sea lice. My aim in this is to use economic models to provide a compass for the salmon farming sector to find the right direction to go in.’
Because resistance to disease cannot always be boosted sufficiently through breeding alone, a lot of research is being done on vaccines and/or stimulating the immune systems of fish. ‘In comparison with the use of vaccines in the livestock sector, we have a way to go in fish farming,’ says Geert Wiegertjes, professor at the Cell Biology and Immunology chair group, where he is studying how fish fight off pathogens.

TREATMENT WITH VACCINES

Wiegertjes is also the coordinator of the European research project Targetfish, which has been running for five years and is aimed at improving fish immunity through measures including vaccination. European aquaculture loses an estimated 20 percent of its annual production value to outbreaks of diseases. ‘In people and animals you usually administer vaccines through injections, so you are talking about an awful lot of injections. That is labour-intensive. What is more, a fish has to be of a minimum size, otherwise the needle will come through on the other side,’ says Wiegertjes. ‘From talks with the industry, I have understood that if administering a fish vaccine costs more than a few cents it is not really cost-effective for many of the cheaper species of fish.’
This means that for the present it is mainly only the more expensive fish such as salmon and salmon trout that are vaccinated. As long as for most types of fish farming it does not pay to vaccinate, pharmaceutical companies will be in no hurry to develop new vaccines, explains Wiegertjes. And even if they do so, patience is required. ‘Take six major fish species in Europe: carp, salmon, trout, bass, sea bream and turbot. Each species is just that bit different, biologically, and each species has three of four pathogens of its own. If you see how many years it takes to develop a vaccine for humans, you shouldn’t expect that we can come up with one for fish farms in two years.’
In order to get around the need for labour-intensive injections, Targetfish has carefully considered the option of vaccines that are administered via the feed. This kind of immunization is cheap but has proven difficult. Wiegertjes: ‘A key exception for humans is polio vaccination. Apparently it is difficult to vaccinate as effectively by that route as by injection. We have incorporated vaccines into fish feed so they get into the intestines in the right form. The only problem is that subsequently they do not provide enough protection.’
An alternative strategy to vaccination is general stimulation of the fish’s congenital immunity, which spontaneously reacts within hours to parts of a bacterium, fungus or virus. That congenital immunity is active from a young age, unlike the immunity that is stimulated by vaccines.
Wiegertjes: ‘I want to study in fish whether exposure to pieces of yeast cell wall can contribute to better general immunity. This should be seen as an additional support or an option for fish species for which vaccination is too expensive.’
The question of whether vaccination is necessary depends a lot on the kind of farming system. In the closed recirculation system at Kingfish Zeeland, water from the Eastern Scheldt estuary is disinfected, so vaccination is not necessary.

FLOWN IN FROM CHILE

At the Kingfish plant another few thousand young yellowtails, now about 15 centimetres long, are swimming around in several large tanks. They were flown in from Chile six weeks ago as babies weighing one gram. Bram Rohaan wants to get some experience with these fish.
When the fish weigh one kilo, in a couple of months, sales will start to restaurants. These will form the main client base: chefs in the more exclusive restaurants in Europe, who currently consider kingfish too expensive or too unsustainable to import from farms in Japan and Australia. Connoisseurs see the fish as a delicatessen, with its white to light pink, rather meaty flesh that is reminiscent of tuna.
Despite its impressive size, this plant is really just a trial run. The real production facility is under construction 500 metres away, and will be completed at the end of this year. The building will include eight tanks of 12 metres in diameter, and 14 of a somewhat smaller size.
The current building will then be converted into a research facility. ‘That is what those glass boxes are for, for instance,’ says Rohaan, pointing to a wall of empty aquaria. WUR is mentioned on the website as one of Kingfish’s strategic partners, and that collaboration will revolve mainly around involvement in research. Because however well the breeding has gone up to now, continued research is needed. Rohaan: ‘for one thing, there is no manufacturer that makes a feed specifically for kingfish in a recirculation system. We can try out all sorts of options here before we apply them on a large scale.’ ■

www.wur.eu/fishfarming

AQUACULTURE COURSE

Wageningen Centre for Development Innovation will be running the course on Responsible Aquaculture Development at the beginning of 2018.
www.wur.eu/cdi/shortcourses2018