GREENPEACE

Genetically Engineered Fish: Swimming Against the Tide of Reason

A background briefing prepared by Dr. Jan van Aken, January 2000

Greenpeace International
Genetic Engineering Campaign
Chausseestr. 131 - 10115 Berlin - Germany
Phone: +49-30-308899-14
Fax: +49-30-308899-30
e-mail: ge@diala.greenpeace.org
www.greenpeace.org/~geneng

Genetically Engineered Fish: Swimming Against the Tide of Reason

This briefing examines the development of genetically engineered (GE) fish, which could soon be produced on a commercial scale. It concludes that the physical containment of these fish cannot be guaranteed and any escapes into the environment could have devastating effects on wild fish populations and biodiversity.

Introduction

Although GE fish for food purposes is not yet on the market, the first products could be ready for commercialisation by the year 2002 if regulatory approval is granted. Since the development of the first GE fish in the early 1990s[1], laboratory researchers and aquaculture companies have concentrated on genetically engineering fish that would grow faster and need less feed. Many research groups have successfully introduced growth hormone genes from human or animal sources into several fish species such as salmon, carp, trout, medaka and tilapia, causing them to grow several times faster than their natural counterparts.

Environmental risks

Genetically engineering fish is a high risk technology with potentially disastrous consequences if the GE fish escape into the environment. Fish species used in aquaculture are very similar to wild fish and may survive and reproduce in the natural environment[2] and readily crossbreed with their wild relatives.

Whenever a newly introduced gene enhances the mating success of a GE fish while at the same time decreasing the viability of the offspring, a few GE fish could ultimately cause the extinction of healthy, wild populations. This has recently been verified by researchers at the Purdue University in the USA who discovered that even a small number of growth-enhanced GE fish could eradicate a large population of wild fish[3]. Stressing that body size is an important trait for mating success in many fish species, the researchers used computer models based on experimental research and revealed that, due to the mating advantage of growth-enhanced GE fish, the genetically engineered trait will be transferred to the natural population, but reduced offspring viability means that this “Trojan gene” will eventually lead to extinction.

There are other scenarios that highlight the global risks associated with the escape of GE fish into the environment. Since enhancing their growth rate increases their daily feed requirements, this could have a devastating effect on the natural environment, especially as most fish that are currently being engineered - e.g. salmon, trout, carp and tilapia - are predators. Past experience has shown that introducing large predatory species into new environments can lead to ecological disasters. In the 1960s, for instance, the Nile perch was introduced into Lake Victoria in Africa and, within a decade, the local population of over 400 different smaller fish species declined from 80% to 2% of the lake’s total fish stocks. Probably 50% of the native species disappeared from Lake Victoria because they were not able to cope with the new invader exhibiting its insatiable hunger. Similarly, the release of a growth (and hunger) enhanced salmon or carp into a natural environment could load a heavy burden on the native fish populations. Such fears have recently been fuelled by the findings of Canadian researchers who discovered that GE coho salmon were far more aggressive than natural salmon.[4]

Another trait that is currently being investigated by genetic engineers is tolerance to cold temperatures. This would enable GE fish to survive in areas from which they were previously excluded and compete with native species, therefore adding to the existing global problem in aquatic ecosystems caused by exotic invaders such as zebra mussels in the Great Lakes.

In view of the potential for serious harm to arise, research into the possible effects of GE fish escaping into the environment is urgently needed and extreme caution should be exercised before considering any commercialisation approvals.

Inadequate safety measures

Some companies and researchers that are involved in the production of GE fish claim that the commercial use of their products would not harm the environment since the fish could be contained in land-based water tanks. They further argue that the GE fish could be sterilised and thus be unable to crossbreed with natural populations even if they were to escape into the environment. However, none of the safety measures that have so far been developed are adequate to safely contain GE fish and prevent accidental releases. Any open sea cultivation will lead to escapes, mistakes will happen, and there will be an economic incentive to circumvent safety measures.

Landlocked systems:

Once the production of GE fish becomes commercialised, it will be impossible to control the whereabouts of every single individual and assure compliance with appropriate containment measures. This lesson can be learned from experiences with GE crops, where mistakes have occurred and unapproved varieties have been illegally planted in several countries[5]. Mistakes will also be made in the case of GE fish with batches being accidentally mixed and GE fish finding their way into open water. As GE fish are intended for use on a global scale, a reliable containment regime following commercialisation is just not conceivable.

Furthermore, landlocked systems need specific safety measures to avoid accidental releases into the environment. Recently, the Environmental Risk Management Authority in New Zealand identified flaws in the safety system of the GE salmon tanks of the private company King Salmon where GE salmon eggs could have come into contact with sperm before escaping into the environment.[6] Although there is no evidence that such an escape has yet occurred, this example highlights the difficulties in designing safety measures which are 100% effective.

In addition, land-based water tanks with appropriate security measures (e.g. water sterilisation) are not cost effective and large scale aquaculture in sea pens is much more economical. Consequently, there will be a strong financial incentive for unscrupulous operators to put GE fish in sea pens. Experience with traditional aquaculture shows that any cultivation in the open sea cannot entirely prevent the escape of cultivated fish, however strong the net pens might be. In 1988, for instance, a storm tore apart the moorings and nets of hundreds of sea pens along the Norwegian coast, allowing a million farmed salmon to escape. No economically viable open sea system could cope with all - sometimes extreme - environmental conditions.

Sterilisation:

If all GE fish were sterile, those which escaped into the environment could neither transfer their genes into wild populations nor establish themselves in natural habitats. However, there are currently no techniques available that are able to guarantee 100% sterilisation of the target fish. The most common sterilisation technique involves manipulating the number of chromosome sets. While natural lines have two chromosome sets (diploid), fish with three chromosome sets (triploid) are sterile. Triploidisation of fish, e.g. through pressure-shocking fish eggs, is possible but it is not reliable enough to be used as a containment measure for GE fish since, with the current procedures, a certain percentage of the treated fish remains fertile.[7]

In order to be fully effective as a containment measure, sterilisation must ensure that every single GE fish is, and remains, sterile under all environmental conditions. A 99% reliability is not enough since, as the researchers at Purdue University concluded, even a single fertile GE fish could be sufficient to destroy a local population under certain circumstances.

In the late 1980s, the companies involved in developing GE crops insisted that their products would be safely contained during field tests and that no contamination of the environment would occur. Several years later, when the first GE crops were commercialised, it became evident that any commercial use would mean unrestricted releases into the environment. It can be anticipated that the same will be true for GE fish.

Approaching commercialisation

Although traits such as cold tolerance, disease resistance and pollution detection are also being investigated, the majority of research and development work on GE fish is currently focused on growth enhancement and is being carried out in several countries around the world (e.g. in the USA[8, ,9], Canada[10], New Zealand,[11], Israel[12], Thailand[13], Taiwan[14], the UK[15] and China[16]).

The race to commercialise growth enhanced GE fish is currently being led by the Massachusetts-based US/Canadian company, A/F Protein Inc., which has engineered a growth enhanced Atlantic salmon containing a growth hormone gene from chinook salmon. This “AquAdvantage salmon”, as it is called, grows 4 to 6 time faster than ordinary salmon and A/F also claims that it has a higher food conversion ratio and thus needs 25% less feed over the entire life cycle.[17]

Nearly 100,000 GE salmon and trout are already swimming in several hundred fibreglass tanks belonging to the A/F subsidiary, Aqua Bounty Farms, in the Canadian provinces of Prince Edward Island, Newfoundland and New Brunswick[18]. The first eggs for commercial breeding could be available in 2000 and the first transgenic fish could be in the supermarkets from 2002. A/F Protein is waiting for regulatory approval in the USA, Canada and Chile[19] although no formal regulation appears to exist in the two latter countries. It has also licensed the ‘super salmon’ to fish-breeders in Scotland and New Zealand.[20] A/F Protein has used the same technology to design growth enhanced flounder, trout, arctic char and tilapia.[19]

Other companies are also involved in the drive to commercialise GE fish and Kent SeaFarms in San Diego, USA, are working with a $1.8 million grant from the US Department of Commerce to develop GE fish that grow quicker, require less feed and are more disease resistant.[21] Elsewhere in the world, King Salmon - the largest salmon producer in New Zealand - is known to be performing trials with growth enhanced GE salmon that also contains a gene from chinook salmon[22]. In Cuba, a biologist from the Centro de Ingenieria Genetica y Biotecnologia recently told a German newspaper that they have already produced 30 tons of growth enhanced tilapia and that they are awaiting approval for commercial use in Cuba.[23]

It remains to be seen how the fish farming community will react to GE fish. According to a recent news report, the International Salmon Growers Association voted overwhelmingly in 1998 to shun GE fish[19] and representatives of the US aquaculture community have been somewhat negative. This is perhaps not surprising since salmon is already in such worldwide overabundance that the wholesale price has sunk to $2 a pound from $6 in the last ten years.

Greenpeace demands

- Genetic engineering of fish for commercial purposes should be prohibited, as should all associated research. Once approved for commercial use, GE fish may never be contained.
- Until this happens, each sovereign nation must take full responsibility for all research, development and releases of GE fish. Fish obey no boundaries and any releases into the environment must necessarily be considered as global releases.
- The Biosafety Protocol to the Convention on Biological Diversity should apply to all GE organisms, including those destined for contained use so that GE fish are subject to international controls.
- Each sovereign nation which imports GE fish must decide whether containment measures recommended by exporting nations provide adequate protection for the importing nation's biodiversity. This should not be decided by the exporter or exporting nation.

For more details on Greenpeace's comprehensive demands for the Biosafety Protocol, please refer to **http://www.greenpeace.org/~geneng/**

References

[1] Du S et al. (1992), BioTechnology 10:176-181

[2] News Release, Minnesota Sea Grant Media Center, Safeguards proposed for genetically altered fish, www.seagrantnews.org/news/minnesota.html

[3] Muir WM, Howard RD (1999) Possible ecological risks of transgenic organism release when transgenes affect mating success: sexual selection and the Trojan gene hypothesis. PNAS 96:13853-13856

[4] National Post, September 4 1999, pB12: 'Frankenfish or salmon saviour?' by Sarah Schmidt

[5] In 1997, Monsanto mistakenly sold unapproved GE canola (oilseed rape) varieties in Canada and had to recall some 60,000 bags (enough for sowing 600,000 acres). Some fields where the unapproved varieties had already been sown had to be ploughed up. (The Western Producer, April 24 1997: Canola seed recalled because of genetic contamination; Reuters newswire April 17, 1997). In 1998, a test batch of Monsanto GE sugar beets was mistakenly sent to a Dutch refiner and mixed with normal sugar (Reuters newswire Dec. 3, 1998)

[6] The Dominion, Nov. 25, 1999: Concern at genetic salmon egg escape.

[7] Shelton WL, Reproductive manipulation of fishes: ecologically safe assessment of introductions.US-ARS, Biotechnology Risk Assessment Research Grants, Program Abstract of Funded Research 1996.

[8] www.ag.auburn.edu/dept/faa/facil6.html

[9] http://vm.uconn.edu

[10] Devlin RH et al. (1994) Extraordinary salmon growth. Nature 371:209-210

[11] Dr. Frank Sin at the University of Canterbury, www.canterbury.ac.nz./publish/research/97/A19.htm

[12] Benzion Cavari at Hebrew University, Jerusalem, http://ocean.org.il/nio/staff/3.htm

[13] At the Aquatic Resources Research Institute of the Chulalongkorn University, www.chula.ac.th

[14] At the Division of Cellular and Molecular Zoology of the Academia Sinica, www.sinica.edu.tw

[15] E.g. by Prof. Norman Maclean of Southampton University, according to Times, May 26 1997: Gene-modified fish grow three times faster than normal

[16] Wu Chingjiang (1990) at the 3. Int. Symposium on genetics in aquaculture, Trondheim, June 20-24 1988 (in: Gjedrem T (ed) 1990, Genetics in Aquaculture III, Aquaculture vol. 85, pp 61-68)

[17] http:/webhost.avint.net/afprotein/bounty.html; see also: Under the microscope: We can build super fish, but should we?, by Dan McGovern, May 1999, www.biotech-info.net/super_fish.html

[18] http:/webhost.avint.net/afprotein/news.html

[19] Christian Science Monitor: Designer fish flounder over legal hurdles. www.csmonitor.com/durable/1999/03/04/text/p19s1.html

[20] The Vancouver Sun, March 3, 1997

[21] Under the microscope: We can build super fish, but should we?, by Dan McGovern, May 1999, www.biotech-info.net/super_fish.html

[22] AFP newswire April 6, 1999: Genetically manipulated salmon exposed in New Zealand

[23] Der Spiegel, July 5 1999, page 188