FISH

GENETICALLY ENGINEERED FISH
– NEW THREATS TO THE ENVIRONMENT

REPORT 2004

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GREENPEACE

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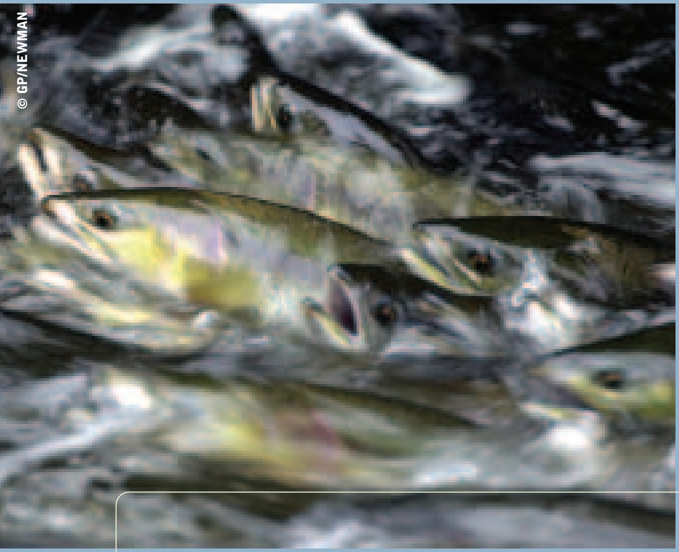

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author Luke Anderson
Greenpeace Genetic Engineering Campaign
editor Dr Janet Cotter
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contact person isabelle.meister@int.greenpeace.org

Luke Anderson
Author of *Genetic Engineering, Food and Our Environment* (1999). Since 1997 he has worked with environmental, farming and social justice groups around the world as an advisor on genetic engineering and related issues. He can be reached at luke@geaction.org

summary

This briefing examines the development of genetically engineered (GE) fish, which could soon be produced on a commercial scale.

There are many GE fish under development, often engineered with growth hormones to make the GE fish grow faster enabling them to reach marketable size at an earlier age.

* There are numerous concerns over the welfare and environmental impact of these unhealthy, fast growing fish.
* The techniques of producing GE fish are crude, and generally involve the random insertion of DNA into the fish genome. This process may disrupt the tightly controlled network of DNA in the fish.

Current understanding of the way in which genes are regulated is extremely limited, and any change to the DNA of an organism at any point may well have effects that are impossible to predict or control.

There is already concern regarding environmental effects, human health impacts and welfare of intensive fish farming in aquaculture. Fish are known to escape frequently from aquaculture facilities, which can then interbreed with, or displace, native fish populations. There is a high potential for ecological disruption should GE fish escape from aquaculture facilities. Fast growing GE fish could compete for food, disrupting aquatic food webs and ecosystems.

* Researchers have shown that GE fish with a growth hormone gene could have a mating advantage due to their increased size. An experimental study was developed (called the 'Trojan gene' model), which demonstrated that the release of just 60 GE fish could lead to an extinction of a wild population within only 40 generations.
* Contrary to industry claims, sterilisation of GE fish will not be 100 % effective in a commercial situation, and will not prevent all crossbreeding between GE fish and wild fish.

There is widespread opposition to the farming of GE fish in aquaculture facilities, the most economically profitable method of rearing farmed fish. Several governments and intergovernmental organisations have already taken steps to ensure that any GE fish (e.g. for scientific research purposes) are kept in secure, land-based facilities.

However, escaped GE fish will not respect national boundaries, GE fish must be considered as global releases by the multilateral environmental agreement, the UN Cartagena Protocol on Biosafety.

* In a commercial aquaculture situation, the physical containment of these fish can never be guaranteed. Escapes of GE fish into the aquatic environment could have devastating effects on wild fish populations and biodiversity.

Therefore, Greenpeace demands that the genetic engineering of fish for commercial purposes should be prohibited.

introduction

Greenpeace first published a report in 2000 on the hazards of genetically engineered fish.[1] This report is an update, presenting the new scientific findings on threats to the environment of genetically engineered fish.

The first genetically engineered (GE), also called genetically modified (GM) or transgenic, fish was reported in China in 1985. Since then, experiments have been conducted with over 35 different kinds of GE fish in about 50 laboratories around the world.[2] Most of the fish being engineered are varieties important to the aquaculture industry, such as salmon, carp, trout, catfish, and tilapia. Genes introduced into GE fish have come from a wide range of sources, including other fish, chickens, humans, cattle and rats.

Some GE fish are used in laboratory research (e.g. for the study of gene regulation and function) and some have been developed as 'drug factories', their bodies engineered to contain products that are useful to the pharmaceutical industry. **However, much of the research into GE fish has focused on the development of traits such as rapid growth that are valued by companies involved in intensive fish farming.**

TABLE 1: EXAMPLES OF GE FISH BEING DEVELOPED[3]

SPECIES*	FOREIGN GENE	DESIRED EFFECT	COUNTRY**
atlantic salmon	Antifreeze promoter gene from ocean pout, growth hormone gene from chinook salmon	Increased growth and feed efficiency	United States, Canada
rainbow trout	Growth hormone gene from sockeye salmon	Increased growth and feed efficiency	United States, Canada
goldfish	Antifreeze gene	Cold tolerance	China, Canada
tilapia	Human gene for clotting factor VII	Production of clotting factor for pharmaceutical production	United States, United Kingdom
tilapia	Tilapia growth hormone gene and promoter sequence from human cytomegalovirus	Increased growth	Cuba
tilapia	Modified tilapia insulin-producing gene	Production of human insulin	Canada
salmon	Lysosome gene from rainbow trout and pleurocidin gene from flounder	Disease resistance	United States, Canada
zebra fish	Green fluorescing protein gene from jellyfish, red fluorescing protein gene taken from Discosoma (Indo Pacific relative of sea anemones and coral)	The GloFish are marketed as pets and designed to glow in fish tanks	Singapore. Sold commercially as pets in United States and Taiwan
channel catfish	Growth hormone gene from salmon, cecropin genes from moth	Increased growth, non-specific bacterial immunity	United States
striped bass	Insect genes	Disease resistance	United States
mud loach	Mud loach growth hormone gene, promoter genes from mud loach and mouse	Increased growth and feed efficiency; 2 to 30-fold increase in growth	China
common carp	Growth hormone genes from salmon and human	150% growth improvement in culture conditions, improved disease resistance, tolerance of low oxygen level	China, United States
grass carp	Human interferon gene	Disease resistance	China
indian major carps	Human growth hormone gene	Increased growth	India
abalone	Growth hormone gene from coho salmon	Increased growth	United States
oyster	Growth hormone gene from coho salmon	Increased growth	United States

* OTHER FISH THAT HAVE BEEN GE INCLUDE ARCTIC CHAR, AFRICAN CATFISH, INDIAN CATFISH, BLUNTNOSE BREAM, BROWN TROUT, GILTHEAD BREAM, BLACKHEAD BREAM, WUCHANG BREAM, CHINOOK SALMON, COHO SALMON, KILLIFISH, LARGEMOUTH BASS, JAPANESE MEDAKA, MUD CARP, MUMMICHOG, SILVER CRUCIAN CARP, RED CRUCIAN CARP, LOACH, NORTHERN PIKE, PENAEID SHRIMP, SEA BREAM, STRIPED BASS AND WALLEYE.[4]

** COUNTRIES WITH LABORATORIES INVOLVED IN GE FISH RESEARCH BETWEEN 1996-2003 INCLUDE THE UNITED STATES, CANADA, CUBA, INDIA, SINGAPORE, SOUTH KOREA, JAPAN, CHINA, ISRAEL, SCOTLAND, ENGLAND, FINLAND, THE NETHERLANDS, HUNGARY, NEW ZEALAND AND TAIWAN.[5]

FISH

GENETICALLY ENGINEERED FISH — NEW THREATS TO THE ENVIRONMENT

I GENETIC ENGINEERING OF FISH – CRUDE SCIENCE

There are several ways of producing GE fish, all of which are crude and can lead to unexpected and unintended effects. One way to make GE fish is by genetically altering the sperm of male fish. There are a number of methods to do this, including:

* Attaching the new genes to viruses which then 'smuggle' these genes into the sperm,
* Using an electric shock to create pores in the sperms' cell membrane, and then introducing the genes into the sperm.[6]

However, by far the most commonly employed method used to engineer fish is by microinjection,[7] where:

* Scientists make billions of copies of the DNA that they want to end up in the GE fish by inserting the genes into a piece of DNA called a plasmid that can be reproduced inside bacteria in the laboratory.
* The genes are then isolated and millions of copies are injected with a very fine needle into fertilised fish eggs as soon as possible after fertilisation (usually at the one or two cell stage). A piece of DNA called a 'promoter' is also inserted along with the 'new' gene in order to 'switch it on' in its new host. Promoters, that often force genes to express their traits at very high levels, also have the potential to influence other genes in the organism.[8]
* Some of these eggs will have successfully incorporated the new genes, and some of the fish that hatch will therefore be GE. As it is not possible to insert a new gene with any accuracy, the gene transfer may also disrupt the tightly controlled network of DNA in the fish. Current understanding of the way in which genes are regulated is extremely limited, and any change to the DNA of an organism at any point may well have effects that are impossible to predict or control. The new gene could, for example, alter chemical reactions within the cell or disturb cell functions. This could lead to changes in behaviour, instability, and the creation of novel substances in the fish such as new toxins or allergens or changes in nutritional value.[9]

An example of unexpected effects in GE fish:

When GE coho salmon were compared to a control group of non-GE coho salmon, it was found that the genetic engineering process had affected the activity of a number of non-target genes in the GE fish. These changes included an increased amount of the protein parvalbumin-b in the GE salmon, a protein that has been identified as a major food allergen in fish.[11]

For further examples of unexpected effects in GE fish, see Section iv ii "Unexpected effects and Trojan genes".

II FAST GROWING, UNHEALTHY GE FISH

Most aquaculture-related research on GE fish has focused on increasing the growth rates of farmed fish so that they reach marketable size more quickly.[12] Growth hormone genes taken from humans, other mammals or fish have been engineered into at least 15 species of fish.[13]

* In one experiment, Atlantic salmon were engineered with growth hormones to enable them to reach adult size more quickly. After one year, most had a two- to six-fold increase in growth, whilst the largest was 13 times normal size for its age.[14]
* A company called Aqua Bounty Farms (a division of A/F Protein) is currently seeking approval in the United States to commercialise a GE Atlantic salmon. This salmon has been engineered with an extra gene for growth hormone production taken from a chinook salmon and a 'promoter' gene which forces the salmon to produce high levels of the growth hormone all year round. This means that instead of only growing during the spring and summer months, the GE salmon grows constantly, reaching adult size in about 18 months. This compares to 24-30 months for a non-GE salmon.[15]
* One study noted that when growth hormone is engineered into salmon, "the endocrine stimulation can be elevated to pathological levels in some cases", such as abnormally enlarged skulls in the GE fish, leading to difficulty in respiration and feeding.[16] Other studies have reported that GE carp have suffered from similar abnormalities.[17]

In summary, forced expression of the growth hormone in GE fish raises a number of animal welfare concerns.

III CURRENT PROBLEMS WITH AQUACULTURE

GE fish are to be introduced within the context of intensive fish farming. In order to begin to understand the hazards and risks posed by GE fish, it is first necessary to examine the many problems that already exist within current aquaculture systems.

According to the Food and Agriculture Organization of the United Nations, global demand for seafood may double by 2040.[18] With wild fisheries suffering major declines due to over-fishing and habitat destruction, it is widely suggested that the projected shortfalls in fish supply will be met by expansion within the aquaculture sector.[19]

Since 1987, global aquaculture production has more than doubled. By 1995, it accounted for 18.5% of the total world seafood supply.[20] More than 160 species of finfish and shellfish are currently farmed, including catfish, trout, salmon, tilapia, oysters, crayfish, clams and shrimp.[21]

Aquaculture has a long history – fish farming has been integrated into diverse sustainable farming practices in Asia for at least 2000 years. Modern intensive aquaculture operations, however, are often grossly inefficient, damaging to the environment and raise many welfare concerns.

One of the first kinds of GE fish expected to reach commercial approval is salmon.

In salmon farming:

* The fish are kept in net pens, which are tethered in coastal waters. The fish are so densely stocked that ideal conditions are created for disease. These diseases race rapidly through the crowded fish pens, and in order for the salmon to survive they are fed antibiotics, and dosed with pesticides. The pesticides, uneaten feed and wastes from the fish smother and pollute the sea floor beneath the fish farms, affecting bottom dwelling organisms.[22]
* The salmon often incubate sea lice and other parasites, which then spread to wild salmon populations. In Norway, parasites from fish farms were so devastating to wild fish that the government made the decision to poison all aquatic life in dozens of rivers and streams in the hope that disease-free populations could then be restored.[23]
* Farmed salmon are fed synthetic pigments in order to give their flesh the pink colour normally associated with salmon. Without this pigment, the flesh of these salmon would be an unhealthy looking pale grey.[24]
* Farmed salmon accumulate cancer-causing chemicals in their bodies called polychlorinated biphenols (PCBs) from the fishmeal they are fed. On average, farmed salmon have 16 times the PCBs found in wild salmon. PCBs not only cause cancer but also present other health risks as well. These include neurodevelopmental risks to unborn children from maternal consumption of PCB-contaminated fish.[25]

It is often suggested that fish farming will compensate for the collapse of wild fisheries and is a means to provide more animal protein to hungry people. Most intensive fish farming operations are, however, extremely inefficient and require more protein in the form of fishmeal to feed the farmed fish than is supplied by the end harvest. The fishmeal is commonly made with wild-caught fish such as anchovy, jack mackerel, pilchard, capelin, menhaden, herring, and sardines.

* It can take three to five pounds of fishmeal to produce a single pound of farmed salmon.[26]

In summary, modern intensive aquaculture operations are often grossly inefficient, damaging to the environment, and raise animal welfare concerns.

i fish escape from fish farms

In commercial aquaculture, fish are farmed in pens in contact with aquatic systems for practical and economic reasons. However, fish frequently escape in large numbers from fish farms. These escapes can occur due to human accidents, harsh weather conditions or because of predators such as seals tearing holes in the net pens and cages the fish are kept in.

* In 1988, a storm tore apart the moorings and nets of hundreds of sea pens along the Norwegian coast, allowing a million farmed salmon to escape.[27] Between 1992-1996, losses of salmon from fish farms in Norway averaged 1.3 million a year.[28] As a result of incidents such as these, in some parts of the country escaped fish that have bred and formed their own populations outnumber wild ones by five to one.[29]

FISH

GENETICALLY ENGINEERED FISH — NEW THREATS TO THE ENVIRONMENT

* Between 1994 and 1996, at least 120,000 salmon escaped from fish farms in British Columbia. About 20,000 of them escaped from a tanker truck spill on Vancouver Island.[30]
* From 1996 to 2000, almost 600,000 Atlantic salmon escaped from the net pens in Washington State waters. There is evidence that Atlantic salmon that have escaped from Washington or British Columbia fish farms are beginning to establish a breeding population off Vancouver Island.[31]
* During 1999, 255,000 salmon escaped from Scottish fish farms.[32]
* A storm in December 2000 caused steel cages containing salmon to buckle in Machias Bay in the US state of Maine, leading to the escape of 100,000 fish.[33]
* In the Magaguadavic River in New Brunswick, Canada, the number of farmed fish entering the river between 1992 and 1999 was two to eight times that of the wild salmon returning to the same river to spawn.[34]

Farmed salmon are genetically very uniform, bred to the needs of the industry with traits such as rapid growth or high tolerance to the crowded conditions in the fish farms. Wild salmon populations, on the other hand, are genetically diverse and "highly adapted to the specific conditions of the local river systems to which they return to spawn".[35]

Interbreeding between wild salmon and those that escape from farms alters the genetic makeup of the wild salmon populations.

* There is evidence that escaped Atlantic salmon are beginning to establish a breeding population in the Pacific, off Vancouver Island in Canada. There is much concern that these Atlantic salmon may compete for food and habitat with the fragile populations of Pacific salmon, many of which have already been listed under the Endangered Species Act.[36] The Washington State Hearings Board in the northwestern US has ruled that Atlantic salmon that escape from fish farms should be classified as a "pollutant".[37]
* In Maine, on the Atlantic coast of the US, Atlantic salmon have been listed under the Endangered Species Act. It is estimated that only 500 Atlantic salmon with a truly native genetic makeup remain in the wild. Escapes of farmed salmon pose a major threat to the recovery of these genetically distinct wild salmon.[38]

In summary, fish regularly escape from commercial aquaculture facilities and can threaten native fish populations.

IV POTENTIAL ECOLOGICAL IMPACTS OF GE FISH

"For more than half a century theoretical biologists have been developing ideas about biological networks and hierarchies and applying them to our knowledge of molecular genetics. The task of assessing the environmental impact of a genetically engineered organism is to understand what effect, no matter how small, the genetic modification has had on every one of the characteristics relevant to the organism's interactions with members of other species (as well as the physical environment); and then to predict all of the resultant effects that may occur in the organism's ecological network. With our current, very sketchy knowledge of how complex networks behave, it is impossible to carry out this task in a satisfactory way. Our understanding of ecological networks and their evolution is insufficient for any meaningful assessment of the impacts of artificial genetic change accomplished by genetic engineering." **Dr. Peter Wills, theoretical biologist.**[39]

When examining the potential ecological consequences of the release of a GE fish, it is important to keep in mind that the complexity and dynamic behaviour of biological systems means that there are fundamental limitations inherent in any risk assessment.[40] It is possible to make an evaluation of the behaviour of a GE fish based on any new traits it may have (e.g. engineered cold tolerance increasing the geographic range of GE fish, leading to possible invasion of any escaped fish into new ecosystems). However, experience shows us that the most devastating ecological consequences can often be completely unexpected.

For example:

* The intentional introduction of the myxoma virus (causing myxomatosis) to control rabbit populations in England is one such example. As desired by those introducing it, the myxoma virus caused a dramatic decline in rabbit populations. However, it also led to a surge in the abundance of a particular species of grass on which the rabbits previously grazed. Another previously dominant species of grass was unable to compete and declined substantially, giving rise to a shortage of nesting material for a certain variety of ant. This, in turn, triggered the extinction of the already endangered Large Blue butterfly *(Maculina arion)* due to a symbiotic relationship between the ant and the butterfly.[41]

In summary, ecological networks are complex and poorly understood. Therefore, the ecological impact of any escapes of GE fish cannot be fully taken into account by risk assessment; the precautionary principle must be applied.[42]

i impacts on native fish populations

Escaped GE fish will probably be able to travel over considerable distances and may have novel traits that have never previously existed within a particular ecosystem. Characteristics such as increased rates of growth, cold tolerance or faster breeding cycles could give GE fish a competitive advantage over native fish and potentially lead to the displacement of native fish populations. In many cases, they may disrupt ecological systems in some or all of the same ways as non-native species that have been introduced into new habitats.[43]

* In 1954, the British colonial administration in Uganda first introduced Nile perch into Lake Victoria, with the intention to increase fish production. Within 30 years the carnivorous perch, which can grow up to 6 feet in length, had decimated the indigenous fish populations, leading to the extinction of 50% of the over 400 different species of small fish in the lake. With the loss of so many species of algae-eating fish, the waters of Lake Victoria are now frequently choked with algal blooms and oxygen levels are seriously depleted. Several species of insect, which were once kept under control by fish now gone from the lake, breed in unprecedented numbers. Also, unlike the native fish, the Nile perch do not dry well in the sun, and the wood fires needed to dry the Nile perch have increased the rate of deforestation and consequent erosion of the lake's shoreline.[44]
* Forty-four native species of fish in the United States are currently threatened or endangered by non-indigenous fish. These introduced fish have had far reaching impacts on the ecology of aquatic ecosystems and have competed with native fish for food, shelter, mates, habitat and breeding sites.[45] In Florida, for example, blue tilapia escaped from two aquaculture facilities and have since become established in Everglades National Park and other waterways. In a number of streams where these fish have become abundant, almost all vegetation and native fish species have disappeared.[46]
* The European zebra mussel has spread into most freshwater habitats in the eastern United States, having arrived in the Great Lakes via ballast water released from ships that travelled from Europe. Zebra mussels compete directly with native mussels, clams, and snails, and reduce food and oxygen for native fauna.[47] The invasive mussels also clog water intake pipes and water filtration and electric generating plants, with an estimated US$3 billion a year spent on control and cleaning measures.[48]

COLD TOLERANCE – AN INVASIVE TRAIT?

In 1982, a scientist at Memorial University of Newfoundland in Canada accidentally froze a tank filled with a species of arctic fish called a flounder. When the tank was thawed out it was found that the fish were still alive. This led to the discovery of a gene in the flounder that produces an 'antifreeze' protein, enabling it to tolerate freezing waters.[49] Since then, biotech researchers have been engineering salmon with this flounder gene in an attempt to incorporate the antifreeze protein into the GE fish, in the hope that salmon farms could operate in waters that would normally be excluded because of subzero water conditions. Although researchers have managed to engineer the salmon with the antifreeze gene with some success, the antifreeze protein in the GE salmon is currently being expressed at levels that are too low to make it commercially useful for this purpose. However it is expected that the use of more powerful 'promoter' genes, taken from insects, may increase the amounts of antifreeze protein in the salmon. Increased tolerance to cold water could increase the geographic range of GE fish, leading to possible invasion of any escaped fish into new ecosystems.

In summary, escaped GE fish could disrupt natural fish populations in a similar fashion to other escaped non-native fish. However, because of their novel characteristics, they could pose additional problems as described by the "Trojan gene effect" below.

ii unexpected effects and trojan genes

"Unfortunately, for an exotic organism it is almost impossible to determine either the risk of species spread or hazard to the environment before introduction because of the nearly infinite number of direct and indirect biotic interactions that occur in nature." **William Muir & Richard Howard, authors of the Trojan Gene Hypothesis[50]**

Genes are engineered into fish because the genetic engineers want to confer the GE fish with a particular trait, such as rapid growth. However, due to inherent problems in the genetic engineering process, GE fish often also exhibit a range of unanticipated characteristics.[51]

FISH

GENETICALLY ENGINEERED FISH — NEW THREATS TO THE ENVIRONMENT

* With salmon GE with growth hormones, for example, growth hormone genes in the GE fish have also influenced swimming ability,[52] feeding rates,[53] muscle structure and enzyme production,[54] disease resistance,[55] body morphometry,[56] pituitary gland structure,[57] life span,[58] larval developmental rate,[59] smoltification,[60] risk-avoidance behaviour,[61] cranial morphology and gill irrigation.[62]

These unanticipated consequences of the genetic engineering process, which are also in many cases undesired effects, add to the difficulties of assessing the ecological hazards associated with a GE fish. For example, although fish genetically engineered with a growth hormone may have characteristics such as increased size which increase their ability to compete with their wild counterparts, the genetic engineering process often leaves them with some kind of disadvantage, such as increased mortality in their offspring.[63]

Some scientists have argued that disadvantages, such as increased mortality in the offspring of GE fish, mean that there is little risk that GE fish will prove to be invasive or in other ways hazardous to the environment.[64] Researchers at Purdue University in the US, however, found that interactions between traits that would appear to offer a disadvantage and other traits in GE fish that appear to offer some kind of competitive advantage, could actually increase the hazard of GE fish to aquatic ecosystems.

The Purdue laboratory studies used GE and non-GE Japanese medaka fish as experimental models to study the potential effects of the release of a small number of GE fish into the wild. The GE fish were engineered with a human growth hormone gene and had a competitive advantage — the males were larger, making them more attractive to female mates. But the genetic engineering process had also given the GE fish a disadvantage — their offspring were less likely to survive.[65] These data were then fed into computer models, which came up with startling results. The first study found that **the release of just sixty of these GE fish into a wild population of sixty thousand led to the extinction of both fish populations in just 40 generations.**[66]

"You have the very strange situation where the least fit individual in the population is getting all the matings—this is the reverse of Darwin's model," says William Muir, one of the researchers. ***"The sexual selection drives the gene into the population and the reduced viability drives the population to extinction.'"***[67]

"What surprised us was how fast a GMO mating advantage could cause a transgene to spread in a population," said Richard Howard, another of the Purdue researchers. ***"A population invaded by a few genetically modified individuals would become more and more transgenic, and as it did the population would get smaller and smaller. We call this the 'Trojan gene effect'."***

"Imagine a pie, and you eat 30 percent of it every day," said Howard. ***"Half of it is gone in two days, and within a week less than one-tenth of it remains. It is conceivable that a similar effect could occur among fish populations if GMOs with 'Trojan genes' escape into the wild.'"***[68]

Further research on the "Trojan gene" effect has now been published in scientific journals.[69] **Together, this research shows that there are numerous ways in which genes engineered into GE fish could invade wild fish populations, reduce their fitness, and potentially cause their extinction.**

One of the ways in which an escaped GE fish could impact on other fish within an ecosystem, and end up being invasive, is through competition for food. One study found that genetically engineered salmon with a growth hormone gene consumed 250 % more food than non-GE salmon of the same size, suggesting that they could be highly competitive. GE predatory fish such as salmon, trout, or tilapia may also prey on other fish at unusual times during the season, as many GE fish mature at an earlier age than their non-GE counterparts. Altered feeding patterns such as these could result in major disruptions to aquatic ecosystems.[70]

When researchers placed non-GE coho salmon and coho salmon GE with a growth hormone gene together, they found that when food supplies were low, the genetically engineered salmon dominated the acquisition of food resources, consistently outgrew the non-GE salmon and affected their growth. Dominant GE individuals emerged which then became cannibalistic towards the other fish, including other GE salmon that were weaker than them. When there was low availability of food, all the groups containing genetically engineered salmon also then experienced population crashes or complete extinctions, whereas groups containing only non-GE salmon had good survival and growth rates.[71]


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iii Sterilisation will not be 100 % effective

"One of the most significant issues raised by environmentalists is the potential for negative effects on wild stock posed by "gene flow" [from GE fish]. Use of sterile fish will eliminate this issue."
Elliot Entis, President of Aqua Bounty Farms[72]

Companies currently seeking commercial approval to market GE fish are claiming that sterilisation of these fish can protect the environment from the hazards associated with the escape of GE fish from fish farms. They claim that the methods used can be 100 % effective.[73] However, other evidence indicates that this cannot be achieved under commercial conditions.

A number of different methods can be used to sterilise fish, but there is one principal technique being proposed for GE fish, called 'triploidy.' With this method, temperature or pressure shock is applied to fish eggs shortly after fertilisation. This produces eggs that contain three chromosomes (triploids) instead of the normal two and fish grown from these eggs usually do not develop normal sexual characteristics.[74]

Although most of the fish produced by triploidy will be sterile, it is widely acknowledged that a small percentage of triploid fish will develop sexual characteristics and be fertile.[75]

* A study of GE tilapia fish that were triploids, for example, found that some of the male fish had sperm in their testes, 'indicative of reproductive functionality'.[76] One of the reasons that low fertility in male fish is of concern was highlighted in publications by Muir and Howard, authors of the Trojan Gene Hypothesis. Among their scenarios where escaped GE fish could lead to extinction of both GE and native fish populations,[77] was one where GE male fish have lowered fertility,[78] while at the same time being more viable (through a trait such as increased disease resistance).[79] The researchers concluded that ***"attempts to reduce GE male fertility that do not result in complete male sterility may increase the hazard rather than reduce it".[80]***

Aqua Bounty Farms, the company currently seeking commercial approval for its GE salmon, say that the company will ensure that all the triploid eggs will be female and that every batch of eggs will be thoroughly screened.[81] While it is possible to achieve close to 100% sterilisation of eggs through careful screening, many people in the industry (including from companies developing the GE fish) are doubtful that this kind of screening would be economical under conditions of commercial production.[82]

When GE crops were commercialised, the biotech industry demanded 'tolerance' levels to legalise genetic contamination of other crops with pollen from GE plants, having denied for years that such contamination would ever occur. Since the widespread commercialisation of these crops in the 1990's, there have been numerous instances of contamination from GE crops.[83] It is extremely likely, therefore, that faced with economic considerations under commercial production, the companies developing GE fish will demand acceptance of less than 100 % success rates in the sterilisation of GE fish.[84]

Even without GE fish reproducing, escapes of sterile GE fish could still have a major impact on wild fish populations. This could occur through the spreading of diseases or through competition with wild fish for resources, such as food or habitat.[85] Damage to wild fish populations could also occur if sterile GE fish compete with wild fish for mates.[86] This fruitless mating could depress populations of already endangered species of fish.[87]

There are other major problems associated with triploid fish, which raise questions as to whether the technique will be suitable for commercial aquaculture operations, as well as major animal welfare concerns.

* Triploid Atlantic salmon exhibit greater variability in growth,[88] diminished tolerance of chronic stress,[89] reduced survival during egg incubation and, during marine grow-out,[90] a number of abnormalities including spinal abnormalities,[91] abnormalities of the lower jaw,[92] and greater susceptibility to cataract formation.[93] Triploid fish have also been found to suffer from breathing difficulties, low blood haemoglobin levels and higher rates of mortality.[94]

In summary, sterilisation is unlikely to be 100 % effective in a commercial situation. In addition, there are welfare concerns regarding triploid fish.

FISH

GENETICALLY ENGINEERED FISH — NEW THREATS TO THE ENVIRONMENT

V NO! TO THE COMMERCIALISATION OF GE FISH

GE fish could be the first GE animals to receive any government approval for sale as food.[95] No official approval has yet been granted for the sale of GE fish for human consumption, but there are at least three countries where approval could be in the pipeline.

* In the United States, commercial approval is currently being sought for GE salmon and catfish. The company developing the GE salmon, Aqua Bounty Farms, says that it has pre-orders for 15 million eggs and it had hoped to receive commercial approval by 2002. There has been intense controversy over GE fish in recent years, however, and the company now says that it does not expect its application to be approved until late 2004 at the earliest. The US Food and Drug Administration (FDA) decided to regulate the salmon, GE with a gene for a growth hormone, as a new 'animal drug'. The FDA has been widely criticised as lacking both the legal authority and ecological expertise to regulate GE fish.[96]
* Researchers at the Center for Genetic Engineering and Biotechnology in Cuba are seeking government approval for GE tilapia. Mario Estrada, leader of the project, says that feeding studies have been conducted, including an experiment in which the tilapia were eaten by human volunteers. The researchers expect that it will be 2005 before they hear whether or nor approval will be granted.[97]
* In China, GE carp is currently being tested for possible commercial production.[98] However, concerns about their impact on the environment mean that commercialisation is unlikely in the near future.[99]

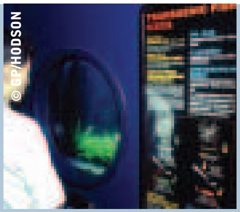
Although regulatory bodies in the US or elsewhere may soon decide to give commercial approval for a GE fish, it is not possible to say if these GE fish will be safe to eat. The process of genetic engineering itself typically results in unexpected and unintended changes in the organism that is being genetically engineered. In the case of a GE fish, this could include the modification of an existing fish protein, or the creation of a new protein that could cause allergic reactions.[100] Such modifications could go unnoticed by government regulators who often depend on the very companies who stand to profit from commercial approval of a GE organism to do the safety assessment. In most cases, government regulators require companies to assess the safety of GE organisms by examining a narrow range of known characteristics, while failing to require any thorough analysis of the hazards posed by unexpected new molecules that could be harmful.[101]

GLOFISH — A GE PET

For just US$5, you too could be the proud owner of the world's first GE household pet. On sale since January 2004 in pet stores across the United States, the GE fish called GloFish, are being marketed by a Texas biotech firm called Yorktown Technologies. Originally developed from zebra fish by researchers at the University of Singapore, GloFish engineered with a fluorescing gene taken from a jellyfish glow green, while those engineered with genes taken from Discosoma (a relative of sea anemones and coral) have a reddish hue when exposed to black or fluorescent light.

While this GloFish might sound cute to some aquarium owners, the attempt to win acceptance for this GE pet is really the thin end of a much more ambitious wedge as far as the genetic engineering industry is concerned. The industry has been told again and again by its public relations advisors that there might have been more success in winning global acceptance of GE foods if the first ones introduced had offered something perceived as a 'consumer benefit', such as increased vitamin content. The industry hopes a cute GE pet could be a good way to prepare the public for a flood of other GE animals in the pipeline, such as fast growing fish or pigs engineered for intensive factory farming operations.

The US Food and Drug Administration declined to regulate the GE GloFish, because there are currently no regulations that pertain to ornamental fish. ***"Allowing the unregulated sale of GloFish provides a gateway for GE fish to find their way on to our dinner plates and into our environment,"*** commented Joseph Mendelson, legal director of the Washington based Center for Food Safety. ***"By not stepping in to regulate these fish, the US regulatory agencies are establishing a dangerous precedent for all future gene-altered animals, whether created as food or pet fads".***[102]



i widespread opposition to the commercial development of GE fish

Increasing awareness of the considerable hazards associated with GE fish means that the commercial future of GE fish is far from certain. Opposition to the commercial development of GE fish has been voiced by governments, industry bodies, scientific institutions and a wide range of other organisations.

* Deep concern about the ecological impacts of GE fish has been expressed by highly influential scientific bodies such the Royal Society and the US National Academy of Sciences.[103] The Royal Society called for a moratorium on the release of GE fish in sea pens and recommended that commercial approval only be granted for GE fish kept in contained land-based facilities. Although land-based facilities are an improvement on fish farms located in open water, experience with such facilities shows that animals, floods and human accident mean that fish could still end up escaping into open waterways.[104] Birds, for example, pick up fish from land-based farms and then sometimes drop them into open water. Flooding, which is increasingly common as climate change alters weather patterns, can also provide routes for fish to escape.

* In 1992, the Oregon Department of Fish and Wildlife in the US published an administrative rule, stating that: ***"The Department shall consider releases of GE fish to pose a serious risk to wild populations. The Department shall not authorize the release of GE fish into locations where such fish may gain access to wild fish populations".***[105] In 2001, the state of Maryland in the US placed a five-year prohibition on the introduction of any GE fish into any state waterways that flow into any other body of water.[106] In 2002, the Washington Fish and Wildlife Commission banned all GE fish from Washington State fish farms in marine waters.[107] In 2003, California passed a law making it illegal to spawn, cultivate, or incubate any GE fish in the waters of the Pacific Ocean over which the state has jurisdiction.[108]

* During recent meetings of the National Atlantic Salmon Conservation Organization (NASCO, established by international treaty and consisting of Canada, Denmark, the European Union, Iceland, Norway, the Russian Federation, and the United States), the parties agreed to support a resolution, which states that the parties will ***"take all possible actions to ensure that the use of GE salmon, in any part of the NASCO Convention Area, is confined to secure, self-contained, land-based facilities".***[109]

* In March 2002, European ministers agreed at the 5th North Sea Conference at Bergen, Sweden to take all possible actions to prevent the release of GE marine organisms to the marine environment, and to ensure that their culture is confined to secure, self-contained, land-based facilities.[110] Other bans on the environmental release of GE fish are in place at a local and national level in Europe.[111] In Austria, for example, the federal counties of Salzburg, Styria and Vorarlberg adopted amendments to their fisheries law, which ban the release of GE fish.[112]

* A number of industry bodies representing aquaculture and fisheries interests are strongly opposed to the use of GE fish.[113] The Swedish Fish Industry Association, for example, recommends its member companies ***"to completely refrain from having anything to do with GE fish".***[114]

* In June 2003, the Baltic Marine Environment Protection Commission, the Helsinki Commission and the Commission for the Protection of the Marine Environment of the North East Atlantic held a joint ministerial meeting in Bergen, Germany. In the joint declaration from this meeting, they stated that: ***"Recognising that the release of genetically modified marine organisms presents an inherent threat of potentially severe, irreversible and transboundary effects, and the need to apply the precautionary principle, we agree to take all possible actions, in accordance with the requirements of the Directive 2001/18/EC and comparable national legislation, to ensure that the culture of genetically modified marine organisms is confined to secure, self-contained, land-based facilities in order to prevent their release to the marine environment."***[115]

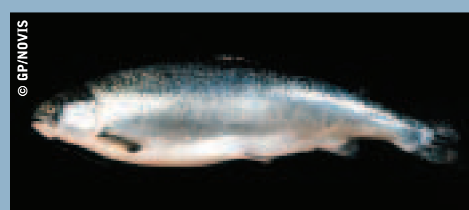
Several governments, intergovernmental organisations and conventions have already taken steps to try to prevent GE fish from being accidentally or deliberately released into aquatic systems. However, steps need to be taken globally, as any released GE fish will not respect national boundaries. A suitable multilateral instrument would be the Cartagena Protocol on Biosafety of the Convention on Biological Diversity, which seeks to protect biological diversity from the potential hazards posed by GE organisms.

conclusions

This report has examined many of the hazards associated with GE fish. The physical containment of these fish cannot be guaranteed under commercial conditions and any escapes into the environment could have devastating effects on wild fish populations and biodiversity.

Greenpeace demands that:

* Genetic engineering of fish for commercial purposes should be prohibited. Once approved for commercial use, GE fish may never be contained;
* The Parties to the Cartagena Protocol on Biosafety of the Convention on Biological Diversity consider the special transboundary challenges posed by GE fish, including the risks they pose to the environment, with a view to prohibiting any facilities that could result in the introduction (either accidental or deliberate) of GE fish into freshwater and marine ecosystems.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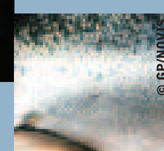
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FISH

GENETICALLY ENGINEERED FISH — NEW THREATS TO THE ENVIRONMENT

REFERENCES

references

1 | van Aken, J. 2000 'Genetically engineered fish: swimming against the tide of reason', Greenpeace International. <http://archive.greenpeace.org/geneng/highlights/gmo/swimming.PDF>

2 | Devlin, R.H. 2000. Risk assessment of genetically-distinct salmonids: difficulties in ecological risk assessment of transgenic and domesticated fish. In: P. Gallaugher & C. Orr (eds.), Aquaculture and the Protection of Wild Salmon, 63–69. Vancouver: Simon Fraser University.
Reichardt, T. 2000. Will souped up salmon sink or swim?, Nature 406: 10–12.

3 | UN FAO (Food and Agriculture Organization of the United Nations) 2000. Genetically Modified Organisms and Fisheries In: UN FAO The State of World Fisheries and Aquaculture. pp. 71-77
<www.fao.org/DOCREP/003/X8002E/x8002e05.htm#P30>
Pew Initiative on Food and Biotechnology 2003. Future fish – Issues in Science and Regulation of Transgenic Fish. Chapter 1, Table 2.
Zbikowska, H.M. 2003. Fish can be first – advances in fish transgenesis for commercial applications. Transgenic Research 12: 379–389.

4 | The Royal Society of Canada 2001.Elements of precaution: recommendations for the regulation of food biotechnology in Canada. Ottawa, p.182 <www.rsc.ca/foodbiotechnology/GMreportEN.pdf>
Goldburg, R. 2000. Something Fishy. The Gene Exchange, May 2000, <www.ucsusa.org/Gene/su98.fishy.html>

5 | Lu, J-K., Chen, T.T., Allen, S.K., Matsubara, T., & Burns, J.C. 1996. Production of transgenic dwarf surfclams, Mulinia lateralis, with pantropic retroviral vectors. Proceedings of the National Academy of Sciences 93: 3482-3486.
Peek, A.S., Wheeler, P.A., Ostberg, C.O. & Thorgaard, G.H. 1997. A minichromosome carrying a pigmentation gene and brook trout DNA sequences in transgenic rainbow trout. Genome 40: 594-599.
Lu, J.K., Burns, J.C., Chen, T.T. 1997. Pantropic retroviral vector integration, expression and germline transmission in medaka *(Oryzias latipes)*. Molecular Marine Biology and Biotechnology 6: 289-295.
Varadi, L., Benko, I., Varga, J., & Horvath, L. 1999. Induction of diploid gynogenesis using interspecific sperm and production of tetraploids in African catfish, *Clarias gariepinus* Burchell (1822). Aquaculture 73: 399-409.
Szelei, J., Varadi, L., Muller, F., Erdelyi, F., Orban, L., Horvath, L. & Duda, E. 1994. Liposome-mediated gene transfer in fish embryos. Transgenic Research 3: 116-119.
Martinez, R., Arenal, A., Estrada, M.P., Herrera, F., Huerta, V., Vazquez, J., Sanchez, T. & de la Fuente, J. 1999. Mendelian transmission, transgene dosage and growth phenotype in transgenic tilapia *(Oreochromis hornorum)* showing ectopic expression of homologous growth hormone. Aquaculture 173: 271-283.
Sheela, S.G., Pandian, T.J. & Mathavan, S. 1999. Electroporatic transfer, stable integration, expression and transmission of pZpssypGH and pZpssrtGH in Indian catfish. Aquaculture Research, 30: 233-248.
Alok D., Talwar, G.P. & Garg, L.C. 2000. In vivo activity of salmon gonadotropin releasing hormone (GnRH), its agonists with structural modifications at positions 6 and 9, mammalian GnRH agonists and native cGnRH-II on the spawning of an Indian catfish. Aquaculture International 7: 383-392.
Rahman, M.A. & Maclean, N. 1999. Growth performance of transgenic tilapia containing an exogenous piscine growth hormone gene. Aquaculture 173: 333-346.
Pitkanen, T.I., Krasnov, A., Reinisalo, M., & Molsa H. 1999. Transfer and expression of glucose transporter and hexokinase genes in salmonid fish. Aquaculture 173: 319-332.
Nam, Y.K., Noh, C.H. & Kim, D.S. 1999. Transmission and expression of an integrated reporter construct in three generations of transgenic mud leach (Misgurnus mizolepis). Aquaculture 172: 229-245.
Kinoshita, M., Toyohara, H., Sakaguchi, M., Inoue, K., Yamashita, S., Satake, M., Wakamatsu, Y. & Ozato, K. 1999 A stable line of transgenic medaka (*Oryzias latipes*) carrying the CAT gene Aquaculture 143: 267-276.
Hinits, Y, & Moav, B. 1999 Growth performance studies in transgenic *Cyprinus carpio*. Aquaculture, 173: 285-296.
Fu, C.H., Cui, Y.B., Hung, S.S.O. & Zhu, Z.Y. 2000 Whole-body amino acid pattern of F-4 human growth hormone gene-transgenic red common carp *(Cyprinus carpio)* fed diets with different protein levels. Aquaculture, 189: 287-292.
Ju, B., Xu, Y., He, J., Liao, J.Yan, T., Hew, C.L.. Lam T.J. & Gong, Z. 1999. Faithful expression of green fluorescent protein (GFP) in transgenic zebrafish embryos under zebrafish gene promoters. Developmental Genetics 25:1-10.
Many of the academic listings in the U.S are "sea grant" universities, with aquaculture programs established in collaboration with industry and government. For a full listing of U.S. sea grant programs, see <www.nsgo.seagrant.org/NationalSeaGrant.html#NE>
See also the following weblinks:
<www.AquaGene.com>
<www.ag.auburn.edu/genemap/ok1.html#GENEMAP>
<www.intrafish.com/article.php?articleID=3066>
<www.sg.ohio-state.edu/Project/f-PIlist.html >
<www.iisgcp.org/resrch/aq/AnnualR/aqr9.htm>
<www.seagrant.uconn.edu/biotech.html, http://chemistry.uconn.edu/FrankGroup/fish.html>
<www.mcb.uconn.edu/fac/fac/chen.htm, http://www.bme.uconn.edu/faculty/chen.html>
<www.ocean.udel.edu/level1/facultystaff/faculty/jgallagher/Presentation1/index.htm>
<www.uga.edu/gm/1299/FrontFind.html>
<www.umbi.umd.edu/~comb/programs/aquaculture/arc.html>
<www.flseagrant.org>http://www.rsmas.miami.edu/divs/mbf/people/mschmale.html
<www.gcd.med.umn.edu/faculty/hackett.html>
<www.seagrant.wisc.edu/research/subprograms/biotechnology/research.html >
<www.sci.wsu.edu/sbs/faculty/ghthorgaard.html>
<www.scitech.gc.ca/fptt/bc.html>
<www.bioatlantech.nb.ca/rv99/abstracts/james_wright.htm>
<www.mun.ca/osc>
<www.science.uwaterloo.ca/biology/faculty/bols.html>
<http://staff.science.nus.edu.sg/~choy-l%20hew/research_programs.html>
<www.dbs.nus.edu.sg/Staff/gong.html>
<www.science.nus.edu.sg/Research/pdf/pdfprojects/GFP.htm>
<www.nbiap.vt.edu>
<www.stw.nl/projecten/B/bbi4161.html>
<www.canterbury.ac.nz/publish/research/97/A19.htm>
<www.iisgcp.org/resrch/aq/AnnualR/aqr9.htm>
< www.chula.ac.th>
<www.ebnic.org/aquacult/CN%20Speakers/prof_zhu_zuoyan.htm>

6 | Squires, E.J. 1999. Status of sperm-mediated delivery methods for gene transfer. Murray, J.D., Anderson, G.B., Oberbauer, A.M. & McGloughlin, M.M. (eds.), Transgenic Animals in Agriculture. New York: CABI Publishing.
Inoue, K., Yamashita, S., Hata, J., Kabeno, S. Asada, S., Nagahisa, E., Shiba, T. & Fujita, T. 1990. Electroporation as a new technique for producing transgenic fish. Cell Differentiation and Development 29: 123–28.
Inoue, K., & Yamashita, S. 1997. The techniques using electroporation to generate GE fish. In: Houdebine, L.M. (ed.), Transgenic Animals: Generation and Use. Harwood Academic Publishers, Amsterdam, pp. 129-132.
Sin, F.Y.T., Barkley, A.C., Walker, S.P., Sin, P.L., Symonds, J.E., Hawke, L.& Hawkins, C.C. 1993. Gene transfer in chinook salmon by electroporating sperm in the presence of PRSV-lac Z DNA. Aquaculture 117: 57–69.

7 | MacLean, N., & Rahman. A. 1994. Transgenic fish. In: MacLean, N. (ed.), Animals with Novel Genes, Cambridge University Press, Cambridge, pp. 63-105.

8 | Steinbrecher, R. & Ho, M.-W. 1996. Fatal flaws in food safety assessment: critique of the Joint FAO/WHO Biotechnology and Food Safety Report. <www.psrast.org/fao96.htm>
Kapuscinski, A.R. & Hallermanm, E.M.. 1991. Implications of introduction of GE fish into natural ecosystems. Canadian Journal of Fisheries and Aquatic Sciences 48 (Suppl. 1): 99–107.

9 | US Congress Office of Technology Assessment (OTA) 1993. Harmful non-indigenous species in the United States. OTA-F-565, Washington, DC. USA. <www.wws.princeton.edu/~ota/ns20/alpha_f.html>
Fagan, J. Assessing the safety and nutritional quality of genetically engineered foods. <www.psrast.org/jfassess.htm>.

10 | Hill, J.A., Kiessling, A. & Devlin, R.H. 2000. Coho salmon *(Oncorhynchus kisutch)* transgenic for a growth hormone gene construct exhibit increased rates of muscle hyperplasia and detectable levels of differential gene expression. Canadian Journal of Fisheries and Aquatic Sciences 57: 939–950.

11 | Lindstrom, C.D.V., van Do, T., Hordvik, I., Endresen, C. & Elsayed, S. 1996. Cloning of two distinct cDNAs encoding parvalbumin, the major allergen of Atlantic salmon *Salmo salar*. Scandinavian Journal of Immunology 44: 335–344.

12 | Devlin, R.H. 1997. Transgenic salmonids. In Houdebine, L.M. (ed.), Transgenic Animals: Generation and Use. Harwood Academic Publishers, Amsterdam, pp.105-117.

13 | Dunham, R.A. & Devlin, R.H. 1999. Comparison of traditional breeding and transgenesis in farmed fish with implications for growth enhancement and fitness. In: Murray, J.D., Anderson, G.B., Oberbauer, A.M. & McGloughlin, M.M. (eds.), Transgenic Animals in Agriculture. CABI Publishing, New York, USA.
Pinkert, C.A. & Murray, J.D. 1999. Transgenic farm animals. In: Murray, J.D., Anderson, G.B., Oberbauer, A.M. & McGloughlin, M.M. (eds.), Transgenic Animals in Agriculture. CABI Publishing, New York, USA.

14 | Du, S.J., Gong, Z.Y., Fletcher, G.L., Shears, M.A., King, M.J., Idler, D.R. & Hew, C.L. 1992. Growth enhancement in transgenic Atlantic salmon by the use of an all fish chimeric growth-hormone gene construct. Bio Technology 10: 176-181.

15 | Stokstad, E. 2002 Engineered fish: friend or foe of the environment? Science 297: 1797.
Stoll, M. 1999 Designer fish flounder over legal hurdles. Christian Science Monitor 4th March, 1999. <www.csmonitor.com/durable/1999/03/04/p19s1.htm>

16 | Dunham, R.A. & Devlin, R.H. 1999. Comparison of traditional breeding and transgenesis in farmed fish with implications for growth enhancement and fitness. Murray, J.D., Anderson, G.B., Oberbauer, A.M. & McGloughlin, M.M. (eds.), Transgenic Animals in Agriculture. CABI Publishing, New York, USA.
Devlin, R.H., Yesaki, T.Y., Donaldson, E.M., Du, S.J., Hew, C.L. 1995. Production of germline transgenic pacific salmonids with dramatically increased growth-performance. Canadian Journal of Fisheries and Aquatic Sciences 52: 1376–84.

17 | Chen, T.T.,Kight, K., Lin, C.M., Powers, D.A., Hayat, M., Chatakondi, N., Ramboux, A.C., Duncan, P.L. & Dunham, R.A. 1993. Expression and inheritance of RSVLTR-rtGH1 complementary DNA in the transgenic common carp, *Cyprinus carpio*. Molecular Marine Biology and Biotechnology 2: 88–95.
Dunham, R.A., R.H. Devlin. 1999. Comparison of traditional breeding and transgenesis in farmed fish with implications for growth enhancement and fitness. In Murray, J.D., Anderson, G.B., Oberbauer, A.M. & McGloughlin, M.M. (eds.), Transgenic Animals in Agriculture. CABI Publishing, New York, USA.

18 | Stokstad, E. 2002 Engineered fish: friend or foe of the environment? Science 297: 1797.

19 | Rana, K.J. 1997. Global overview of production and production trends 1984-1995. In: Review of the State of World Aquaculture. FAO Fisheries Circular no. 886 FIRI/C886(Rev.1) <www.fao.org/docrep/003/w7499e/w7499e05.htm>

FISH

GENETICALLY ENGINEERED FISH — NEW THREATS TO THE ENVIRONMENT

REFERENCES

20 | Rana, K. & Immink, A. 2001. Trends in global aquaculture production: 1984-1996. UN FAO (Food and Agriculture Organization of the United Nations) <www.fao.org/DOCREP/FIELD/006/AD742E/AD742E00.HTM>
Graing, R. 2001. Recent trends in global fishery production up to 1996. UN FAO (Food and Agriculture Organization of the United Nations) <http://www.fao.org/fi/trends/catch/catch.asp>
Goldburg, R. 2000. Something fishy. The Gene Exchange, May 2000, <www.ucsusa.org/Gene/su98.fishy.html>

21 | Garibaldi, L. 1996. List of animal species used in aquaculture. FAO Fisheries Circular no. 914 FIRI/C914, <www.fao.org/docrep/W2333E/W2333E01.htm>

22 | Goldburg R. & Triplett, T. 1997. Murky waters: environmental effects of aquaculture in the US. The Environmental Defense Fund. <www.environmentaldefense.org/pdf.cfm?contentid=490&filename=AQUA%2Epdf>
Johnston, P., Santillo, D., Stringer, R., Ashton, J., McKay, B., Verbeek, M., Jackson, E., Landman, J., van den Broek, J., Samsom, D., & Simmonds, M. 1998. Greenpeace report on the world's oceans. Greenpeace Research Laboratories Report, May 1998. Publ: Stichting Greenpeace Council. ISBN: 90/73361/45/1: 154 pp. Chapter 5. <www.greenpeace.to/pdfs/reportworldsoceans.pdf>
Johnston, P. & Santillo, D. 2002. Chemical usage in aquaculture: implications for residues in market products. Greenpeace Research Laboratories Technical Note 06/2002: 15 pp. <www.greenpeace.to/pdfs/Technical_Note_06_02.pdf>

23 | Weiss, K.R. 2002. Fish farms become feedlots of the sea, Los Angeles Times, December 9 2002, <http://curezone.com/art/read.asp?ID=69&db=6&C0=1>

24 | Weiss, K.R. 2002. Fish farms become feedlots of the sea, Los Angeles Times, December 9 2002, <http://curezone.com/art/read.asp?ID=69&db=6&C0=1>

25 | Environmental Working Group <www.ewg.org/reports/farmedPCBs/es.php>
Hites, R.A., Foran, J.A., Carpenter, D.O., Hamilton,M.C. Knuth, B.A. & Schwager, S.J. 2004. Global assessment of organic contaminants in farmed salmon. Science, 303: 226-229.

26 | Tacon, A.G.J. 1996. Feeding tomorrow's fish. World Aquaculture. Sept. 27, 1996, 20-32.
Goldburg R. & Triplett, T. 1997. Murky waters: environmental effects of aquaculture in the US. The Environmental Defense Fund. <www.environmentaldefense.org/pdf.cfm?contentid=490&filename=AQUA%2Epdf>

27 | van Aken, J. 2000 'Genetically engineered fish: swimming against the tide of reason', Greenpeace International. <http://archive.greenpeace.org/geneng/highlights/gmo/swimming.PDF>

28 | Fleischman, J, 1997. Muddying the waters. Audubon 99:64-69.

29 | MacKenzie, D, 1996. Can we make supersalmon safe? New Scientist, 27 January 1996, 14-15.

30 | Slaney, T.L., Hyatt, K.D., Northcote, T.G. & Fielden, R.J. 1996. Status of anadromous salmon and trout in British Columbia and Yukon. Fisheries 21: 20-35.
Blumenthal, L 2000. Genetically altered salmon cause debate among U.S. officials. The News Tribune, Tacoma, Washington, Aug 21, 2000.
Ludwig, B. 1996. Position of the British Columbia Ministry of Environment, Land and Parks on the use of non-reproductive Atlantic Salmon., Bulletin of the Aquaculture Association of Canada 96:32-37.

31 | Blumenthal, L 2000. Genetically altered salmon cause debate among U.S. officials. The News Tribune, Tacoma, Washington, Aug 21, 2000.
Mottram, B. 1996. Firm's Atlantic salmon loss NW anglers' gain. Morning News Tribune, Tacoma, WA, October 23, 1996.
Dodge, J. 1997. Escaped fish open to anglers. Olympian, WA, July 23 1997.

32 | Lymbery, P. 2001. In too deep - the welfare of intensively farmed fish. Compassion In World Farming Trust, Feb 2001

33 | Runyon C. 2001. Transgenic Fish. Research Memorandum for Environment, Energy and Transportation Program, national conference of state legislatures, April 2001 <www.ncsl.org/programs/esnr/transgfish.htm>
Stokstad, E. 2002 Engineered fish: friend or foe of the environment? Science 297: 1797.
Daley, B 2001 Escaped farm salmon raise alarm in Maine. The Boston Globe, Feb 23, 2001, <www.boston.com/dailyglobe2/0.../Escaped_farm_salmon_raise_alarm_in_Maine+.shtm>

34 | At the time of writing of this report, the Magaguadavic River is the only Canadian river for which there is annual data on escaped farmed fish and wild fish.
The Royal Society of Canada 2001.Elements of precaution: recommendations for the regulation of food biotechnology in Canada. Ottawa, p.151 <www.rsc.ca/foodbiotechnology/GMreportEN.pdf>
Carr, J., Anderson, J.M., Whoriskey, F.G.& Dilworth, T. 1997. The occurrence and spawning of cultured Atlantic salmon *(Salmo salar L.)* in a Canadian river. ICES Journal of Marine Science 54: 1064–1073.
Whoriskey, F. 2000. The North American east coast salmon aquaculture industry: the challenges for wild salmon. Atlantic Salmon Federation, St. Andrews, NB, USA.

35 | Goldburg R. & Triplett, T. 1997. Murky waters: environmental effects of aquaculture in the US. The Environmental Defense Fund. <www.environmentaldefense.org/pdf.cfm?contentid=490&filename=AQUA%2Epdf>

36 | Rimmer, D.W. 1998, Atlantic salmon *(Salmo salar)* in Tsitika river, 1998. Ministry of Environment, Lands and Parks, Fisheries Section, B.C., V9T 6J9.
Volpe, J.P., Taylor, E.G. Rimmer, D.W. Glickman. B.W. 2000. Evidence of natural reproduction of aquaculture-escaped Atlantic salmon in a coastal British Columbia river. Conservation Biology 14: 899–903.
Gross, M.R. 2000. Will farmed Atlantic salmon invade the ecological niches of wild Atlantic salmon? In: P. Gallaugher, C. Orr (eds.), Aquaculture and the Protection of Wild Salmon. Simon Fraser University, Cont. Stud. Sci., Burnaby, BC: pp. 25–28.
Reichardt, T. Will souped up salmon sink or swim?, Nature 406: 10–12.
Goldburg, R. 2000. Something Fishy. The Gene Exchange, May 2000, <www.ucsusa.org/Gene/su98.fishy.html>

37 | Doughton, S. 1997. Hearings set on impact of farmed fish that escape from floating pens. News Tribune, Tacoma, WA, June 18, 1997, B1.

38 | Goldburg R. & Triplett, T. 1997. Murky waters: environmental effects of aquaculture in the US. The Environmental Defense Fund. <www.environmentaldefense.org/pdf.cfm?contentid=490&filename=AQUA%2Epdf>

39 | Wills, P. Biological Complexity, <www.phy.auckland.ac.nz/staff/prw/biocomplexity/bio_complexity_home.htm>

40 | Wills, P. Biological Complexity, <www.phy.auckland.ac.nz/staff/prw/biocomplexity/bio_complexity_home.htm>

41 | Solé, R.V. & Newman, M. 1999. Patterns of extinction and biodiversity in the fossil record', Santa Fe Institute Working Paper 99-12-097, December 1999. Example taken from Peter Wills' website on biological complexity, <www.phy.auckland.ac.nz/staff/prw/biocomplexity/bio_complexity_home.htm>

42 | The Precautionary Principle has been defined and adopted by several international environment agreements, including Principle 15 of the Rio Declaration (http://www.unep.org), the preamble of the Convention on Biological Diversity (http://www.biodiv.org).

43 | Tiedje, J.M. Colwell, R.K., Grossman, Y.L. Hodson, R.E., Lenski, R.E., Mack, R.N. & Regal, P.J. 1989. The planned introduction of genetically engineered organisms: ecological considerations and recommendations. Ecology 70: 298–315.
Kapuscinski, A.R. & Hallerman, E.M. 1990. Transgenic fish and public policy: anticipating environmental impacts of transgenic fish. Fisheries 15: 2–11.
Kapuscinski, A.R. & Hallerman, E.M. 1991. Implications of introduction of transgenic fish into natural ecosystems. Canadian Journal of Fisheries and Aquatic Sciences 48: 99–107.
Hallerman, E.M. & Kapuscinski, A.R. 1992. Ecological and regulatory uncertainties associated with transgenic fish. In: Hew,C.L. & Fletcher, G.L. (eds.) Transgenic Fish. World Scientific Publishing Company, Singapore. pp. 209-288.
Regal, P.J. 1986. Models of genetically engineered organisms and their ecological impact. In: Mooney, H.A. & Drake, J.A. (eds.), Ecology of Biological Invasions of North America and Hawaii. Ecological Studies: Analysis and Synthesis 58, Spring-Verlag, New York, USA pp. 111–129.
Tiedje, J.M., Colwell, R.K., Grossman, Y.L., Hodson, R.E., Lenski, R.E., Mack, R.N. & Regal, P.J. 1989. The planned introduction of genetically engineered organisms: ecological considerations and recommendations. Ecology 70: 298–315.

44 | Grosman, E. 1995. Nile Perch Trade and Environment. Trade and Environment (TED) case study no. 206 <www.american.edu/TED/PERCH.HTM>
Gophen, M., Ochumba, P.B.O. & Kaufman, L.S. 1995. Some aspects of perturbation in the structure and biodiversity of the ecosystem of Lake Victoria (East Africa). Aquatic Living Resources 8: 27-41.
See also The American Museum of Natural History 'Endangered - exploring a world at risk', <www.amnh.org/nationalcenter/Endangered/perch.html>
O' Riordan, B. 1992. Fishing out the gene pool. Appropriate Technology 18: 6-9.
Toner, M. 1991. Are test-tube fish such a hot idea? International Wildlife, Nov-Dec 1991: 34.

45 | Wilcove D.S. & Bean, M.J.. 1994. The big kill: declining biodiversity in America's lakes and rivers. Environmental Defense Fund, Washington, DC. 275 pp.
Taylor, J.N., Courtenay, W.R. & McCann, J.A. 1984. Known impacts of exotic fishes in the continental United States. In: Courtenay, W.R. & Stauffer, J.R. (eds.) Distribution, Biology, and Management of Exotic Fishes. Johns Hopkins University Press, Baltimore, USA pp. 322-373.
Pimentel, D, Lach, L, Zuniga, R, Morrison, D 2000. Environmental and economic costs associated with non-indigenous species in the United States. Bioscience 50: 53-65.

46 | Goldburg, R. & Triplett, T. 1997. Murky waters: environmental effects of aquaculture in the US. Environmental Defense, New York USA. p.11. <www.environmentaldefense.org/documents/490_AQUA.pdf>

47 | Benson, A.J. & Boydstun, C.P. 1995. Invasion of the zebra mussel into the United States. In: LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D. & Mac, M.J. (eds.) Our Living Resources: a Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals and Ecosystems. U.S. Department of the Interior, National Biological Service, Washington, DC, USA pp. 445-446. http://biology.usgs.gov/s+t/index.htm
Keniry, T. & Marsden, J.E. 1995. Zebra mussels in southwestern Lake Michigan. In: LaRoe, E.T., Farris, G.S., Puckett, C.E., Doran, P.D. & Mac, M.J. (eds.) Our Living Resources: a Report to the Nation on the Distribution, Abundance, and Health of U.S. Plants, Animals and Ecosystems. U.S. Department of the Interior, National Biological Service, Washington, DC, USA pp. 445-448. http://biology.usgs.gov/s+t/index.htm

48 | US Congress Office of Technology Assessment (OTA) 1993. Harmful non-indigenous species in the United States. OTA-F-565, Washington, DC, USA. <www.wws.princeton.edu/~ota/ns20/alpha_f.html>

49 | Lewis, C. 2001. A new kind of fish story: the coming of biotech animals. U.S. Food and Drug Administration Consumer Magazine, January-February 2001.

50 | Muir, W.M. & Howard, R.D. 2002. Assessment of possible ecological risks and hazards of GE fish with implications for other sexually reproducing organisms. Transgenic Research 11: 101-114.

51 | The Royal Society of Canada 2001. Elements of precaution: recommendations for the regulation of food biotechnology in Canada. Ottawa, Canada, p.156 <www.rsc.ca/foodbiotechnology/GMreportEN.pdf>
Rahman, M.A. & Maclean, N. 1999. Growth performance of transgenic tilapia containing an exogenous piscine growth hormone gene. Aquaculture 173: 333–346.

52 | Farrell, A.P., Bennett, W. & Devlin. R.H. 1997. Growth-enhanced transgenic salmon can be inferior swimmers. Canadian Journal of Zoology 75: 335–337.

53 | Devlin, R.H., Johnsson, J.I., Smailus, D.E., Biagi, C.A., Jonsson, E. & Bjornsson, B.T. 1999. Increased ability to compete for food by growth hormone-transgenic coho salmon *Oncorhynchus kisutch* (Walbaum). Aquaculture Research 30: 479-482.
Abrahams, M.V. & Sutterlin. A. 1999. The foraging and antipredator behaviour of growth enhanced transgenic Atlantic salmon. Animal Behaviour 58: 933–942.

54 | Hill, J.A., Kiessling, A. & Devlin, R.H. 2000. Coho salmon *(Oncorhynchus kisutch)* transgenic for a growth hormone gene construct exhibit increased rates of muscle hyperplasia and detectable levels of differential gene expression. Canadian Journal of Fisheries and Aquatic Sciences 57: 939–950.

55 | Devlin, R.H. 2000. Risk assessment of genetically-distinct salmonids: difficulties in ecological risk assessment of transgenic and domesticated fish. In: P. Gallaugher & C. Orr (eds.), Aquaculture and the Protection of Wild Salmon, 63–69. Simon Fraser University, Vancouver, Canada.

56 | Ostenfeld, T.H., McLean, E. & Devlin. R.H. 1998. Transgenesis changes body and head shape in Pacific salmon. Journal of Fish Biology 52: 850–854.

57 | Mori, T. & Devlin. R.H. 1999. Transgene and host growth hormone gene expression in pituitary and nonpituitary tissues of normal and growth hormone transgenic salmon. Molecular and Cellular Endocrinology149: 129–139.

58 | Devlin, R.H., Yesaki, T.Y., Donaldson, E.M., Du, S.J., Hew, C.L. 1995. Production of germline transgenic pacific salmonids with dramatically increased growth-performance. Canadian Journal of Fisheries and Aquatic Sciences 52: 1376–1384.
Devlin, R.H., Yesaki, T.Y., Donaldson, E.M. & Hew, C.L. 1995. Transmission and phenotypic effects of antifreeze/GH gene construct in coho salmon *(Oncorhynchus kisutch)*. Aquaculture 137: 161–169.

59 | Devlin, R.H., Yesaki, T.Y., Donaldson, E.M. & Hew, C.L. 1995. Transmission and phenotypic effects of antifreeze/GH gene construct in coho salmon *(Oncorhynchus kisutch)*. Aquaculture 137: 161–169.

60 | Saunders, R.L., Fletcher, G.L. & Hew, C.L. 1998. Smolt development in growth hormone transgenic Atlantic salmon. Aquaculture 168: 177–193.

61 | Abrahams, M.V. & Sutterlin. A. 1999. The foraging and antipredator behaviour of growth enhanced transgenic Atlantic salmon. Animal Behaviour 58: 933–942.

62 | Devlin, R.H., Yesaki, T.Y., Donaldson, E.M., Du, S.J., Hew, C.L. 1995. Production of germline transgenic pacific salmonids with dramatically increased growth-performance. Canadian Journal of Fisheries and Aquatic Sciences 52: 1376–1384.
Devlin, R.H., Yesaki, T.Y., Donaldson, E.M. & Hew, C.L. 1995. Transmission and phenotypic effects of antifreeze/GH gene construct in coho salmon *(Oncorhynchus kisutch)*. Aquaculture 137: 161–169.

63 | Devlin, R.H., Biagi, C.A., Yesaki, T.Y., Smailus, D.E. & Byatt, J.C. 2001. Growth of domesticated transgenic fish - a growth-hormone transgene boosts the size of wild but not domesticated trout. Nature 409: 781–782.

64 | Knibb, W. 1997. Risk from genetically engineered and modified marine fish. Transgenic Research 6: 59–67.
Dunham, R.A. 1999. Utilization of transgenic fish in developing countries: potential benefits and risks. Journal of the World Aquaculture Society 30: 1–11.

65 | Muir, W.M., Howard, R.D. 1999. Possible ecological risks of transgenic organism release when transgenes affect mating success: sexual selection and the Trojan gene hypothesis. Proceedings of the National Academy of Sciences of the United States of America 96: 13853-13856.
Howard, R.D., DeWoody, J.A. & Muir, W.M. 2004. Transgenic male mating advantage provides opportunity for Trojan gene effect in a fish. Proceedings of the National Academy of Sciences of the United States of America 101: 2934-2938.

66 | Muir, W.M., Howard, R.D. 1999. Possible ecological risks of transgenic organism release when transgenes affect mating success: sexual selection and the Trojan gene hypothesis. Proceedings of the National Academy of Sciences of the United States of America 96: 13853-13856.

67 | Walker, M. 1999. Could one genetically modified fish invade a species and destroy it? New Scientist, 4 December 1999.

68 | Boutin, C. 2004. Purdue scientists: genetically modified fish could damage ecology. <www.innovations-report.com/html/reports/environment_sciences/report-26148.html> 24 Feb 2004.

69 | Muir, W.M. & Howard, R.D. 2002. Assessment of possible ecological risks and hazards of GE fish with implications for other sexually reproducing organisms. Transgenic Research, 11: 101-114.
Hedrick, P.W. 2001. Invasion of transgenes from salmon or other genetically modified organisms into natural populations (vol 58, pg 841, 2001), Canadian Journal of Fisheries and Aquatic Sciences 58: 2317.

70 | Devlin, R.H., Johnsson, J.I., Smailus, D.E., Biagi, C.A., Jonsson, E. & Bjornsson, B.T. 1999. Increased ability to compete for food by growth hormone-transgenic coho salmon *Oncorhynchus kisutch* (Walbaum). Aquaculture Research 30: 479-482.
Royal Society, 2001. The use of genetically modified animals, In: GM Animals for Agricultural Uses. The Royal Society, London. Ch. 4.6, para. 59. <www.royalsoc.ac.uk>
Reichardt, T. 2000. Will souped up salmon sink or swim? Nature 406: 10–12.
Stokstad, E. 2002 Engineered fish: friend or foe of the environment? Science 297: 1797.

71 | Devlin, R.H., D'Andrade, M., Uh, M. & Biagi, C.A. 2004. Population effects of growth hormone transgenic coho salmon depend on food availability and genotype by environment interactions. Proceedings of the National Academy of Sciences, 101: 9303–9308.
Howard, R.D., DeWoody, J.A. & Muir, W.M. 2004. Transgenic male mating advantage provides opportunity for Trojan gene effect in a fish. Proceedings of the National Academy of Sciences of the United States of America 101: 2934-2938.

72 | Entis, E. 2003. Genetically modified fish: promise or problematic?', fromViewpoint, a live discussion forum on washingtonpost.com, January 23, 2003
<www.washingtonpost.com/wp-srv/liveonline/advertisers/viewpoint_pew012303.htm>

73 | Hileman, R. 2000. Biotech regulation under attack. Chemical & Engineering News 78: 28-31 22nd May 2000.

74 | The Royal Society of Canada 2001. Elements of precaution: recommendations for the regulation of food biotechnology in Canada. Ottawa, Canada, p.160 <www.rsc.ca/foodbiotechnology/GMreportEN.pdf>

75 | Goldburg, R. & Triplett, T. 1997. Murky waters: environmental effects of aquaculture in the US. Environmental Defense, New York USA. p.77 <www.environmentaldefense.org/documents/490_AQUA.pdf>
Shelton, W.L. 1996. Reproductive manipulation of fishes: ecologically safe assessment of introductions. US-ARS, Biotechnology Risk Assessment Research Grants, Program Abstract of Funded Research 1996.
Benfey, T.J., Solar, I.I., De Jong, G. & Donaldson, E.M. 1986. Flow-cytometric confirmation of aneuploidy in sperm from triploid rainbow trout. Transactions of the American Fisheries Society 115:838-840.
Lincoln, R.F. & Scott, A.P. 1984. Sexual maturation in triploid rainbow trout, *Salmo gairdneri* Richardson. Journal of Fish Biology 25:385-392.
Thorgaard, G.H., & Allen, K. 1992. Environmental impacts of inbred, hybrid and polyploid aquatic species. In: Rosenfield, A. & Mann, R. (eds.) Dispersal of Living Organisms into Aquatic Ecosystems. College Park, University of Maryland, USA pp. 281-288.
Allen, S.K., Jr. 1987. Reproductive sterility of triploid shellfish and fish. Ph.D. dissertation, University of Washington, Seattle. Cited in Thorgaard & Allen 1992.
Blankenship, K. 1994. Experiment with Japanese oysters ends abruptly. Bay Journal 10 (July/August 1994):1-4. Alliance for the Chesapeake Bay, Baltimore, USA <www.bayjournal.com/94-08/oyster.htm>
Royal Society, 2001. Potential hazards of GM animals. In: GM Animals for Agricultural Uses. The Royal Society, London. Ch. 5.2, para. 105. <www.royalsoc.ac.uk>
Royal Society of Canada 2001. Elements of precaution: recommendations for the regulation of food biotechnology in Canada. Ottawa, Canada. <www.rsc.ca/foodbiotechnology/GMreportEN.pdf>
US Congress Office of Technology Assessment (OTA) 1995. Current Status of Federal Involvement in U.S. Aquaculture. OTA-BPENV- 170 Washington, DC. USA <www.wws.princeton.edu/~ota/ns20/alpha_f.html>
Reichardt, T. 2000. Will souped up salmon sink or swim? Nature 406: 10–12.
Stokstad, E. 2002. Engineered fish: friend or foe of the environment? Science 297: 1797.
Wang, Z.P., Guo, X.M., Allen, S.K. & Wang, R. 1999 Aneuploid Pacific oyster (*Crassostrea gigas* Thunberg) as incidentals from triploid production. Aquaculture 173: 347-57
National Research Council 2004. Biological Confinement of Genetically Engineered Organisms. The National Academies Press, Washington, D.C., USA. <www.nap.edu/books/0309090857/html>
Stokstad, E. 2004. Experts recommend a cautious approach. Science 303: 449.

76 | Razak, S.A., Hwang, G.L., Rhman, M. A. & Maclean, N. 1999. Growth performance and gonadal development of growth enhanced transgenic tilapia *Oreochromis niloticus (L.)* following heat-shock-induced tripoidy, Marine Biotechnology 1:533-544.

77 | Muir, W.M. & Howard, R.D. 2002. Assessment of possible ecological risks and hazards of GE fish with implications for other sexually reproducing organisms. Transgenic Research 11: 101-114.

78 | Maclean, N. & Laight, R.J. 2000, Transgenic fish: an evaluation of benefits and risks. Fish Fish 1: 146–172.

79 | Maclean, N. & Laight, R.J. 2000, Transgenic fish: an evaluation of benefits and risks. Fish Fish 1: 146–172.

80 | Muir, W.M. & Howard, R.D. 2002. Assessment of possible ecological risks and hazards of GE fish with implications for other sexually reproducing organisms. Transgenic Research 11: 101-114.

FISH

GENETICALLY ENGINEERED FISH — NEW THREATS TO THE ENVIRONMENT

REFERENCES

81 | Kay, J. 2002. 'Frankenfish' spawn controversy. Debate over genetically altered salmon. San Francisco Chronicle, San Francisco, USA, April 29, 2002.
http://sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/2002/04/29/MN155761.DTL

82 | Hileman, R. 2000. Biotech regulation under attack. Chemical & Engineering News 78: 28-31 22nd May 2000.

83 | see, e.g. Boyce, N. (2000) Taco trouble. New Scientist, 7th October 2000, p.6.
Quist, D. & Chapela, I.H. (2001) Transgenic DNA introgressed into traditional maize landraces in Oaxaca, Mexico. Nature 414: 541-543;
Greenpeace (2002) Genetic pollution - a multiplying nightmare. Greenpeace Genetic Engineering Briefing Pack. Feb. 2002, <www.greenpeace.org/international_en/multimedia/download/1/10062/0/genetic_pollution.pdf>
Union of Concerned Scientists (UCS) 2004. Gone to Seed.
<www.ucsusa.org/food_and_environment/biotechnology/page.cfm?pageID=1315>

84 | Sutterlin, A., Fletcher, G., Hew, C. & Benfey, T. 1996. Environmental risks in using transgenic Atlantic salmon and rainbow trout for commercial marine production in Canada. Proceedings U.S. Department of Agriculture Biotechnology Risk Assessment Research Grants Symposium 1996, Ch. 10 Fish.
<www.nbiap.vt.edu/brarg/brasym96/sutterlin96.htm>

85 | Sutterlin, A.M. & Collier, C. 1991. Some observations on the commercial use of triploid rainbow trout and Atlantic salmon in Newfoundland. Proceedings of the Fish Sterility Workshop, Feb. 20, Halifax, N.S. Canadian Technical Report of Fisheries and Aquatic Sciences no. 1789. 15-33.

86 | Thorgaard, G.H., & Allen, K. 1992. Environmental impacts of inbred, hybrid and polyploid aquatic species. In: Rosenfield, A. & Mann, R. (eds.) Dispersal of Living Organisms into Aquatic Ecosystems. College Park, University of Maryland, USA pp. 281-288.

87 | Musick, J.A., Harbin, M.M., Berkeley, S.A., Burgess, G.H., Eklund, A.M., Findley, L., Gilmore, R.G., Golden, J.T., Ha, D.S., Huntsman, G.R., McGovern, J.C., Parker, S.J., Poss, S.G., Sala, E., Schmidt, T.W., Sedberry, G.R., Weeks, H. & Wright, S.G. 2000. Marine, estuarine, and diadromous fish stocks at risk of extinction in North America (exclusive of Pacific salmonids). Fisheries 25: 6-30.

88 | Friars, G.W., McMillan, I., Quinton, V.M., O'Flynn, F.M., McGeachy, S.A., & Benfey, T.J. 2001. Family differences in relative growth of diploid and triploid Atlantic salmon *(Salmo salar L.)*. Aquaculture 192: 23-29.

89 | Benfey, T.J. 1996. Use of all-female and triploid salmonids for aquaculture in Canada. Bulletin of the Aquaculture Association of Canada 96-2: 6-8. <www.aquacultureassociation.ca/bulletin/bull96-2.html>

90 | McGeachy, S.A., Benfey, T.J. & Friars, G.W. 1995. Freshwater performance of triploid Atlantic salmon *(Salmo salar)* in New Brunswick aquaculture. Aquaculture 137: 333-341.

91 | Lymbery, P. 2002. In too deep - the welfare of intensively farmed fish. Compassion in World Farming Trust.
<www.ciwf.org.uk/publications/reports/in_too_deep_2001.pdf>

92 | Sutterlin, A., Fletcher, G., Hew, C. & Benfey, T. 1996. Environmental risks in using transgenic Atlantic salmon and rainbow trout for commercial marine production in Canada. Proceedings U.S. Department of Agriculture Biotechnology Risk Assessment Research Grants Symposium 1996, Ch. 10 Fish.
<www.nbiap.vt.edu/brarg/brasym96/sutterlin96.htm>
Sutterlin, A.M., Holder, J. & Benfey, T.J. 1987. Early survival rates and morphological abnormalities in landlocked, anadromous and hybrid (landlocked x anadromous) diploid and triploid Atlantic salmon. Aquaculture: 64: 157-164.
Jungalwalla, P.J. 1991. Production of non-maturing Atlantic salmon in Tasmania. Canadian Technical Report of Fisheries and Aquatic Sciences no. 1789: 47-71.
Hughes, D.R. 1992. Lower jaw deformity in farmed Tasmanian Atlantic salmon, *Salmo salar* (Salmoniformes, Teleosti). Final report. In: Proceedings of the Saltas Research Review Seminar, 29th April, 1992. Salmon Enterprises of Tasmania, Hobart, Tasmania pp. 17-64.
King, H. & Lee, P. 1993. Jaw deformities and respiratory physiology of triploids. Progress report In: Proceedings of the Saltas Research Review Seminar, 29th April, 1993. Salmon Enterprises of Tasmania, Hobart, Tasmania pp. 37-44.
Lee, P. & King, H. 1994. Effects of reduced dietary energy on the incidence of jaw deformities in Tasmanian Atlantic salmon. In: Reports from the Saltas 1993-94 Research and Development Programme. Salmon Enterprises of Tasmania, Hobart, Tasmania. pp. 61-69.
O'Flynn, F.M., McGeachy, S.A., Friars, G.W., Benfey, T.J. & Bailey, J.K. 1997. Comparisons of cultured triploid and diploid Atlantic salmon *(Salmo salar L.)* ICES Journal of marine science 54: 1160-1165.

93 | Wall, A.E. & Richards, R.H. 1992. Occurrences of cataracts in triploid Atlantic salmon *(Salmo salar)* on four farms in Scotland. Veterinary Record 131: 553-557.

94 | Lymbery, P. 2002. In too deep - the welfare of intensively farmed fish. Compassion in World Farming Trust.
<www.ciwf.org.uk/publications/reports/in_too_deep_2001.pdf>

95 | There have been examples of 'mistakes' where genetically engineered animals have ended up in the human food supply, but these animals have not been officially approved for human consumption. E.g, Westphal, S.P. 2001. Pig out. New Scientist, 28th July 2001 p. 14.
Reuters Commodities News (Eng) US biotech researchers careless with 386 pigs. 6th February, 2003.
Anon 2004. Pig feed blunder. New Scientist 28th February 2004, p.4.

96 | Hoag, H. 2003 Transgenic salmon still out in the cold in United States. Nature 421: 304.
Center for Food Safety 2001. Petition seeking a moratorium on the domestic marketing and importation of genetically engineered fish. Citizen petition before the United States Food and Drug Administration.
<www.centerforfoodsafety.org/legal_acti2.cfm>.
Pew Initiative on Food and Biotechnology, 2003. Future fish – issues in science and regulation of transgenic fish.
<http://pewagbiotech.org/research/fish/fish.pdf>
Luoma, J.R. 2001. Fish or Foul? Coming soon to a dinner table near you: DNA filet., Mother Jones, March/April 2001 <www.motherjones.com/news/outfront/2001/03/xgenic.html>
Zitner, A. 2001. Gene-altered Frankenfish coming to market' Los Angeles Times, January 2, 2001 Available at
<www.organicconsumers.org/ge/dunhamfish.cfm>
Goldburg, R. 2000. Something Fishy. The Gene Exchange, May 2000, <www.ucsusa.org/Gene/su98.fishy.html>
Blumenthal, L 2000. Genetically altered salmon cause debate among U.S. officials. The News Tribune, Tacoma, Washington, Aug 21, 2000.
Reichardt, A. 2000. Will souped up salmon sink or swim? Nature 406: 10–12.
Stoll, M. 1999 Designer fish flounder over legal hurdles. Christian Science Monitor 4th March, 1999.
<www.csmonitor.com/durable/1999/03/04/p19s1.htm>
Stokstad, E. 2002 Engineered fish: friend or foe of the environment? Science 297: 1797.
Kaufman, M. 2000 Frankenfish or tomorrow's dinner? Washington Post, October 17, 2000, p A01 Available at:
<www.mindfully.org/GE/Frankenfish-Tomorrows-Dinner.htm>
Matheson, J. 1999. Will transgenic fish be the first ag-biotech food-producing animals? FDA Veterinarian Newsletter, May June 1999, Volume XIV, No III <www.fda.gov/cvm/index/fdavet/1999/may.html#GEs>

97 | Hoag, H. 2003. Transgenic salmon still out in the cold in United States. Nature 421: 304.

98 | Wu, G., Sun, Y. & Zhu, Z. 2003. Growth hormone gene transfer in common carp. Aquatic Living Resources 16: 416-420.

99 | Wu, G., Sun, Y. & Zhu, Z. 2003. Growth hormone gene transfer in common carp. Aquatic Living Resources 16: 416-420.

100| Hill, J.A., Kiessling, A. & Devlin, R.H. 2000. Coho salmon *(Oncorhynchus kisutch)* transgenic for a growth hormone gene construct exhibit increased rates of muscle hyperplasia and detectable levels of differential gene expression. Canadian Journal of Fisheries and Aquatic Sciences 57: 939–950.
Royal Society of Canada 2001. Elements of precaution: recommendations for the regulation of food biotechnology in Canada. Ottawa, Canada. p.182 <www.rsc.ca/foodbiotechnology/GMreportEN.pdf>
Lindstrom C.D.V., van Do, T., Hordvik, I., Endresen, C. & Elsayed, S. 1996. Cloning of two distinct cDNAs encoding parvalbumin, the major allergen of Atlantic salmon *(Salmo salar)*. Scandinavian Journal of Immunology 44: 335–344.

101| See Greenpeace 2002. GE food –safe to eat? Genetic Engineering Briefing Pack, May 2002
<www.eu.greenpeace.org/downloads/gmo/GEFOODsaftey.doc>

102| Personal communication between Joseph Mendelson and Luke Anderson

103| National Research Council 2002. Animal Biotechnology: Science Based Concerns. The National Academies Press, Washington DC, USA <http://books.nap.edu/books/0309084393/html/89.html#pagetop>
Royal Society of Canada 2001. Elements of precaution: recommendations for the regulation of food biotechnology in Canada Ottawa, Canada, January 2001 <www.rsc.ca/foodbiotechnology/GMreportEN.pdf>
Royal Society, 2001. The use of genetically modified animals, In: GM Animals for Agricultural Uses. The Royal Society, London. <www.royalsoc.ac.uk>

104| About 20,000 salmon escaped from a tanker truck spill on Vancouver Island, Ref. Slaney, T.L., Hyatt, K.D., Northcote, T.G. & Fielden, R.J. 1996. Status of anadromous salmon and trout in British Columbia and Yukon. Fisheries 21: 20-35.

105| Oregon Administrative Rule 635-007-0595
<http://arcweb.sos.state.or.us/rules/OARS_600/OAR_635/635_007.html>

106| H.B. 189, Maryland. Laws, Chap. #54. April 10 2001 <http://mlis.state.md.us/2001rs/billfile/HB0189.htm>

107| Anon 2002. Washington state issues ban on transgenic fish. Seafood News, 18 Dec 2002
<www.fass.org/fasstrack/news_item.asp?news_id=891>

108| California SB 245, Signed by Governor 10/12/03; Chpt 871, Statutes of 2003.
<http://pewagbiotech.org/resources/factsheets/legislation/index.php?StatusID=1&Year=2003>

109| Resolution by the Parties to the Convention for the Conservation of Salmon in the North Atlantic Ocean to Minimise Impacts from Aquaculture, Introductions and Transfers, and Transgenics on the Wild Salmon Stocks. The Williamsburg Resolution Adopted at the Twentieth Annual Meeting of NASCO in June 2003 and amended at the Twenty-First Annual Meeting of NASCO in June 2004. p.23 <www.nasco.int/pdf/nasco_cnl_04_54.pdf>

110| The Bergen Declaration (Ministerial Declaration from 5th North Sea Conference, Bergen, March 2002) "Recognizing that the release of genetically modified marine organisms is an emerging issue in the North Sea owing to the inherent, potentially severe, irreversible and transboundary effects, and the need to apply the precautionary principle, the Ministers agree to take all possible actions, in accordance with the requirements of the Directive 2001/18 EC and comparable national legislation, to ensure that the culture of genetically modifed marine organisms is confined to secure, self-contained, land-based facilities in order to prevent their release to the marine environment."
Full text of the declaration, and further information and background to the North Sea Conference itself, is available at <http://odin.dep.no/md/nsc/>

111| Letter to Greenpeace from Margareta Winberg, Swedish Minister of Agriculture, Sep 2002: 'According to a decision taken by the Swedish Parliament last year "Alien species and genetically modified organisms that may be a threat to biological diversity may not be introduced". Further, the decision states "Genetically modified fish may not be released". This decision is the national position regarded as an instruction for Swedish delegations in future international deliberations concerning genetically engineered salmon.
MAFF (Ministry of Agriculture, Fisheries and Food) 2001. Review of salmon and freshwater fisheries', UK Government Response. Available at: <www.defra.gov.uk/fish/salmon/salmon.pdf> Recommendation 51: "Any GE fish kept in England and Wales should be confined to self- contained land-based and escape-proof facilities, with all necessary measures taken to ensure they cannot deliberately (by, for example, vandals) or accidentally be released into the natural environment."

112| Styria: Gesetz vom 18. Mai 1999 über das Fischereirecht in Steiermark (Steiermärkisches Fischereigesetz 2000) LGBl. Nr. 85/1999. http://ris.bka.gv.at/lr-steiermark/
Vorarlberg: Gesetz über die Fischerei in den Binnengewässern (Fischereigesetz) LGBl. Nr. 47/2000, <www.vorarlberg.at/vorarlberg/land_politik/land/gesetzgebung/weitereinformationen/landesrecht/voris.htm>

113| Stoll, M. 1999 Designer fish flounder over legal hurdles. Christian Science Monitor 4th March, 1999. <www.csmonitor.com/durable/1999/03/04/p19s1.htm>
One of the biggest fish farming companies in the world, Nutreco Aquaculture, based in the Netherlands, say that they "will never use GE eggs." Forbes magazine, February 19, 2001 p. 106
Also, 'Norwegians applaud Greenpeace stance', Intrafish, 6 Apr 2001. Excerpt from Ethical rules for the aquaculture association: "The association do not accept GM fish which differ from natural populations and which can affect biodiversity and surrounding environment in a negative way"... "It's marvellous that Greenpeace is also taking up the fight against genetically modified salmon," said NFF chairman, Tarald Sivertsen. On the Norwegian salmon farming organisation's website it is abundantly clear that Norwegian fish farmers and fish farmers across the globe are against plans by the American company Aqua Bounty Farms to produce genetically modified salmon on a commercial basis.

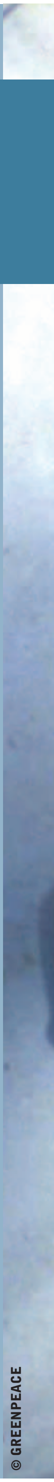
114| Comments sent in response to information requests from Greenpeace. Other replies include:
FEDIS (Belgian Federation of retailers) "As agreed, we're informing you of the position adopted on 9 May by the Commission 'food safety' of FEDIS re: international commercialisation of eggs from GM salmon. (....) In the case of GM salmon, members of FEDIS cannot accept its commercialization because the risks of environmental damage have been clearly identified. It is now to competent authorities to verify them. The utmost precaution is therefore necessary. (...). Besides, if one cannot say anymore that there is global overproduction of salmon, one can still say that supply meets demand, which remains high. Consequently, an insufficient production can certainly not be invoked to justify a demand for authorisation as the one introduced by A/F Protein. We will forward this standpoint to our European organization EuroCommerce, as well as to the Ag Min Jaak Gabriels." - Letter to Greenpeace May 2001.
In 1996 the ISFA (organisation for salmon-producing countries around the world), implemented the following resolution: In line with good environmental practice, the ISFA rejects unequivocally the production of genetically modified salmon. "In connection with the aim of maintaining a high animal ethics standard, the ISFA's members will not make use of growth hormones in their salmon production."... . "It is not possible to make a clearer statement. Nevertheless, every year we bear the brunt of attempts to connect gene manipulation to salmon through [publicity] from this firm. We very much appreciate Greenpeace's engagement in focusing attention on this issue. I am hoping in any case that a united salmon industry and Greenpeace's efforts can bring an end to these attempts. Consumers across the globe should be made aware that Norwegian fish farmers base their livelihoods on a sustainable and environmentally friendly production of a healthy and good product. The consumers deserve this much and they can rely on this."

115| Declaration of the Joint Ministerial Meeting of the Helsinki and OSPAR Commissions - (JMM 2003/3(final version)-E) <www.ospar.org/eng/html/md/joint_declaration_2003.htm>

FISH

GENETICALLY ENGINEERED FISH
– NEW THREATS TO THE ENVIRONMENT

greenpeace international
Ottho Heldringstraat 5, 1066 AZ Amsterdam, Netherlands
t +31 20 514 8150 f +31 20 514 8151
www.greenpeace.org



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