Commentary

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Basic Research in Genetics and Development for Fish Farming

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Description

Genetically modified fish (GM fish) are organisms from the taxonomic clade which includes the class's agnatha (jawless fish), chondrichthyes (cartilaginous fish) and osteichthyes (bony fish) whose genetic material has been altered using genetic engineering techniques. In most cases, the aim is to introduce a new trait to the fish which does not occur naturally in the species, transgenesis.

Food and Drug Administration

GM fish are used in scientific research and kept as pets. They are being developed as environmental pollutant sentinels and for use in aquaculture food production. In 2015, the aqua-advantage salmon was approved by the US Food and Drug Administration (FDA) for commercial production, sale and consumption, making it the first genetically modified animal to be approved for human consumption. Some GM fish that have been created have promoters driving an over-production of "all fish" growth hormone.

Critics have objected to GM fish on several grounds, including ecological concerns, animal welfare concerns and with respect to whether using them as food is safe and whether GM fish are needed to help address the world's food needs.

Most GM fish are used in basic research in genetics and development. Two species of fish, zebrafish and medaka, are most commonly modified because they have optically clear chorions (shells), develop rapidly, the 1-cell embryo is easy to see and micro-inject with transgenic DNA, and zebrafish have the capability of regenerating their organ tissues. They are also used in drug discovery. GM zebrafish are being explored for benefits of unlocking human organ tissue diseases and failure mysteries. For instance, zebrafish are used to understand heart tissue repair and regeneration in efforts to study and discover cures for cardiovascular diseases.

Transgenic rainbow trout have been developed to study muscle development. The introduced transgene causes green fluorescence to appear in fast twitch muscle fibres early in development which persist throughout life. It has been suggested the fish might be used as indicators of aquatic pollutants or other factors which influence development.

In intensive fish farming, the fish are kept at high stocking densities. This means they suffer from frequent transmission of contagious diseases, a problem which is being addressed by GM research. Grass carp have been modified with a transgene coding for human lactoferrin, which doubles their survival rate relative to control fish after exposure to aeromonas bacteria and grass carp hemorrhage virus.

Aquatic Pollution

Several research groups have been developing GM zebrafish to detect aquatic pollution. The laboratory that developed the glo-fish originally intended them to change color in the presence of pollutants, as environmental sentinels. Several transgenic methods have been used to introduce target DNA into zebrafish for environmental monitoring, including micro-injection, electroporation, particle gun bombardment, liposome-mediated gene transfer, and sperm-mediated gene transfer. Micro-injection is the most commonly used method to produce transgenic zebrafish as this produces the highest survival rate.

In transgenic fast-growing fish genetically modified for growth hormone, the mosaic founder fish vary greatly in their growth rate, reflecting the highly variable proportion and distribution of transgenic cells in their bodies. Fish with these high growth rates (and their progeny) sometimes develop a morphological abnormality similar to acromegaly in humans, exhibiting an enlarged head relative to the body and a bulging operculum. This becomes progressively worse as the fish ages. It can interfere with feeding and may ultimately cause death. According to a study commissioned by compassion in world farming, the abnormalities are probably a direct consequence of growth hormone over-expression and have been reported in GM coho salmon, rainbow trout, common carp, channel catfish and loach, but to a lesser extent in nile tilapia.

In GM coho salmon there are morphological changes and changed allometry that leads to reduced swimming abilities. They also exhibit abnormal behaviour such as increased levels of activity with respect to feed-intake and swimming. Several other transgenic fish show decreased swimming ability, likely due to body shape and muscle structure.

Genetically modified triploid fish are more susceptible to temperature stress, have a higher incidence of deformities (abnormalities in the eye and lower jaw and are less aggressive than diploids. Other welfare concerns of GM fish include increased stress under oxygen-deprived conditions caused by increased need for oxygen. It has been shown that deaths due to low levels of oxygen (hypoxia) in coho salmon are most pronounced in transgenic. It has been suggested the increased sensitivity to hypoxia is caused by the insertion of the extra set of chromosomes requiring a larger nucleus which thereby causes a larger cell overall and a reduction in the surface area to volume ratio of the cell.

A wide range of concerns about the consequences of genetically modified fish escaping have been expressed. For polyploids, these include the degree of sterility, interference with spawning, competing with resources without contributing to subsequent generations. For transgenics, the concerns include characteristics of the genotype, the function of the gene, the type of the gene, potential for causing pleiotropic effects, potential for interacting with the remainder of the genome. One study, using relevant life history data from the Japanese medaka predicts that a transgene introduced into a natural population by a small number of transgenic fish will spread as a result of enhanced mating advantage, but the reduced viability of offspring will cause eventual local extinction of both populations GM coho salmon show greater risk-taking behaviour and better use of limited food than wild-type fish.

Transgenic coho salmon have enhanced feeding capacity and growth, which can result in a considerably larger body size (>7-fold) compared to non-transgenic salmon. When transgenic and non-transgenic salmon in the same enclosure compete for different levels of food, transgenic individuals consistently outgrow non-transgenic individuals. When food abundance is low, dominant individuals emerge, invariably transgenic, that show strong agonistic and cannibalistic behavior to cohorts and dominate the acquisition of limited food resources. When food availability is low, all groups containing transgenic salmon experience population crashes or complete extinctions, whereas groups containing only non-transgenic salmon have good (72%) survival rates. This has led to the suggestion that these GM fish will survive better than the wild-type when conditions are very poor.