

Annotated Bibliography on Environmental and Ecological Impacts of Transgenic Animals

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Sundstrom, L. F., Devlin, R. H., Johnsson, J. I. and Biagi, C. A. 2003. Vertical position reflects increased feeding motivation in growth hormone transgenic coho salmon (*Oncorhynchus kisutch*). *Ethology* **109**: 701-712.

Growth hormone (GH) gene transgenesis has allowed the production of salmon with an inherently increased growth potential, on average two to threefold higher compared with daily specific growth rates observed in normal, non-transgenic fish. This difference quickly results in animals of very different sizes at age, and is associated with specific morphological effects and enhanced appetites in transgenic animals. However, less is known of the feeding and antipredator behaviour of GH-transgenic fish, information that can help with predictions of potential ecological consequences of release or escape of transgenic fish into the wild. In a series of experiments, transgenic (T) and normal (N) coho salmon of varying age and size (from 0.5 to 40 g, 3.5-21 mo) were studied singly, in pairs, and in groups during feeding and simulated predation threat. Vertical position generally did not differ between T and N fry, but at larger size (>4 g) T fish remained closer to the surface than N fish both during feeding and predatory attacks, probably as a consequence of inherent differences in feeding motivation and later reinforcement by associative learning. This difference in vertical position was not the result of competition as it remained even after either fish in the pair had been removed. In nature, where predators may attack from above (birds) or below (fish), this kind of behaviour may translate into higher risk of predation, which could increase mortality and lower the fitness of transgenic fish, unless their increased growth rate can compensate for the increased risk-taking.

Muir, W. M. and Howard, R. D. 2002. Assessment of possible ecological risks and hazards of transgenic fish with implications for other sexually reproducing organisms. *Transgenic Res* **11**: 101-114.

Transgenic technology is developing rapidly; however, consumers and environmentalists remain wary of its safety for use in agriculture. Research is needed to ensure the safe use of transgenic technology and thus increase consumer confidence. This goal is best accomplished by using a thorough, unbiased examination of risks associated with agricultural biotechnology. In this paper, we review discussion on risk and extend our approach to predict risk. We also distinguish between the risk and hazard of transgenic organisms in natural environments. We define transgene risk as the probability a transgene will spread into natural conspecific populations and define hazard as the probability of species extinction, displacement, or ecosystem disruption given that the transgene has spread. Our methods primarily address risk relative to two types of hazards: extinction which has a high hazard, and invasion which has an unknown level of hazard, similar to that of an introduced exotic species. Our method of risk assessment is unique in that we concentrate on the six major fitness components of an organism's life cycle to determine if transgenic individuals differ in survival or reproductive capacity from wild type. Our approach then combines estimates of the net fitness parameters into a mathematical model to determine the fate of the transgene and the affected wild population. We also review aspects of fish ecology and behavior that contribute to risk and examine combinations of net fitness parameters which can lead to invasion and extinction hazards. We describe three new ways that a transgene could result in an extinction hazard: (1) when the transgene increases male mating success but reduces daily adult viability, (2) when the transgene increases adult viability but reduces male fertility, and (3) when the transgene increases both male mating success and adult viability but reduces male fertility. The last scenario is predicted to cause rapid extinction, thus it poses an extreme risk. Although we limit our discussion to aquacultural applications, our methods can easily be adapted to other sexually reproducing organisms with suitable adjustments of terminology.

Hedrick, P. W. 2001. Invasion of transgenes from salmon or other genetically modified organisms into natural populations. *Can J Fish Aquat Sci* **58**: 841-844.

In recent years, there has been widespread concern about the ecological and genetic effects of genetically modified organisms. In salmon and other fishes, transgenic growth hormone genes have been shown to have large effects on size and various traits related to fitness. In this paper, I have shown by using a deterministic model that if such a transgene has a male-mating advantage and a general viability disadvantage, then the conditions for its invasion in a natural population are very broad. More specifically, for 66.7% of the possible combinations of the possible mating and viability parameters, the transgene increases in frequency, and for 50% of the combinations, it goes to fixation. In addition, by this increase in the frequency of the transgene, the viability of the natural population is reduced, increasing the probability of extinction of the natural population. These findings provide independent confirmation of previous concerns about the inherent risks of transgenic organisms, especially for native salmon populations potentially affected by commercial salmon production using transgenic stocks.

Henderson, S. T. and Johnson, T. E. 2001. daf-16 integrates developmental and environmental inputs to mediate aging in the nematode *Caenorhabditis elegans*. *Curr Biol* **11**: 1975-1980.

Evolutionary models of aging propose that a tradeoff exists between the resources an organism devotes to reproduction and growth and those devoted to cellular maintenance and repair, such that an optimal life history always entails an imperfect ability to resist stress. Yet, since environmental stressors, such as caloric restriction [1] or exposure to mild stress [2, 3], can increase stress resistance and life span, it is possible that a common genetic mechanism could regulate the allocation of resources in response to a changing environment (for overview, see [4-7]). Consistent with predictions of evolutionary trade-off models, we show that nematodes carrying an integrated DAF-16::GFP transgene grow and reproduce more slowly yet are more stress resistant and longer lived than controls carrying the integration marker alone. We also show that the nuclear localization of the DAF-16::GFP fusion protein responds to environmental inputs as well as genetic. Environmental stresses, such as starvation, heat, and oxidative stress, cause rapid nuclear localization of DAF-16. In conditions rich in food, we find that DAF-16::GFP is inhibited from entry into the nucleus by *daf-2* and *akt-1/akt-2*, both components of insulin-like signaling in nematodes. We suggest that changes in the subcellular localization of DAF-16 by environmental cues allows for rapid reallocation of resources in response to a changing environment at all stages of life.

Muir, W. M. and Howard, R. D. 2001. Fitness components and ecological risk of transgenic release: A model using Japanese medaka (*Oryzias latipes*). *Am Nat* **158**: 1-16.

Any release of transgenic organisms into nature is a concern because ecological relationships between genetically engineered organisms and other organisms (including their wild-type conspecifics) are unknown. To address this concern, we developed a method to evaluate risk in which we input estimates of fitness parameters from a founder population into a recurrence model to predict changes in transgene frequency after a simulated transgenic release. With this method, we grouped various aspects of an organism's life cycle into six net fitness components: juvenile viability, adult viability, age at sexual maturity, female fecundity, male fertility, and mating advantage. We estimated these components for wild-type and transgenic individuals using the fish, Japanese medaka (*Oryzias latipes*). We generalized our model's predictions using various combinations of fitness component values in addition to our experimentally derived estimates. Our model predicted that, for a wide range of parameter values, transgenes could spread in populations despite high juvenile viability costs if transgenes also have sufficiently high positive effects on other fitness components. Sensitivity analyses indicated that transgene effects on age at sexual maturity should have the greatest impact on transgene frequency, followed by juvenile viability, mating advantage, female fecundity, and male fertility, with changes in adult viability, resulting in the least impact.

Winn, R. N., Norris, M., Muller, S., Torres, C. and Brayer, K. 2001. Bacteriophage lambda and plasmid pUR288 transgenic fish models for detecting in vivo mutations. *Mar Biotechnol* **3**: S185-S195.

We adapted transgenic rodent mutation assays based on fish carrying bacteriophage lambda and plasmid pUR288 vectors to address the needs for improved methods to assess health risks from exposure to environmental mutagens and also to establish new animal models to study in vivo mutagenesis. The approach entails separating the vectors from fish genomic DNA and then shuttling them into specialized strains of *E. coli* bacteria to analyze spontaneous and induced mutations in either *lacI* and *cII* or *lacZ* mutational targets. Fish exhibited low frequencies of spontaneous mutants comparable to the sensitivity of transgenic rodent models. Mutations detected after treating fish with chemical mutagens showed concentration-dependent, tissue-specific, and time-dependent relationships. Spontaneous and induced mutational spectra also were consistent with the specificity of known mutagens, further supporting the utility of transgenic fish for studies of in vivo mutagenesis.

Youngson, A. F., Dosdat, A., Saroglia, M. and Jordan, W. C. 2001. Genetic interactions between marine finfish species in European aquaculture and wild conspecifics. *J Appl Ichthyol* **17**: 153-162.

The principal species of marine aquaculture in Europe are Atlantic salmon (*Salmo salar*), sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus auratus*). For Atlantic salmon and sea bass, a substantial part of total genetic variation is partitioned at the geographical population level. In the case of sea bream, gene flow across the Azores/Mediterranean scale appears to be extensive and population structuring is not detected. For Atlantic salmon and sea bass, natural population structure is at risk from genetic interaction with escaped aquaculture conspecifics. The locally adaptive features of populations are at risk from interbreeding with nonlocal aquaculture fish. Wild populations, generally, are at risk from interactions with aquaculture fish that have been subject to artificial selection or domestication. Atlantic salmon is the main European aquaculture species and its population genetics and ecology have been well-studied. A general case regarding genetic interactions can be based on the information available for salmon and extended to cover other species, in the appropriate context. A generalized flow chart for interactions is presented.

Salmon escape from aquaculture at all life stages, and some survive to breed among wild salmon. Reproductive fitness in the escaped fish is lower than in native, wild fish because of behavioural deficiencies at spawning. However, as the number of salmon in aquaculture greatly exceeds the number of wild fish, even small fractional rates of escape may result in the local presence of large numbers, and high frequencies, of escaped fish. At present, policy and legislation in relation to minimizing genetic interactions between wild and aquaculture fish is best developed for Atlantic salmon, through the recommendations of the Oslo Agreement developed by the North Atlantic Salmon Conservation Organization and subsequent agreements on their implementation. In future, the potential use of genetically modified fish in aquaculture will make additional policy development necessary. Improved containment is recommended as the key to minimizing the numbers and therefore the effects of escaped fish. Emergency recovery procedures are recommended as a back-up measure in the case of containment failure. Reproductive sterility is recommended as a future key to eliminating the genetic potential of escaped fish. The maintenance of robust populations of wild fish is recommended as a key to minimizing the effects of escaped fish on wild populations.

Hoy, M. A. 2000. Transgenic arthropods for pest management programs: Risks and realities. *Exp Appl Acarol* **24**: 463-495.

The ability to genetically engineer arthropods using recombinant DNA meopens new opportunities for improving pest management programs but also creates new responsibilities, including evaluation of the potential risks of releasing transgenic arthropods into the environment. It is now becoming easier to transform diverse species of arthropods by a variety of recombinant DNA methods. Useful genes and genetic regulatory elements are being identified for pest arthropods, but less effort is being expended to identify genes that could improve the efficacy of beneficial arthropods. A transgenic strain of the natural enemy *Metaseiulus* (= *Typhlodromus* or *Galendromus*) *occidentalis* (Acari: Phytoseiidae) was developed using a method termed maternal microinjection. This transgenic strain was released into an experimental site on the campus of the University of Florida in 1996 after extensive reviews by the University of Florida Biosafety Committee, Florida Department of Agriculture and Consumer Services, United States Department of Agriculture Animal and Plant Health Inspection Service, and the United States Fish and Wildlife Service. The short term releases established a precedent for releasing a transgenic arthropod but, at present, no guidelines are available that would allow transgenic arthropods to be released permanently into the environment. Several scientific, environmental, and policy issues must be resolved before transgenic pests or beneficial arthropods can be deployed in practical pest management programs.

Levy, J. A., Marins, L. F. and Sanchez, A. 2000. Gene transfer technology in aquaculture. *Hydrobiologia* **420**: 91-94.

The gene transfer technique, transgenesis, has permitted the transfer of genes from one organism to another to create new lineages of organisms with improvement in traits important to aquaculture. Genetically modified organisms (GMOs), therefore, hold promise for producing genetic improvements, such as enhanced growth rate, increased production and efficiency, disease resistance and expanded ecological ranges. The basic procedure to generate transgenic fish for aquaculture includes: (1) design and construction of transgenic DNA; (2) transfer of the gene construct into fish germ cells; (3) screening for transgenic fish; (4) determination of transgene expression and phenotype; (5) study of inheritance; and (6) selection of stable lines of transgenics. GMOs offer economic benefits, but also pose environmental threats. Optimising the mix of benefits and risks is of fundamental importance. The potential economic benefits of transgenic technology to aquaculture are obvious. Transgenic fish production has the goal of producing food for human consumption; thus the design of genetic constructs must take into consideration the potential risks to consumer health, as well as marketing strategies and product acceptance in the market.

Winn, R. N., Norris, M. B., Brayer, K. J., Torres, C. and Muller, S. L. 2000. Detection of mutations in transgenic fish carrying a bacteriophage lambda cII transgene target. *Proc Natl Acad Sci U S A* **97**: 12655-12660.

To address the dual needs for improved methods to assess potential health risks associated with chemical exposure in aquatic environments and for new models for in vivo mutagenesis studies, we developed transgenic fish that carry multiple copies of a bacteriophage lambda vector that harbors the cII gene as a mutational target. We adapted a forward mutation assay, originally developed for lambda transgenic rodents, to recover cII mutants efficiently from fish genomic DNA by lambda in vitro packaging. After infecting and plating phage on a hfl⁻ bacterial host, cII mutants were detected under selective conditions. We demonstrated that many fundamental features of mutation analyses based on lambda transgenic rodents are shared by transgenic fish. Spontaneous mutant frequencies, ranging from 4.3×10^{-5} in liver, 2.9×10^{-5} in whole fish, to 1.8×10^{-5} in testes, were comparable to ranges in lambda

transgenic rodents. Treatment with ethylnitrosourea resulted in concentration-dependent, tissue-specific, and time-dependent mutation inductions consistent with known mechanisms of action. Frequencies of mutants in liver increased insignificantly 5 days after ethylnitrosourea exposure, but increased 3.5-, 5.7- and 6.7-fold above background at 15, 20, and 30 days, respectively. Mutants were induced 5-fold in testes at 5 days, attaining a peak 10-fold induction 15 days after treatment. Spontaneous and induced mutational spectra in the fish were also consistent with those of lambda transgenic rodent models. Our results demonstrate the feasibility of in vivo mutation analyses using transgenic fish and illustrate the potential value of fish as important comparative animal models.

Dunham, R. A. 1999. Utilization of transgenic fish in developing countries: Potential benefits and risks. *J World Aquacult Soc* **30**: 1-11.

Recombinant DNA and gene transfer technology now allow the transfer, inheritance and expression of specific DNA or gene sequences into fish. Preliminary results on the performance of the resulting transgenic fish have been quite dramatic in some cases, especially when growth hormone genes are transferred. Utilization of high performance transgenic fish has the potential to greatly increase aquaculture production in developing countries and increase the income of poor farmers. Growth of some transgenic fish has been increased more than 10-fold in laboratory conditions. Response appears to be greatest in unimproved fish, which in most cases would benefit developing countries the most. The potential increase in production and production efficiency from successful transgenic fish application could relieve pressure on habitat destruction for food production, relieve pressure on overfished natural stocks and discourage introduction of exotic species. Application of transgenic fish in aquaculture has just begun and could expand within a few years. However, prior to commercialization of transgenic fish, public education, environmental risks and food safety issues should be addressed. Genetically improved fish generated by recombinant DNA technology probably do not pose any greater risk to the environment than fish genetically improved through traditional selective breeding, but environmental risk data is lacking to verify this hypothesis. Environmental risk data will be needed in a case-by-case basis until more is known concerning the aquaculture potential and ecological risk of transgenic fish. Research institutions need to address the lack of environmental risk data to help ensure that any future application of transgenic fish in developing (and developed) countries be done in an environmentally and socioeconomically sound manner. Socioeconomic study is lacking for detailed cost-benefit analysis, and policy research is needed for proper application or regulation of transgenic fish in these countries.

Dunham, R. A., Chitmanat, C., Nichols, A., Argue, B., Powers, D. A. and Chen, T. T. 1999. Predator avoidance of transgenic channel catfish containing salmonid growth hormone genes. *Mar Biotechnol* **1**: 545-551.

Transgenic channel catfish (*Ictalurus punctatus*) containing salmonid growth hormone genes can grow 33% faster than normal channel catfish under aquaculture conditions. However, before transgenic catfish are released and utilized by the private sector, their genetic impact on the natural environment must be examined. Predator avoidance is one of the major fitness traits determining potential environmental risk. To determine the predator avoidance ability and growth performance of transgenic catfish in a natural habitat, various densities of transgenic and nontransgenic channel catfish were communally stocked in 0.04-ha earthen ponds without supplemental feeding. Largemouth bass (*Micropterus salmoides*) and green sunfish (*Lepomis cyanellus*) were stocked as predators. Nontransgenic fry had better predator avoidance than transgenic channel catfish when data were pooled ($p < .01$). When data were not pooled, nontransgenic catfish had better predator avoidance in six trials and transgenic individuals had better predator avoidance in four trials. There was no difference in predator avoidance in three trials. Overall predator avoidance was also better for nontransgenic individuals ($p < .01$) when the fish were evaluated as 3.5-g fingerlings, more clearly than as fry, as transgenic individuals were more vulnerable in 3 of 4 trials at this life stage. There was no significant difference in growth performance between transgenic and nontransgenic channel catfish in ponds without supplemental feeding. These findings indicate that transgenic channel catfish could be used for commercial aquaculture without affecting the natural environment. Although transgenic channel catfish may be released to nature by accident, any ecological effect would be unlikely because the increased susceptibility of transgenic channel catfish to predators would most likely decrease or eliminate the transgenic genotype.

Muir, W. M. and Howard, R. D. 1999. Possible ecological risks of transgenic organism release when transgenes affect mating success: Sexual selection and the Trojan gene hypothesis. *Proc Natl Acad Sci U S A* **96**: 13853-13856.

Widespread interest in producing transgenic organisms is balanced by concern over ecological hazards, such as species extinction if such organisms were to be released into nature. An ecological risk

associated with the introduction of a transgenic organism is that the transgene, though rare, can spread in a natural population. An increase in transgene frequency is often assumed to be unlikely because transgenic organisms typically have some viability disadvantage. Reduced viability is assumed to be common because transgenic individuals are best viewed as macromutants that lack any history of selection that could reduce negative fitness effects. However, these arguments ignore the potential advantageous effects of transgenes on some aspect of fitness such as mating success. Here, we examine the risk to a natural population after release of a few transgenic individuals when the transgene trait simultaneously increases transgenic male mating success and lowers the viability of transgenic offspring. We obtained relevant life history data by using the small cyprinodont fish, Japanese medaka (*Oryzias latipes*) as a model. Our deterministic equations predict 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. Such risks should be evaluated with each new transgenic animal before release.

Idel, A. 1998. Genetically engineered animals: a critique. *Tierarztl Umsch* **53**: 83-87.

Genetic engineering is not comparable to evolution or any other natural event, or a system of breeding. This is because, with genetic engineering, single genes are separated, from their original genotype, and added elsewhere, instead of natural cross-breeding which involves the whole genome. Past breeding programmes have achieved a marked increase in productivity, but at the price of an increased risk for a number of diseases. This is despite the fact that breeding systems should be for the protection of animal welfare, whereas past breeding systems have had the singular objective of increasing productivity. Given this consideration, the research for resistance genes does not benefit the health of animals, but has the objective of reducing the economic disadvantages by reducing the incidence of animal disease instead of improving animals husbandry and appropriate animal breeding. The use of genetic engineering in animal breeding reduces the genetic diversity considerably. The conclusions are that the current objectives of breeding systems do not have the necessary objectives to match the current ethical requirements.

Walker, C. H. 1998. Biomarker strategies to evaluate the environmental effects of chemicals. *Environ Health Perspect* **106**: 613-620.

Environmental risk assessment of chemicals depends on the production of toxicity data for surrogate species of mammals, birds, and fish and on making comparisons between these and estimated or predicted environmental concentrations of the chemicals. This paper gives an overview of biomarker assays and strategies that might be used as alternatives, that is, to replace, reduce, or refine currently used ecotoxicity tests that cause suffering to vertebrates. In the present context a biomarker is a biologic response to an environmental chemical at the individual level or below which demonstrates a departure from normal status. Of immediate interest and relevance are nondestructive assays that provide a measure of toxic effect in vertebrate species and that can be used in both laboratory and parallel field studies. A major shortcoming of this approach is that such assays are currently only available for a limited number of chemicals, primarily when the mode of action is known. Nondestructive assays can be performed on blood, skin, excreta, and eggs of birds, fish, reptiles, and amphibians. An interesting recent development is the use of vertebrate cell cultures, including transgenic cell lines that have been developed specifically for toxicity testing. The ultimate concern in ecotoxicology is the effects of chemicals at the level of populations and above. Current risk assessment practices do not address this problem. The development of biomarker strategies could be part of a movement toward more ecologic end points in the safety evaluation of chemicals, which would effect a reduction in animal tests that cause suffering.

Gaugler, R., Wilson, M. and Shearer, P. 1997. Field release and environmental fate of a transgenic entomopathogenic nematode. *Biol Control* **9**: 75-80.

A strain of the entomopathogenic nematode *Heterorhabditis bacteriophora*, genetically enhanced for thermotolerance by introduction of a heat-shock protein gene from the free-living nematode *Caenorhabditis elegans*, was released in turfgrass field microplots in the spring, summer, and fall of 1996. As predicted, transgenic and wildtype strains did not differ in their ability to persist. We document the regulatory procedures at the federal, state, university, and local levels needed before field release, none of which posed any significant difficulties. Our risk assessment study supports the regulatory view that the transgenic nematode strain is an unlikely environmental threat. Subsequent regulatory reviews in the United States appear likely to continue to be decided on a case-by-case basis according to organism phenotype rather than the techniques used to generate them. This is the first report of a nonmicrobial, genetically engineered insect natural enemy being released into the environment. (C) 1997 Academic Press.

Knibb, W. 1997. Risk from genetically engineered and modified marine fish. *Transgenic Res* **6**:

59-67.

In support of the emerging industries of warmwater marine fish mariculture, genetic engineering and classical genetic improvement programmes have been initiated for a variety of exclusively marine fish. These programmes have the potential to perturb allele and genotype frequencies, or introduce novel alleles and genes into conspecific wild populations. Despite concerns to the contrary, the following hypothesis remains to be falsified: 'laboratory induced allele frequency/genotype changes and novel alleles or genes have a negligible probability of being selectively favoured in wild populations under natural selection, and accordingly, without sustained large scale releases, have little potential for ecological impact'.

McDermott, G. J. and Hoy, M. A. 1997. Persistence and containment of *Metaseiulus occidentalis* (Acari: Phytoseiidae) in Florida: Risk assessment for possible releases of transgenic strains. *Fla Entomol* **80**: 42-53.

Metaseiulus occidentalis (Nesbitt) is a phytoseiid mite which is commercially available as a biological control agent of spider mites. Genetic manipulation of this phytoseiid species has yielded transgenic strains, but none have been released into the environment. Previous data suggested that *M. occidentalis* could not survive the wet, humid summers in Florida. A non-transgenic strain of *M. occidentalis* was released into field plots in Gainesville on soybean plants infested with the two-spotted spider mite, *Tetranychus urticae* Koch. Populations were monitored from April-October 1994, and weather data were gathered at the release site. Permethrin- treated barrier rows were monitored to determine if the mites dispersed outside the plots, and aerial dispersal was monitored with sticky traps. Predator and spider-mite populations repeatedly crashed during the summer months, and population growth was negatively correlated with rainfall. CLIMEX, a population growth model which uses climatic factors to determine whether a given poikilothermic species can colonize and persist in new geographic areas, also indicated that *M. occidentalis* cannot persist through the wet season in Florida, although it may be able to establish and persist through the fall, winter and spring months.

Bruggemann, E. P. 1993. Environmental Safety Issues for Genetically-Modified Animals. *J Anim Sci* **71**: 47-50.

Organisms modified by the techniques of modern biotechnology may differ significantly from normal organisms or organisms modified by other methods. Before transgenic organisms are introduced into the environment, the potential environmental effects should be assessed. In general, modification of ecologically important traits in undomesticated species presents the greatest environmental risk. Transgenic livestock probably pose low risk to the environment. Transgenic fish and live virus-based vaccines pose greater risks and present challenging questions for environmental risk assessment.

Pickering, A. D. 1993. Growth and Stress in Fish Production. *Aquaculture* **111**: 51-63.

Considerable progress has been made towards increasing the growth rate and food conversion efficiency of a variety of fish species reared under aquaculture conditions. Essentially, two approaches have been adopted: the traditional approach of selective breeding from desirable phenotypes and, recently, the application of biochemical/molecular techniques such as genetic engineering. In all situations, however, the performance of the fish is governed not only by its genetic potential but also by its immediate environmental conditions. Certain environmental factors such as water temperature and food supply have an obvious and major influence on growth rate and food conversion efficiency but are not necessarily stressful in themselves. Other factors such as poor water quality, physical disturbance and social domination of one fish by another can act as powerful environmental stresses, thereby reducing the performance of the fish. This paper identifies some of the hormonal pathways linking deleterious environmental conditions to growth processes in fish and considers the implications of these pathways for aquaculture. It is suggested that the selection for broodstock of fish with a reduced cortisol response to common aquacultural stresses would have benefits for disease resistance, reproductive performance and growth rate.

Kapuscinski, A. R. and Hallerman, E. M. 1991. Implications of Introduction of Transgenic Fish into Natural Ecosystems. *Can J Fish Aquat Sci* **48**: 99-107.

Production of transgenic fish has increased in scope, aimed at improving performance traits in economically important species or at creating model systems for basic biological problems. A variety of transgenic phenotypes will become possible as more genes are cloned and characterized. Categories of altered phenotypes include modified: metabolic rates; tolerance of physical factors; behavior; resource or substrate use; and resistance to disease, parasitism, or predation. Ecological impacts of transgenic fishes are uncertain but will depend primarily on their altered phenotypes and secondarily on the scale and frequency of their introduction into ecosystems. Production of ecologically noxious transgenic types is possible, because many fish varieties readily disperse and persist in aquatic ecosystems, are fit in natural

settings, interact substantially with other organisms, and play a role in ecosystem processes. Releases of transgenic fishes may impact aspects of fisheries management. Because future uses of transgenic fish in commercial aquaculture or in stocking of natural waters are contemplated, interdisciplinary teams of fisheries biologists, ecologists, and resource managers must develop integrated approaches to assessing risks of ecological impacts. The current situation of uncertainty demands caution in expecting "safe" uses of transgenic fishes.

Wittmann, G. 1991. Is the Release of Transgenic Animals a Risk for the Environment.
Zuchtungskunde **63**: 241-246.

The author discusses factors which with the release of transgenic animals could become a risk for the environment, the genetic manipulation by means of viral vectors being of primary concern in this discussion. Health problems of transgenic animals and their impact on the environment must also be taken into consideration as well as their utilization for human food manufacture.