ERATS – Ecological risk-assessment of transgenic salmon

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The work does not necessarily reflect the Community's views and in no way anticipates its future policy in this area.

SUMMARY OF WORK PERFORMED AND RESULTS

Presently, studies of transgenic fish cannot be performed in nature due to the difficulty in extirpating the transgene should negative consequences arise. Assessments of transgenic fish in contained facilities therefore need to be conducted under as wide a range of conditions as possible. The ecological consequences of biological differences between transgenic and wild-type fish determined in the laboratory can be uncertain due different responses to varying environmental conditions as well as our limited ability to extrapolate simple phenotypes to complex ecological interactions as occur in nature. Efficient physical and biological containment strategies therefore remain critical to ensure the safe application of transgenic fish technology in the future.

Our results show how rearing conditions prior to escape to nature can greatly influence subsequent ecological consequences, how these effects may depend on seasonal conditions, food availability, predator presence, oxygen conditions, temperature, and water connectivity to mention a few factors found to influence the relative performance of wild-type and transgenic salmon. For example, increasing temperature elevated growth in transgenic fish more than wild-type so that experiments carried out at one temperature may provide a different outcome if carried out at another temperature. During development at the eggs stage, however, transgenic fish appears to cope with oxygen deficiencies less well, but this was only examined at one temperature and we observed that relative developmental rate between transgenic and wild-type fish change with temperature.

Due to the multitude of factors influencing the development of the transgenic fish, uncertainty is likely to increase with fish age, and we only recently started looking at reproductive success of adults, which due to their old age are highly influenced by prior rearing conditions. Most other experiments therefore used newly emerged fry which have minimal environmental experience. At the same time, other traits, such as migratory timing and starvation tolerance, usually considered to be influenced by growth rate and body size, was not found to be greatly altered by growth hormone transgenesis. We also found how responses by other ecosystem members may affect impact of transgenic specimens.

To get a better feel for how fast-growing transgenic fish may function in nature, we have complemented the contained laboratory studies of transgenic fish with work on non-transgenic wild-type salmonids under fully natural conditions. We used natural variations in individual growth history and manipulations of population conditions to assess how changes in growth potential influence subsequent performance in nature. These data are preliminary but suggests that there is scope for individuals with greater growth potential, such as growth-enhanced fish, to survive also under fully natural conditions, although large size was not invariably advantageous. Once again outcomes of experimental treatments proved difficult to predict with several factors affecting performance of the fish in the stream. In addition, it would be desirable to use actual transgenic fish (necessarily sterile) to remove the uncertainty of normal rapid growth (i.e. large wild fish) and artificially induced growth (i.e. individuals large due to the transgene). This has yet to be approved for actual field trials.

Overall, this project has clearly shown that predicting ecological risk of growth enhanced transgenic salmon is a very complicated task and will require further studies and novel experimental approaches before a scientific recommendation can be made. We would recommend science policy regulators and decision makers to carefully consider our data when deciding whether to allow commercial application of transgenic species in aquaculture. At this stage, use of transgenic fish in commercial application would need to consider strict physical and biological containment strategies to prevent the transgene from entering natural genomes.

Additional publications:

Sundström, L.F., Tymchuk, W.E., Lõhmus, M. & Devlin, R.H. 2009. Sustained predation effects of hatchery-reared growth hormone transgenic coho salmon *Oncorhynchus kisutch* in semi-natural environments. Journal of Applied Ecology 46: 762-769. Doi: 10.1111/j.1365-2664.2009.01668.x

Lõhmus, M., Raven, P. A., **Sundström, L.F.** & Devlin, R.H. 2008. Disruption of seasonality in growth hormone-transgenic coho salmon (*Oncorhynchus kisutch)* and the role of cholecystokinin in seasonal feeding behavior. Hormones & Behavior 54: 506-513. doi: 10.1016/j.yhbeh.2008.02.010

Sundström, L.F., Lõhmus, M., Johnsson, J.I. & Devlin, R.H. 2007. Dispersal potential is affected by growth-hormone transgenesis in coho salmon (*Oncorhynchus kisutch*). *Ethology* 113, 403-410. doi: 10.1111/j.1439-0310.2007.01331.x

Sundt-Hansen, L, **Sundström, L.F.**, Einum, S, Hindar, K, Fleming, I & Devlin, R.H. 2007. Genetically enhanced growth causes increased mortality in hypoxic conditions. *Biology Letters* 3: 165-168. doi: 10.1098/rsbl.2006.0598

Sundström, L.F., Lõhmus, M., Tymchuk, W E & Devlin, R.H. 2007. Gene-environment interactions influence ecological consequences of transgenic animals. *Proceedings of the National Academy of Sciences of the USA* 104: 3889-3894. doi: 10.1073/pnas.0608767104

Devlin, R.H., **Sundström, L.F.** & Muir, W.M. 2006. Interface of biotechnology and ecology for environmental risk assessments of transgenic fish. *Trends in Biotechnology* 24: 89-97. doi: 10.1016/j.tibtech.2005.12.008

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