Sterile salmon: toward a more sustainable and eco-friendly industry

Herve Migaud[1], John Taylor[1], Tom Hansen[2]
[1]Institute of Aquaculture, University of Stirling, Scotland. [2]Institute of Marine Research, Bergen, Norway.

In recent years there has been a dramatic increase in the production of farmed Atlantic salmon within Europe raising concerns about the environmental impact of these activities. One particular area for concern is the increase in escapee fish and their effects on wild populations. As an example, in Scotland alone, 52 escapee events were reported between 2003 and 2005. Thus there is an urgent need to address the negative environmental impact of farmed salmon escapees. Furthermore, with greater public awareness and the growing emphasis to protect natural resources, the development and implementation of new environmental regulations is required to maintain a sustainable and eco-friendly industry.

How this could be achieved

Although considerable technological advances have been made in the design of cages, no system will be fully reliable as escapees through natural disasters, human error or mechanical breakdown are inevitable. Furthermore, this does not remove reproductively competent fish from being ongrown in the environment. Therefore, evaluation of the production of sterile fish, to mitigate the environmental impact of escapees contributing to genetic pollution is receiving ever increasing attention.

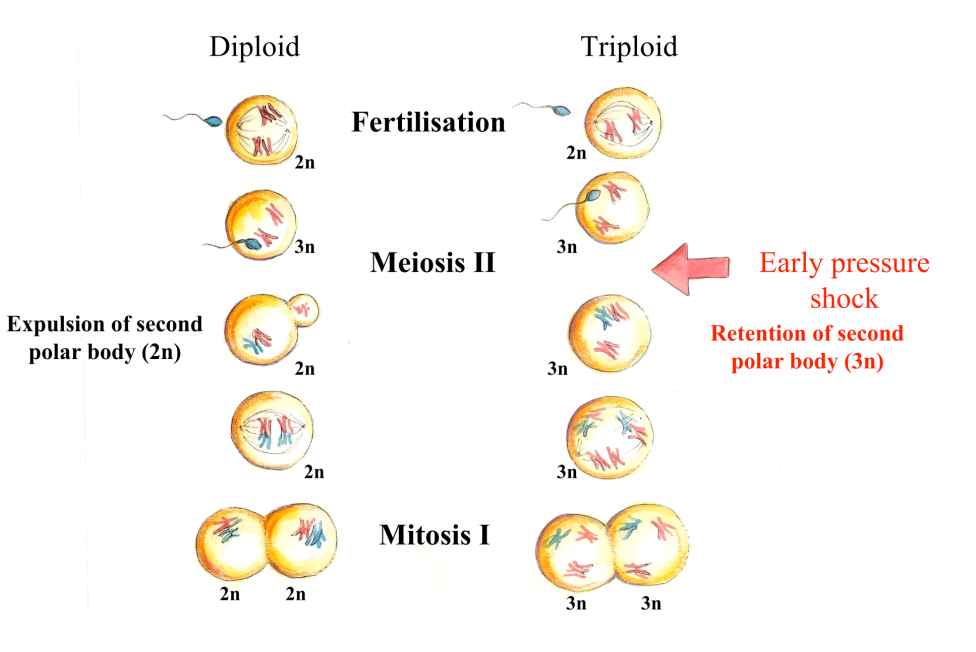
Triploid induction by chromosome set manipulation is one such method and is already used successfully in several species of commercial interest. Over 95% of oysters produced in France are triploid, and a significant proportion of large (>1kg+) rainbow trout production is based on sterile triploids to alleviate pre-harvest maturation problems. Moreover, triploidy is advocated by several NGO's (FAO, International Council of the Exploitation of the Sea, North Atlantic Salmon Conservation Organisation) as a means to limit genetic pollution by escapees. Triploidy is induced by subjecting recently fertilised eggs to a pressure, heat or cold shock at the time of the second meiotic division, causing retention of the polar body in the egg and production of fish with three sets of chromosomes (Fig 1). Depending on species, temperature shock treatments have given mixed results with a variable proportion of triploid yield, while pressure shock treatment is becoming a more consistent method of choice.

Potential Benefits

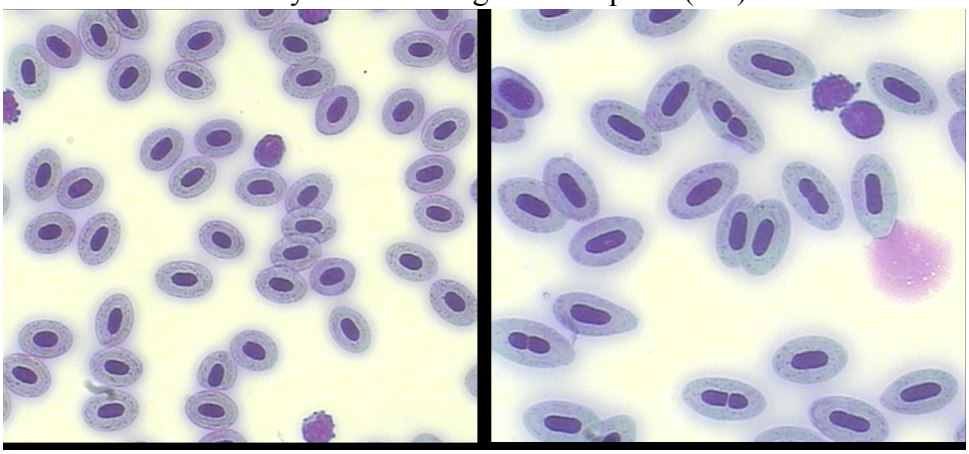
Not only would genetic and ecological threats to wild populations minimised, triploidy could also offer several other benefits these being 1) avoidance or reduction of sexual maturation and the associated loss of condition and increased disease risk 2) increased somatic growth due to extended grow-out as diversion of energy into gonadal tissue is avoided, 3) wider harvest windows, 4) reduced running costs as the

use of photoperiod regimes at sea would potentially no longer be required, and 5) offer a means to salmon breeding companies to protect their IPR on selected strains.

Figure 1: Triploid induction process showing where pressure shock is applied (adapted from Tom Hansen, IMR, Norway).



Typical blood smear used to verify ploidy status. Triploid (right) blood cells are usually 1.5 times larger than diploid (left).

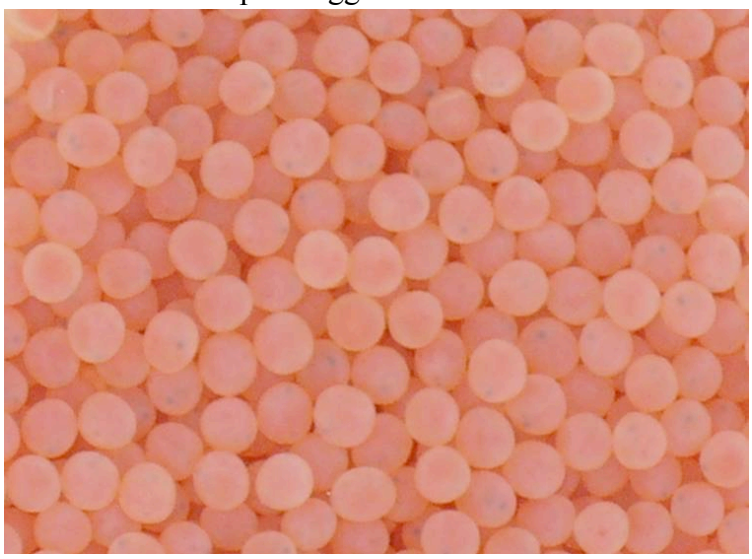


Previous Problems

Triploidy is not a new concept, originally tested in the early 1990's as a means to avoid maturation. Unfortunately, poor performance, higher mortalities and deformities led to the industry abandoning triploidy in favour of photoperiod control of maturation prior to harvest. However, although photoperiod reduces maturation in culture, farmed stocks remain reproductively competent and the threat of genetic pollution following escapes persists. Triploid induction is thus the only present non-chemical, non-GMO method that can produce sterile fish. Furthermore, significant R&D advances in selective breeding, husbandry, diet formulation, operating procedures, and an overall greater knowledge of salmon physiology in the last 10-15

years suggest that some of the problems previously associated with triploidy may be less restrictive than thought. Given the equivocal results regarding performance in previous studies it is imperative to ensure triploids perform as well as if not better than diploids given the correct conditions. With established triploid induction methods and improved husbandry operations, along with growing environmental concerns, it is felt that the revival of the triploid concept is now timely.

Triploid eggs in incubation.



First feeding triploid salmon fry.

Current research

Given the increasing scientific knowledge on triploid physiology it has become apparent that problems encountered with triploids previously may be associated with inappropriate rearing conditions, incomplete smoltification, and inadequate diets to name but a few areas requiring further research. However, by addressing these areas it is clear that production of triploid sterile fish free of welfare issues would be a major step forward for the salmon industry as a means of reducing its environmental footprint by removing the risk of genetic pollution. Triploidy would also alleviate the

welfare issues associated with early maturation and decreased quality standards. As most salmon eggs now come from established breeding companies it is important that triploidy is assessed alongside the other traits being improved and that the best possible families are identified. However, before the implementation of such a radical change to the salmon farming industry can be considered, a clearer understanding of the environmental requirements of triploid fish and their performance on a commercial scale is needed. Furthermore, it is essential that customer-consumer perception and acceptance be explored in order to determine if such a product would be truly viable.

It is for these reasons that a transnational project with R&D and SME partners from Scotland, Norway, Ireland and The Netherlands has been supported by the EC 7th Framework Program to under take a full-scale feasibility study of the potential for the production of triploid Atlantic salmon. The proposed project is currently under negociation to finalise funding. It is envisaged that this network will provide information on 1) alternatives to photoperiodic regimes to alleviate maturation problems: if triploid were to be implemented in a near future, no more artificial lighting systems would be needed resulting in considerable energy savings and the production of a more environmentally friendly product, 2) Provide new recommendations of optimum production protocols and rearing needs of triploid salmon, 3) Recommend on how triploid salmon could be marketed, 4) Provide a means to protect intellectual property for domesticated stocks developed by salmon breeders, and 5) Improve customer perception as the industry tries to overcome issues through application of R&D. Overall, data generated from this collaboration will aid legislative decision making regarding future aquaculture policies and the use of triploidy within the salmon industry.