Use of Single-Sex and Triploid Stocks to Eliminate Early Maturation of Atlantic Salmon

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Negatives of Sexual Maturation

• Pre-harvest maturation (= loss of product)
  – Flesh quality, external appearance, disease

• Loss of breeding control
  – Investments made in developing novel genotypes

• Possible impacts of escapees
  – Domesticated populations, exotic species, GMOs
Some Possible Solutions

• All-female populations
  – Eliminate maturation of parr (males) and reduce maturation of grilse (male-biased)

• Triploid populations
  – Eliminate maturation of females

• All-female triploid populations
  – Eliminate maturation of all fish
All-Female Populations

Mixed-sex (XX/XY) population + androgen

\[ \downarrow \]

100% phenotypically male population
(still 50% XX, 50% XY) “neomales”

\[ F_1: \text{XX}♂ \times \text{XX}♀ \rightarrow 100\% \text{XX}♀ \]

• Standard procedure for rainbow trout; also used for salmon (Chinook, Atlantic) & halibut
All-Female Populations

- Hormones are one generation removed from production fish
- Fish are no different from ‘normal’ females, but the population is now 100% female
- May be sufficient for controlling maturation; if not, then consider triploids
Triploid Populations

Treatment of eggs immediately after fertilization

- maternally derived genome
- paternally derived genome
- * pressure treatment

Normal diploid: 2 nuclei (1 maternal, 1 paternal)

Triploid: 3 nuclei (2 maternal, 1 paternal)
Triploid Populations

• Off-the-shelf technology
  – TRC Hydraulics, Dieppe, New Brunswick

• Used for many species
  – Salmonids
  – Cod and halibut
  – Sturgeon
  – Bivalves
Triploid Populations

- Sex-specific effects on gonadal development
- Affects …
  - Endocrinology
  - Secondary (external) sexual characteristics
  - Behaviour
- Need all-female triploid populations
All-Female Populations

Mixed-sex (XX/XY) population + androgen

\[ \downarrow \]

100% phenotypically male population

(still 50% XX, 50% XY)

\[ \text{F}_1: \quad XX♀ \times XX♀ \quad \Rightarrow \quad 100\% \ XX♀ \]

+ hydrostatic pressure \( \Rightarrow \) 100\% XXX♀
Female Triploids – the Solution!

3n female rainbow trout

2n female chinook salmon

3n female cod
Triploid Atlantic Salmon

A history lesson …

Bay of Fundy cage culture (3 consecutive trials)

– Better growth (106% of 2n) but lower survival (86% of 2n), for reduced yield (91% of 2n)
– Reduced tolerance of chronic stress
– Characteristic lower jaw deformities


Triploid Atlantic Salmon

- Similar experiences in Scotland and Ireland
  “It is difficult to foresee a situation in the near future where salmon farmers would be able to justify replacing *selected diploid stocks*, with proven performance characteristics, with triploid stocks”
  John Webster, Scottish Quality Salmon, 2005
- Better growth and equal survival in tank culture (Norway)
  - Better suited for RAS?
- Currently only used in Tasmania
- Continued research (Canada and Europe)
Triploid Atlantic Salmon

- 2000-03: “The development of culture techniques and environmental assessment of triploid salmon”
- 2003-06: “Nutritional requirements and culture characteristics of triploid Atlantic salmon”
- Current: “Reproductive confinement for the safe cultivation of genetically improved lines of salmon”
Triploid Atlantic Salmon

• 2008-10: “Feasibility study of triploid Atlantic salmon production”

• Current: “Solving bottlenecks in triploid salmon production – a way to strengthen the sustainability of the salmon aquaculture industry”
Triploid Atlantic Salmon

Conclusions from these studies:
• Triploidy is easy and inexpensive to induce
• Use of all-female triploids is an effective way to ensure reproductive sterility
• Need to:
  – Optimize triploid husbandry
  – Select strains for best triploid performance
  – Target selection programs within strains for best triploid performance
Optimize Triploid Husbandry

• Temperature
  – Do triploids have a lower optimum temperature for growth?

• Dissolved oxygen
  – Do triploids have reduced aerobic scope?

• Nutrition
  – Do triploids have different dietary requirements (e.g., phosphorus and energy)?

• Other differences?
Optimize Triploid Husbandry

Take home message:

Triploids can perform well, but optimum conditions may need to be determined
– May be better suited for RAS, where rearing environment can be better controlled
Select Strains for Best Triploid Performance

Tank trial

Select Strains for Best Triploid Performance

Select Strains for Best Triploid Performance

Take home message:

Triploids can perform well, but best strains need to be identified
Target Selection Programs for Best Triploid Performance

Target Selection Programs for Best Triploid Performance

**Take home message:**

Triploids can perform well, but need to target selection programs for triploid performance