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 <u>all</u> fish**

All-Female Populations

Mixed-sex (XX/XY) population + androgen

⬇

100% phenotypically male population

(still 50% XX, 50% XY) "neomales"

F_1: XX♂ x XX♀ ➡ 100% XX♀

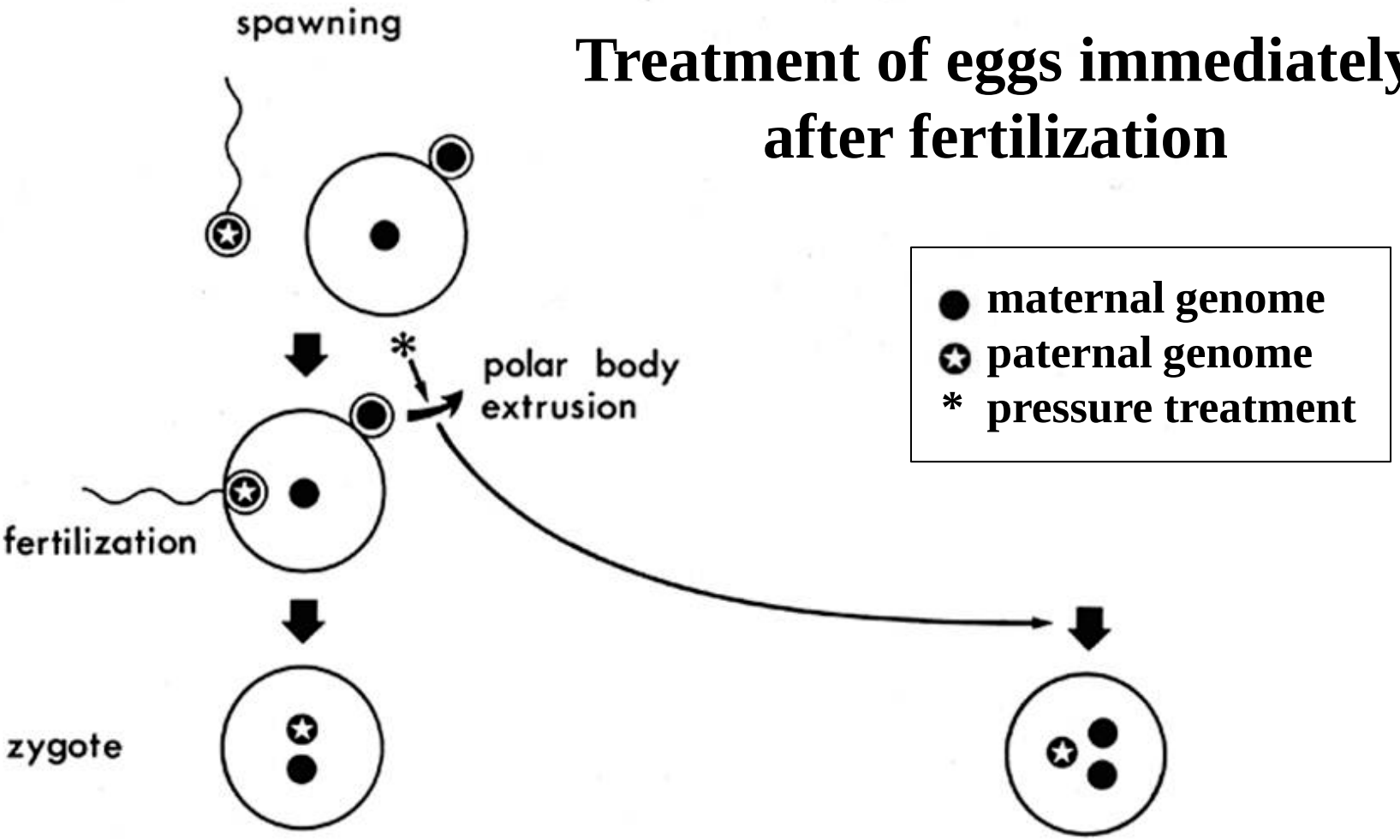
- **Standard procedure for rainbow trout; also used for salmon (Chinook, Atlantic) & halibut**

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



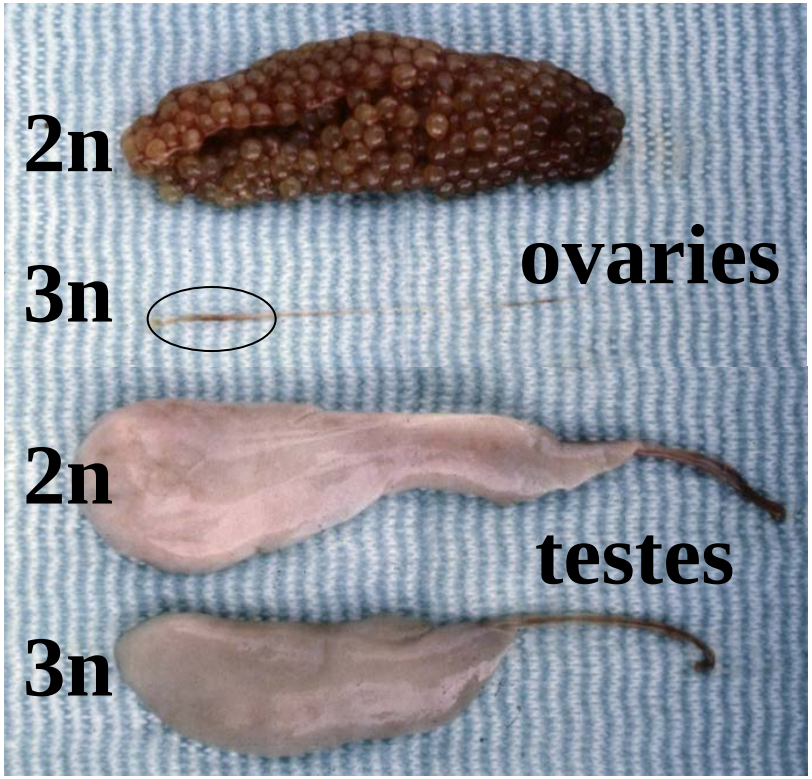
Normal diploid **Triploid**

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

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100% phenotypically male population

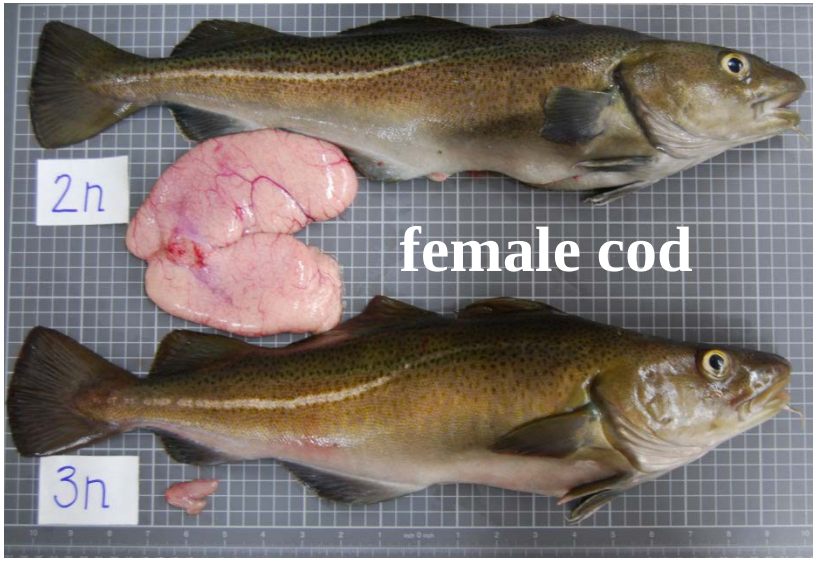
(still 50% XX, 50% XY)

F_1: XX♂ x XX♀ ➡ 100% XX♀

+ hydrostatic pressure ➡ 100% XXX♀

Female Triploids – the Solution!

TROUTLODGE



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**

O'Flynn et al., 1997. Comparisons of cultured triploid and diploid Atlantic salmon. ICES J. Mar. Sci. 54: 1160-1165.

Benfey, 2001. Use of sterile triploid Atlantic salmon for aquaculture in New Brunswick. ICES J. Mar. Sci. 58: 525-529.

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”**

Fisheries and Oceans Canada | Pêches et Océans Canada

- **2003-06: “Nutritional requirements and culture characteristics of triploid Atlantic salmon”**

NSERC CRSNG | Heritage Salmon | Cooke Aquaculture Inc. | Corey Aquafeeds | Atlantic Salmon Federation / Federation du Saumon Atlantique

- **Current: “Reproductive confinement for the safe cultivation of genetically improved lines of salmon”**

Atlantic Canada Opportunities Agency | Agence de promotion économique du Canada atlantique | AquaBounty Technologies

Triploid Atlantic Salmon

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

Salmotrip
Study of Triploid Atlantic Salmon Production

- **Current: “Solving bottlenecks in triploid salmon production – a way to strengthen the sustainability of the salmon aquaculture industry”**

The Research Council of Norway

Triploid Atlantic Salmon

<u>Conclusions from these studies</u>:

- **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?**

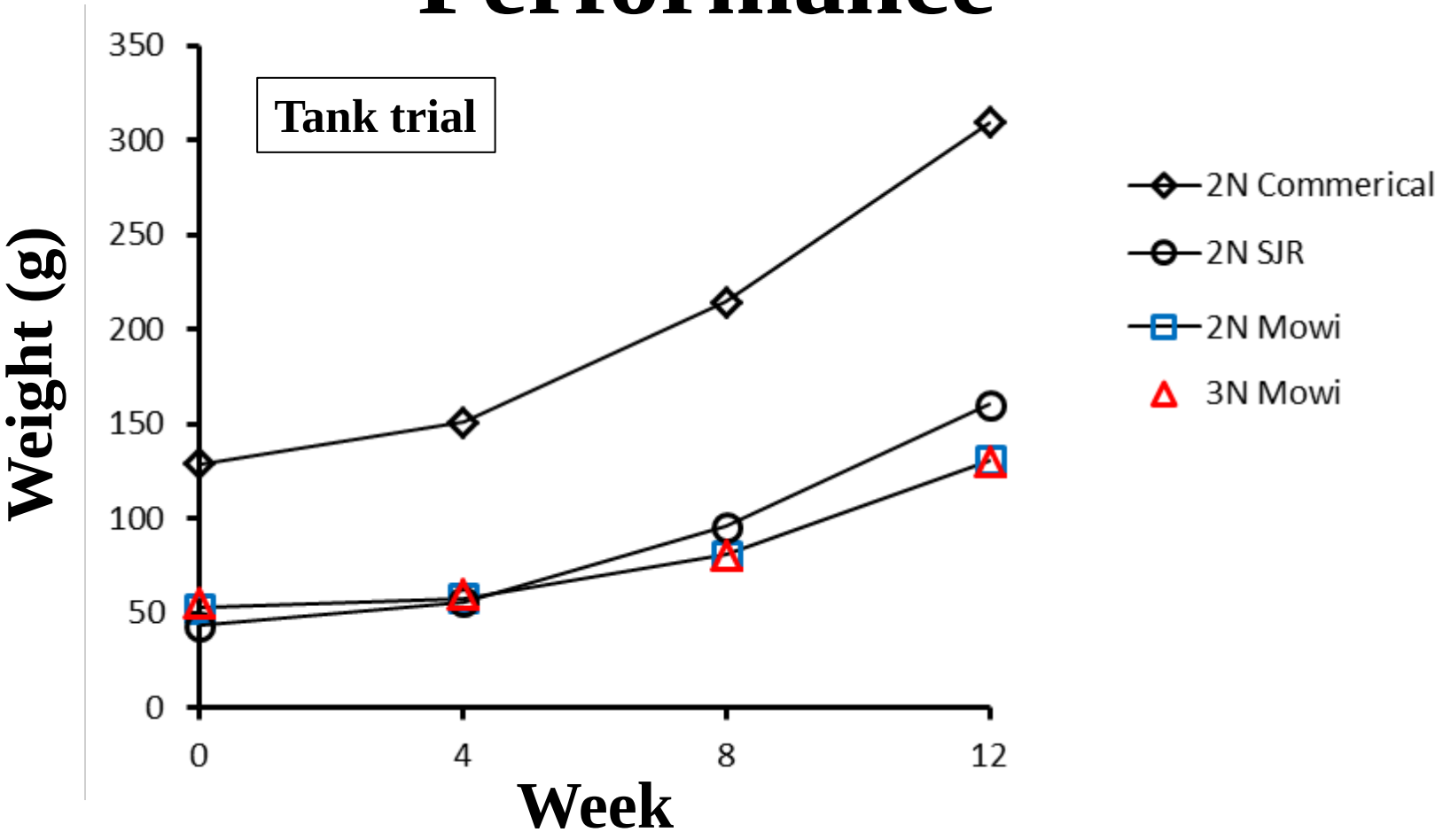
Optimize Triploid Husbandry

<u>Take home message</u>:

Triploids can perform well, but optimum conditions may need to be determined

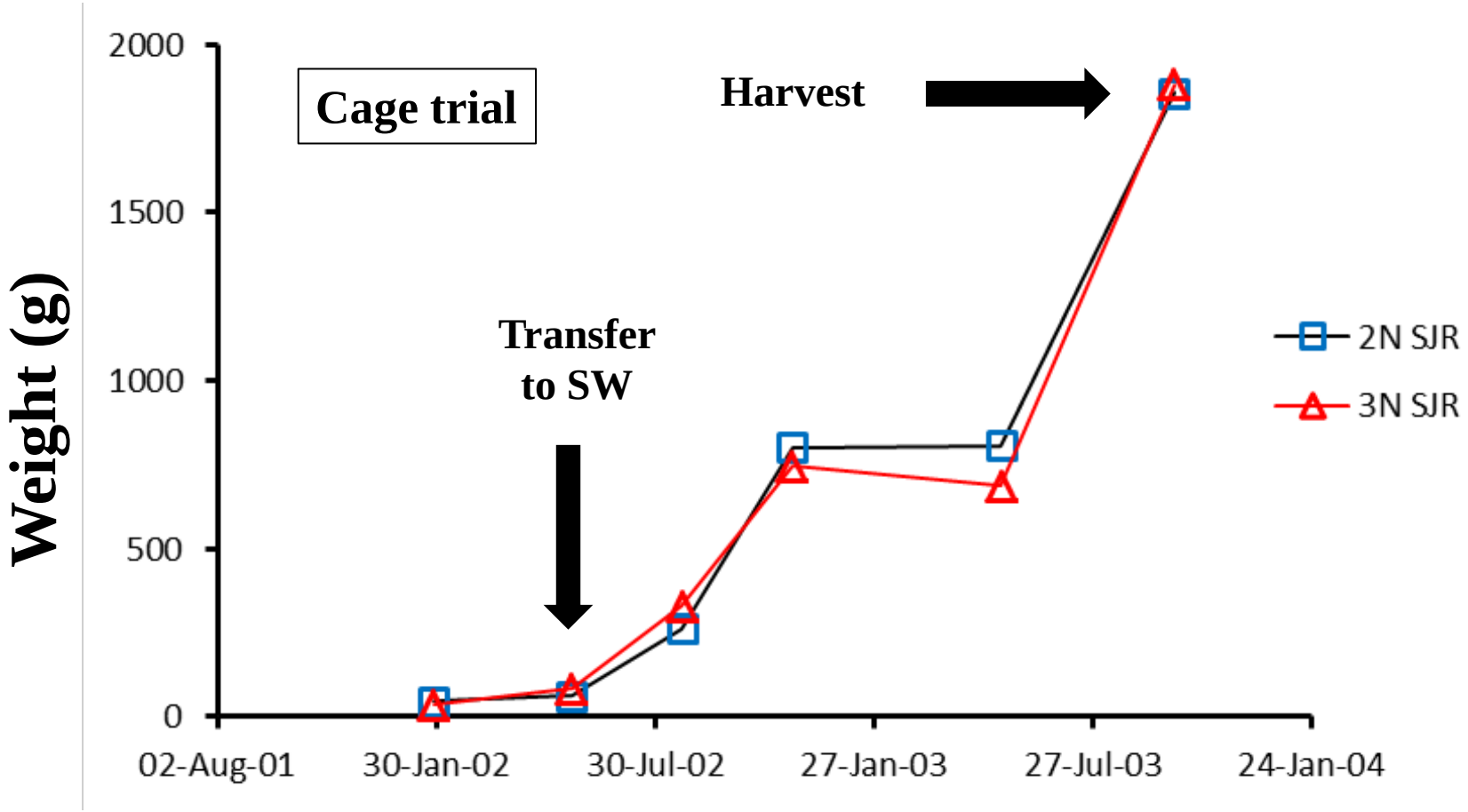
- **May be better suited for RAS, where rearing environment can be better controlled**

Select Strains for Best Triploid Performance



Sacobie et al. 2012. Effect of strain and ploidy on growth performance of Atlantic salmon following seawater transfer. Aquaculture 334-337: 58-64.

Select Strains for Best Triploid Performance



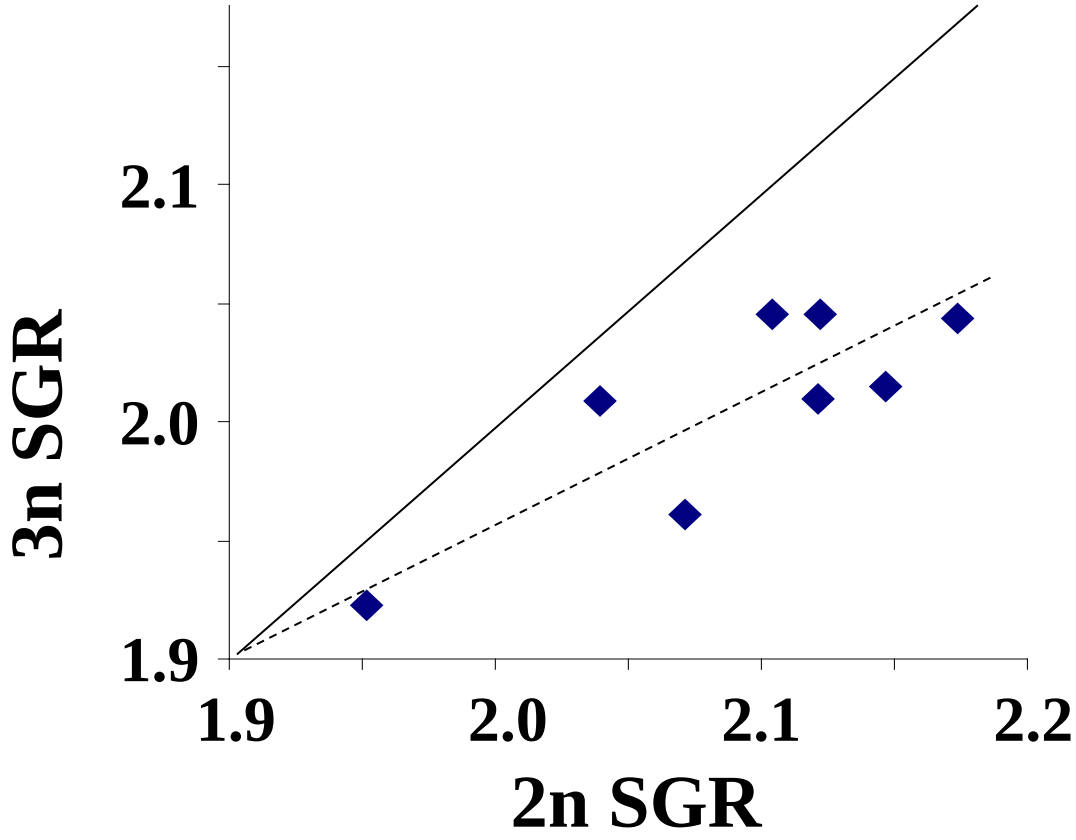
Sacobie 2011. Effect of strain and diet on growth and proximate composition of triploid salmonids. PhD Thesis, UNB Biology.

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



Chiasson, M.A., C.S. Pelletier & T.J. Benfey. 2009. Triploidy and full-sib family effects on survival and growth in juvenile Arctic charr. Aquaculture 289: 244–252.

Target Selection Programs for Best Triploid Performance

<u>Take home message</u>:

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