

Rearing temperatures as a causative factor for deformities

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Temperatures

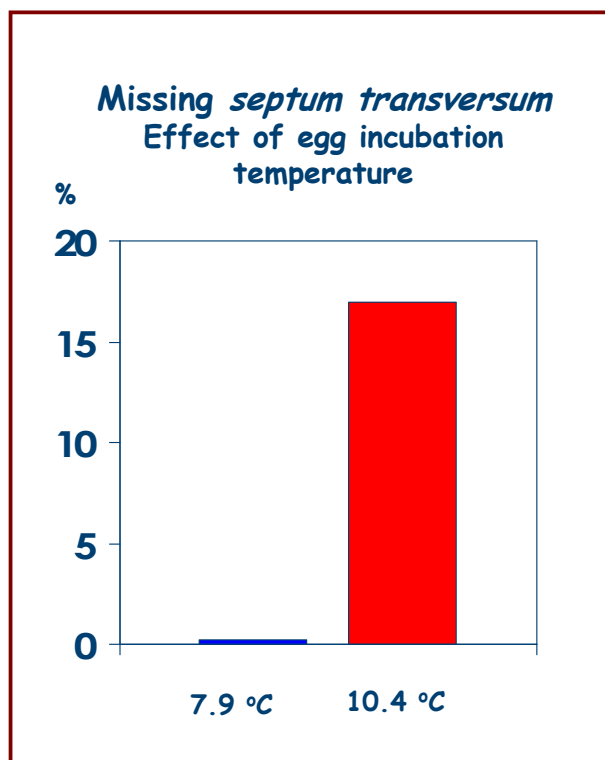
- The Atlantic salmon is a cold-water fish
- There are biological limits for temperature tolerance
- Higher temperature speeds up development and growth
- Known from mammals and birds that temperature is perhaps the most potent teratogenic factor (i.e. induces malformations during embryonic development)
- Warm water was used both in egg incubation and in juvenile rearing in salmon production
 - Egg incubation at 10-12-14 °C
 - First feeding at 15-16 °C and higher

Temperatures during egg incubation

- Teratogenic effect, i.e. disturbance of embryonic development
- Some of the malformations observed in farmed salmon in the mid-90ies were typical for teratogenesis



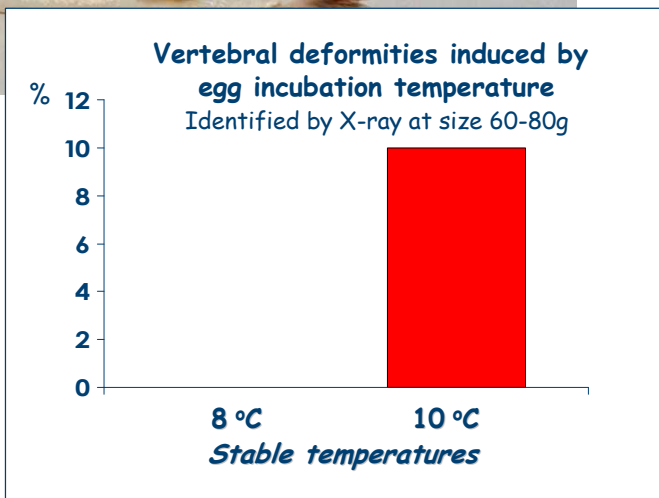
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Embryonic origin of some of the malformations was identified through experiments on salmon eggs

Egg incubation temperature (10.4 °C vs. control groups at 7.9°C) induced a range of deformities, including those seen in practical fish farming

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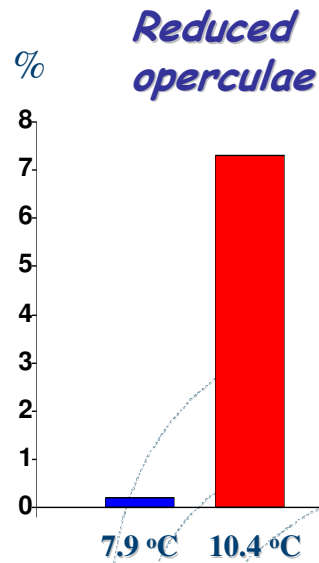
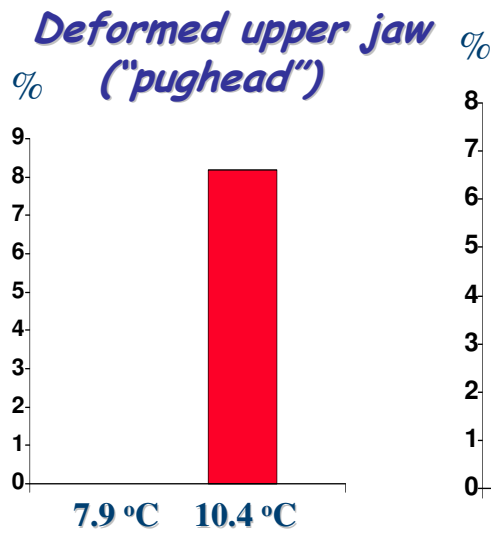


Egg incubation temperature > 8°C in Atlantic salmon can induce:



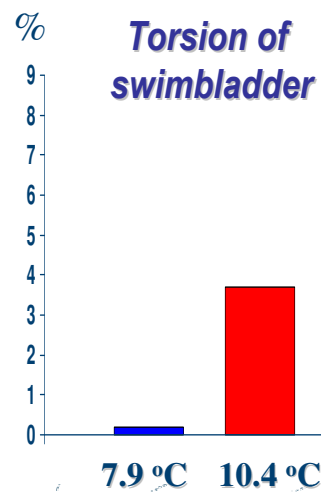
Malformations in Atlantic salmon

Effect of temperature from fertilisation to first feeding



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Embryonic origin of swimbladder malformation

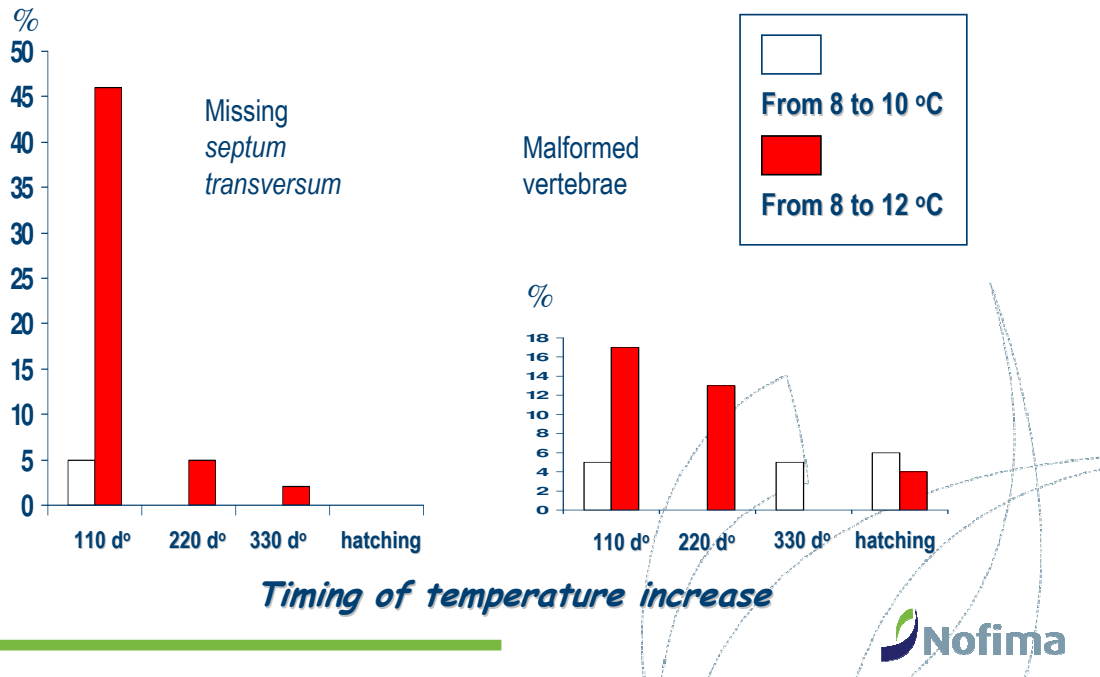


Egg incubation temperature

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Missing *septum transversum* and malformed vertebrae

Effect of temperature increase during egg incubation



Experimental temperature shock in eggs

- Eggs adapted to 8 °C
- 1 hour heat shock, 16 °C, at sensitive stages
- 1 hour cold shock, 1°C, at sensitive stages
- Long term exposure, 12 °C, during early somitogenesis
- Fish groups were reared to 20g size
- **A clear heat shock response was measured, hsp70**
- Hsp70 increased both in response to cold shock and heat shock
- The biggest hsp70-response was in eggs following long term exposure
- **Low incidences of malformations, but significant increase following long term exposure**
- Harald Takle, Grete Baeverfjord, Merete Lunde, Kari Kolstad, Øivind Andersen, 2005. The effect of heat and cold exposure on HSP70 expression and development of deformities during embryogenesis of Atlantic salmon (*Salmo salar*). *Aquaculture* 249, 515-524

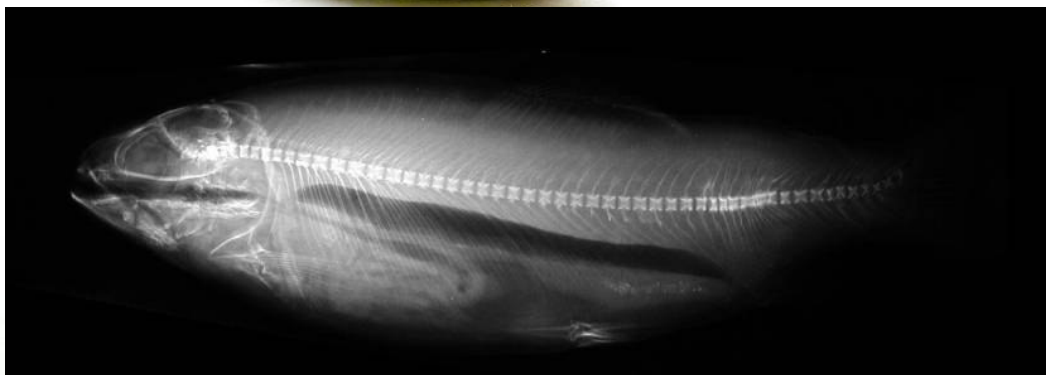
Summary, teratogenic effect of temperature in Atlantic salmon eggs and yolksac stage

- Upper temperature limit for normal development 8°C
- Temperature sensitivity varies during egg incubation and larval development, and is greatest during organogenesis, i.e. before eyeing
- **Vertebra remain temperature sensitive throughout, and remain sensitive also through first feeding**
- Nature and severity of malformations depends on timing of temperature stress
- Similar results for rainbow trout eggs

- Temperature shock will induce a molecular response. Whether or not the temperature shock induces deformities depends on developmental stage, duration and magnitude of change
- Rule of thumb: A temperature change $> 2,5^{\circ}\text{C}$ for more than 24 hours may induce deformities

- **Always remember: Other teratogenic factors exist**

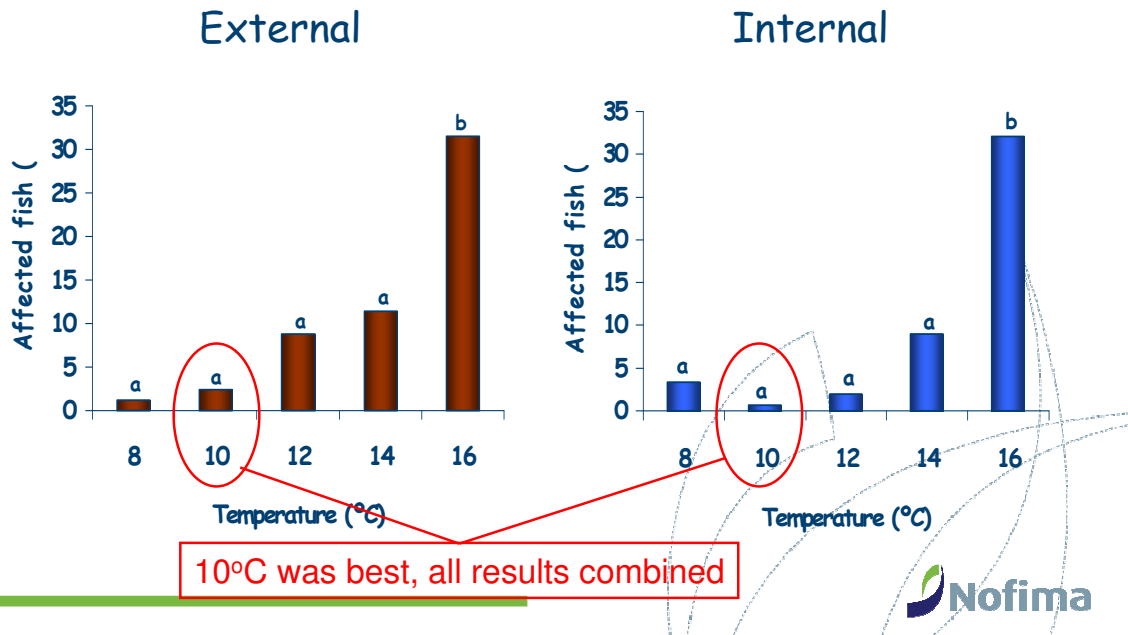
Egg incubation temperatures in rainbow trout



Defomities induced by egg incubation temperature in rainbow trout

Recorded at 20g size

Forsøk i år 2000



Rainbow trout Sunndalsøra, autumn 2008



Eyed eggs bought from commercial producer

Temperature from fertilization to purchase:

Mean temp 5,8°C
Max 8°C
Min 3,5°C

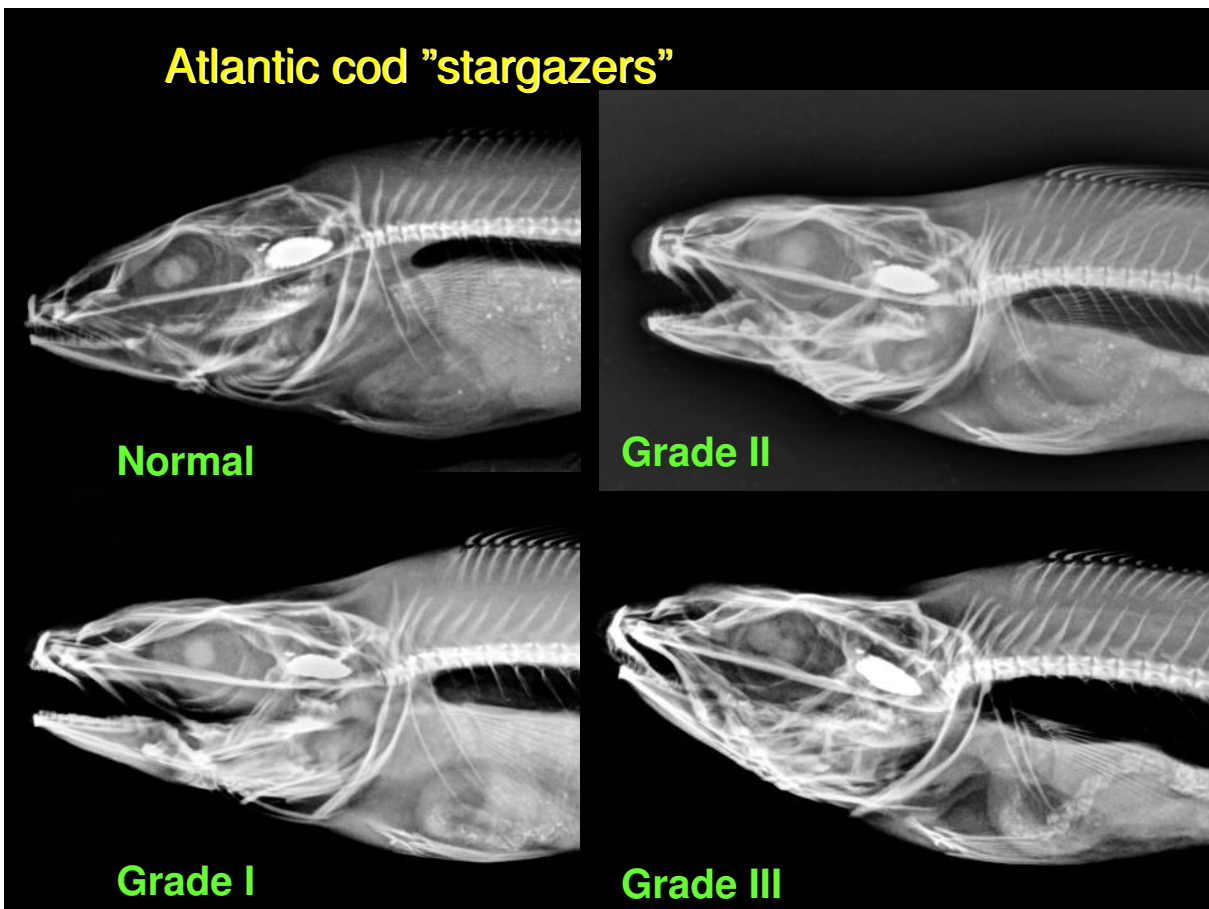
FINE FISH task 4-8

Effect of egg incubation temperature x genetic strain in rainbow trout (2007)

- Objective:
 - To determine whether different strains of rainbow trout have the same temperature limits for malformations or not
 - To find out whether there is a lower temperature limit for egg incubation in rainbow trout
- Eggs from Norway, Denmark and France
- One of the strains were used to produce triploids which were incubated in parallel with the diploids
- Incubation at 6°C, 10°C and 14°C
- Fish were reared to 20g before examination
- Main results:
 - **10°C** was best for all strains
 - **14°C** was too high for all of them
 - **6°C** was too low

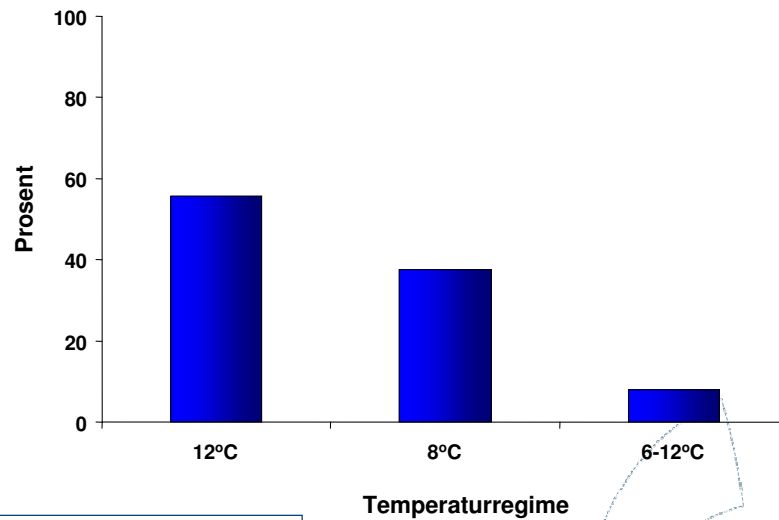


Atlantic cod "stargazers"



Atlantic cod “stargazers”

Effect of temperature regime during first feeding



6-12°C: First feeding at 6°C
Gradual increase to 12°C
from week 3 after first
feeding, 1°C per week.

Lein m. fl., 2006

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Rearing temperatures for juvenile Atlantic salmon

- Epidemiological survey 2001:
 - 25 groups of Atlantic salmon in sea water
 - Broad approach: Genetics, nutrition, production parameters
 - Evaluation of deformities 8-12 months after seawater transfer (1-3kg)
 - 5 best groups: First feeding temperatures below 12,5oC
 - 5 worst groups: First feeding at 14,5 or above

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Long term experiment, Atlantic salmon

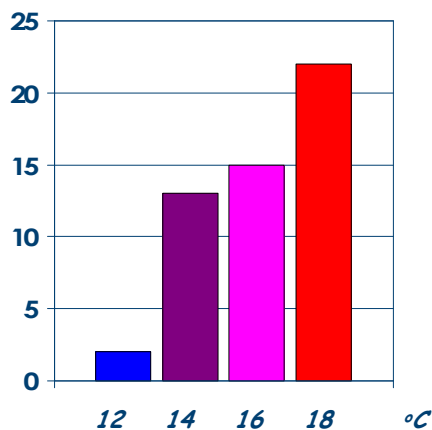
Rearing temperatures for juveniles, 0-60g *Effects on deformities in different life stages*

- Rearing experiment, freshwater
 - First feeding Feb 2001
 - Sea water transfer Apr 2002
 - Harvest June 2003
- Fish reared at 12, 14, 16 and 18°C from first feeding and to 60g size
- Also explored:
 - Basic temperature 12°C
 - Increase in periods to either 14, 16 or 18°C

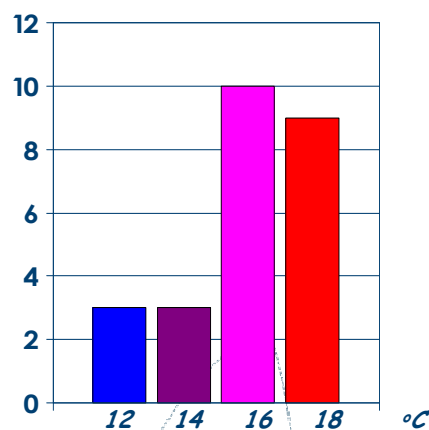
Supported by the Norwegian Research Council



Deformed vertebrae in parr at 60g size *Effect of rearing temperature 0-60g*



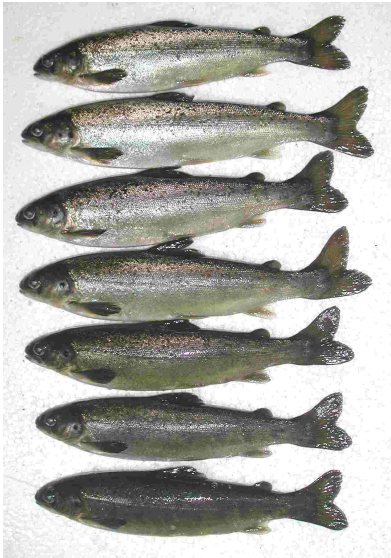
% av fish with malformed vertebrae



Mean number of affected vertebrae per affected fish



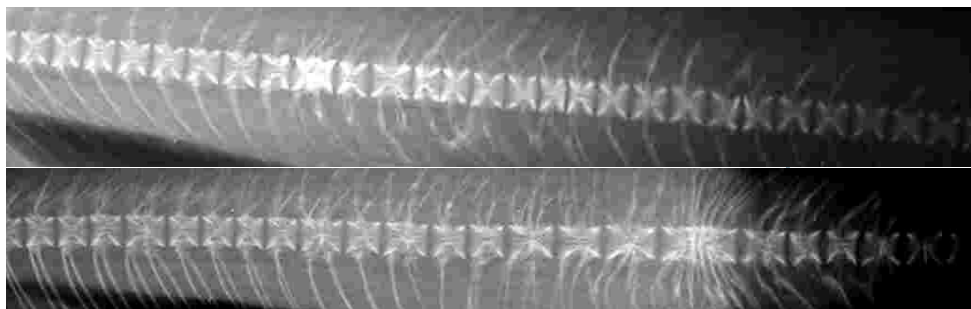
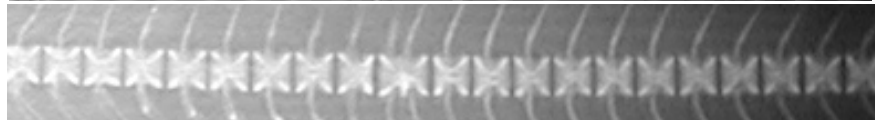
Seawater transfer,
Smolts 80-100g



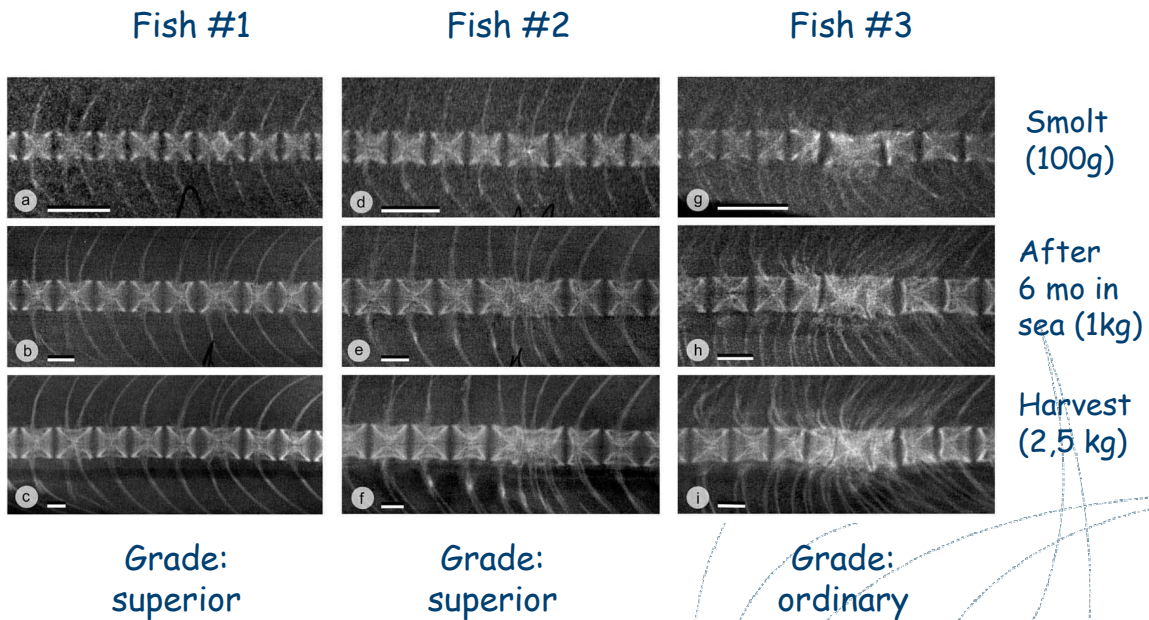
Harvest, 3-5kg



Temperature induced vertebral pathology



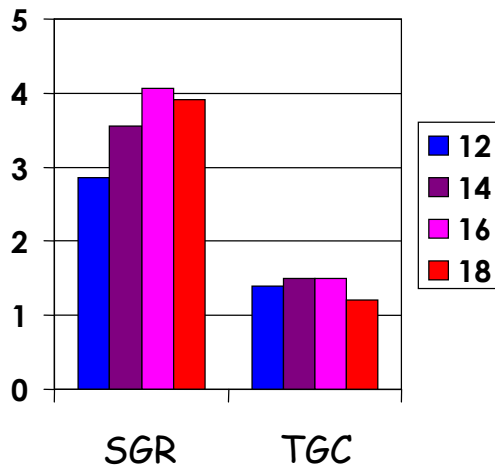
Development of temperature induced deformities with time



Witten et al., in *Manuscript*

Growth rates and freshwater production time

Effect of temperature 0-60g

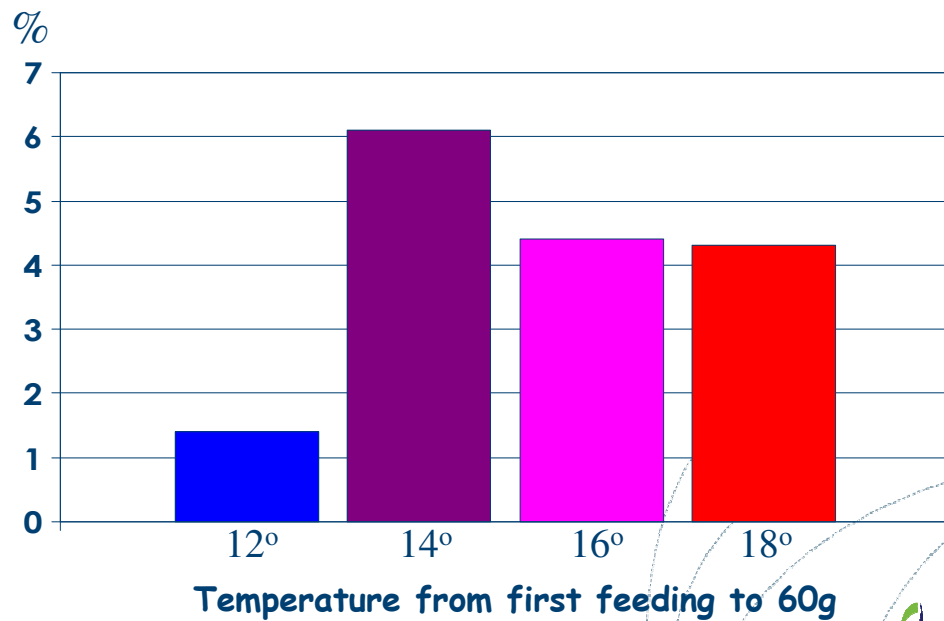


- Production time:

12°: 199 days, 60g	(6,6 mnd)
14°: 158 days, 56g	(5,3 mnd)
16°: 140 days, 58g	(4,7 mnd)
18°: 140 days, 49g	(4,7 mnd)

- NB! Fish were not graded during this period

Downgrading at harvest due to deformities
Effect av rearing temperature from first feeding to 60g



Recommendations:

- Egg incubation <math><8^{\circ}\text{C}</math> in A. salmon
- Control temperature and avoid rapid fluctuations and temperature shocks >2,5°C
- Keep temperature low and controlled also during yolk sac stage
 - Experimental data indicate 8°C
- First feeding at 12°C
- Control temperature and avoid large and/or rapid fluctuations in parr rearing
- Be critical to heat shocks as virus control method
- Keep temperature moderate throughout freshwater production
- Control temperature and cool water if necessary during 12D:12L photomanipulation