Rearing conditions and deformities in Atlantic salmon – what have we learned so far ?

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Deformities… …

- A persisting problem in aquaculture
  - no easy way out
- Complex problems
- Salmonids:
  - A history of organ malformations (late 1990's)
  - Predominantly skeletal defomities
  - Vertebral column, jaws, operculae

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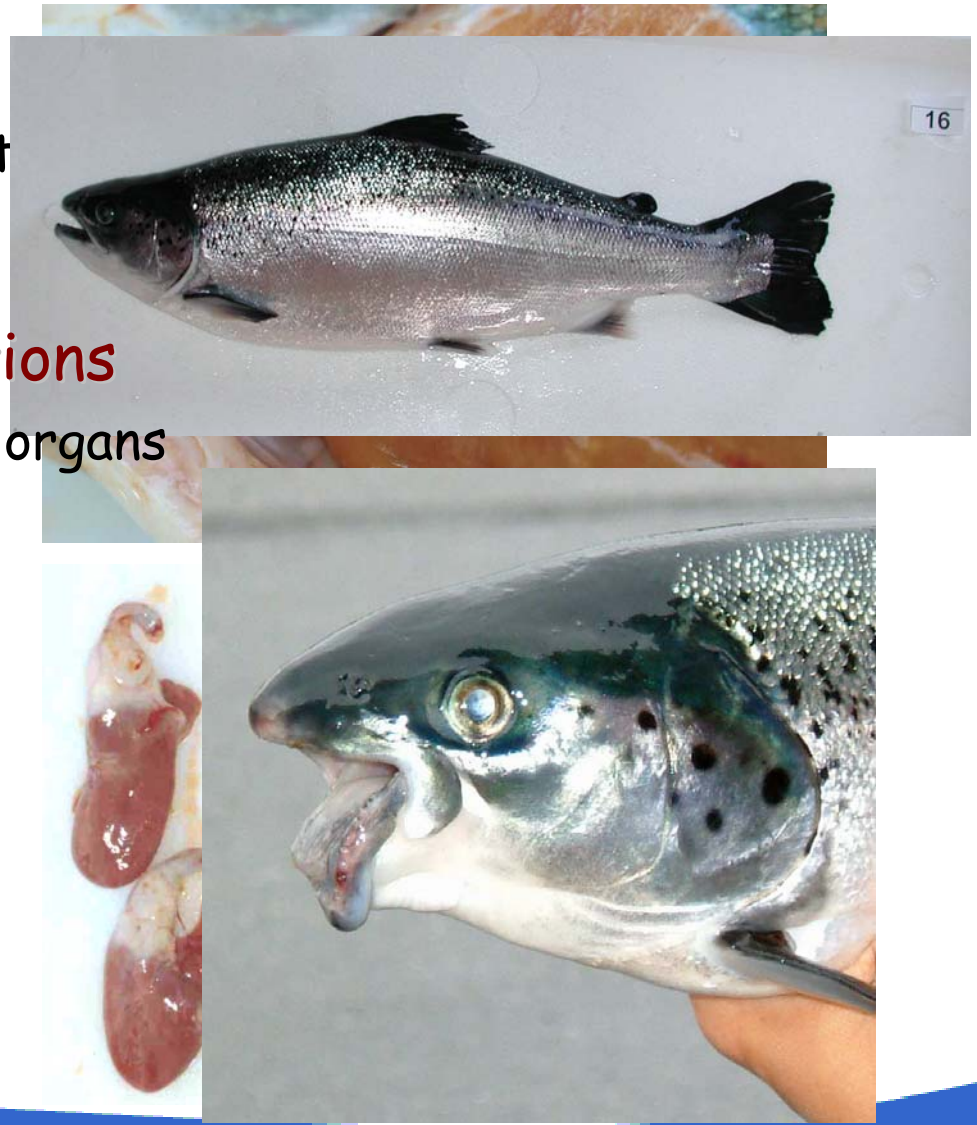
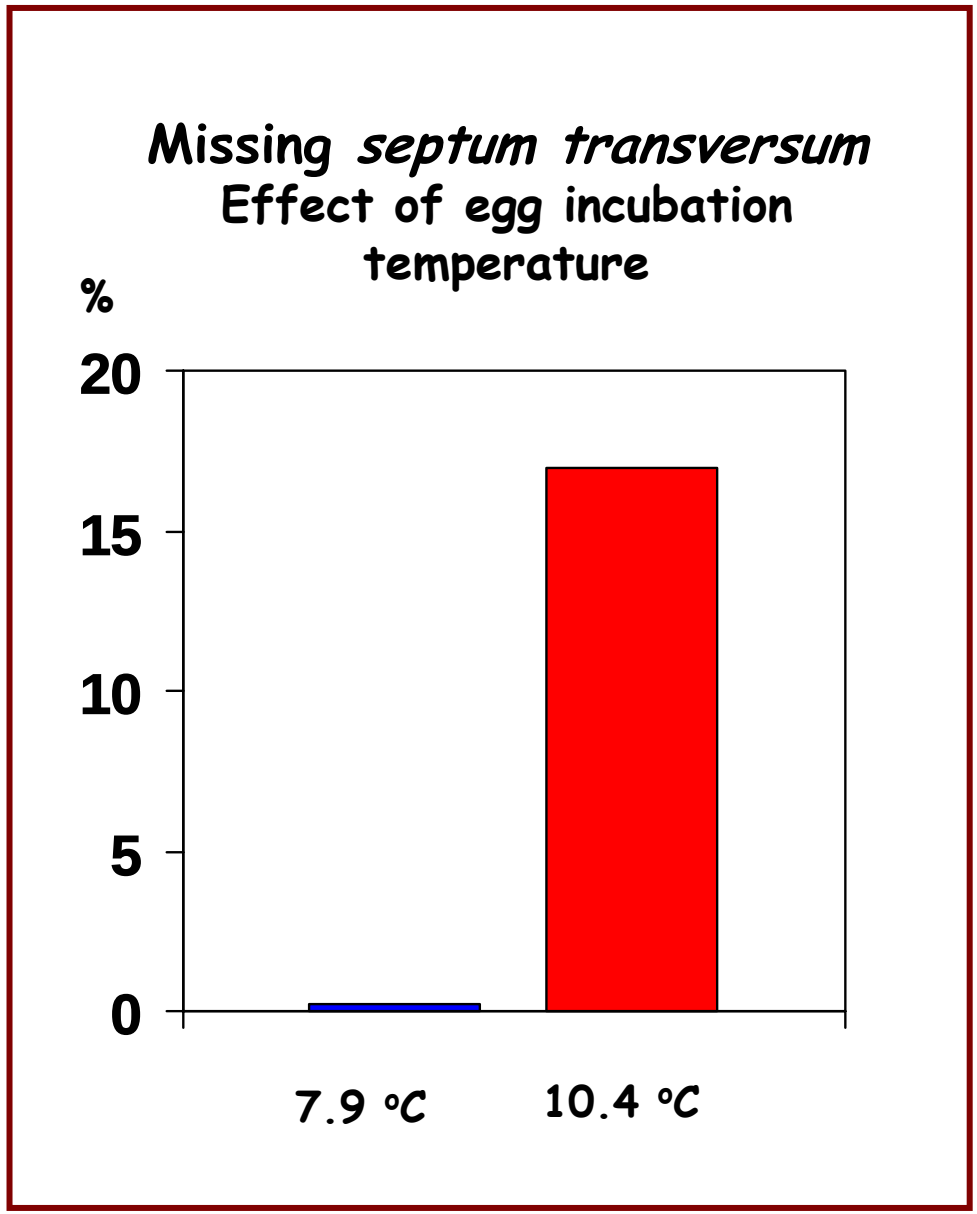
Deformities in farmed salmon

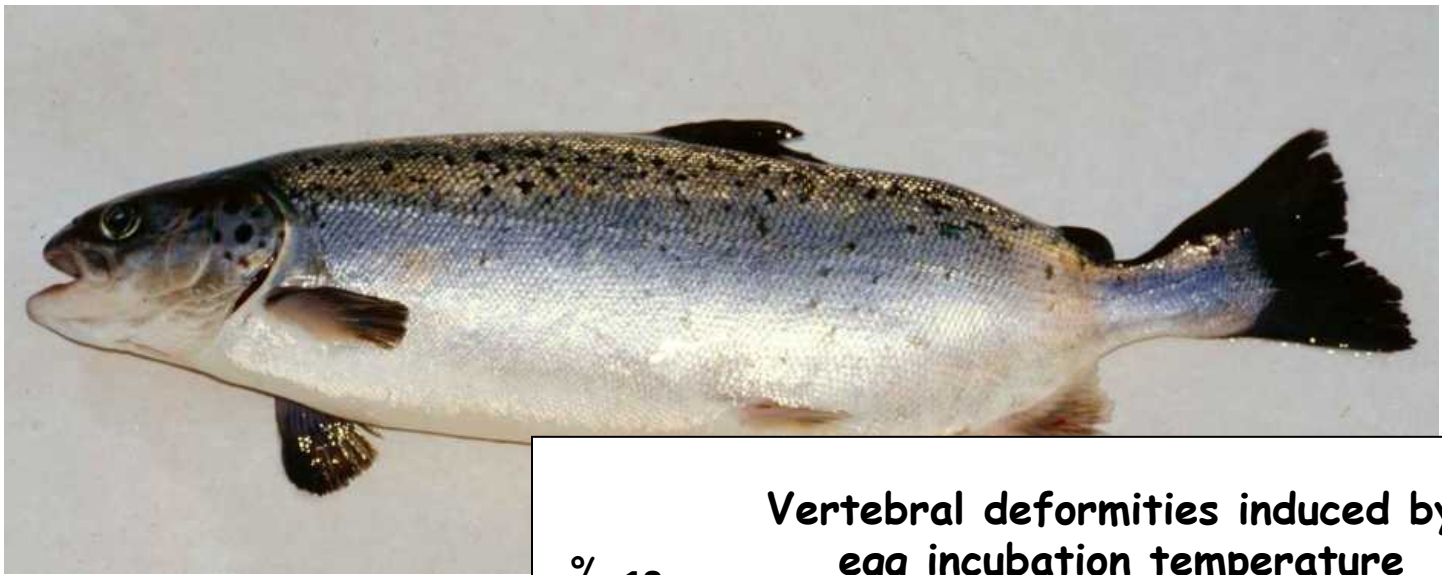
- Skeletal deformities
  - "Humpbacks" and "short
  - Jaw deformities
- Soft tissue malformations
  - Missing and malformed organs
  - Most important:
    Missing *septum transversum*,
    i.e. no separation between heart and abdominal cavity
  - More recently:
    Small and abnormally shaped hearts



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

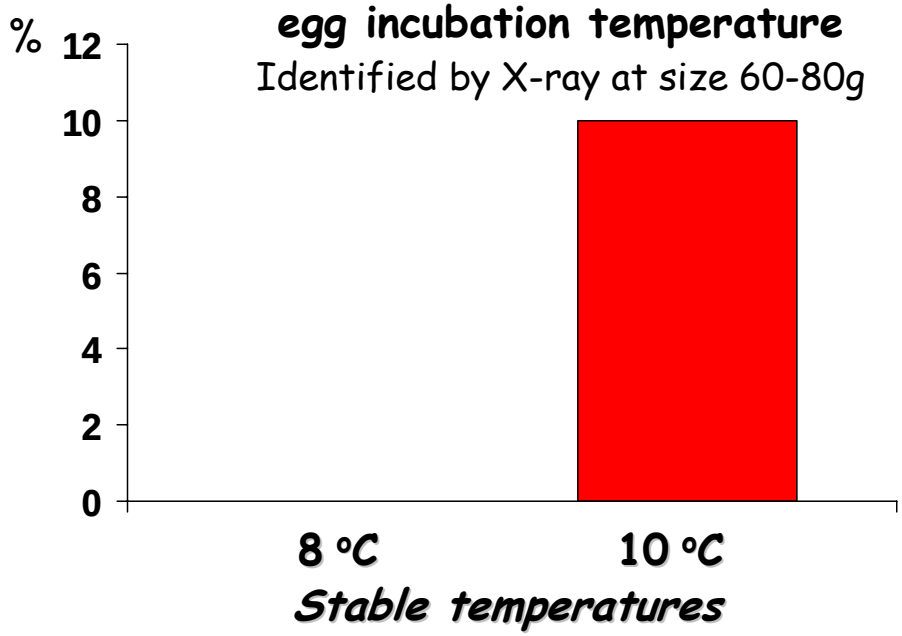
- ***Egg incubation temperature*** (10.4 °C vs. control groups at 7.9°C) induced a range of deformities, including those seen in practical fish farming





Vertebral deformities induced by egg incubation temperature

Identified by X-ray at size 60-80g

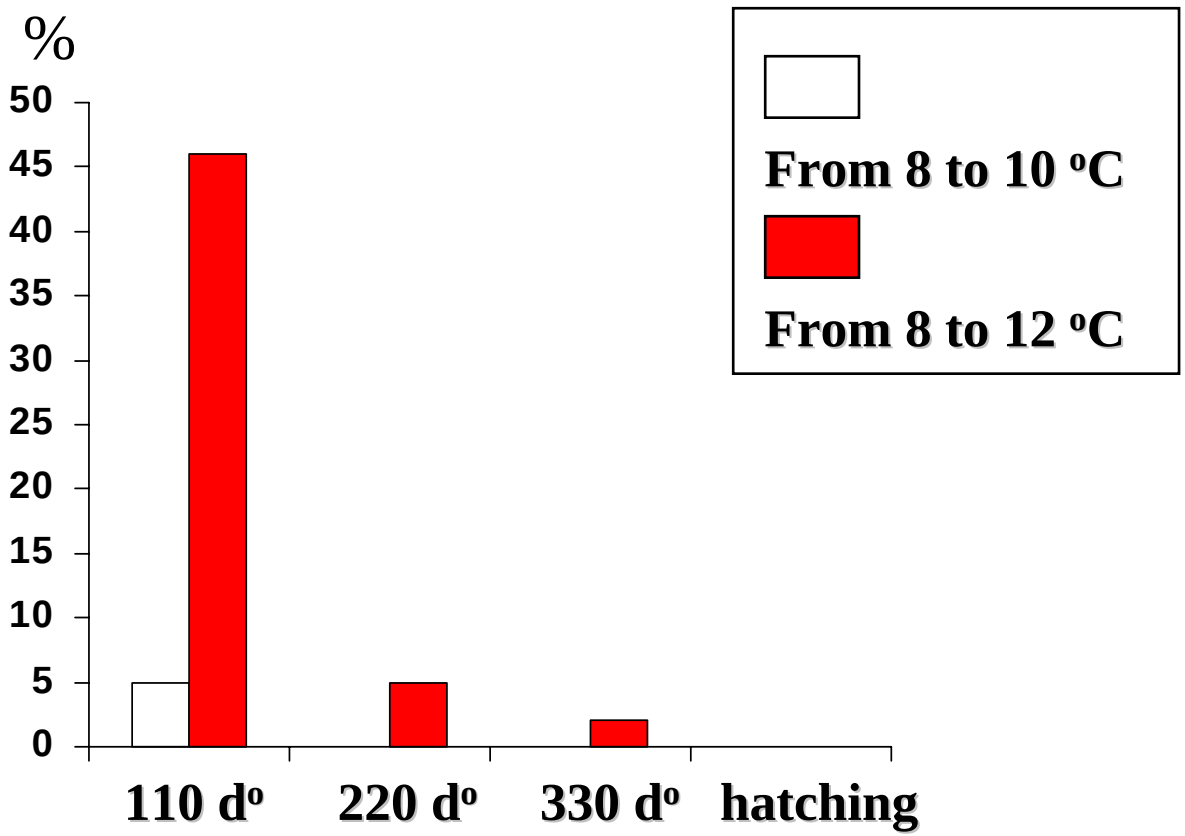


Egg incubation temperature > 8°C in Atlantic salmon can induce:

Aplasia of septum transversum

Effect of temperature increase during egg incubation

(2nd experiment)

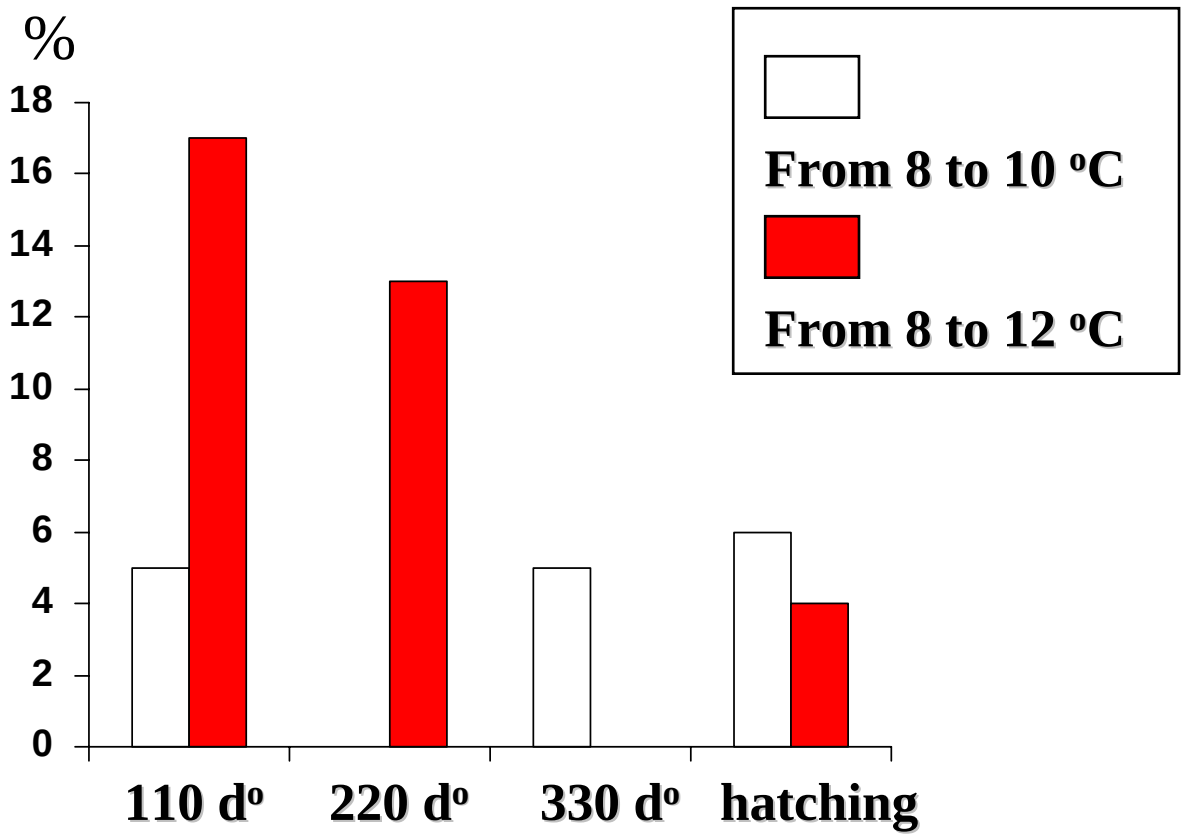


Temperature increased at:

Vertebral deformities

Effect of temperature increase during egg incubation

(2nd experiment)



Temperature increased at:

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Long term experiment, 2001-2003:

Rearing temperatures 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

Supported by the Norwegian Research Council

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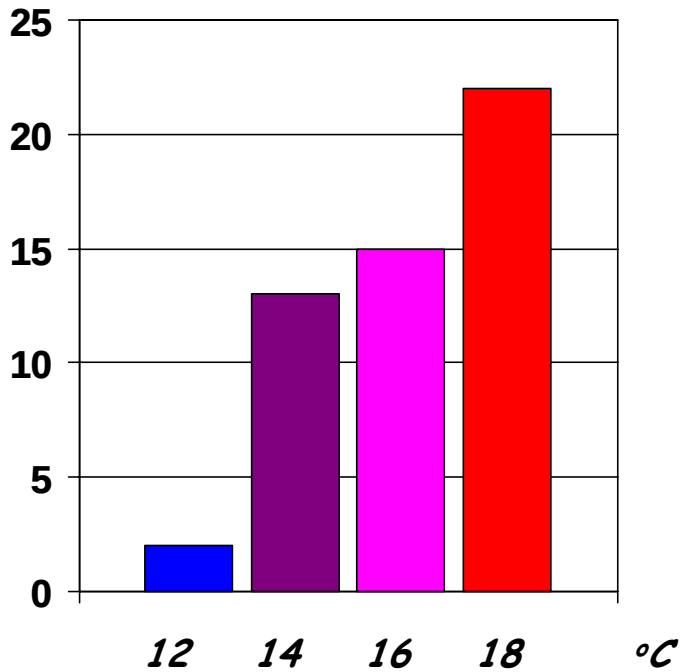
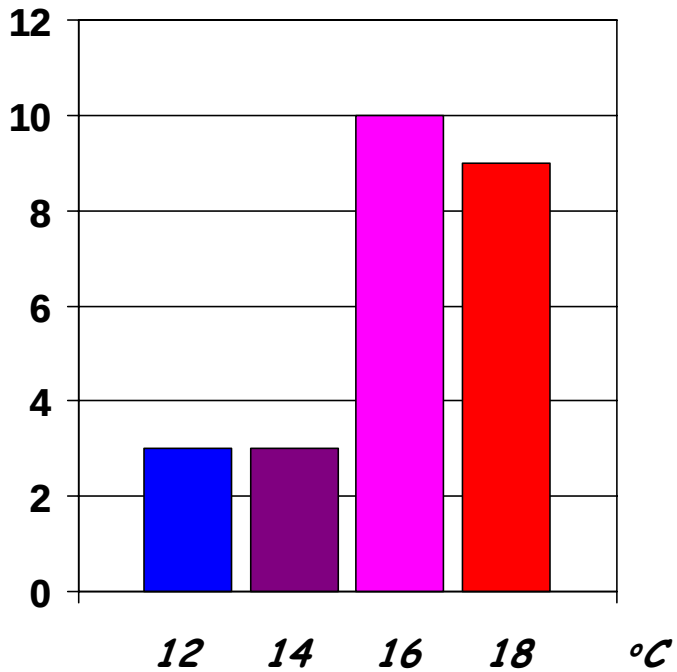
Deformed vertebrae in parr at 60g size

Effect of rearing temperature 0-60g



% of fish with deformed vertebrae

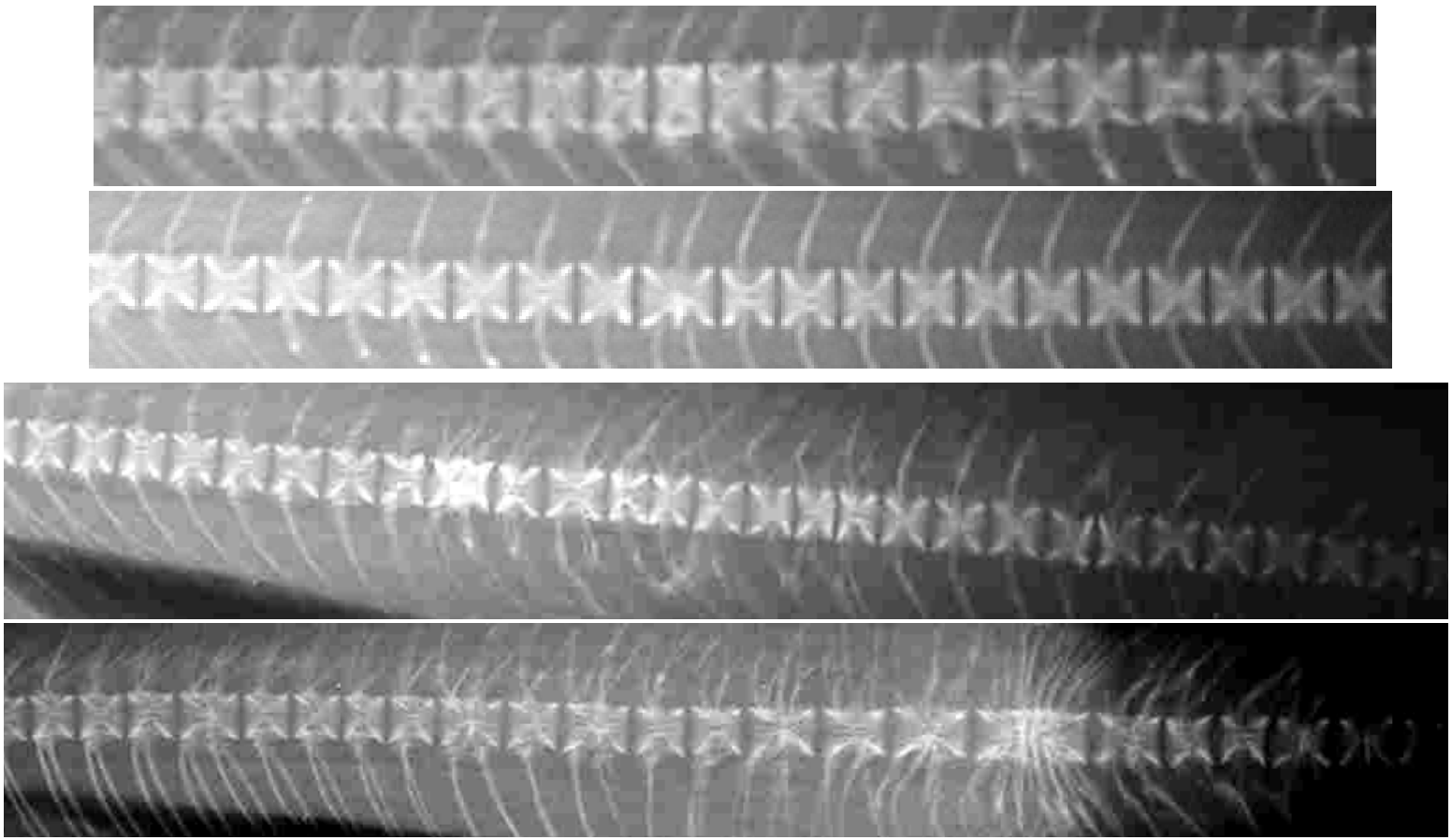


Average number of deformed vertebrae per affected fish

Seawater transfer,
Smolts 80-100g

Harvest, 3-5kg

Temperature induced vertebral pathology



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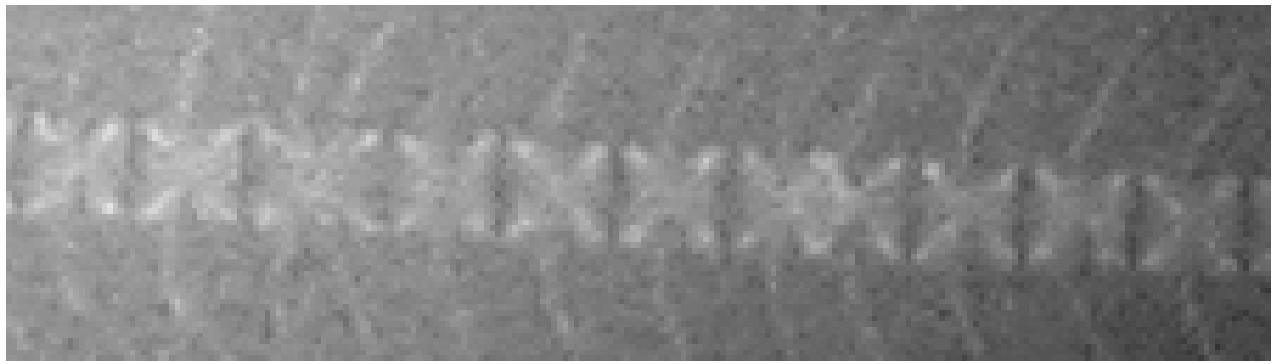
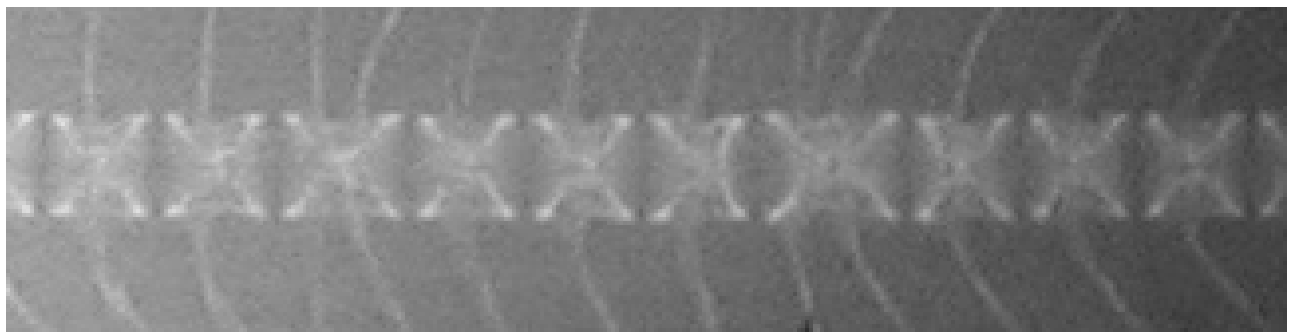
Development of vertebrae in seawater

- 200 fish with PIT-tags were X-rayed in April 2002, at size 80-120g, just before seawater transfer
- Same individuals X-rayed again in November 2002, at average size 1,2 kg
- …… and were X-rayed again at harvest, in June 2003, mean weight 2,5 kg

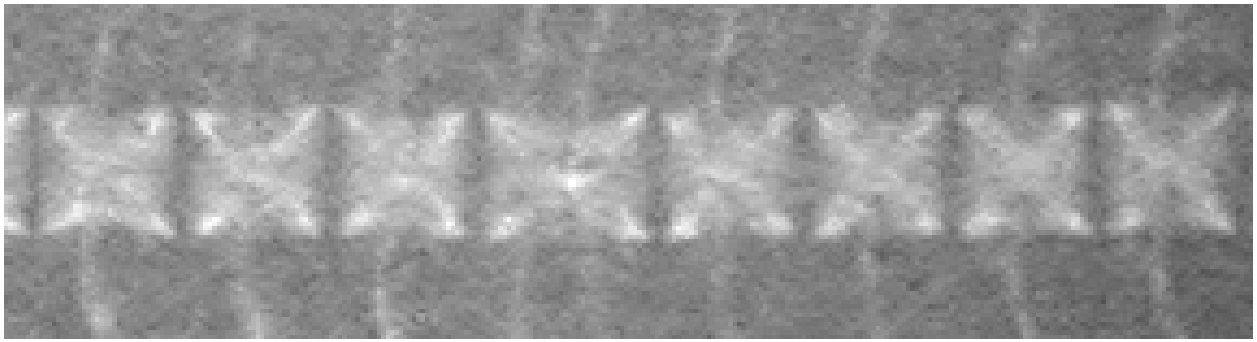
X-rays were taken by Norwegian School of Veterinary Science



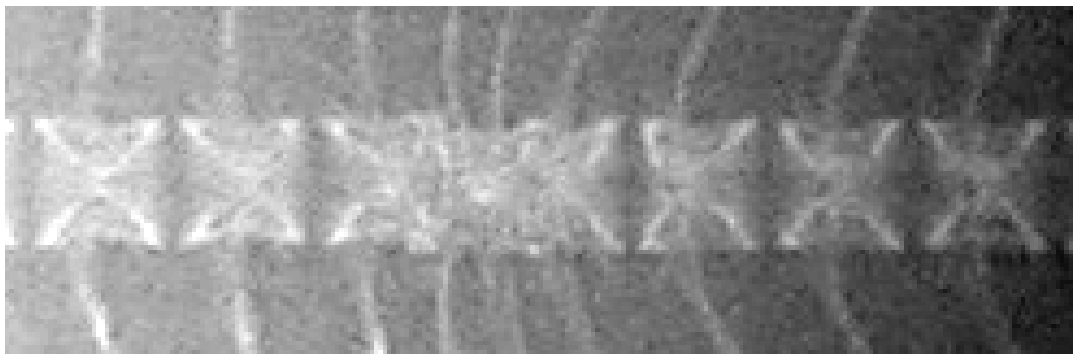
April2002
65g



nov2002
930g



April 2002
163g
Kfakt 1,32



Nov 2002
1920g
Kfakt 1,54

Nutritional aspects of vertebral deformities

- No limit to the number of potential nutritional factors
- In commercial diets, mineral supply may be a limiting factor
- Phosphorus deficiency impaires bone formation
- Mineral supply (dietary level X bioavailability) is a challenge in fast growing animals
- Unpredictable dietary supply in formulated diets
  - Vegetable ingredients impairs absorption
  - Unforeseen variation in availability in fish meal

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2002-2005:
Deformities of vertebral column and jaw in Atlantic salmon.
Effects of genetic susceptibility, mineral nutrition and production temperature

- Funded by Fiskeri- og Havbruksnæringens Forskningsfond (FHF), the industry research foundation
  - AquaGen: Supplied egg groups selected for genetic disposition
  - Ewos Innovation: Experimental feeds

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The study was based on previous results, which demonstrated that....

- … there is **genetic variation** (among family groups) in susceptibility to vertebral deformities (Gjerde et al.,2005)
- … margins may be too narrow for some **minerals** in commercial diets (**contents x bioavailability**), and impaired mineralisation is suspected to contribute to development of vertebral deformities.
- … **high rearing temperatures** induces vertebral pathology in Atlantic salmon juveniles
- … **high growth rates** is known to induce inferior bone quality in poultry and swine. Maximum growth rate in Atlantic salmon at 15-16°C

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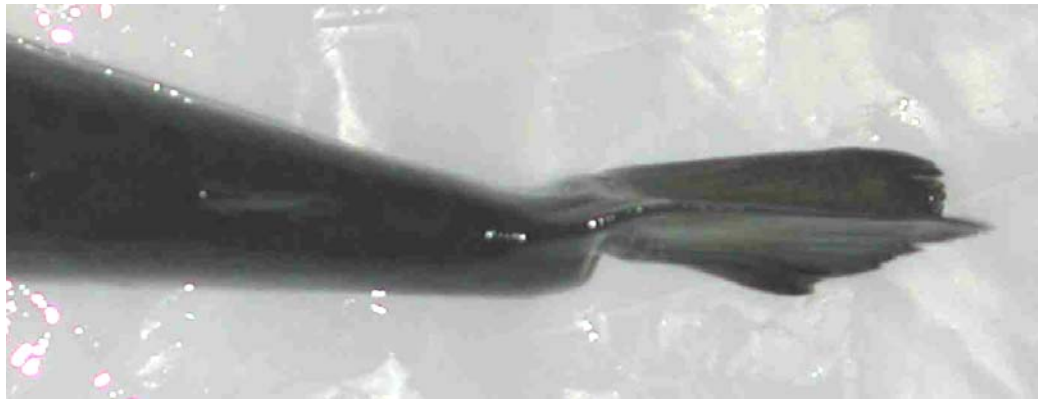
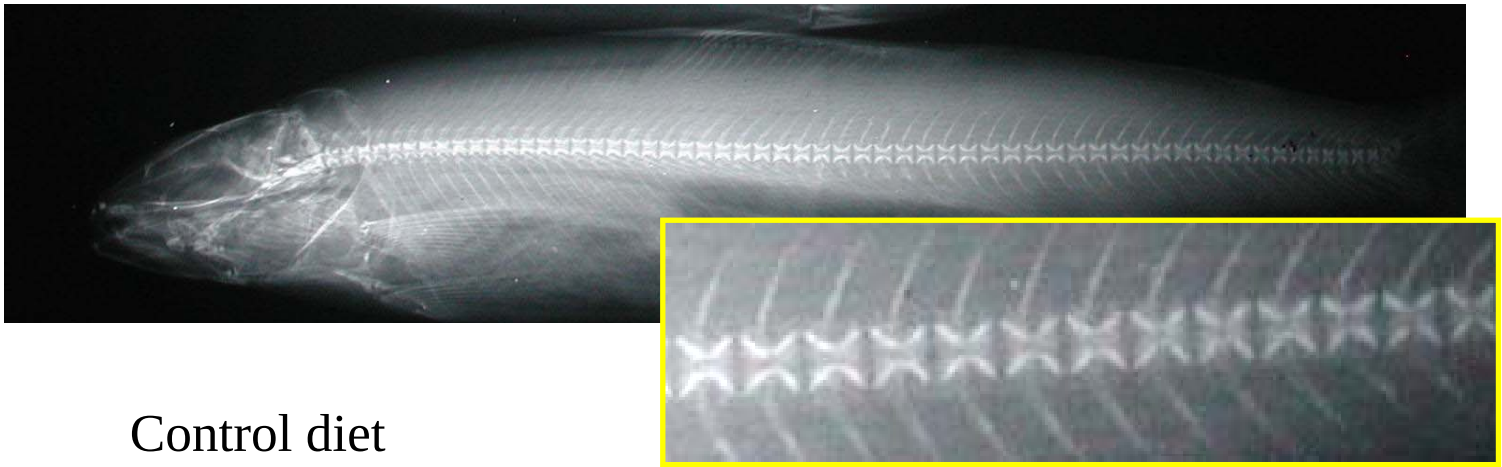
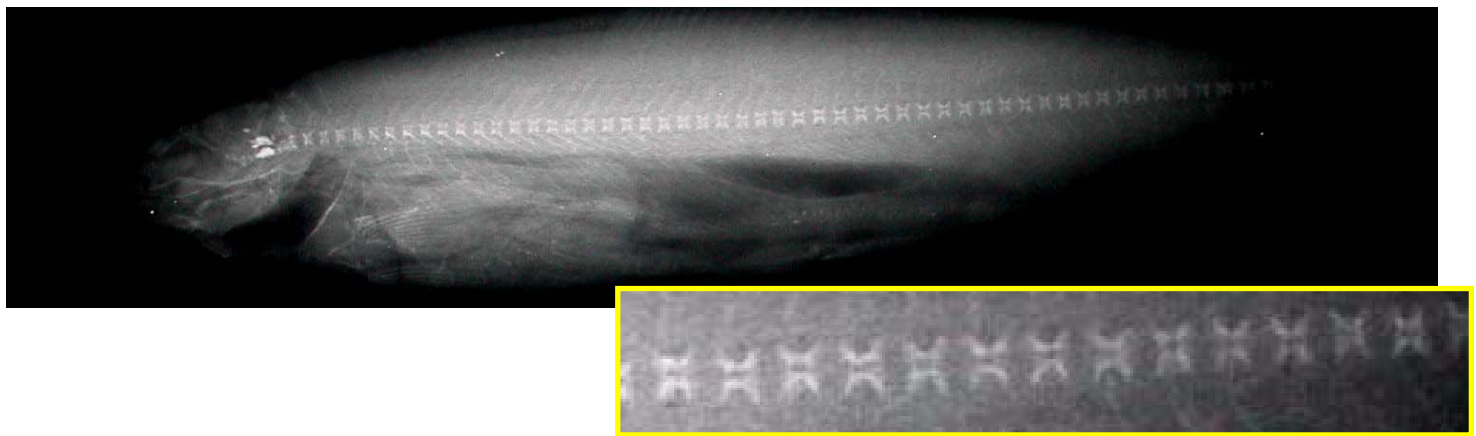
Observations
at 60g size:



Radiography, 20g size:



Control diet



Diet with 1% P and 70 ppm Zn

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Water quality in freshwater production

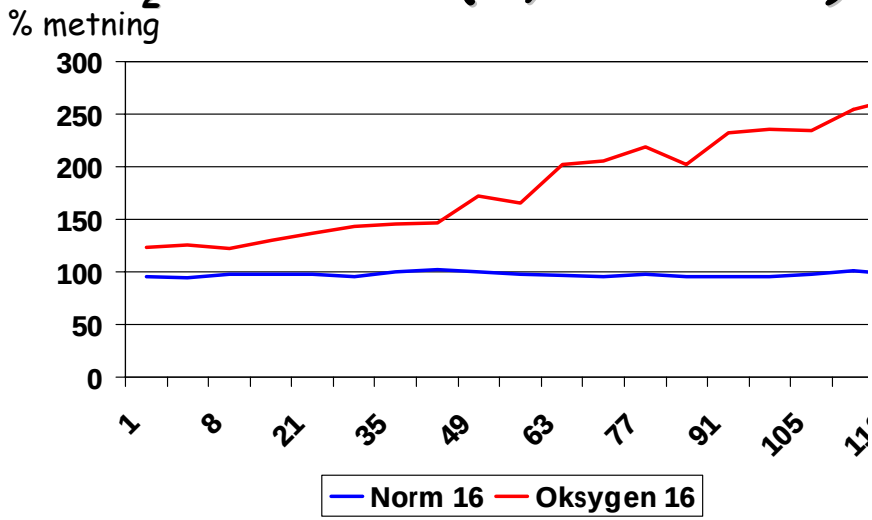
- Increased production of smolts (higher numbers, bigger smolts) at fewer sites
- Available water resources do not increase correspondingly
- Water flow (l/kg/min) is decreased
- Oxygen is added
- CO_2-accumulation and low pH in tank water

- ...any effects on skeletal deformities ?

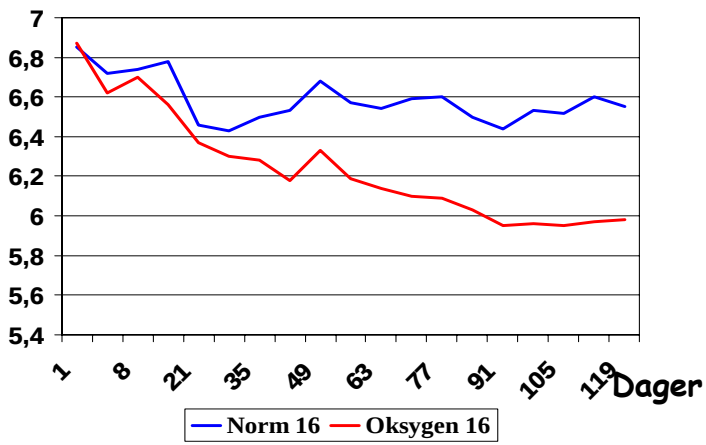
Production exp.# 1

Low density, unlimited water supply,
compared to
High density, low water supply, oxygen added

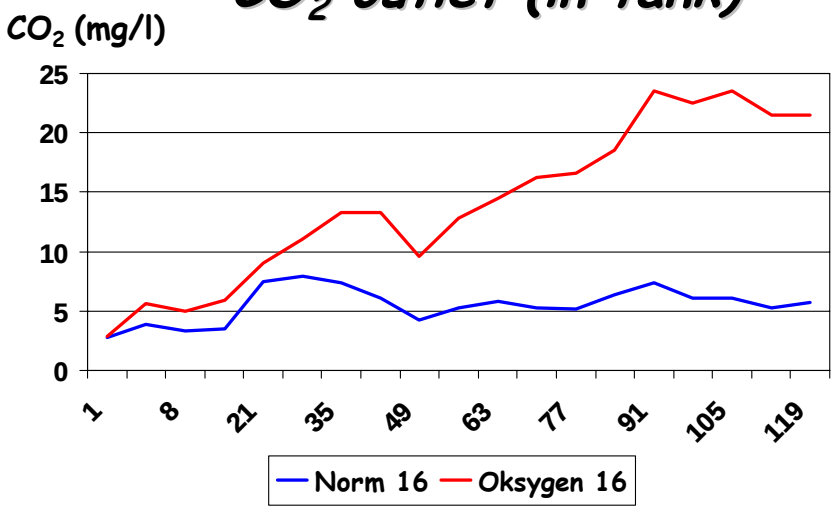
O_2 saturation (%, inlet water)



pH outlet water (= in tank)

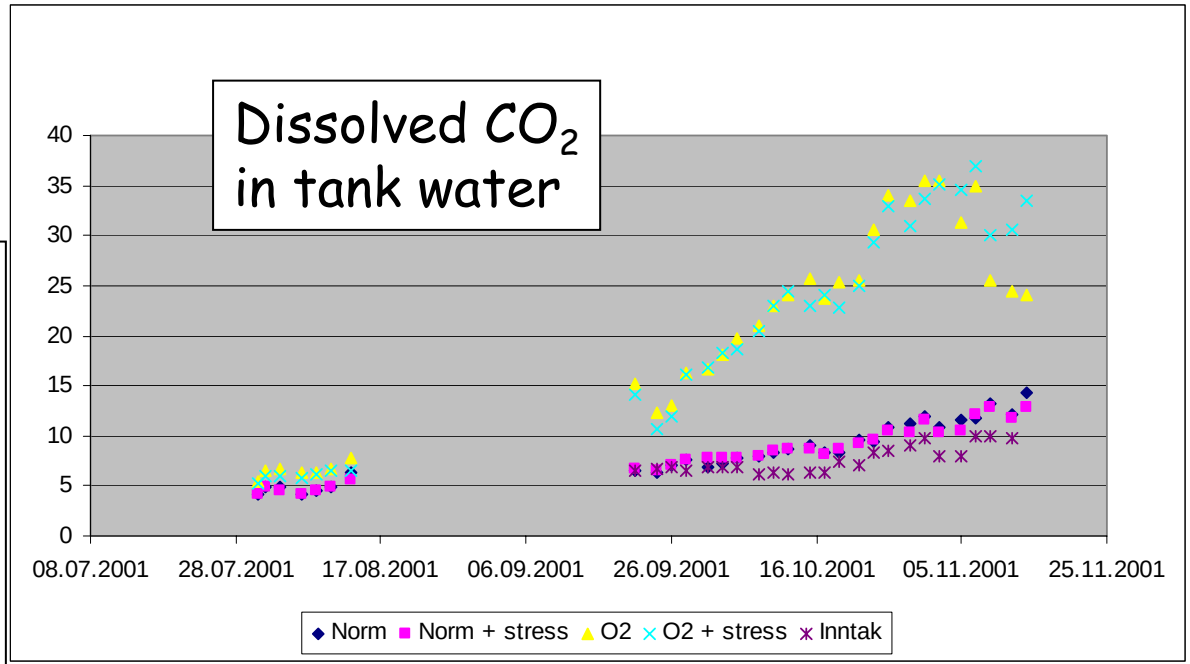


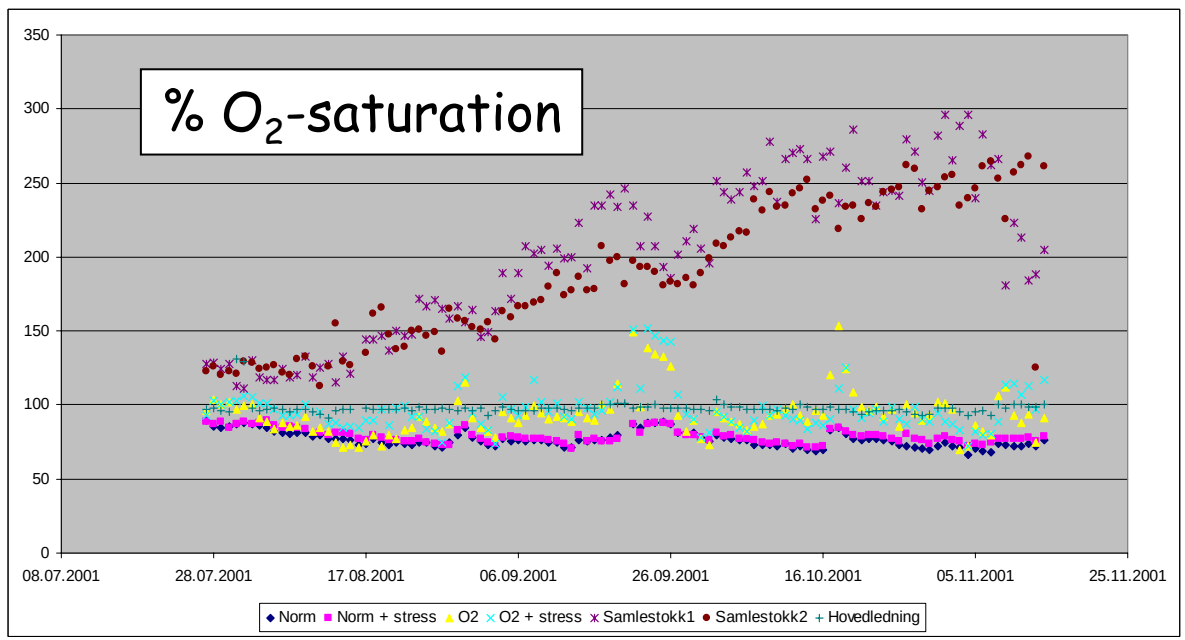
CO_2 outlet (in tank)



Production exp.# 2

Low density, unlimited water supply,
compared to
High density, low water supply, oxygen added,
in fish given diets with different levels of available phosphorus





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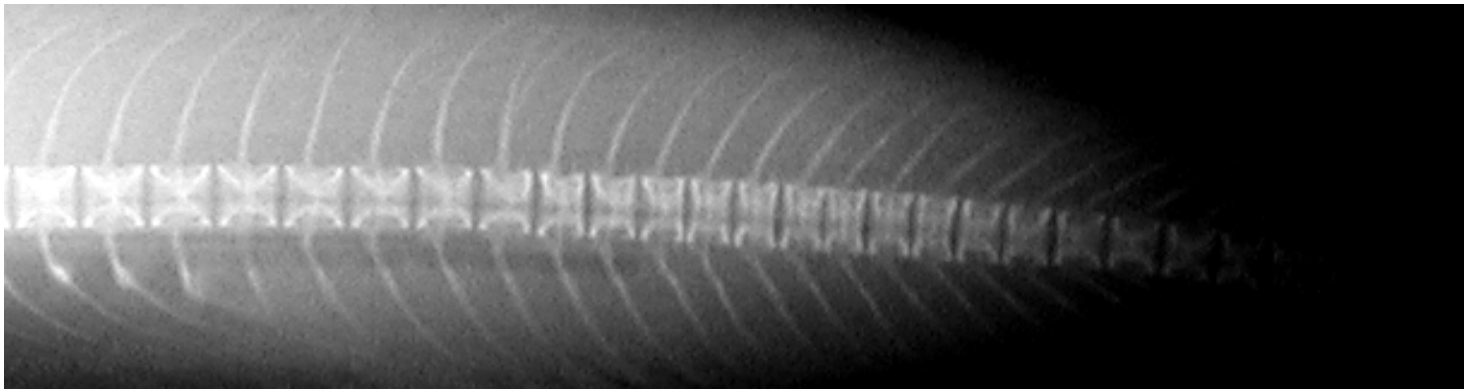
Downgrading of fish at harvest in tanks with unstable conditions

22%

These tanks were characterized by

- Rearing temperature 3-60g: 16°C
- Fluctuating O_2-saturation, periods with supersaturation (>100%)
- Periods with high levels of CO_2 (>30mg/l)
- Periode with low pH (<5,8)
- A near death experience with stop in water supply and hypoxia

Unstable conditions, fluctuations, stress



- In particular, increase in fish with **platyspondyly**
- Vertebrae not fused, just flattened (?)
- Platyspondyly only in caudal region
- Seen only in seawater, no early signs have been detected yet

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Project "Water quality- smolt quality"

O_2-supersaturation in freshwater:
Effects on health condition and seawater performance

AKVAFORSK, NIVA, UMB, NIFES, UiB

- Limited water supply, oxygen added
- What happens if fish are reared in hyperoxic conditions, i.e. with O_2 saturation > 100% ?

- Exposure in two periods
  - From 40 to 80g size, growth under continous light
  - From 80g to smolt, through smoltification, 6 weeks of 12D:12L, 6 weeks of continous light
- Examination of fish after 16 weeks of communal rearing in seawater

Exposure levels:

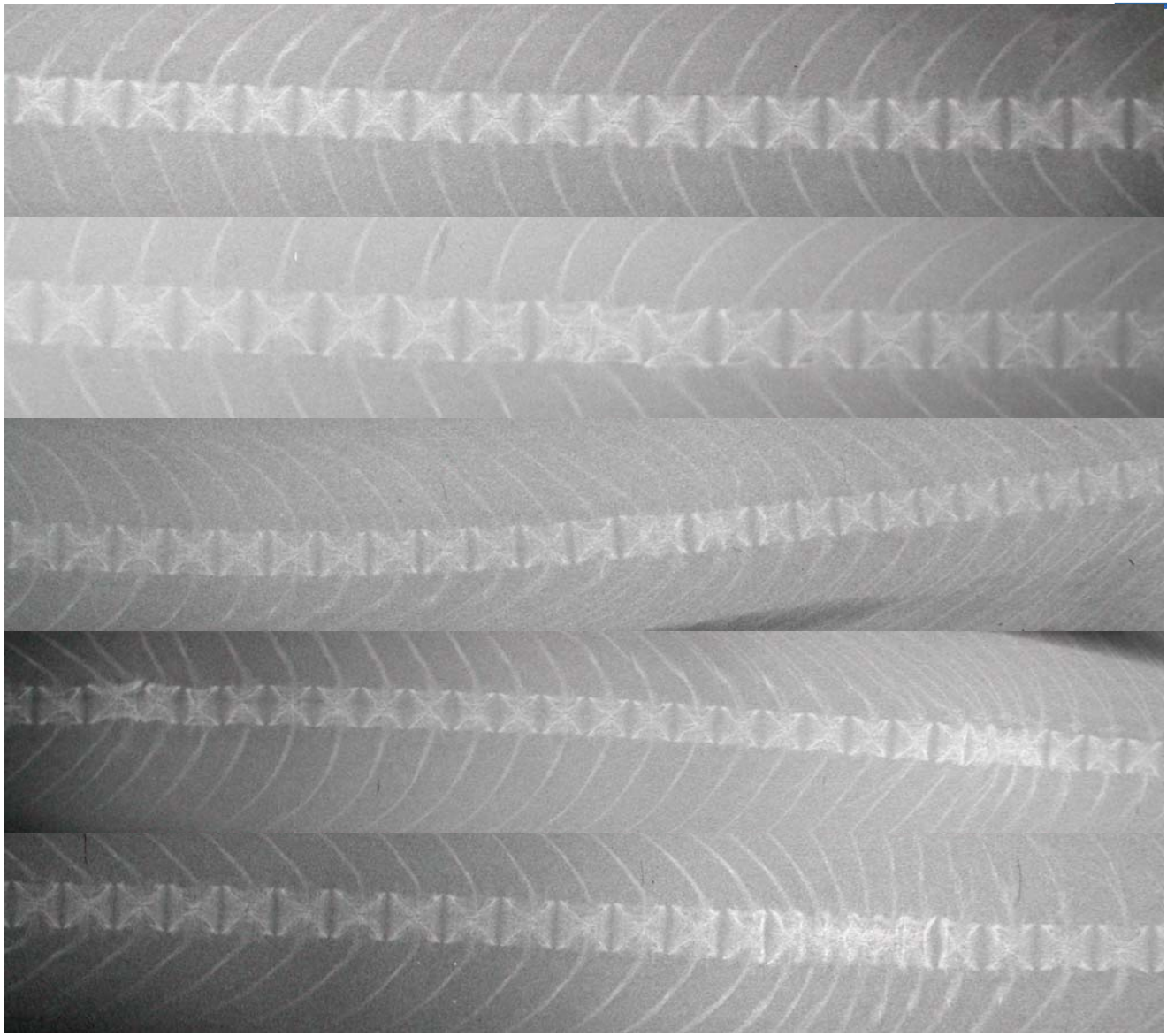
- **First period**

Inlet	Outlet
100	75
150	105
175	130

- **Second period**

Inlet	Outlet
100	85
170	125

Corresponding to O_2 saturation in tanks



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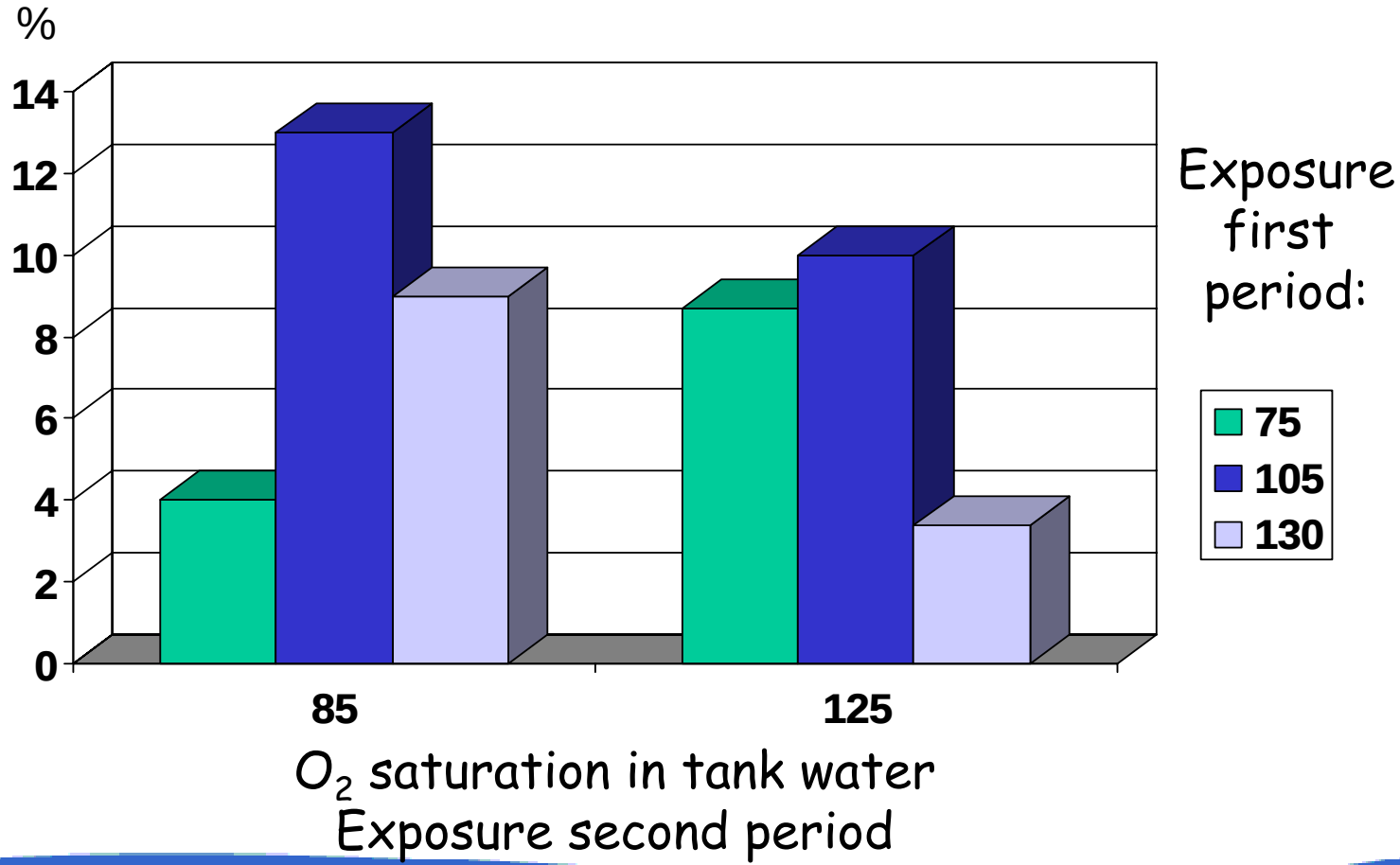
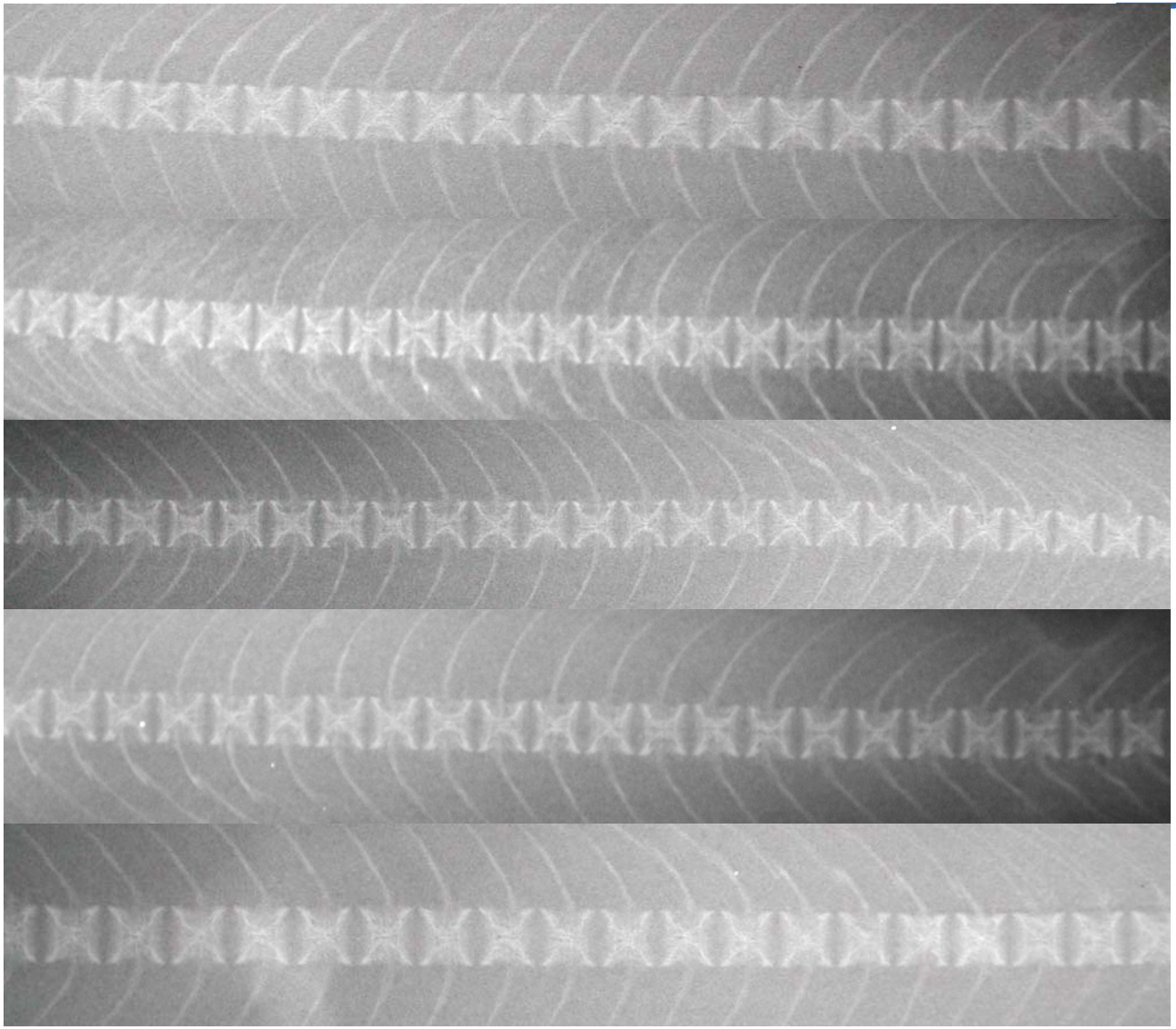
Vertebral pathology

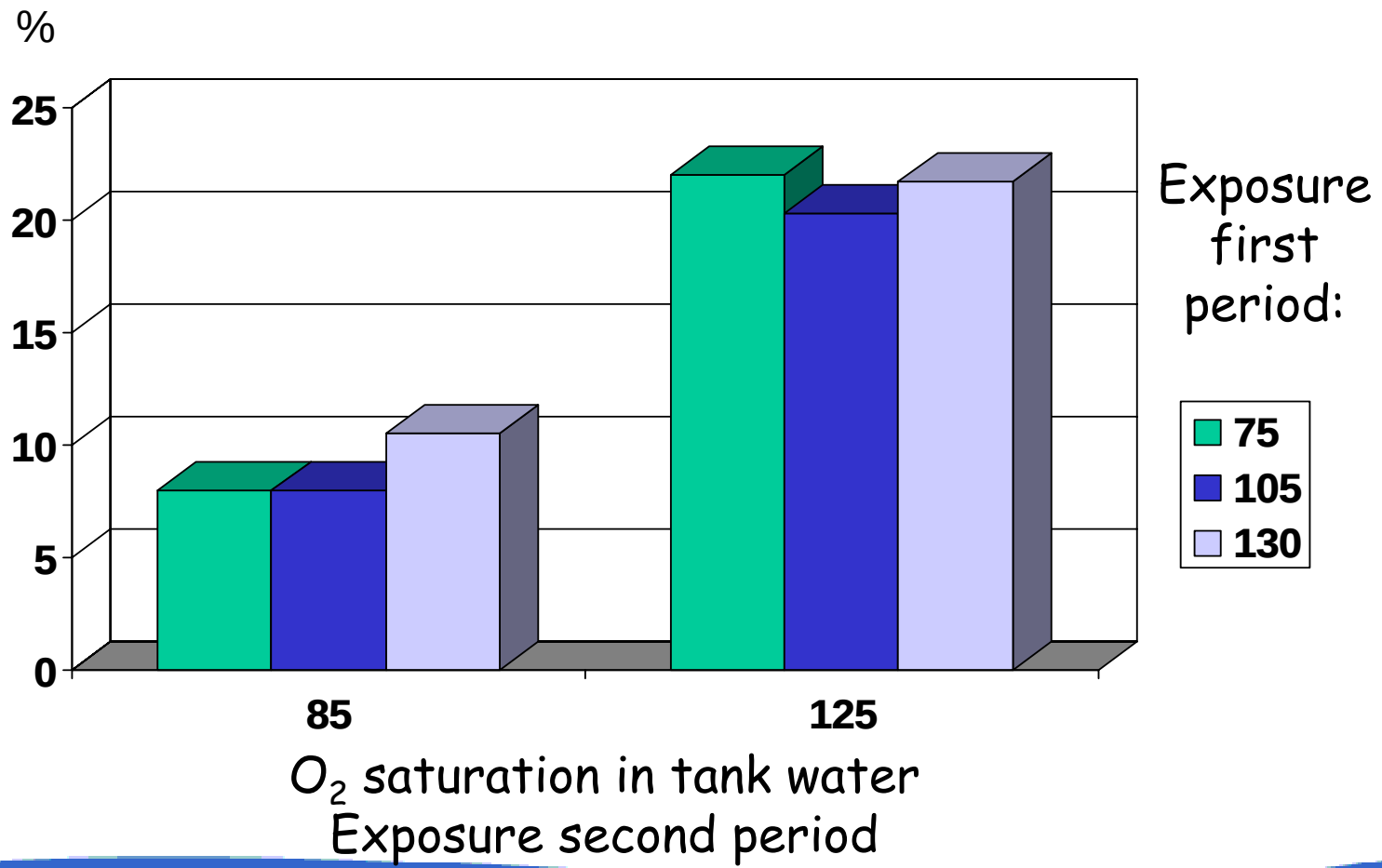
Effect of oxygen supersaturation prior to seawater transfer
Radiography after 16 weeks in seawater





"Irregular vertebrae"

Effect of oxygen supersaturation prior to seawater transfer
Radiography after 16 weeks in seawater



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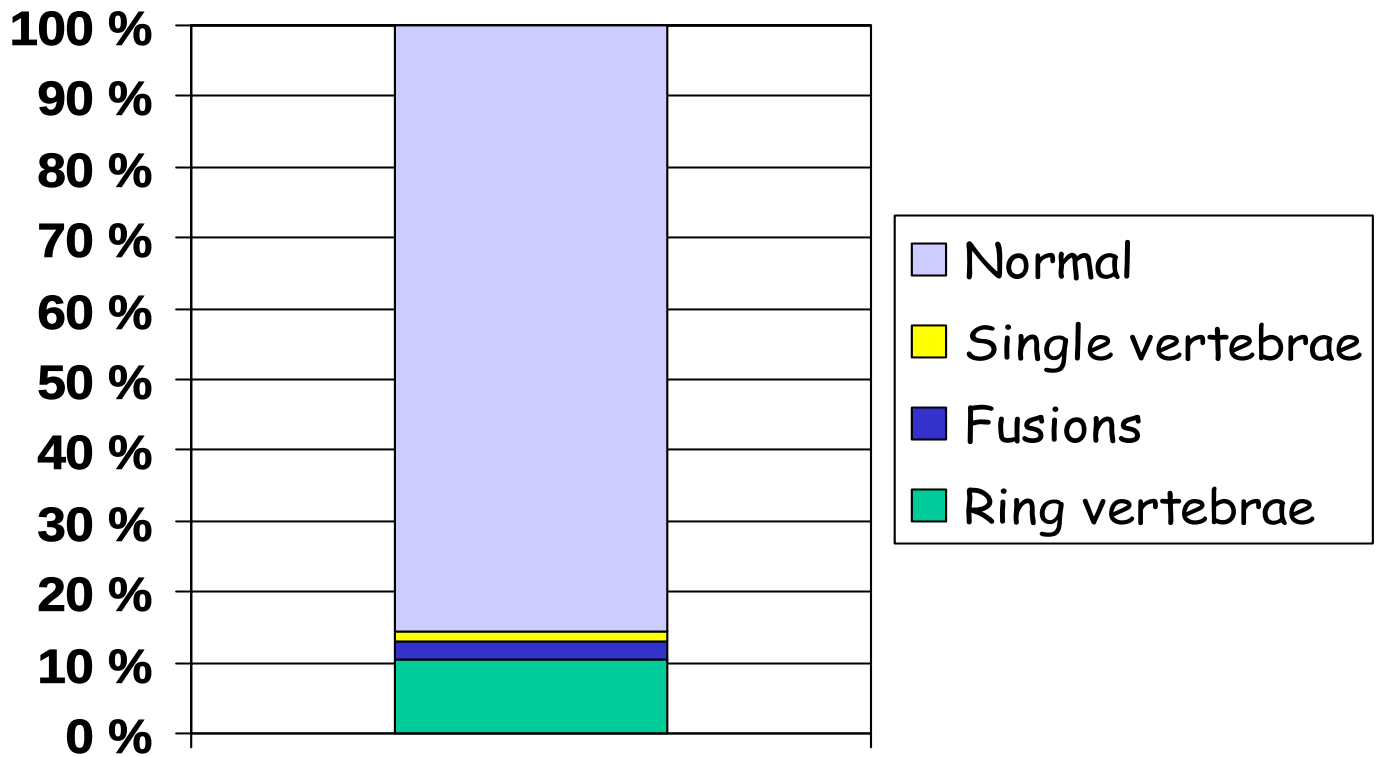
VK2004- Vannkvalitetsundersøkelsen 2004

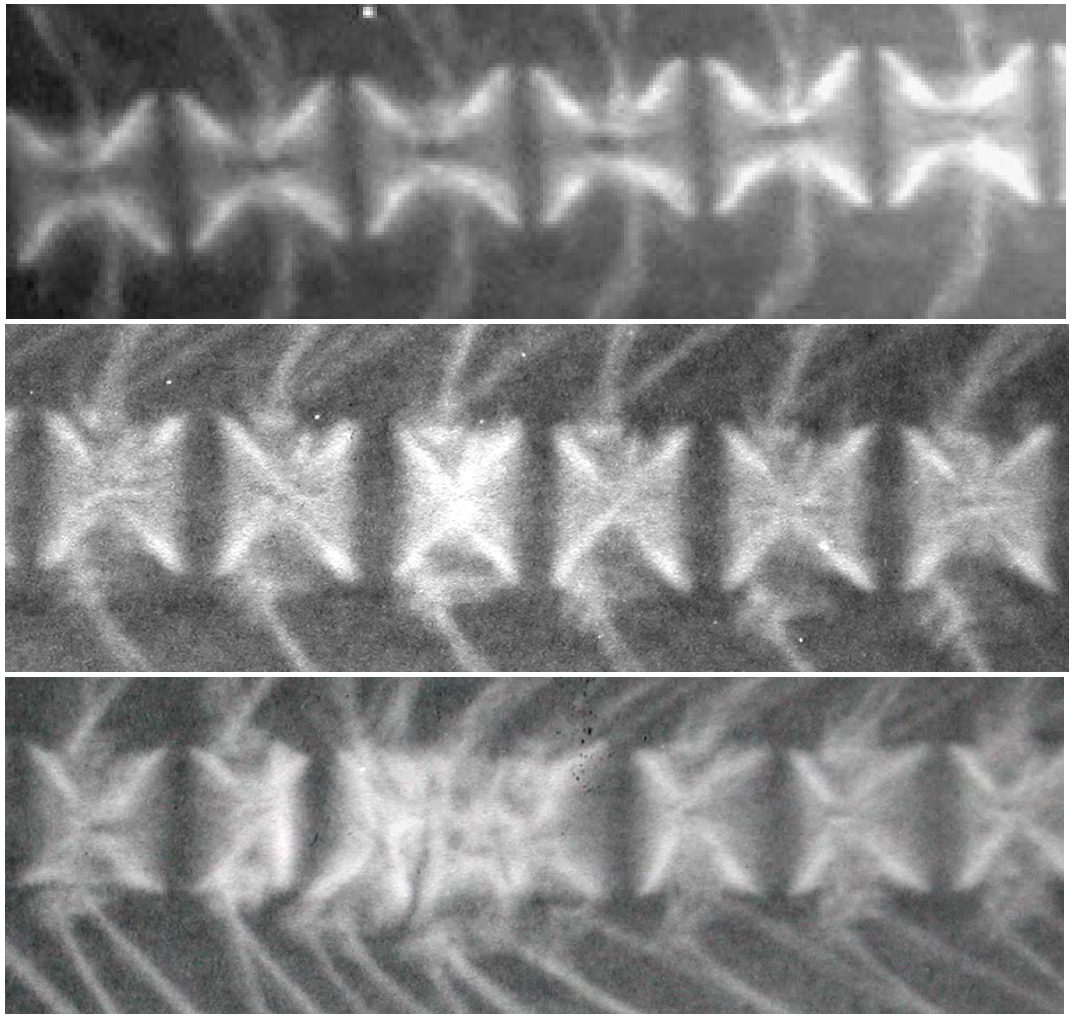
- Benchmarking program for water quality in Norwegian hatcheries
- Since 1999
- NIVA, UMB and AKVAFORSK (from 2004)
- Skeletal deformities (2004 >)
- Fish from 21 hatcheries
- 30 juveniles per hatchery
- Radiographic examination

VK2004

Different forms of vertebral pathology

All fish

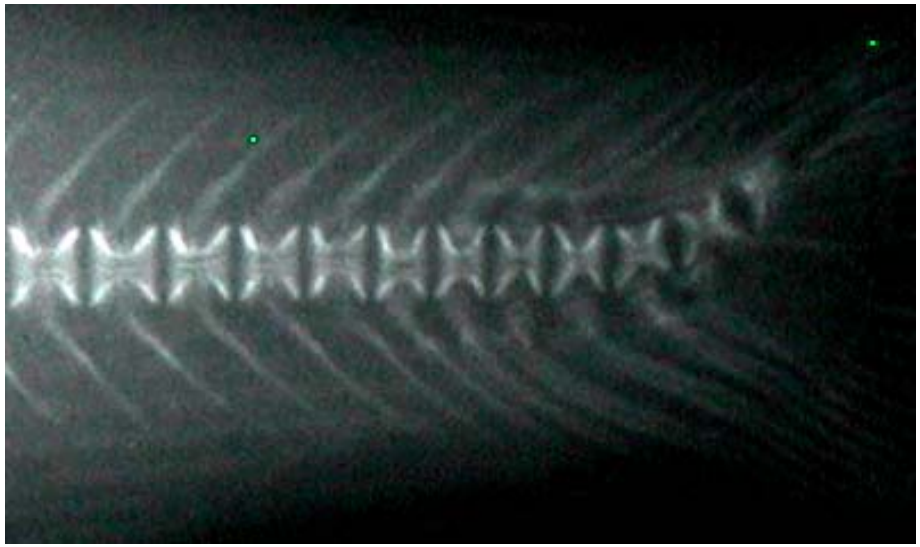




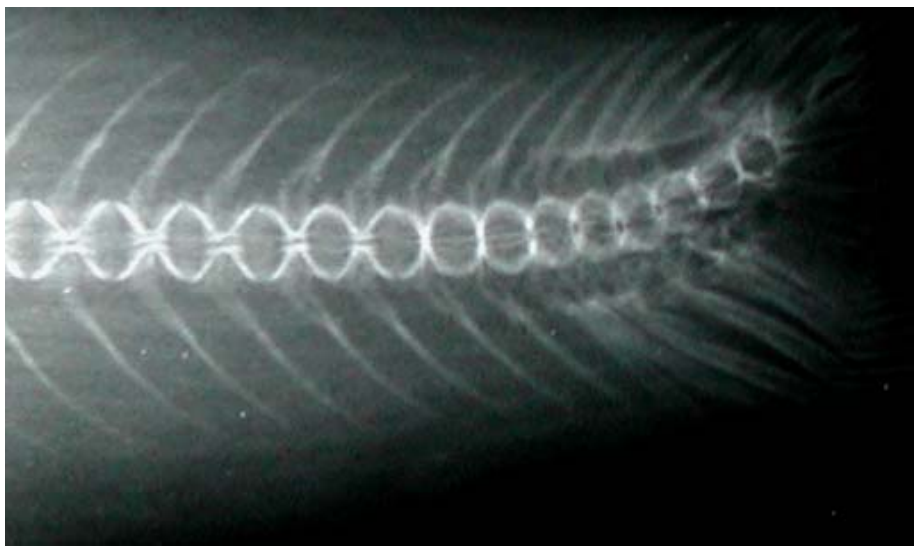
Normal vertebrae

Single deviant vertebrae, small and dense

Fusion



Normal
tail



”Ring vertebrae”

Summary, March 2005:

- Temperature is an important ethiological factor
  - In embryos
  - In juveniles
- Temperature induced changes continue to develop well into seawater rearing
- Dietary mineral supply may be a critical factor, especially when growth rates are high
- Water quality may have an impact, but the pathogenesis seems to be complex
- Vertebral deformities can be induced any time during freshwater rearing, most likely also in seawater