Effects of water salinity and exercise on Atlantic salmon performance as postsmolts in land-based closed-containment systems

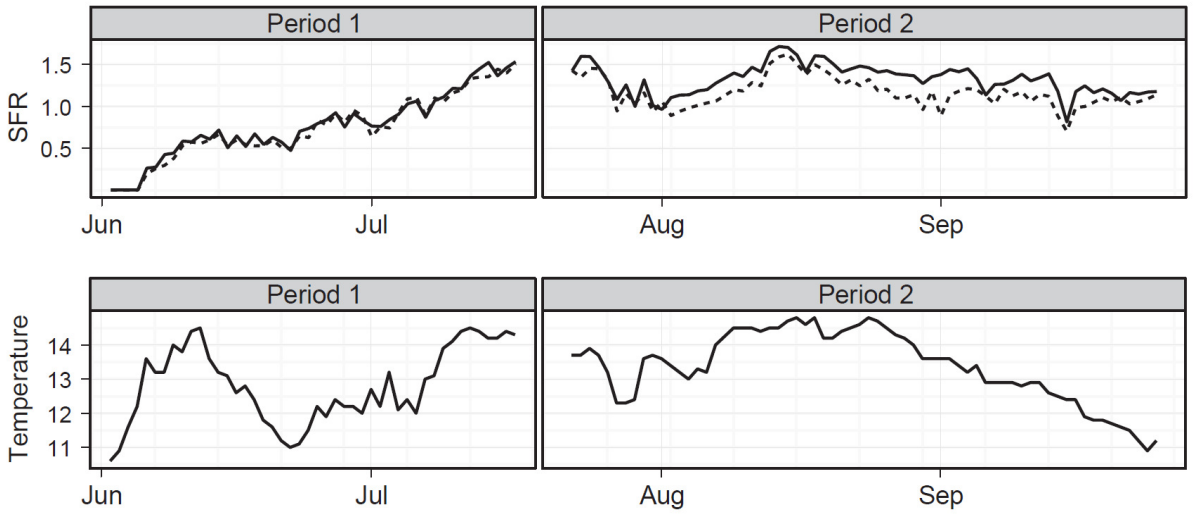
B.F. Terjesen[1*], T. Ytrestøyl[1], J. Kolarevic[1], S. Calabrese[2,3], B.O. Rosseland[4], H-C. Teien[4], Å. Åtland[5], T.O. Nilsen[2], S. Stefansson[2], S.O. Handeland[6], Jorn Schoordik[7], jH. Takle[1]

[1]Nofima, [2]Univ. of Bergen, [3]Marine Harvest Norway, [4]Norw. Univ. of Life Sciences; [5]NIVA; [6]UNI Research; [7]Hoogeschool Zeeland

Background

- Loss of fish in Norwegian production at same level now, ~20% during cage phase, as 12 years ago (Arealutvalget 04/02/11)
- Much of the loss of fish, and feed intake and growth reduction, occur early after stocking small smolts in sea (<100 g/ind) (e.g. Oehme et al., 2010)

Mass specific feeding rate of 1+ salmon (SFR, % day^{-1}) stocked at sea late May

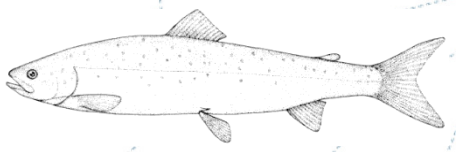


Oehme, M., Grammes, F., Takle, H., Zambonino-Infante, J.-L., Refstie, S., Thomassen, M.S., Rørvik, K.-A., Terjesen, B.F., 2010. Dietary supplementation of glutamate and arginine to Atlantic salmon (*Salmo salar* L.) increases growth during the first autumn in sea. Aquaculture. 310, 156-163

Background cont'd

- Lice problems are considerable in cage production
- One possible solution can be to reduce the time spent in traditional "open" cages in sea
- The Ministry of Fisheries and Coastal Affairs in Norway recently opened for an increase in fish size in land-based facilities, from 250 g to 1 kg
- A larger smolt for stocking at sea,
  - ✓ may reduce lice-problems,
  - ✓ may reduce loss of fish, and improve growth
  - ✓ may reduce prod. time, especially in areas with low winter temp
- Several Norwegian companies and R&D institutions joined forces in 2012 to explore how such post-smolt production can be done, in the RCN project OPP "**O**ptimized **P**ostsmolt **P**roduction"

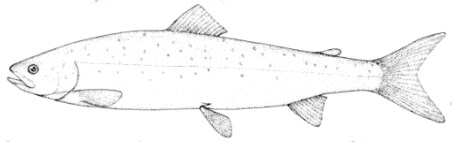
Aerial photo: Erik Røed



Nofima

Main objective in OPP

To develop basic and applied knowledge about how the time spent in open cages in sea can be reduced, by increasing the time on land or in semi-closed systems at sea, and to determine the consequences for the performance, physiology, and welfare of the fish and production costs

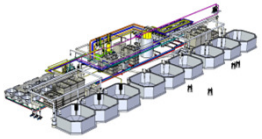


Combination-lines, to 1 kg in closed-containment systems

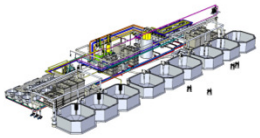
Closed-containment on land

Smolt prod in freshwater RAS land-based → **Postsmolt in seawater? RAS land-based** → **Shorter period in cages before slaughter**

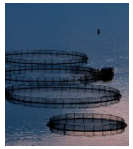
0-70 g



70 g – 1 kg



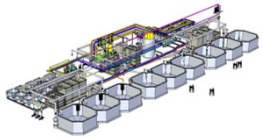
1 kg – 5 kg



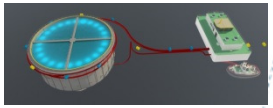
Semi-closed containment in sea

Smolt prod in freshwater RAS land-based → **Postsmolts in semi-closed containment in sea** → **Shorter period in cages before slaughter**

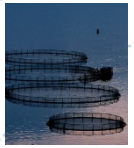
0-70 g



70 g – 1 kg



1 kg – 5 kg



OPP: Problems to tackle

- **Problem**: Cato Lyngøy, former Group Technical Manager Technology & Environment Marine Harvest, and chairman in OPP:

  «So far we have not seen any closed-containment system that is sufficiently cost-effective, for production of a postsmolt up to 1 kg, neither on land or in sea»
  (IntraFish, 29/10/12)

- **Problem**: Insufficient biological knowledge of what the physiological requirements of Atlantic salmon postsmolts are in closed containment systems, for optimal **technology performance**, **fish performance**, **welfare, and health**

To be tested in OPP: Land-based RAS (recirculating aquaculture systems) for production to 1 kg

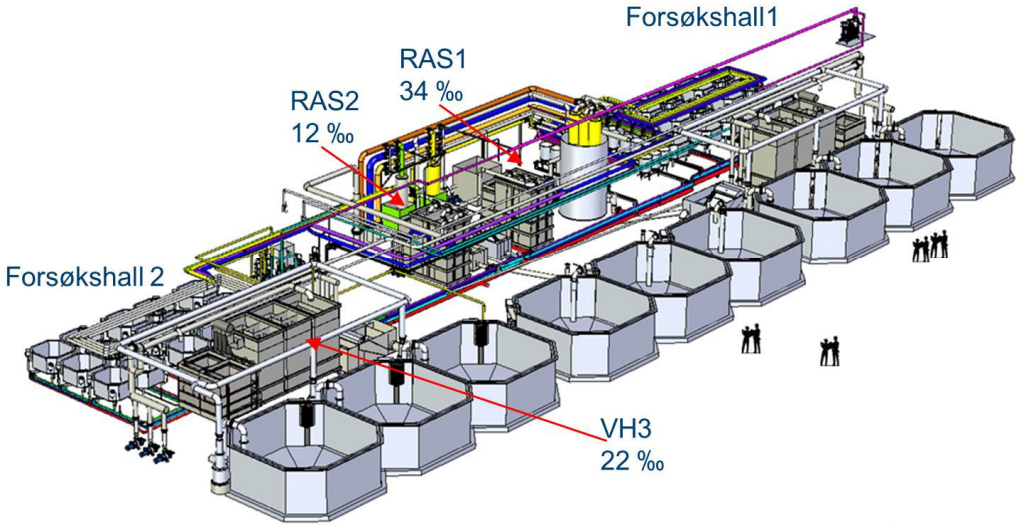
Nofima Centre for Recirculation in Aquaculture, Sunndalsøra, Norway

To be tested in OPP: Production in semi-closed containment systems in sea to 1 kg (21 000 m^3 vol, 450 m^3/min flow)

Photo: Aquafarm Equipment

Salinity in land-based RAS, combination-line

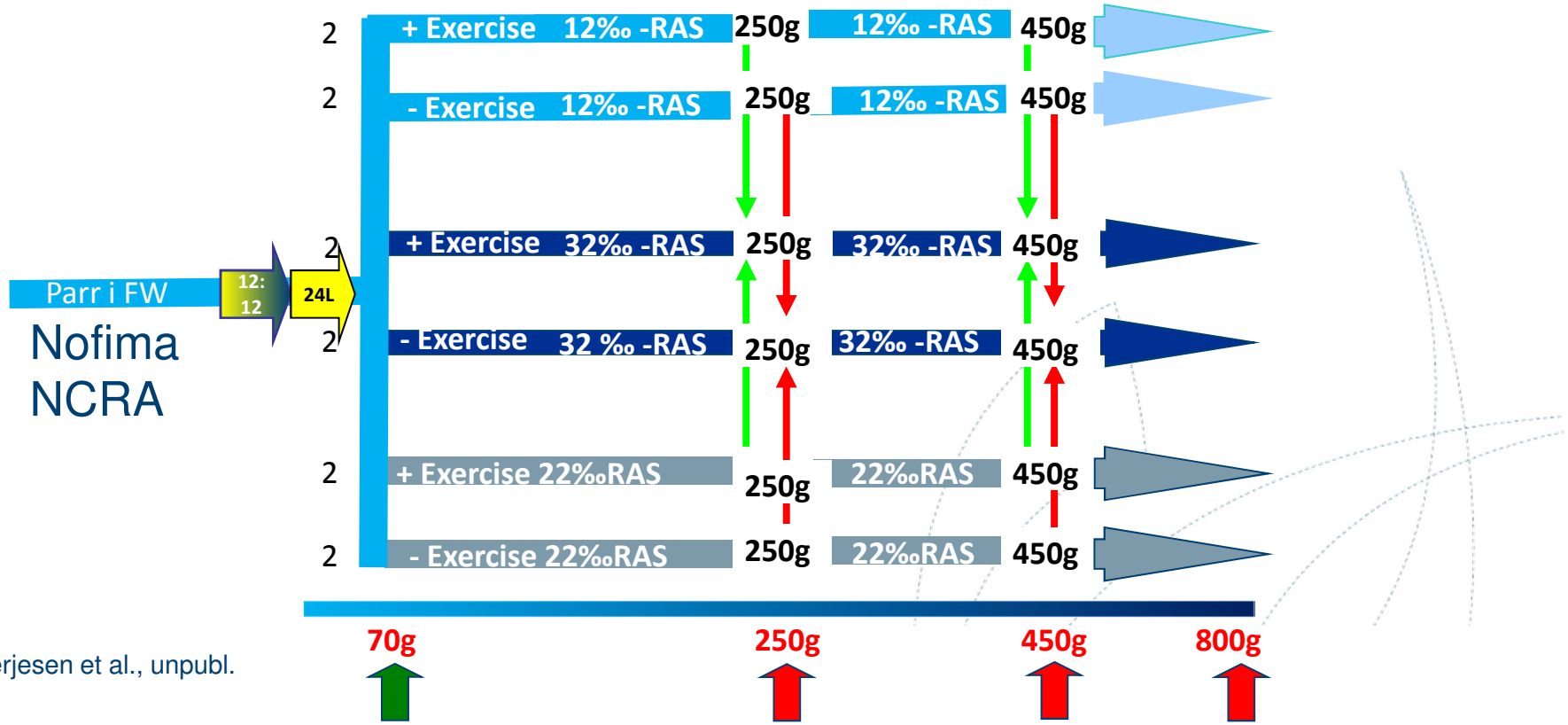
- SW-RAS may have higher running costs than FW-RAS due to:
  - ✓ CO_2 removal efficiencies are lower in SW than in FW
    (e.g. Moran, 2010)
  - ✓ Ammonia removal is lower in SW compared to FW
    (e.g. Chen et al, 2006)
- Results in need for larger installation and/or higher flow
- **Or can postsmolts be kept at lower salinity in RAS, and still handle full-strength SW at stocking in sea?**



Nofima Centre for Recirculation in Aquaculture (NCRA), Sunndalsøra, Norway

Objectives and experimental design, effects of salinity and exercise for postsmolt in RAS

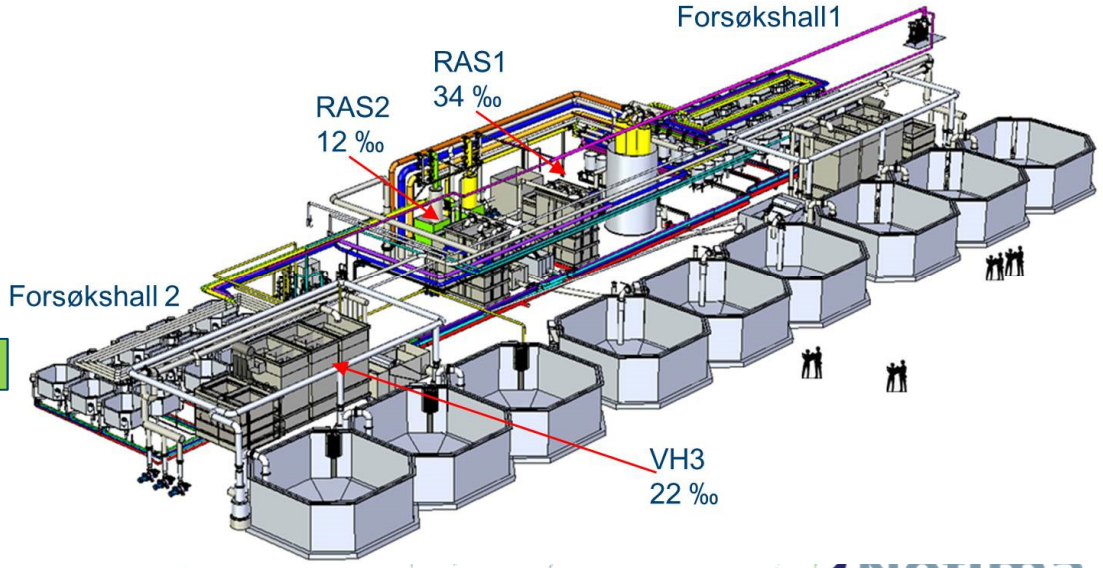
- ✓ What is optimal salinity for postsmolts in RAS, in terms of survival, health, and maturation to 1 kg size?
- ✓ Can lower salinity reduce maintenance costs and increase available energy for growth?
- ✓ Can exercise through water velocity contribute to these factors, and interact with salinity treatment?



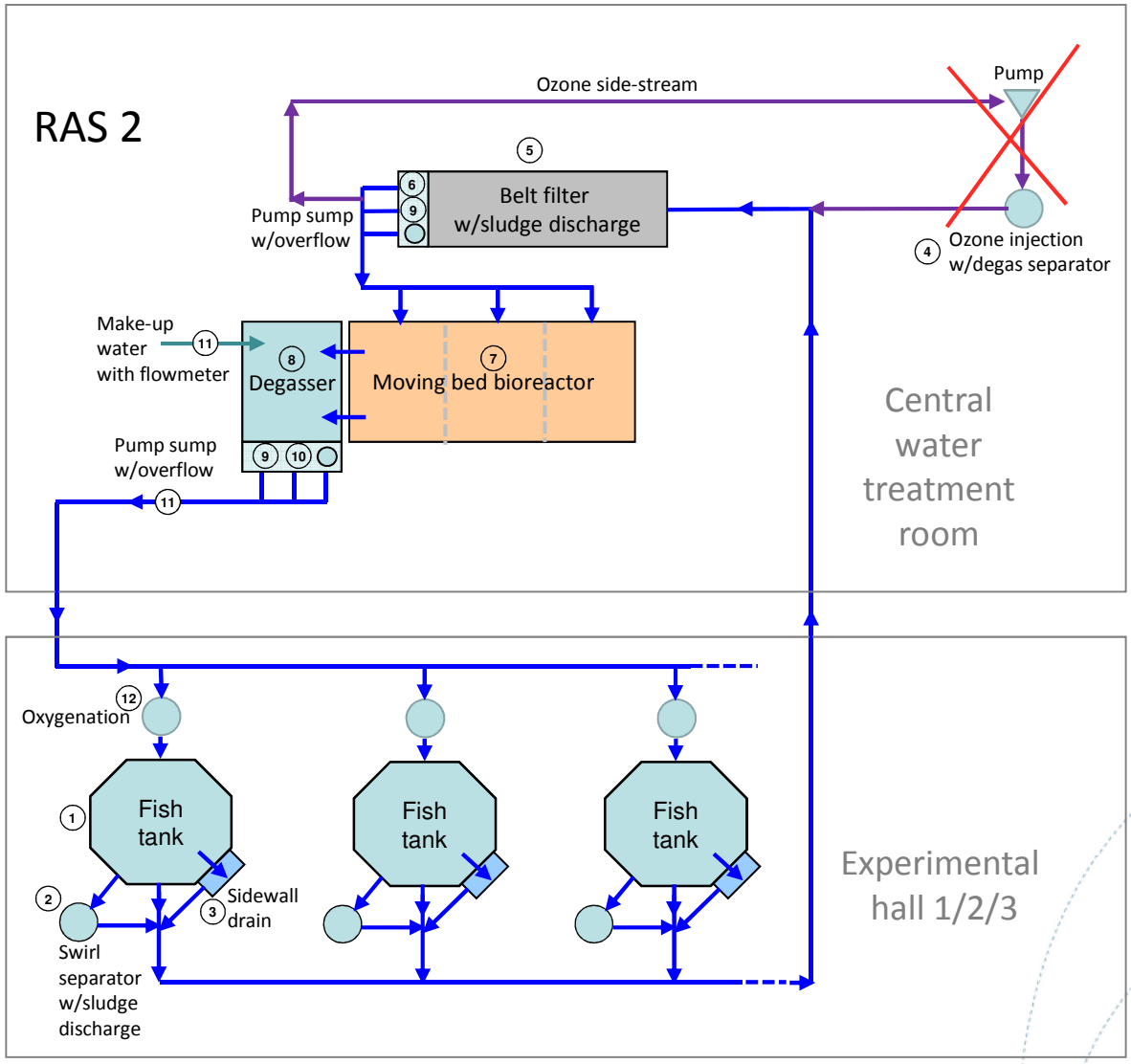
Terjesen et al., unpubl.

Methods

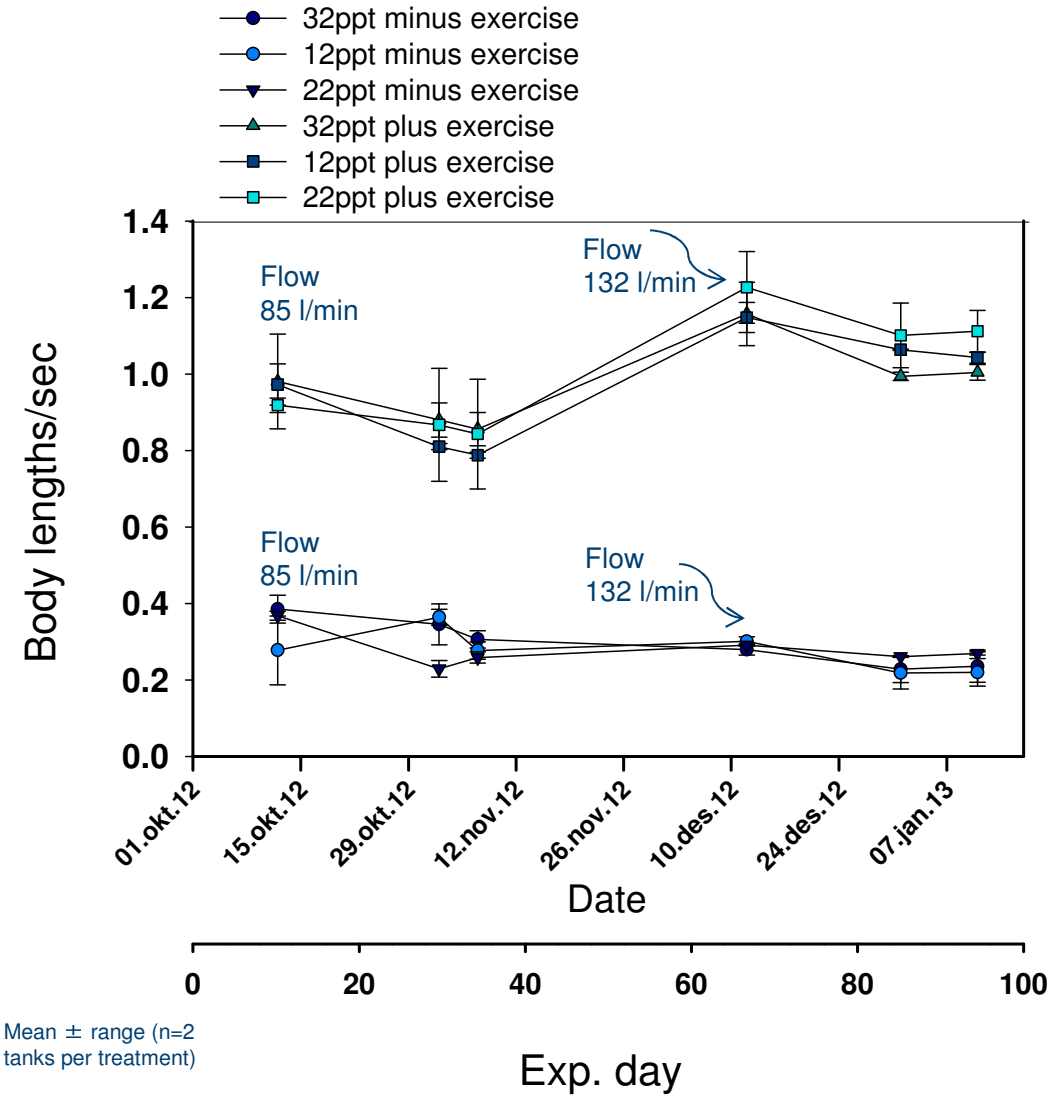
- 3 separate RAS with salinities 12, 22 and 32 ppt, and two exercise levels, i.e. a 3x2 factorial study
- 7 200, 70 g smolts were stocked in 12 tanks (3.2 m^2), duplicate/treatment
- 12:12h light:dark during the experiment, 12-13° C, high marine protein commercial diet (Havsbrun, 3-4 mm pellet), feed intake measurements
- On-line measurements of e.g flow, pH, ORP, temperature, O_2
- A range of tissue samples collected, for trad. physiology, histology, and molecular physiology



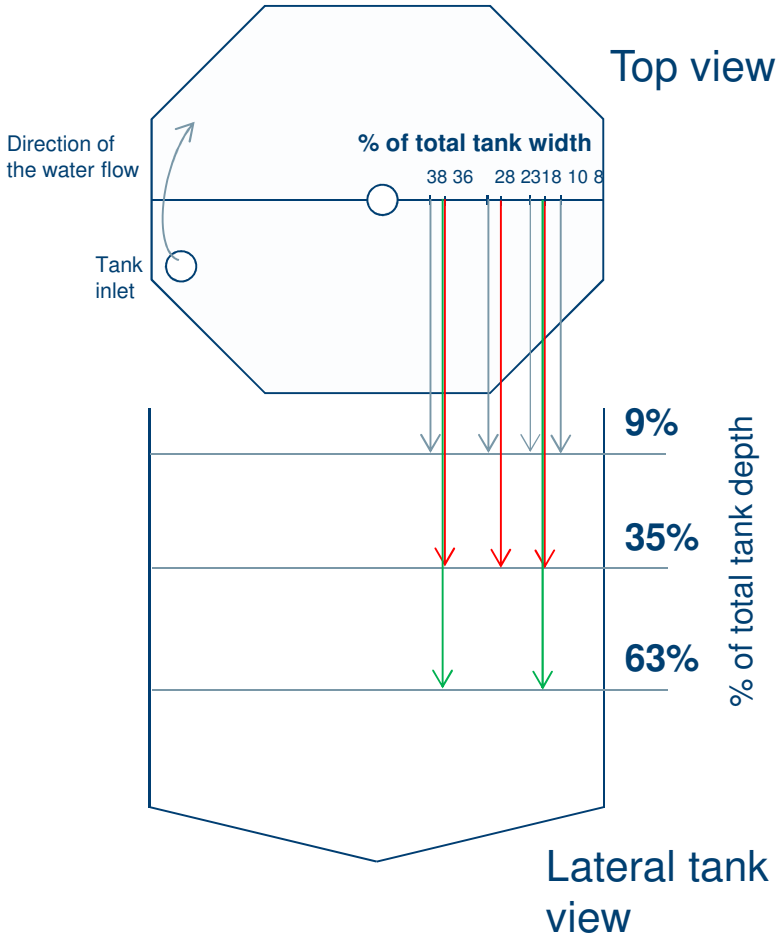
RAS configuration during trial



Swimming speed (BL/s) to ~250 g



Mean ± range (n=2 tanks per treatment)

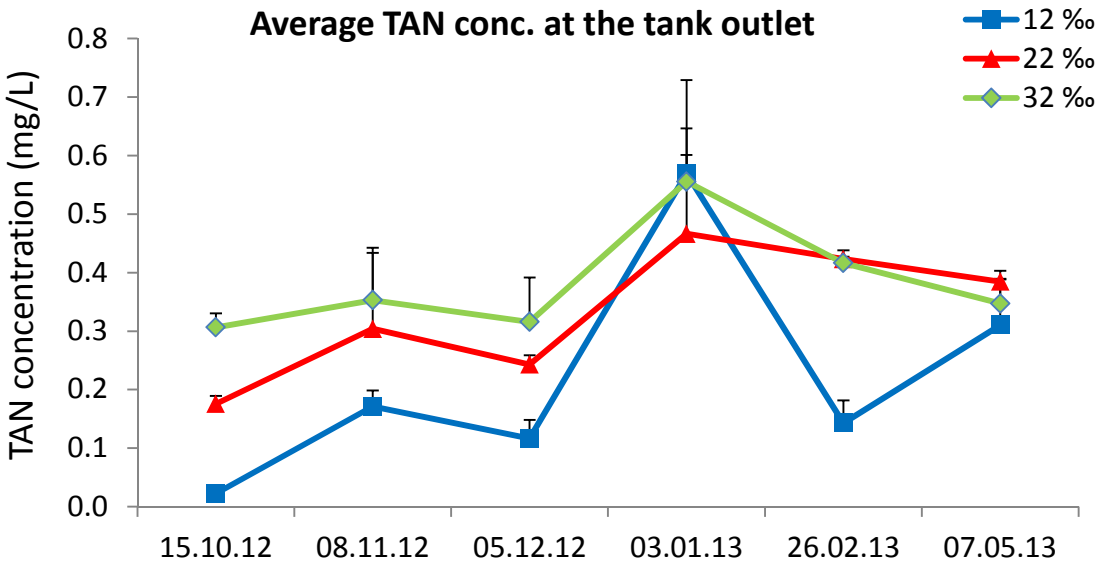


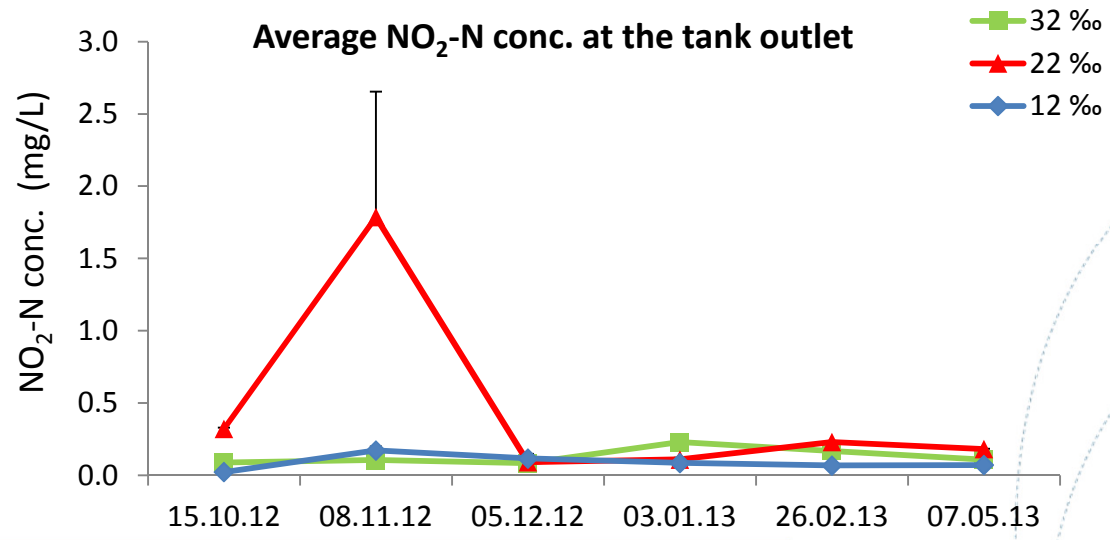
RAS conditions

RAS	Temp ℃	pH	CO_2 mg/l	Alkalinity $CaCO_3$ mg/l	% Reused flow	% Water exchange /day	Feedload , % of capacity	Feedload/ water exh (kg/m^3 /day)
12‰	12.4±0.9	7.5±0.2	6.1±1.5	72±20	98.7±0.8	25±7	11.0±3.4	0.44±0.30
22‰	12.1±0.8	7.6±0.1	7.0±0.2	110±26	98.8±0.7	24±6	10.6±3.9	0.49±0.28
32‰	12.6±0.9	7.8±0.1	6.9±0.4	137±33	98.9±0.4	25±2	9.1±3.9	0.46±0.20

Nofima

Water quality: TAN and NO_2-N concentration

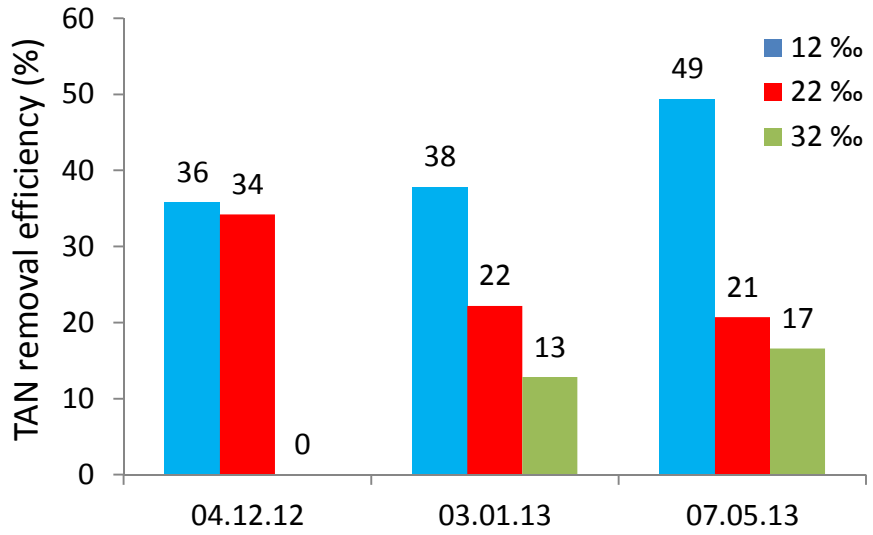


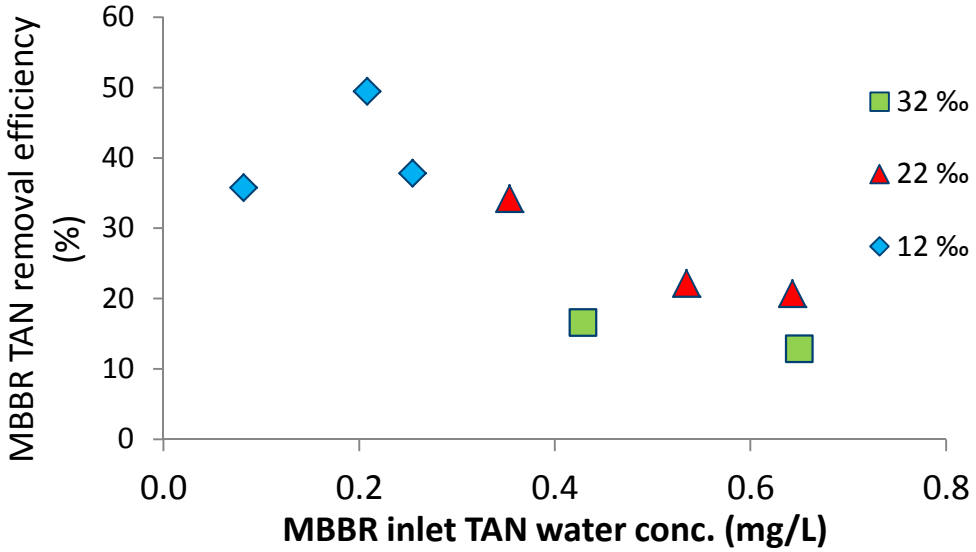


Terjesen et al., unpubl.

Nofima

TAN removal efficiency over MBBR

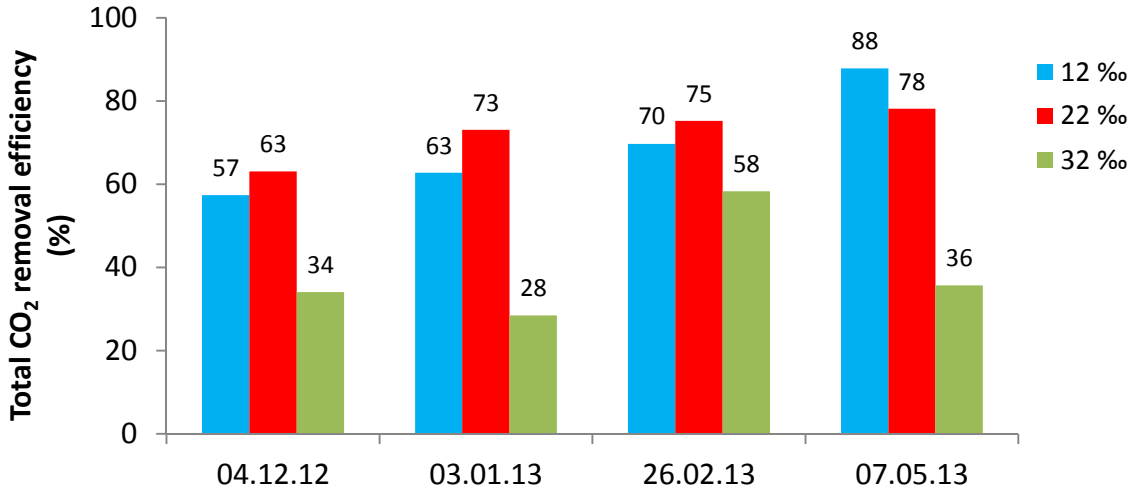


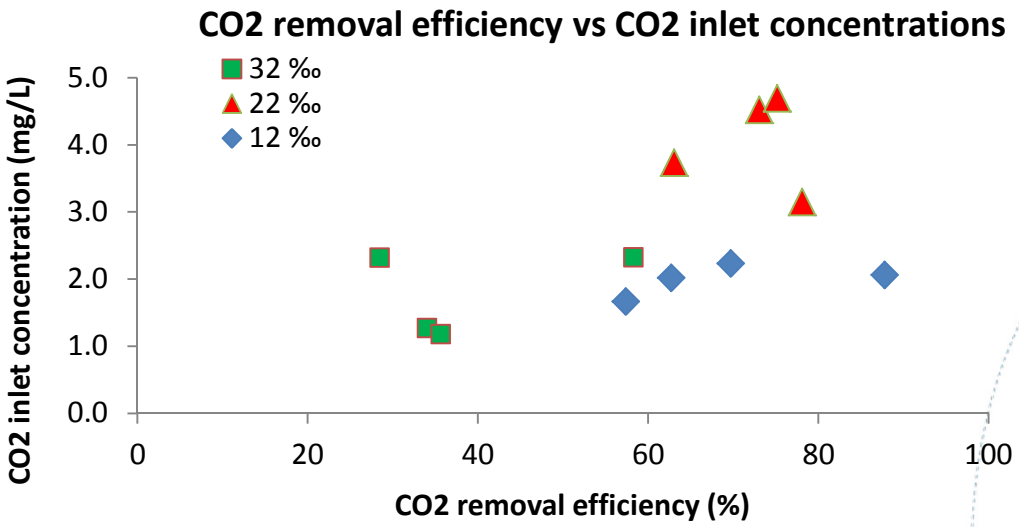


Terjesen et al., unpubl.

Nofima

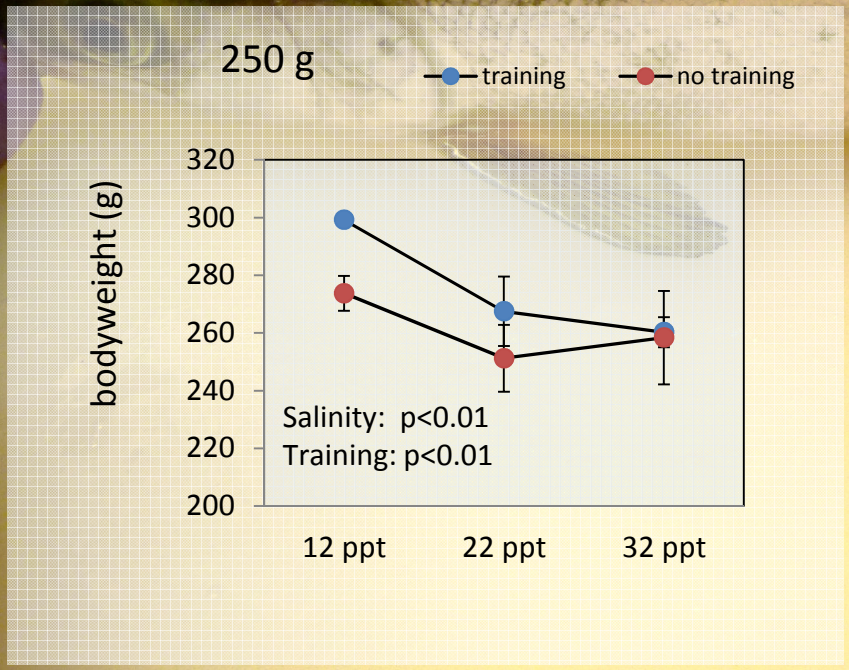
CO_2 removal efficiency over countercurrent, forced-ventilated degasser



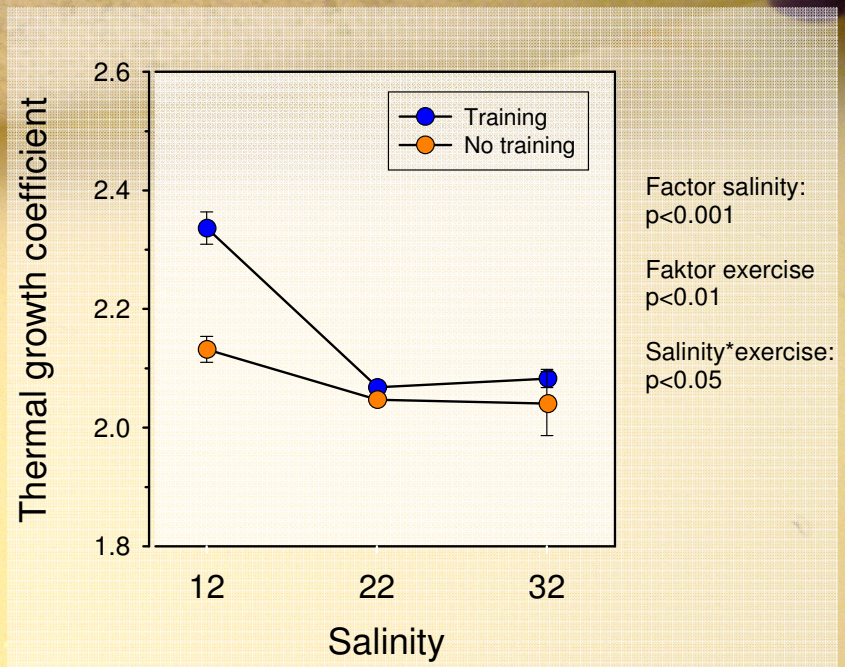


Postmolt sampled at ~250 g, produced in 12 ppt S RAS

Ind. weight at ~250 g/ind



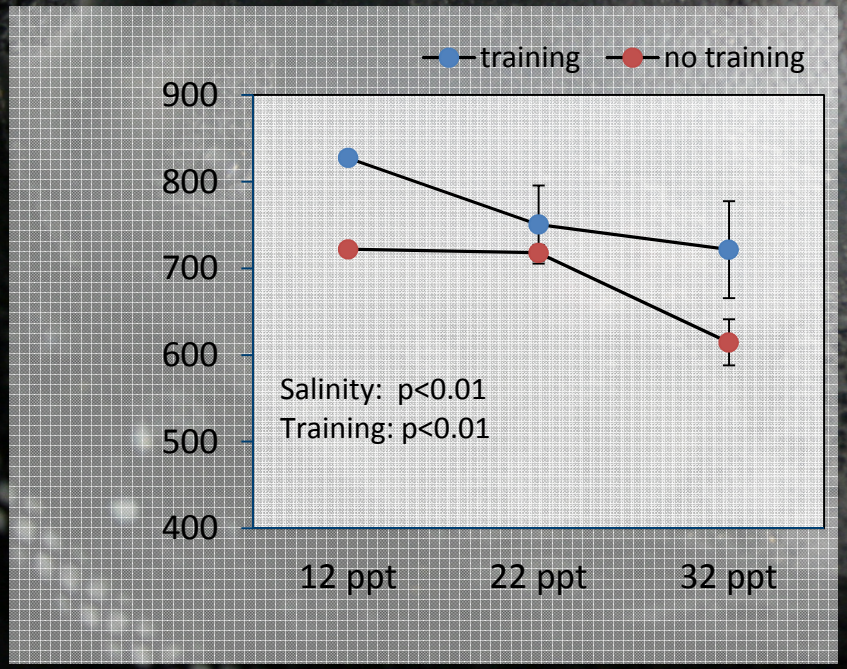
TGC to~250 g/ind



Terjesen et al., unpubl.

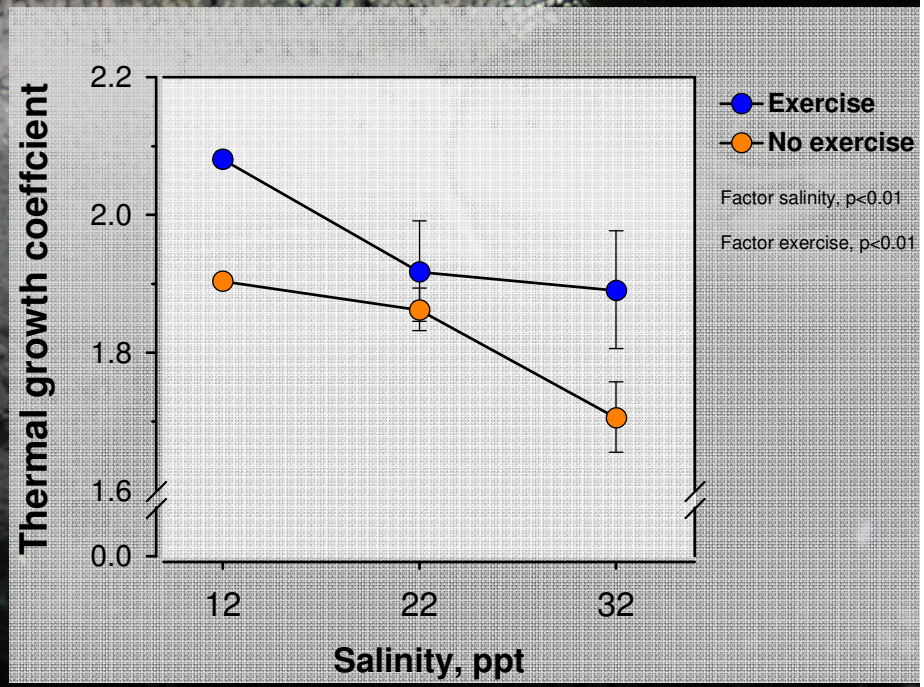
Postmolts sampled at ~800 g, produced in RAS

Final weight



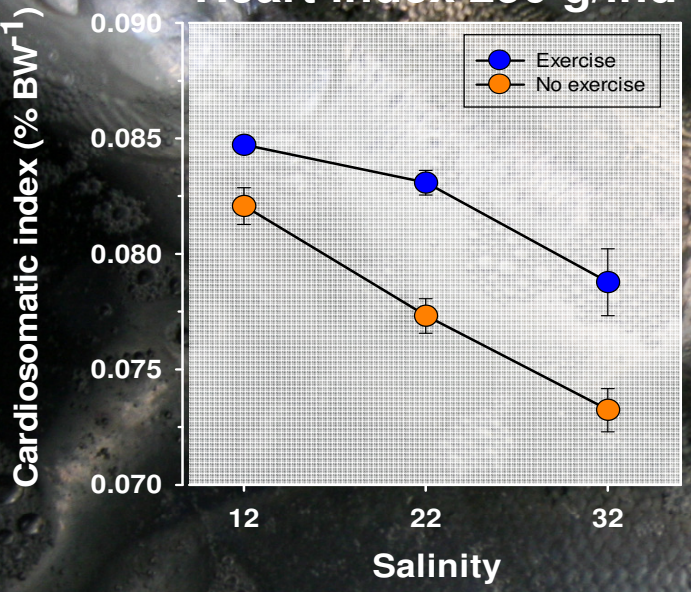
Terjesen et al., unpubl.

TGC entire experiment



Results: Organ indexes at 250 and 800 g

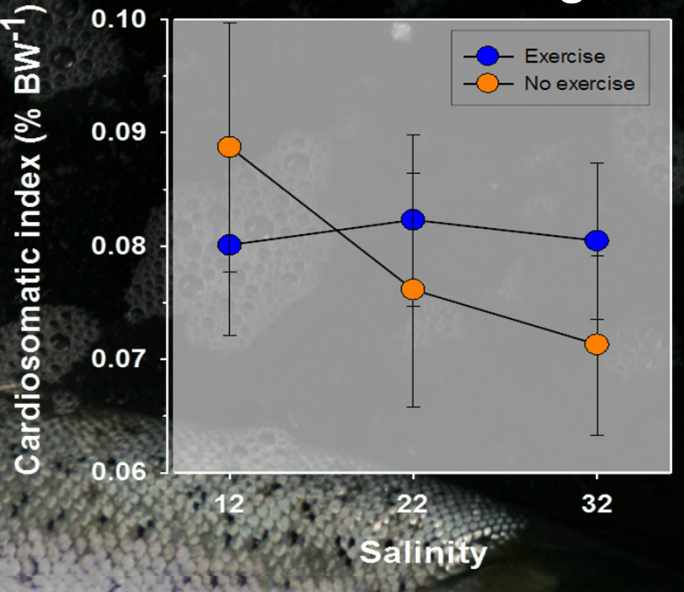
Heart index 250 g/ind



Faktor salinitet: p<0.001

Faktor trening: p<0.001

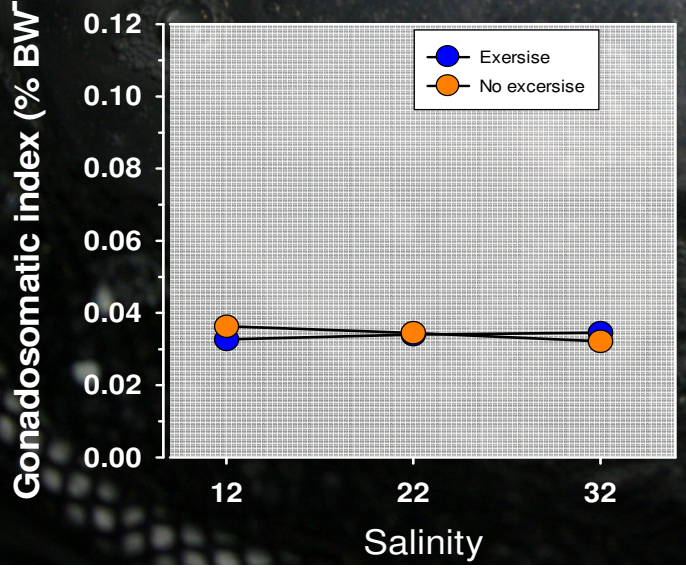
Heart index 800 g/ind



Factor salinity: p<0.025

Factor exercise: NS

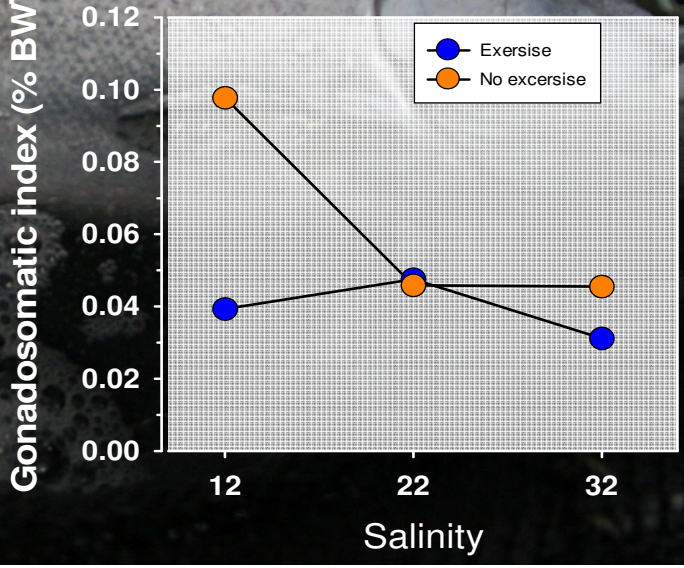
Male gonad size 250 g/ind



Faktor salinitet: NS

Faktor trening: NS

Male gonad size 800 g/ind



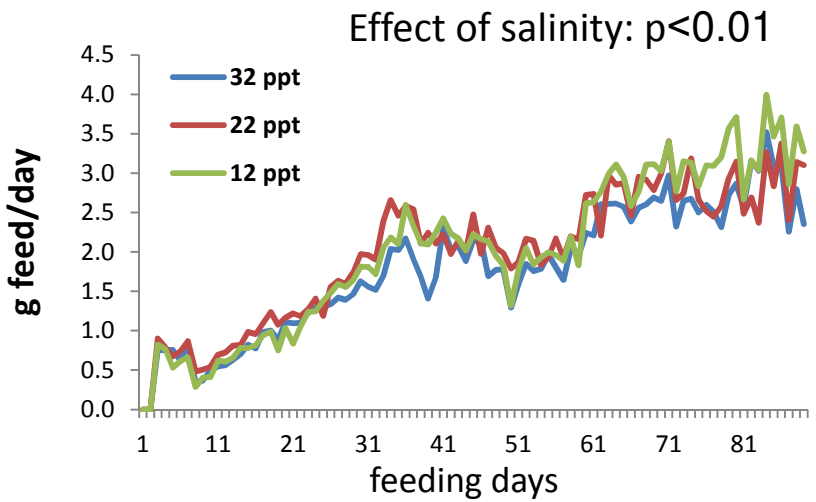
Faktor salin NS

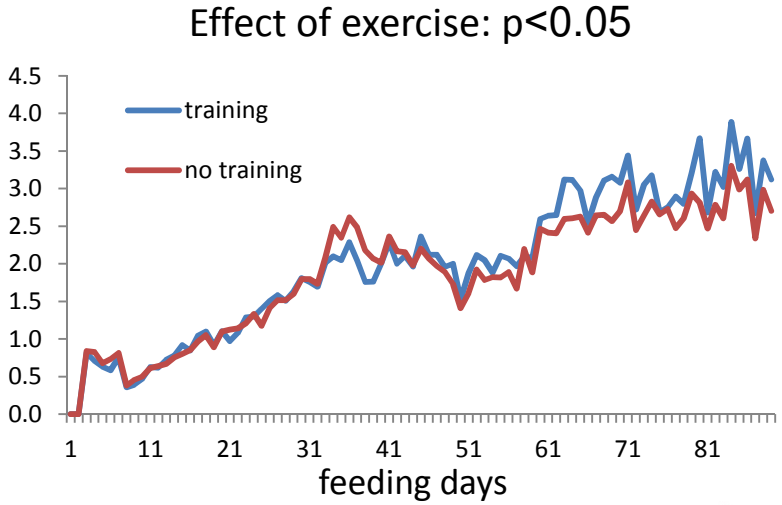
Faktor treni NS

Terjesen et al., unpubl.

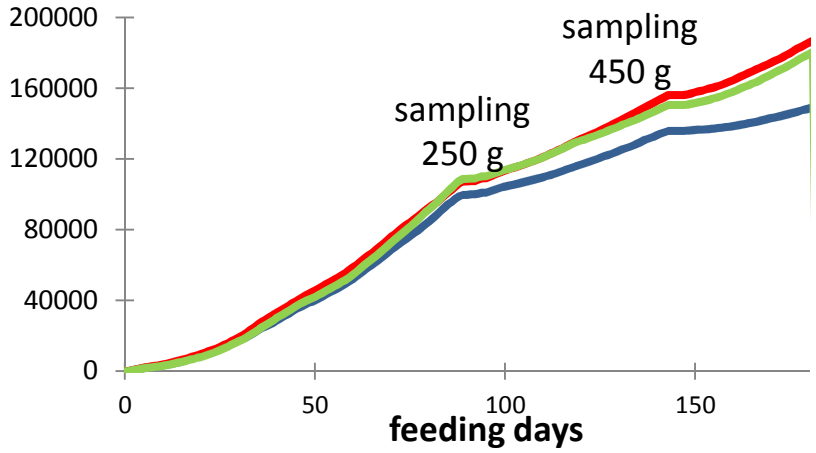
Why is growth higher at lower salinity and training?

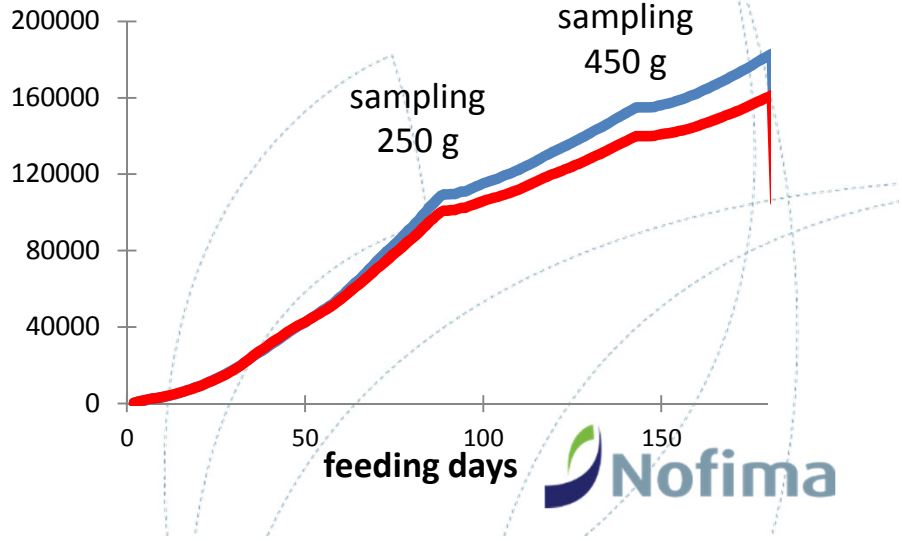
Individual feed intake period 1 (BW 70-250 g)



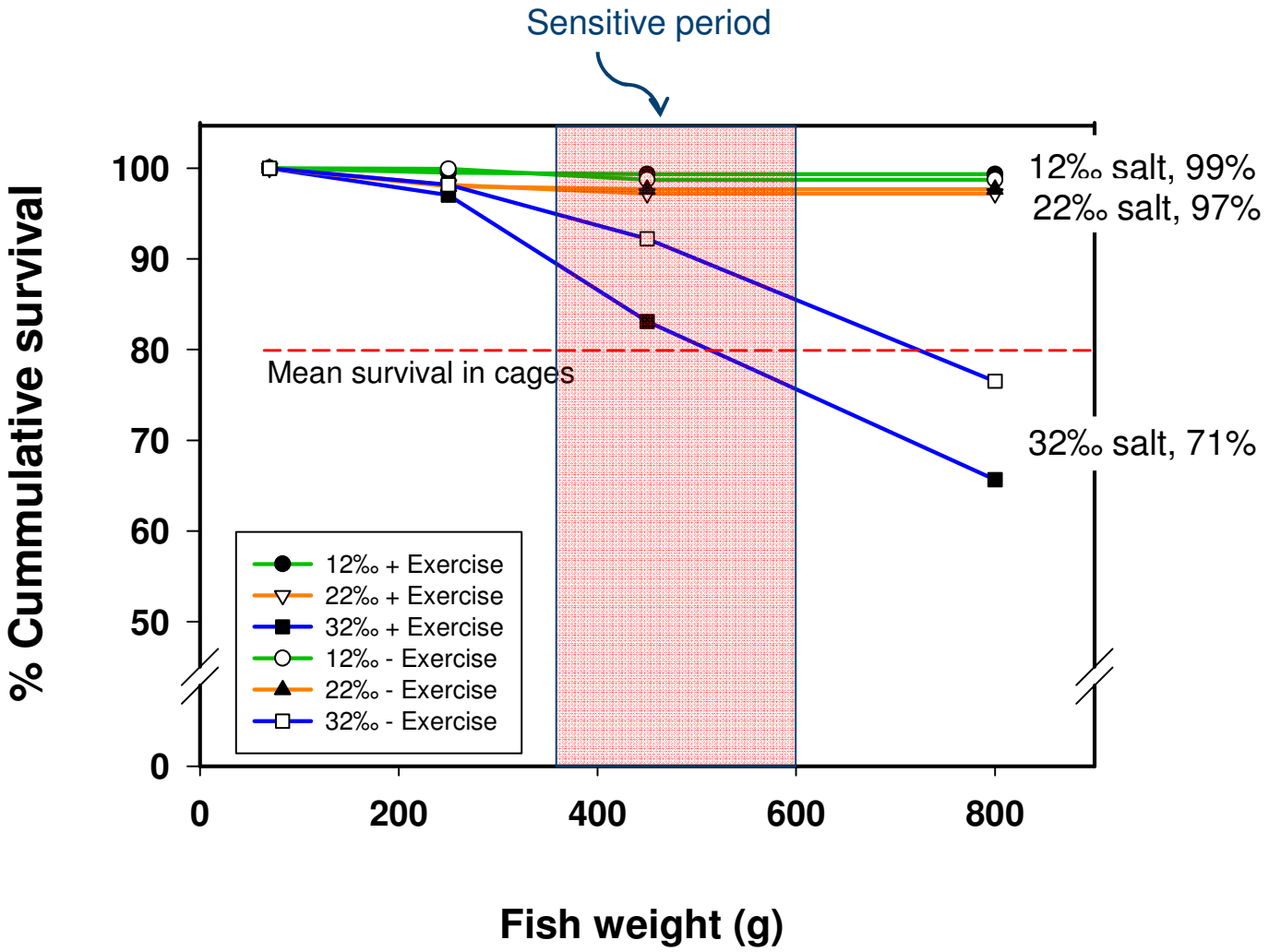


Cumulative feed intake g per tank period 1-3

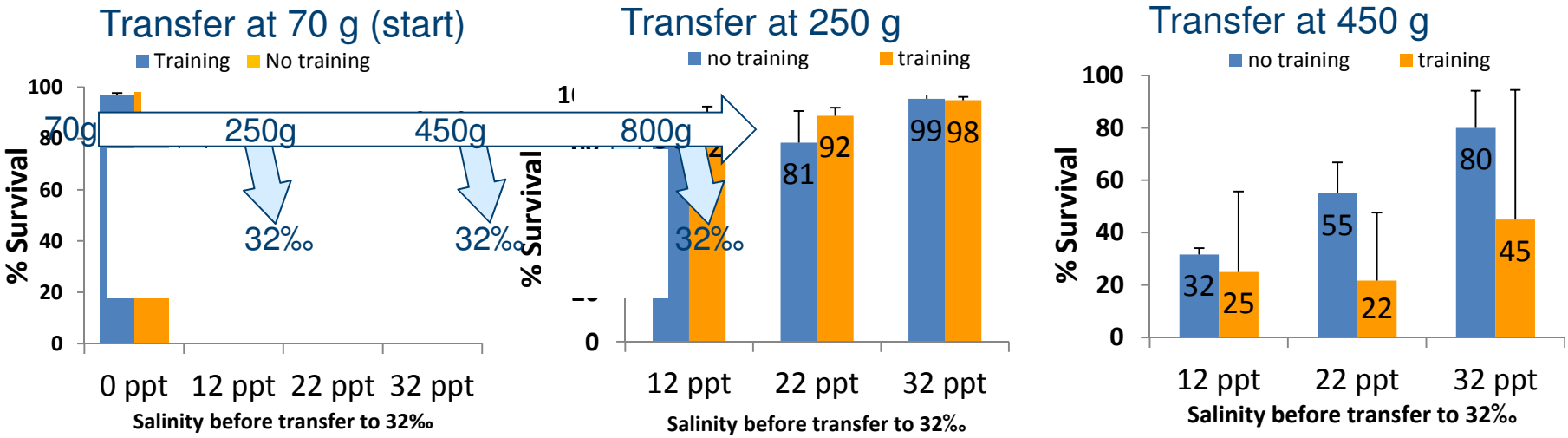




Survival, when the postsmolts were kept at 12, 22, or 32 ‰, through the entire trial

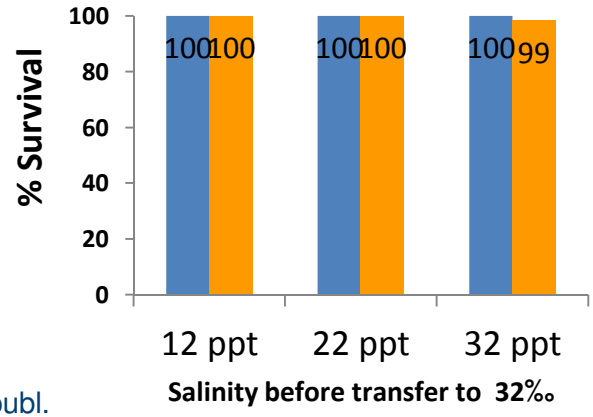


Survival when transfer from 0 ppt (start) or 12/22/32‰ to 32‰ at different sizes

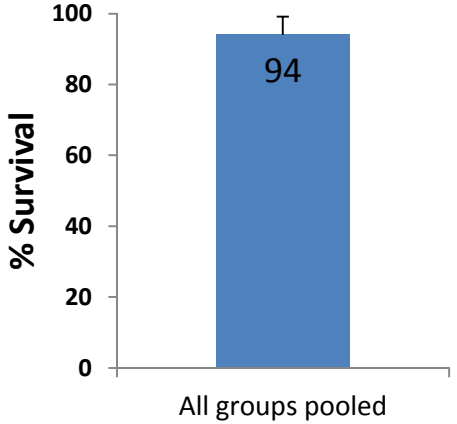


At end of trial ~800 g

Change to 32‰ directly in existing12 tanks

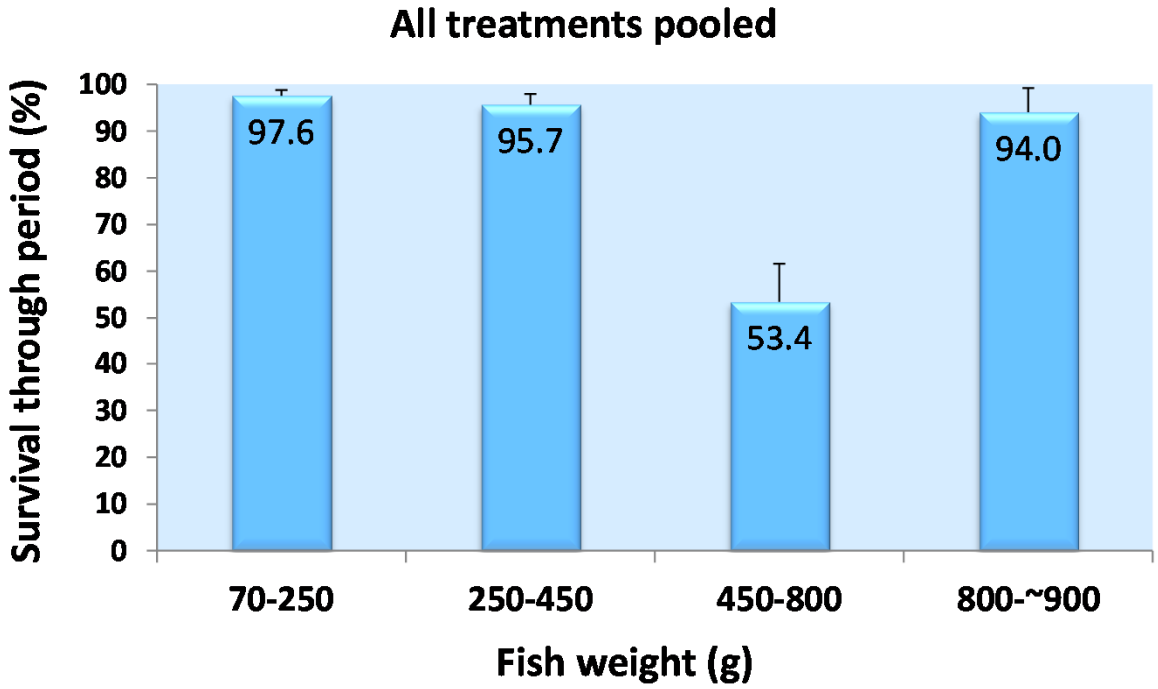


All groups pooled, transferred to 12 new tanks, 32‰ FT

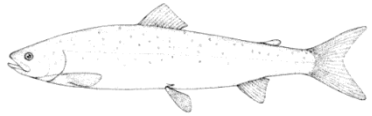


Terjesen et al., unpubl.

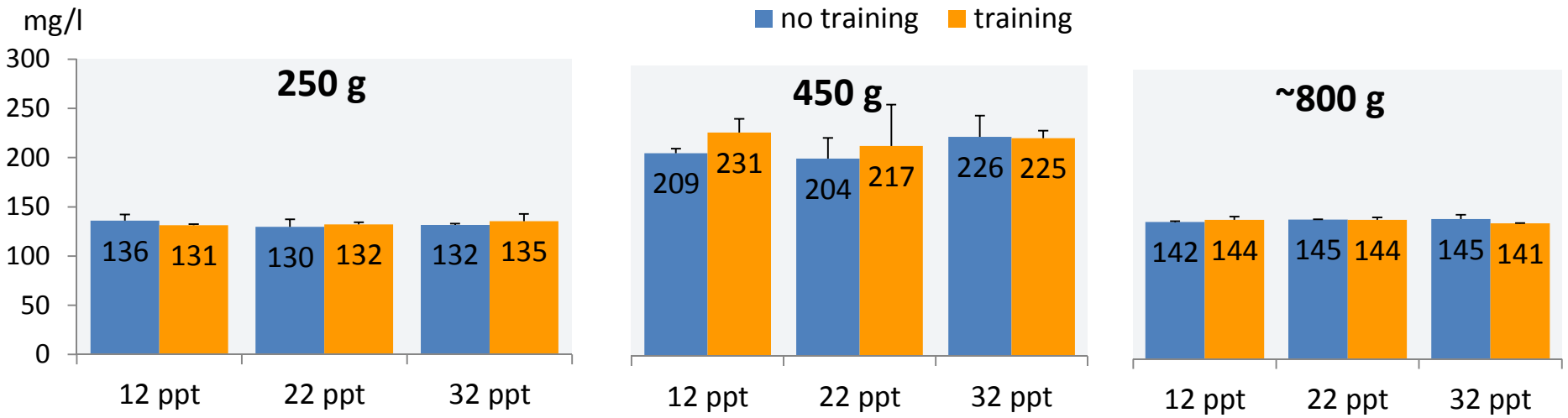
Summary survival, when the fish is transferred to 32‰ at different sizes



Sea water tolerance when transferred to 32-34 ‰, for 72 hours, at different sizes



Plasma chloride

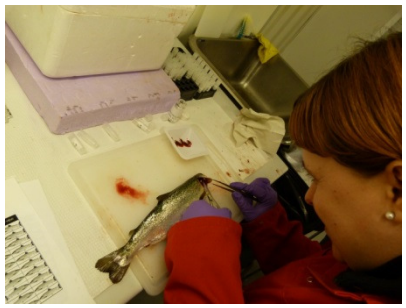


No significant effects of treatment (previous salinity or exercise)

Nofima

Welfare

- **External welfare indcators:**
  - ✓ In our experience a set of sensitive indicators (e.g. density)
  - ✓ Small, inconsistent effects on fin erosions
  - ✓ Earlier manifestation of cataracts in fish kept at 32‰ RAS, versus 12 and 22 ‰
  - ✓ More external skin damage in exercised fish at 22 and 32 ‰, versus non-exercised, but this was not found at 12‰



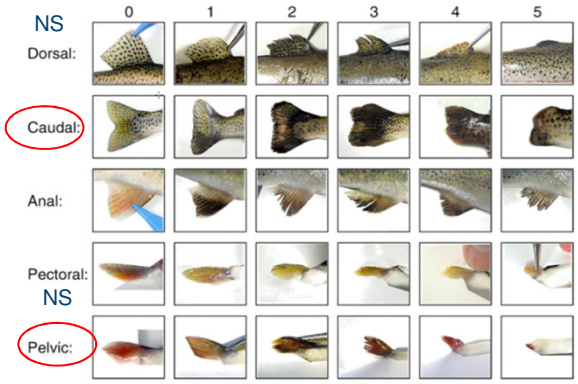
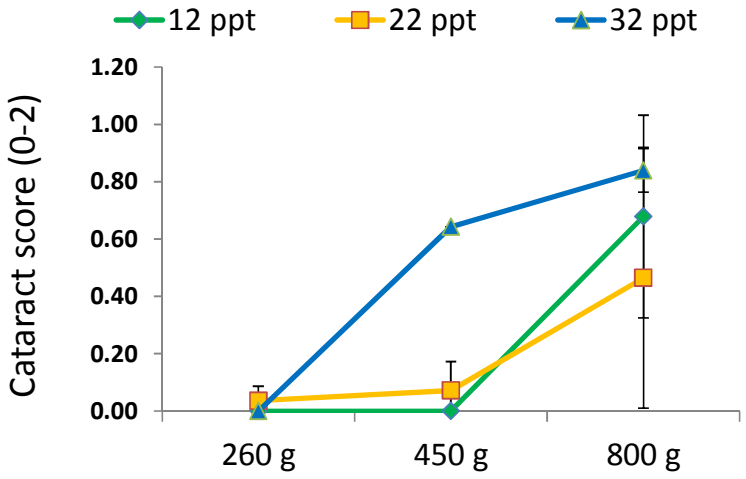
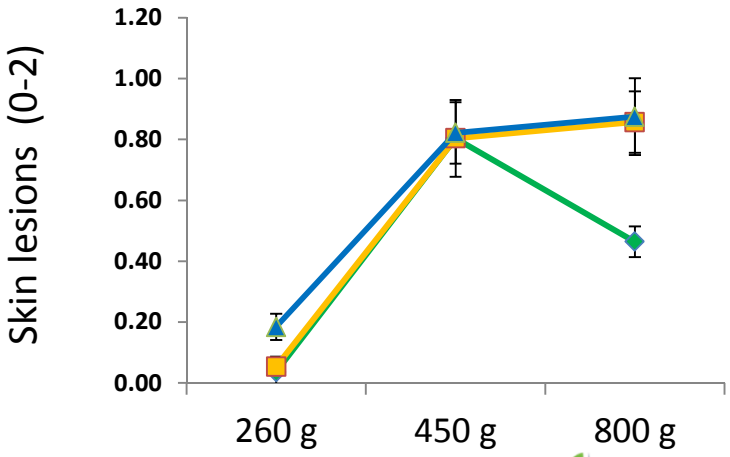


Photo: Hoyle I, et al. (2007): A validated macroscopic key to assess fin damage in farmed rainbow trout (Oncorhynchus mykiss). Aquaculture 270, 142-148.





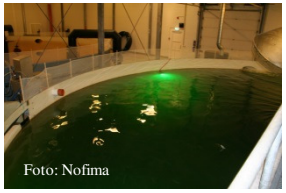
Skin health

- ✓Important organ for pathogen and parasite control
- ✓Les mucous and more tissue damage, at increasing salinity, and size
- ✓Exercise had a negative effect on skin health at 22 and 32, **but not at 12 ‰**
- ✓Up-regulation of the stress related genes HSP70 and iNOS at 32,22 vs 12‰
- ✓We are establishing a skin analytical pipeline, since skin-health may be a particular problem

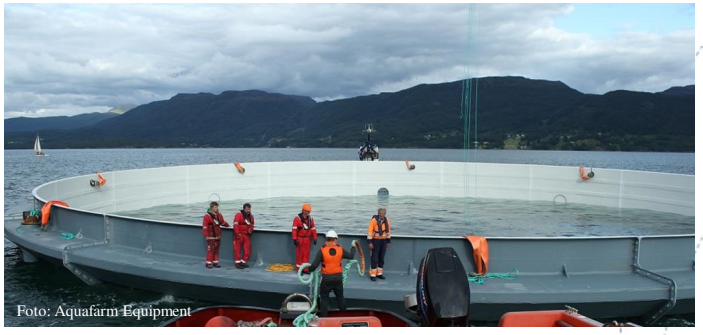
Nofima

Industry-scale testing in OPP

- **Testing combination-line, closed-containment RAS**
  - ✓ Commenced in July at Grieg SeaFood, Finnmark, northern Norway, 12 and 22‰ salinity



- **Testing combination-line, semi-closed in sea**
  - ✓ Start testing in Oct. at Smøla Klekkeri and Settefisk, and in 21 000 m^3 tank, Marine Harvest, western Norway.



Conclusions

- **Also salmon benefits from less salt and more exercise**
  - ✓ Closed-containment systems make environmental control possible
  - ✓ Lower salinity: increased feed intake, growth rate, improved skin health
  - ✓ **Combination with exercise maximized this effect**
  - ✓ No general maturation was observed, via GSI
  - ✓ Lower salinity improved removal efficency of TAN and CO2
  - ✓ Such types of findings may contribute to reduced costs in closed-containment systems

- **Production in closed-containment to 1 kg may contribute to smaller losses in Norwegian production**
  - ✓ Best group, 12‰ + exercise = 99% survival -6% at transfer to 32‰, = 93% survival to ~900 g
  - ✓ BUT: at 400-700 g the fish was very sensitive to handling
  - ✓ This trial suggest a use for closed-contaiment RAS, also in grow-out phase in Norwegian aquaculture

Nofima