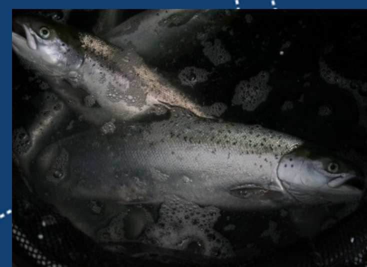
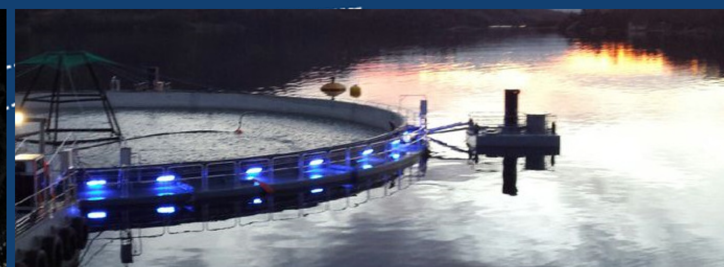
Nofima Atlantic Salmon in Closed-Containment Systems Research Update





Bendik Fyhn Terjesen

Nofima

Aquaculture Innovation Workshop #6

Vancouver, October 27th-28th 2014

Contents

- ✓Current Atlantic salmon production, challenges, and trends in Norway
- ✓Research on postsmolt production in RAS
- ✓Effects of tank scale on postsmolt production (in flow-through)
- ✓Research on postsmolt production in floating semi-closed containment systems in sea

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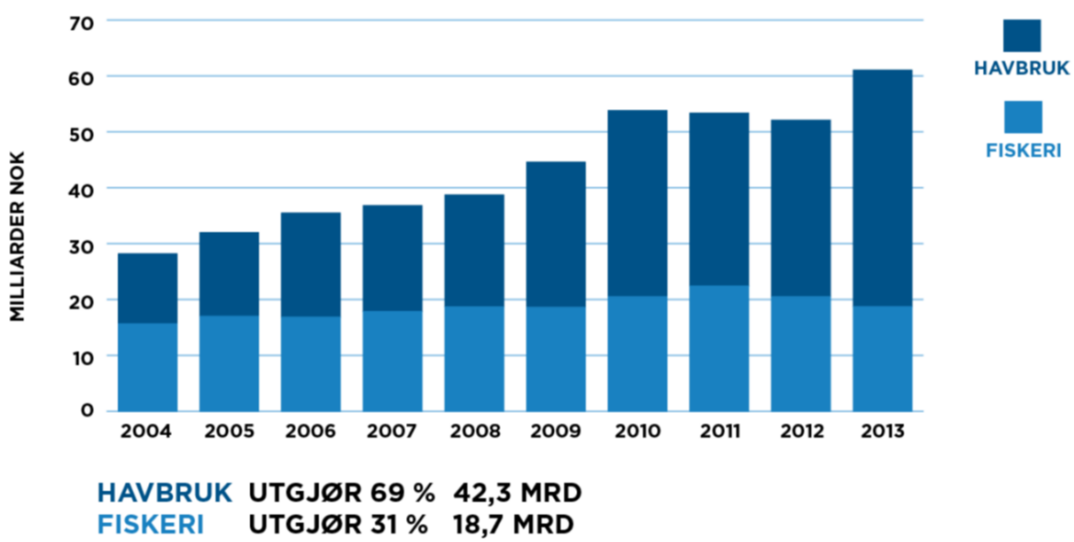
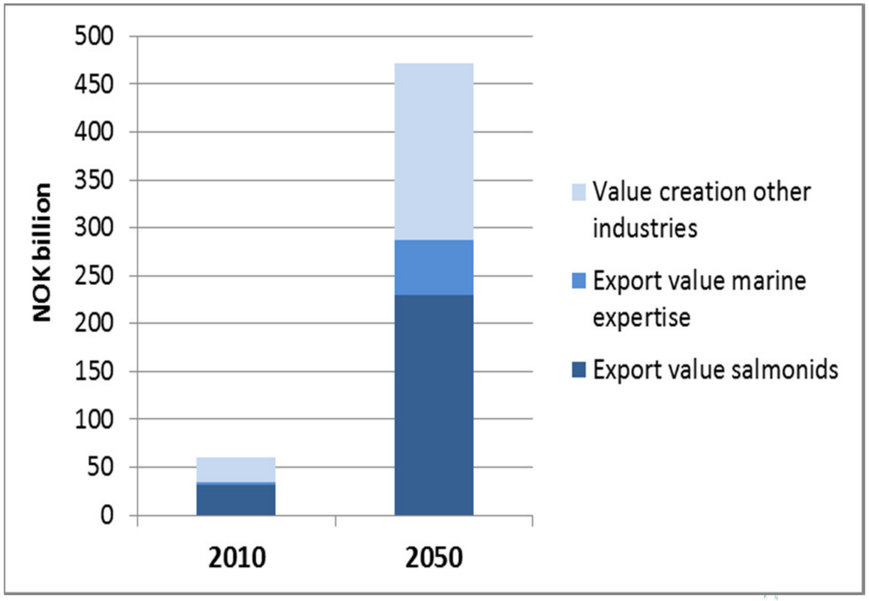
Norwegian salmon farming

- **Norways 2nd largest export commodity ~ 7 billion US$ annual value**
  - ✓ Norway exports salmon to approximately 100 countries
  - ✓ Produced around 1.3 million ton salmonids in 2013, 14 million meals every day
  - ✓ The industry employ > 20 000 persons in Norway



Norwegian salmon farming in 2050

- **5 million ton salmon produced annually i 2050?**
  - ✓ It has been projected that Norway will produce 5 mill. ton salmon annually in 2050 (Olafsen et al 2012)*
  - ✓ 5x increase in production volume, 8x in total value creation
  - ✓ Large increases in related industries, such as water treatment technologies
  - ✓ This projection assumes that sustainability issues are adressed and solved



Envisioned value generation provided limiting factors for growth in the aquaculture value chain are addressed. Value estimates from Olafsen et al (2012)*. 1 US$ ~ 6 NOK

* Olafsen, T., et al., 2012. Value creation from productive seas in 2050. Report from The Royal Norwegian Society of Sciences and the Norwegian Council of Academies of Engineering and Technological Sciences, Trondheim, Norway, 79 p.

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Challenges for Norwegian salmon farming

- Sea lice is a serious challenge, for wild and farmed salmon
- Escapes of farmed salmon may affect wild salmon populations
- New sustainable feed resources must be found
- Loss of fish: Mortality during production is 16.4% on average
- Most of this loss, and lost production capacity, occur soon after stocking at sea, of small smolts (<100 g)

- *Huge efforts and R&D are being done to combat lice; everything from laser canons against lice, cleaner fish, breeding lice-resistant salmon, to submerged cages, tarpaulins, and closed-containment systems*

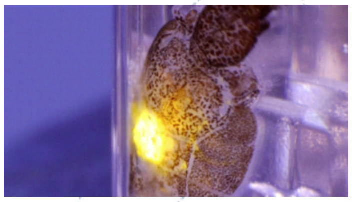
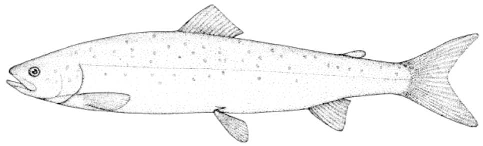


Photo: Stingray

Research on postsmolt production in RAS



Future production strategies in Norway?

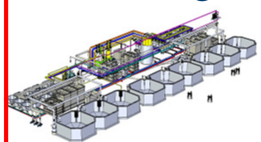
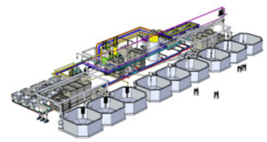
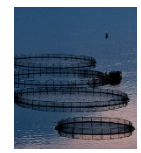
Today: 22 000 tons in closed systems in Norway, as smolt

If all salmon in Norway to 1 kg in closed systems: 290 000, 13x increase!

Closed-containment on land

Smolt prod in closed RAS land-based → Postsmolt in closed RAS land-based → Shorter period in cages before harvest

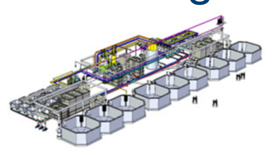
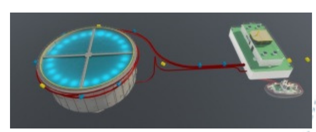
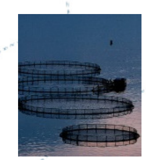
0-80 g | 80 g – 1 kg | 1 kg – 5 kg

Semi-closed containment in sea

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

0-80 g | 80 g – 1 kg | 1 kg – 5 kg

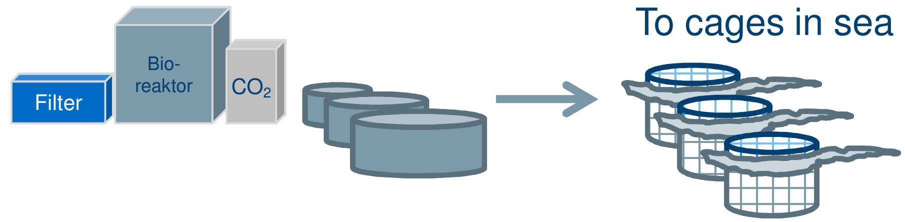




Experimental series to increase knowledge about postsmolt production in RAS

Experiment 3

RAS medium-scale, fixed salinity & water velocity

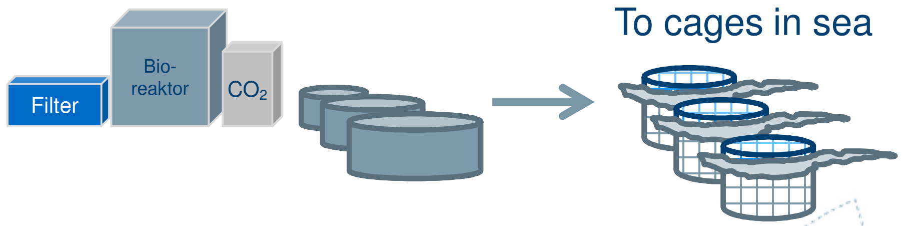
To cages in sea



Experiment 2

RAS industrial scale, varying salinity, fixed water velocity

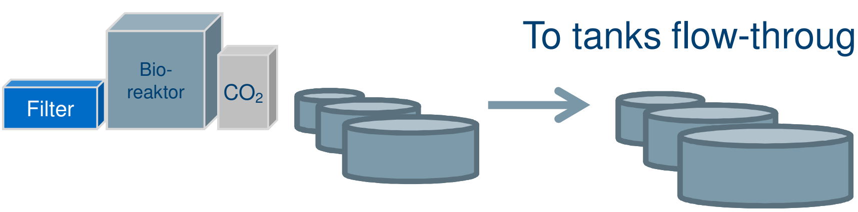
To cages in sea



Experiment 1

RAS medium-scale, varying salinity, varying water velocity

To tanks flow-through, full SW



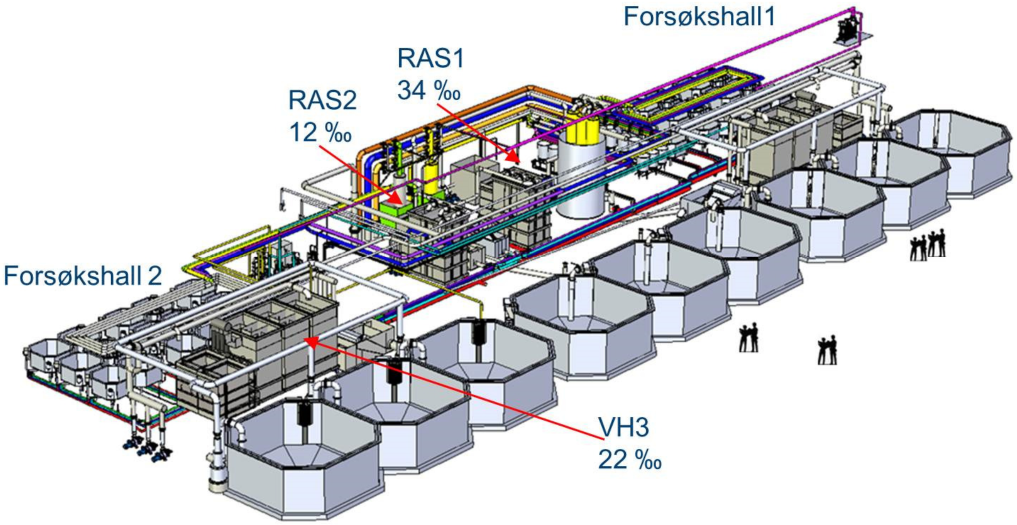
Exp 1. Salinity & water velocity in RAS for postsmolts

- SW-RAS may have higher running costs than FW-RAS due to CO_2 and TAN removal efficiencies are lower than in FW

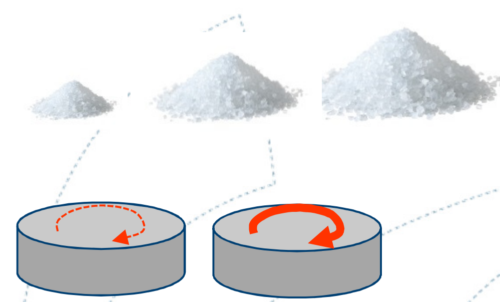
- Results in need for larger installations and/or higher flow

- Or can postsmolts be kept at lower salinity in RAS, and still handle full-strength SW at stocking in sea?

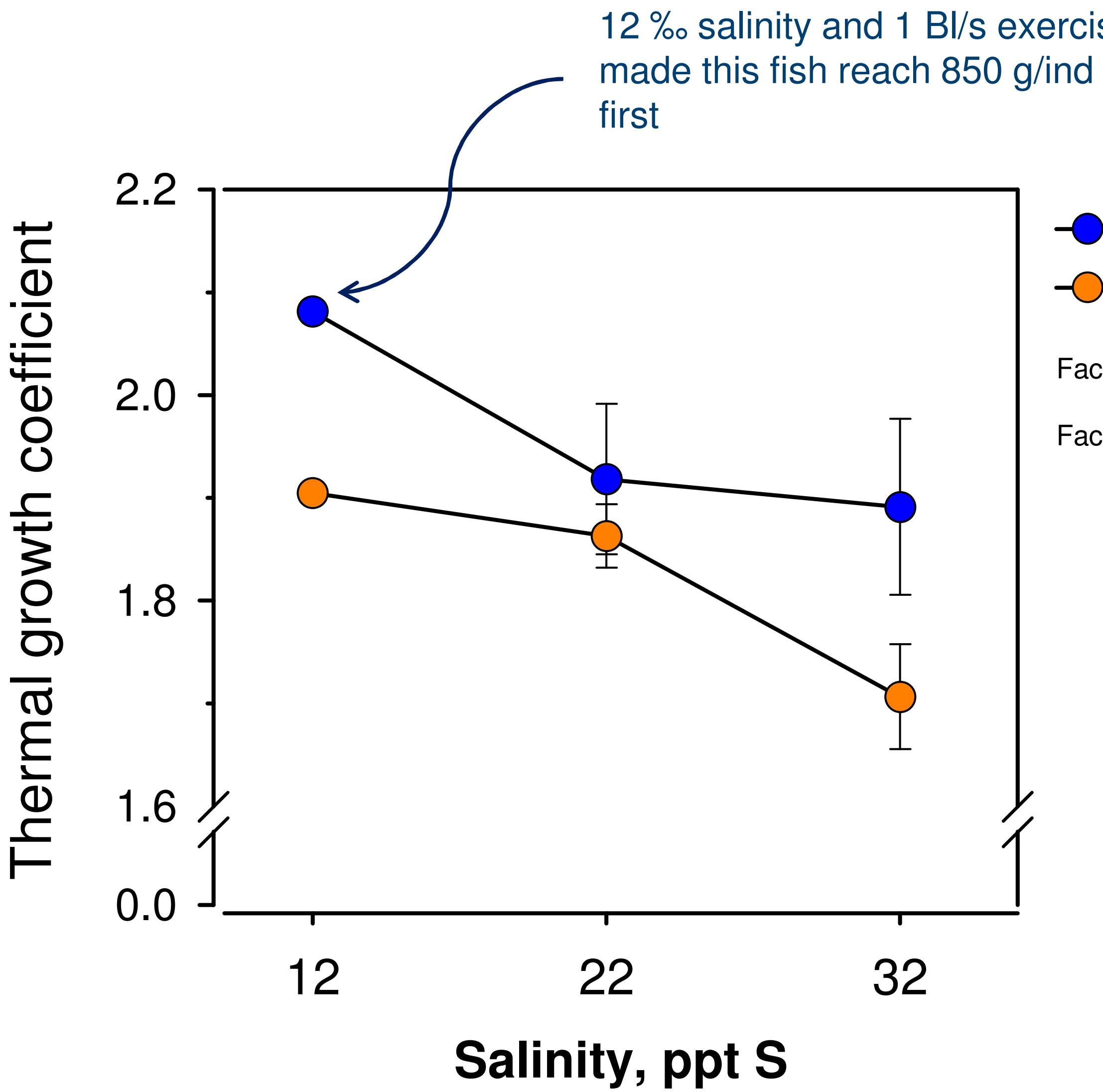
- This exp ran from 70 g til 850 g at different salinities (12-22-32 ppt S) or exersize levels (0.3 og 1 BL/s), at12L:12D photoperiod



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



Exp. 1: Also salmon benefits from less salt and more exercise: Improved growth



Terjesen et al., upublisert, 2013

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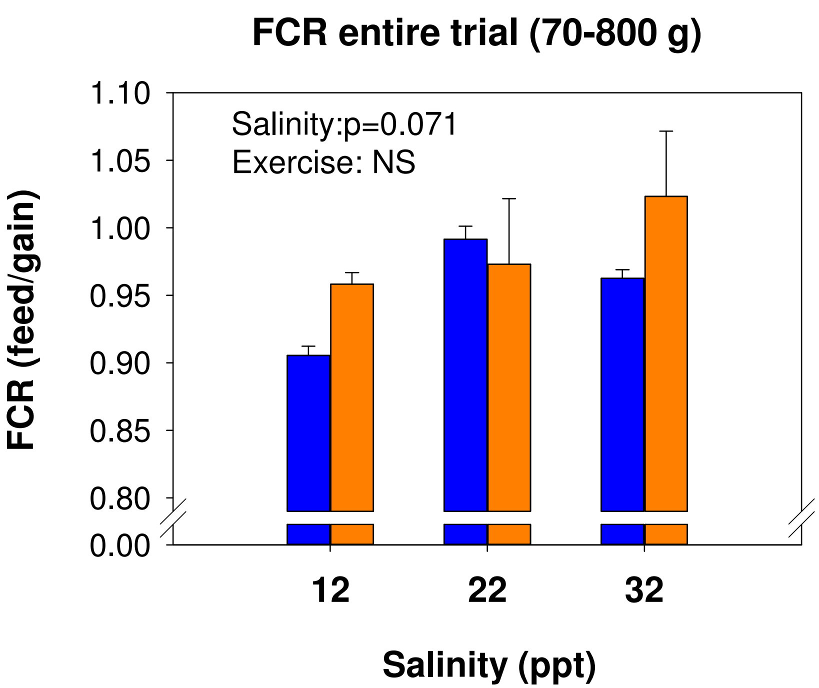
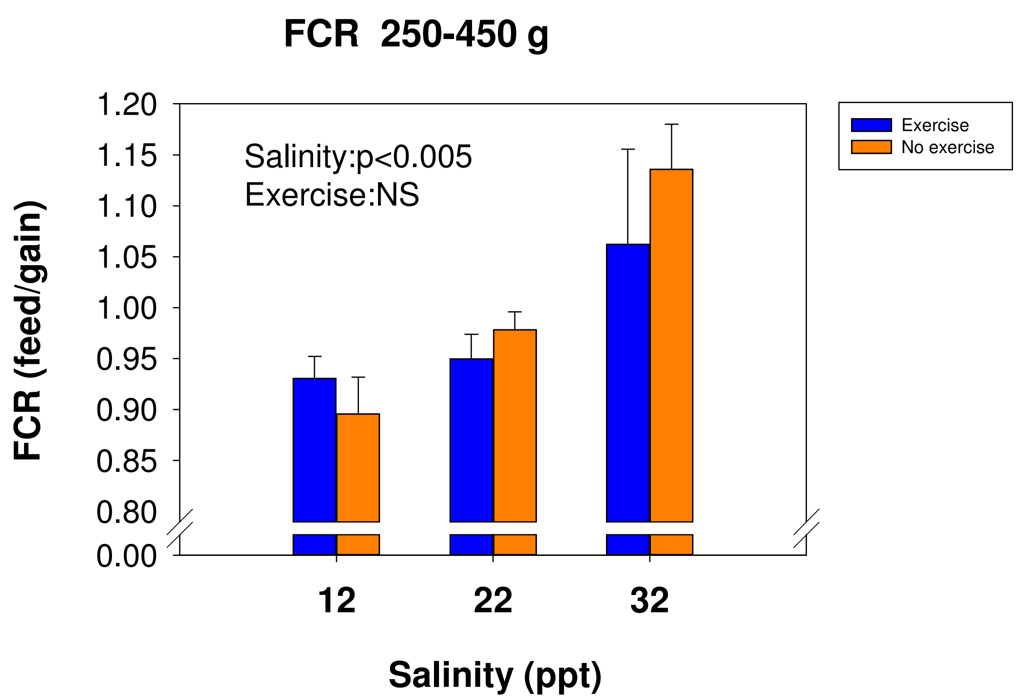
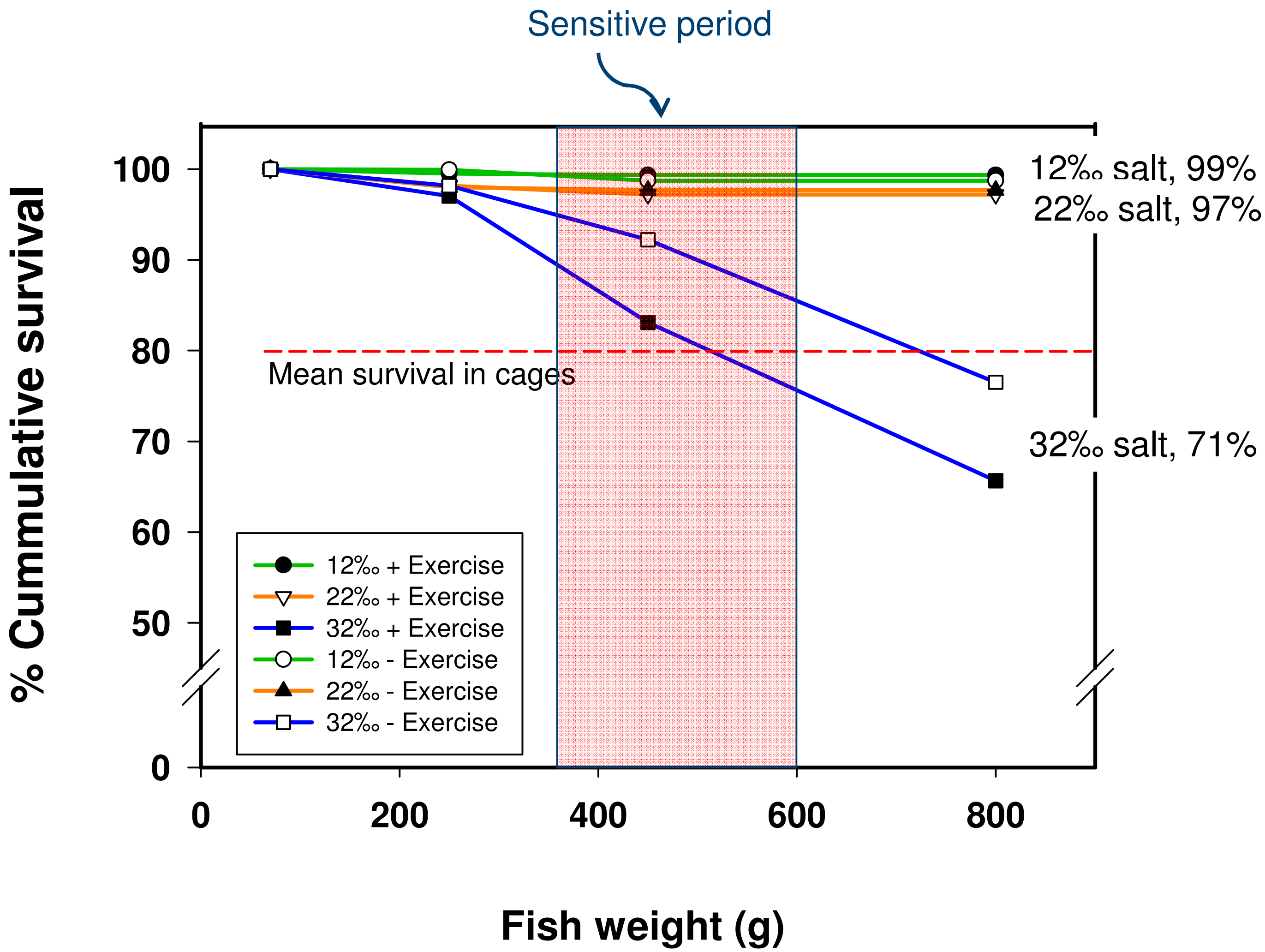
Exp. 1: Improved feed utilization at lower salinities (FCR, feed:gain)





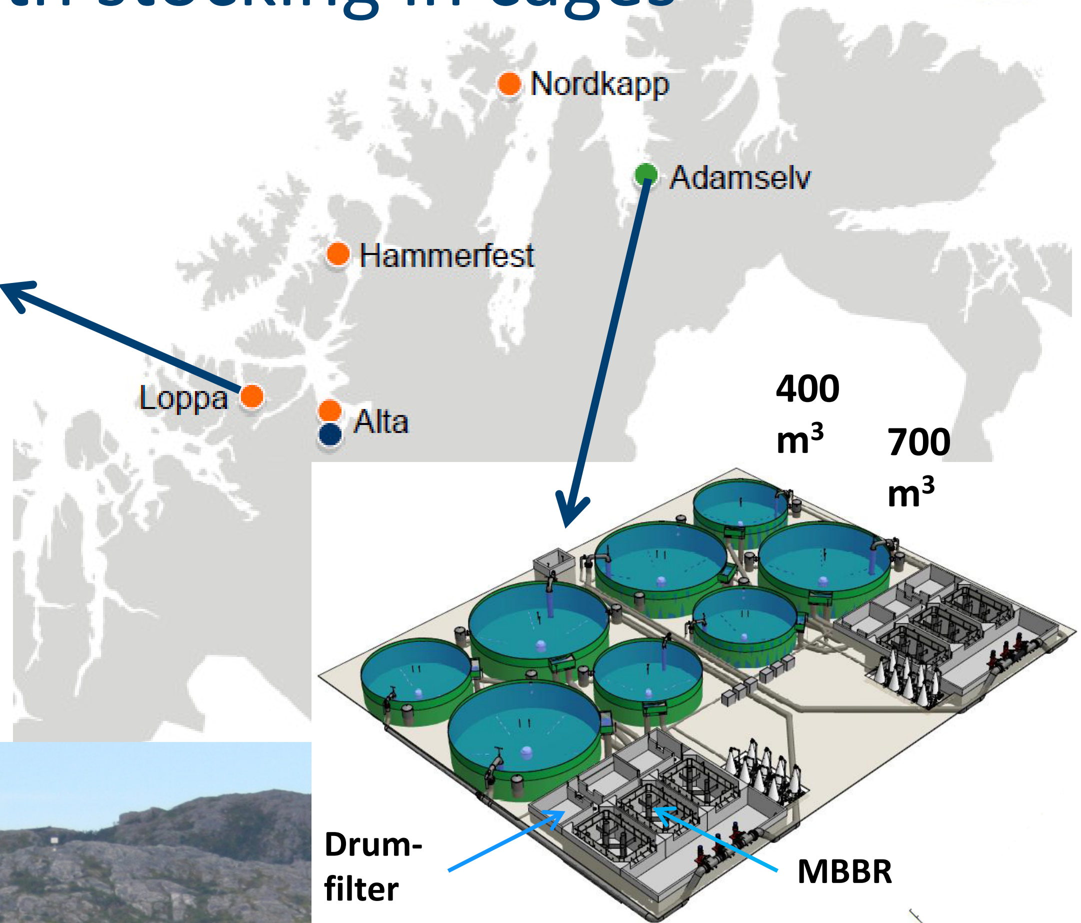
Terjesen et al., upublisert, 2013

Exp.1: Improved survival of low salinities, when kept in similar conditions throughout

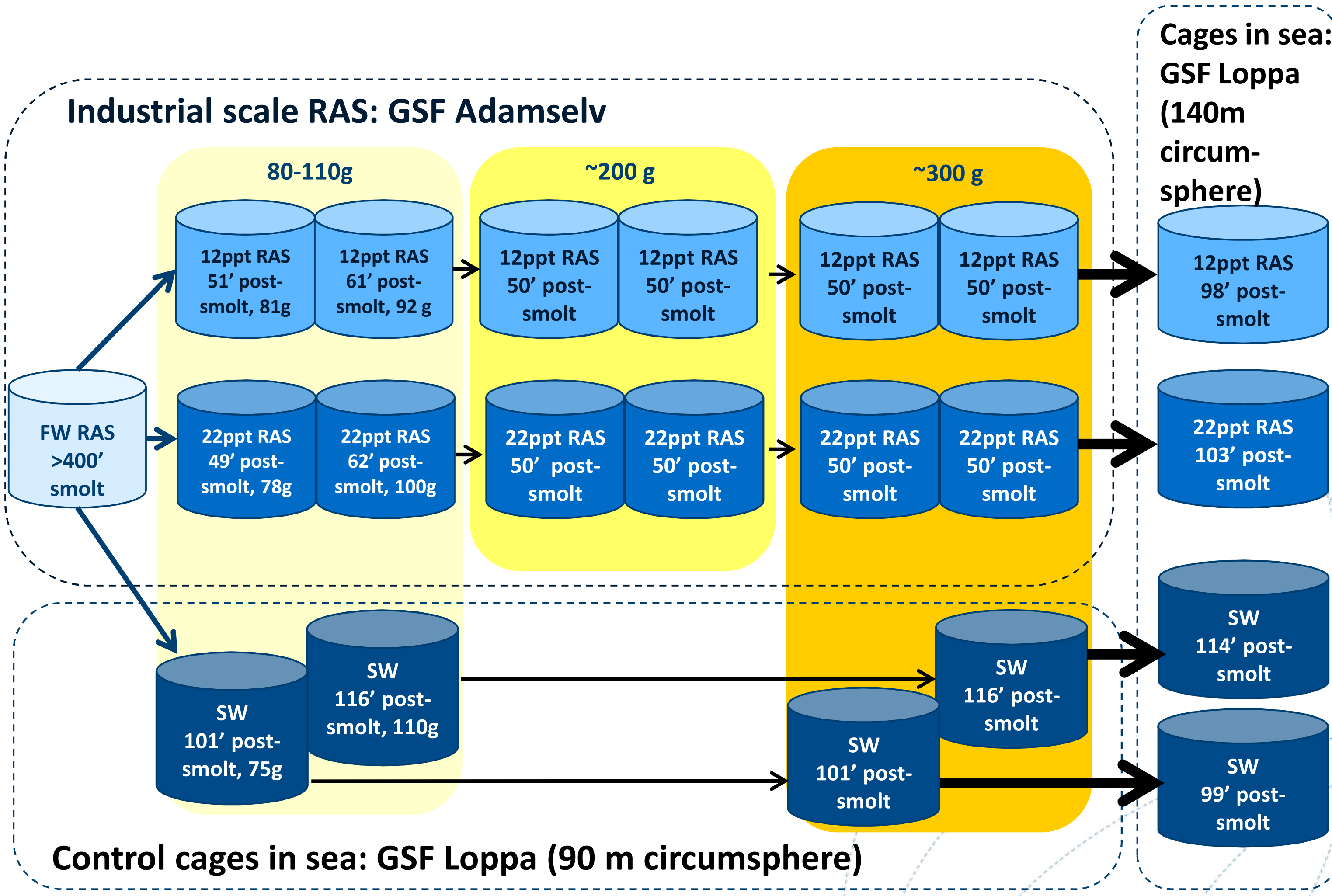


Terjesen et al., unpublished, 2013

Exp.2: Industrial scale RAS; effects of salinity at fixed water velocity, with stocking in cages

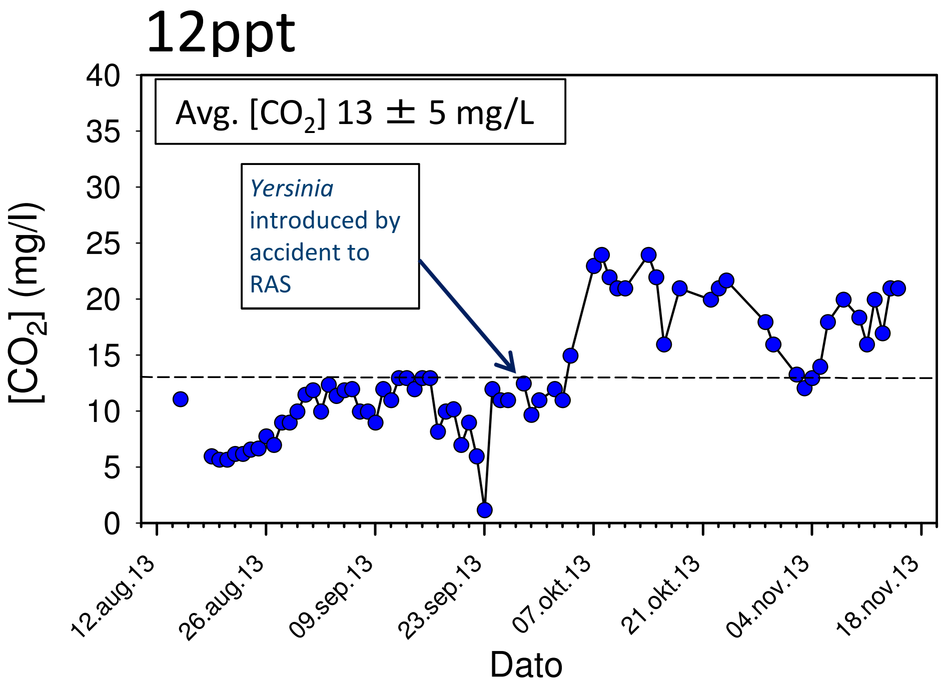


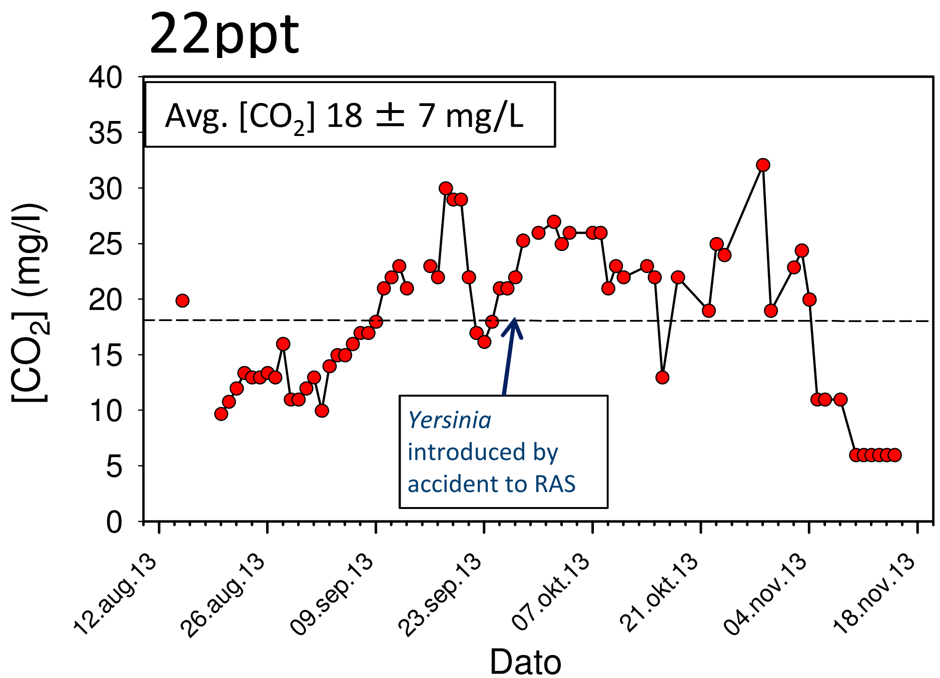
Exp. 2 design: effects of salinity in industrial scale RAS, Grieg SeaFood



Frode Mathisen, unpub., 2013

Exp.2: Industrial scale RAS; effects of salinity at fixed water velocity





Kolarevic, Terjesen et al., unpubl., 2013

FHF Postsmolt E project (Medhus, Norheim, Norwegian Veterinary Institute):

- Detected nephrocalcinosis and red blood cells in kidney tubuli, increasingly with duration of experiment
- Detected *Yersinia ruckeri* at last sampling point
- Detected *Tenacibaculum sp.*

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Exp. 2: Industrial scale RAS, growth and survival

- Good growth rate in RAS, but yersinosis gave negative effect

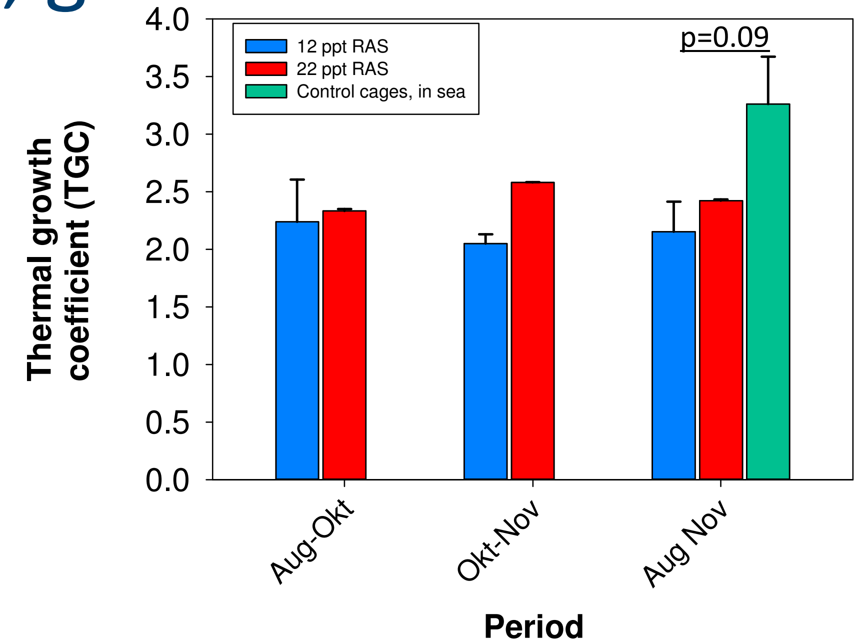
- After stocking at sea, higher mortality in RAS groups, likely due to sub-optimal water quality and yersinosis

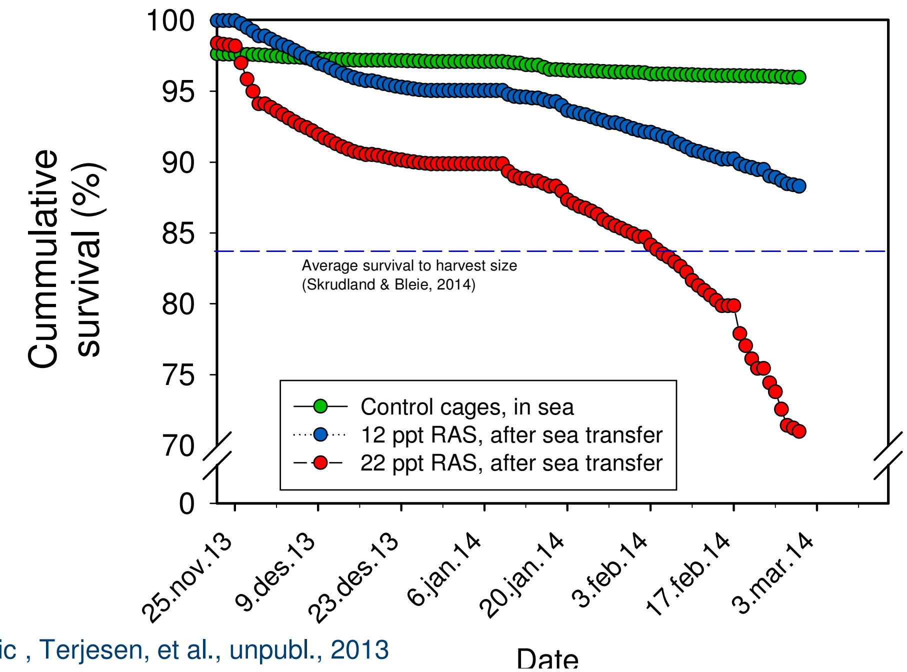
Preliminary conclusions:

- In RAS with no apparent disease issues with, 12 ppt S should be used due to better growth, skin health, and water treatment, as found in Exp. 1

- In RAS with typical FW-pathogen challenges, a higher salinity should be used, provided that water treatment capacity is sufficient

- After this exp., Grieg SeaFood has changed the RAS water treatment and biosecurity, and now have good experiences with post-smolts in RAS

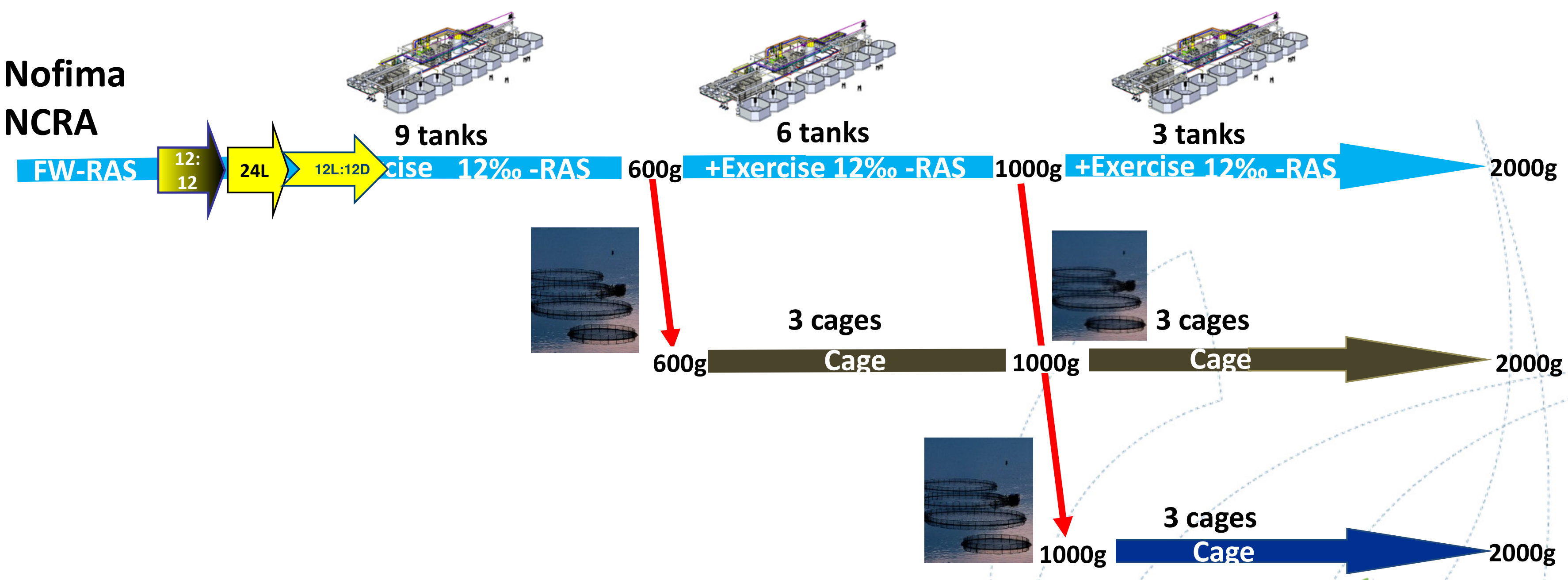




Kolarevic , Terjesen, et al., unpubl., 2013

Exp. **3**: medium-scale RAS with fixed salinity and water velocity, then stocking in cages

- Exp. 1: Potential for very high (99%) survial, but sensitive phase 300-700 g
- Exp. 2: Importance of water quality and biosecurity, and again sensitive postsmolts
- Exp. 3. goal: “test of concept” post-smolt RAS prod, with changes according to Exp.1&3 results, now followed with stocking in cages



Ytrestøyl & Terjesen, unpublished, 2014

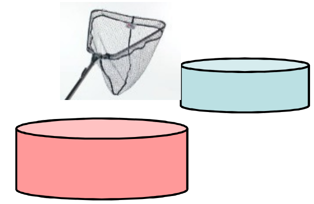
Exp.**3**: Changes to reduce mechanical contact and improve skin health

Temp in RAS kept relatively low (12-13ºC), 0-3ºC differences to cages

Feeding in exp. tanks ended late, -2 days

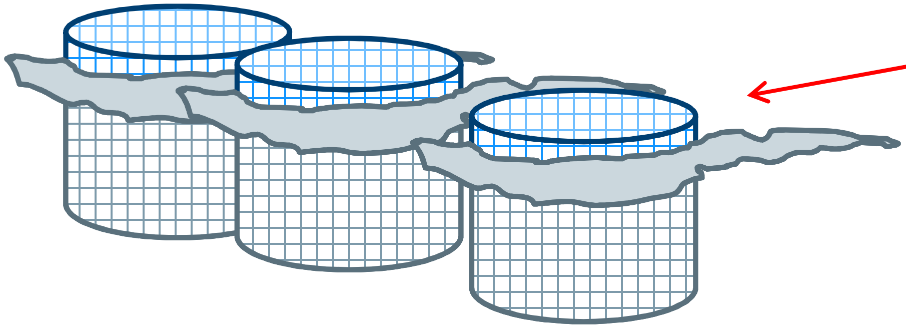
Added product w/iso-eugenol sedation to exp. tanks (2.7 mg/l)

Added product w/ polyvinylpyrrolidone (PVP, 60 mg/l) and EDTA to nets, weighing tanks, holding tanks



Used long time & careful netting and loading (1 h/tank) (w/12 ppt S, iso-eugenol & PVP)

Careful pumping from tanks on truck, to exp. cages

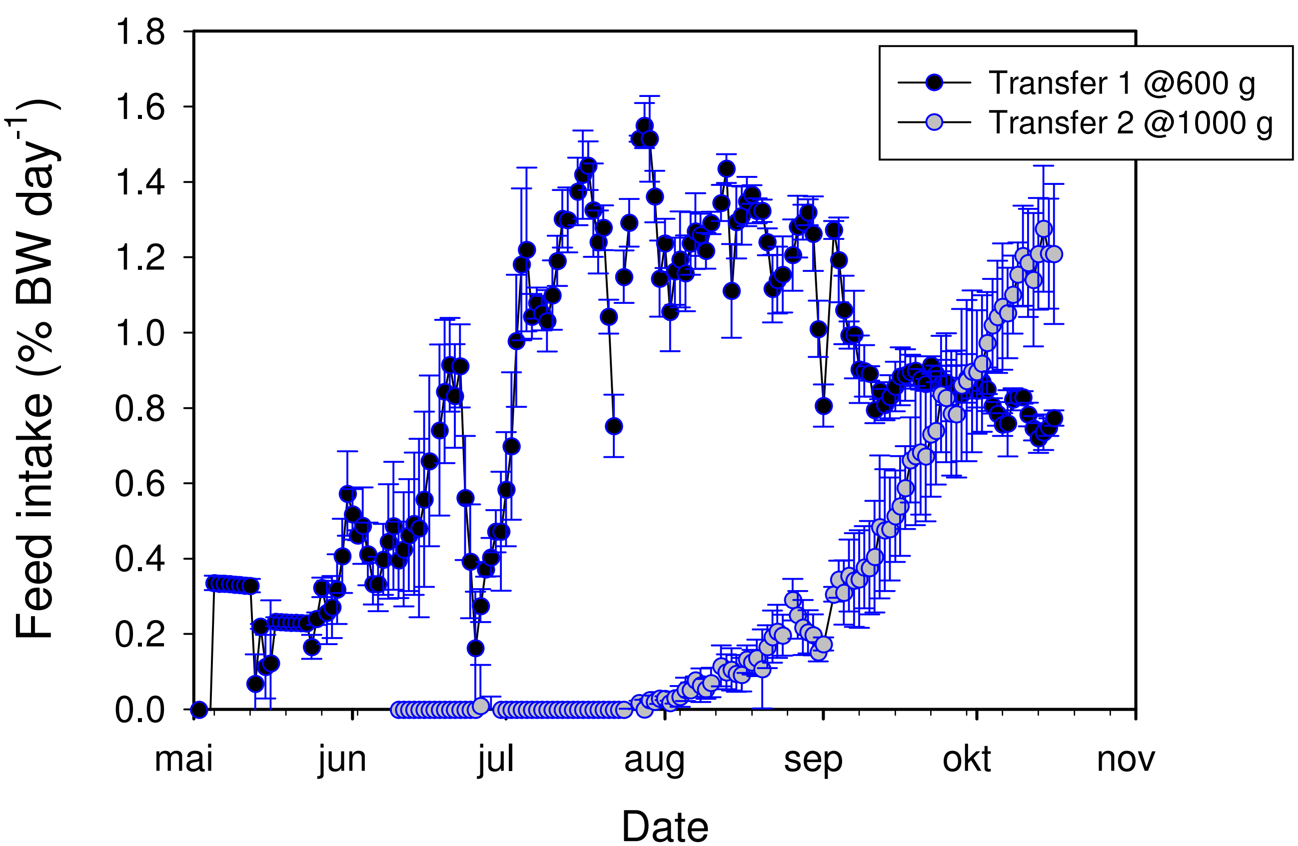


Ytrestøyl and Terjesen, unpubl. 2014

Exp.**3**: Feed intake in postsmolts produced in RAS, after stocking in cages, at two size-classes

✓Transfer @600 g: Appetite right after transfer, and gradual increase to July, from then on above tables for same size/temp

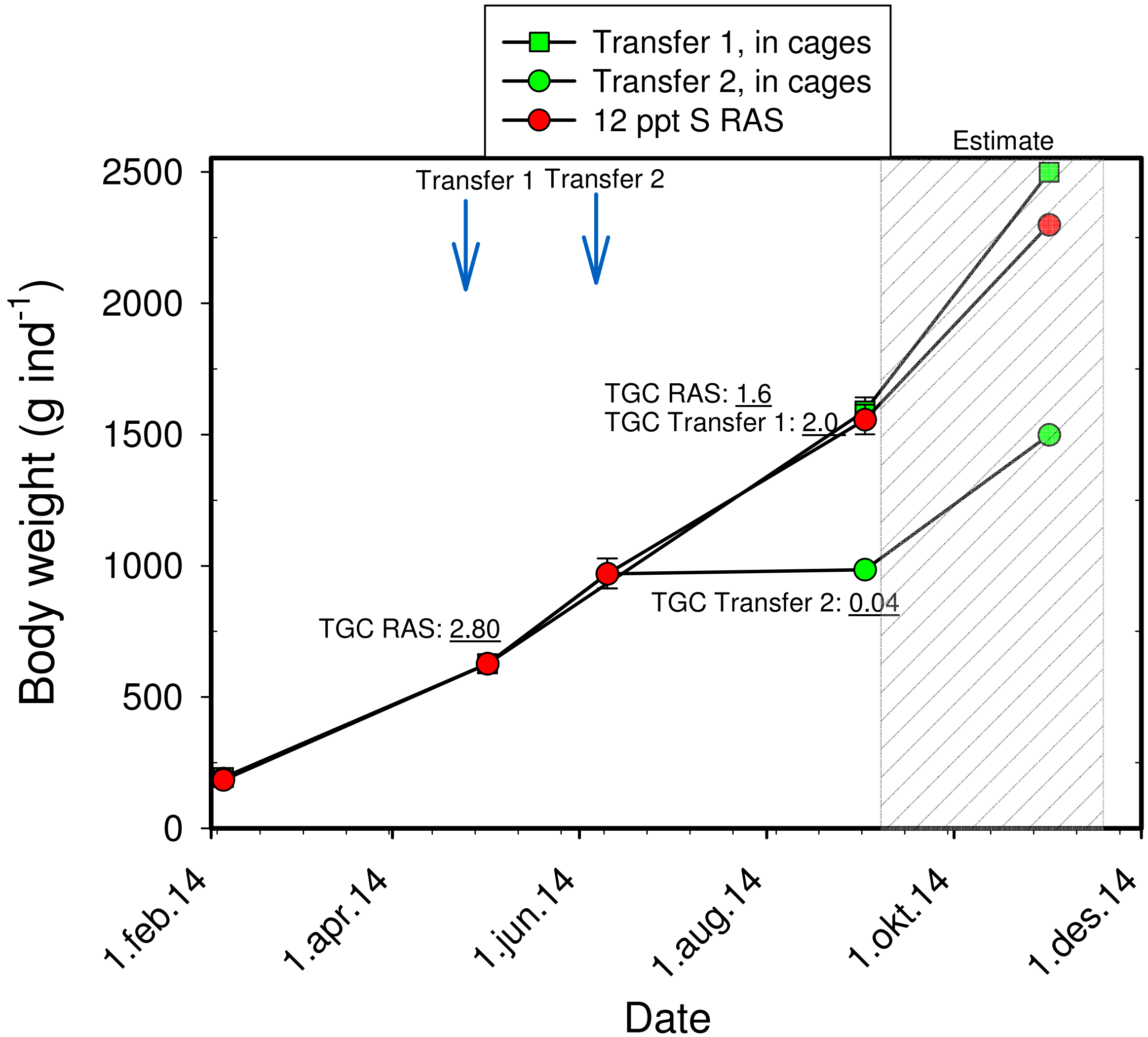
✓Transfer @1000 g: Higher condition factor at transfer. Long time without detectable feed intake. Gradual improvement from August, then above tables for same size/temp



Ytrestøyl and Terjesen, unpub, 2014

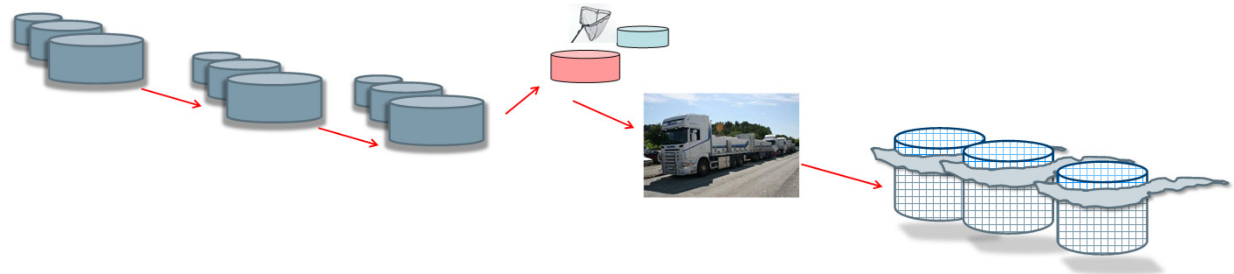
Exp.3: Growth after transfer from RAS to cages in sea, at two size classes

- ✓Good growth rate during time in RAS (TGC=2.8)
- ✓After stocking, comparable weight development between cages and RAS (avg. temp. 12.8ºC og 12.3ºC)
- ✓Growth in the two size classes reflected differences in feed intake
- ✓At ~1 kg, relatively low maturation, this is monitored closely
  - -RAS: 3% (1 kg)
  - -Transfer 1, 7% (1.4 kg)
  - -Transfer 2, 0.7% (1 kg)

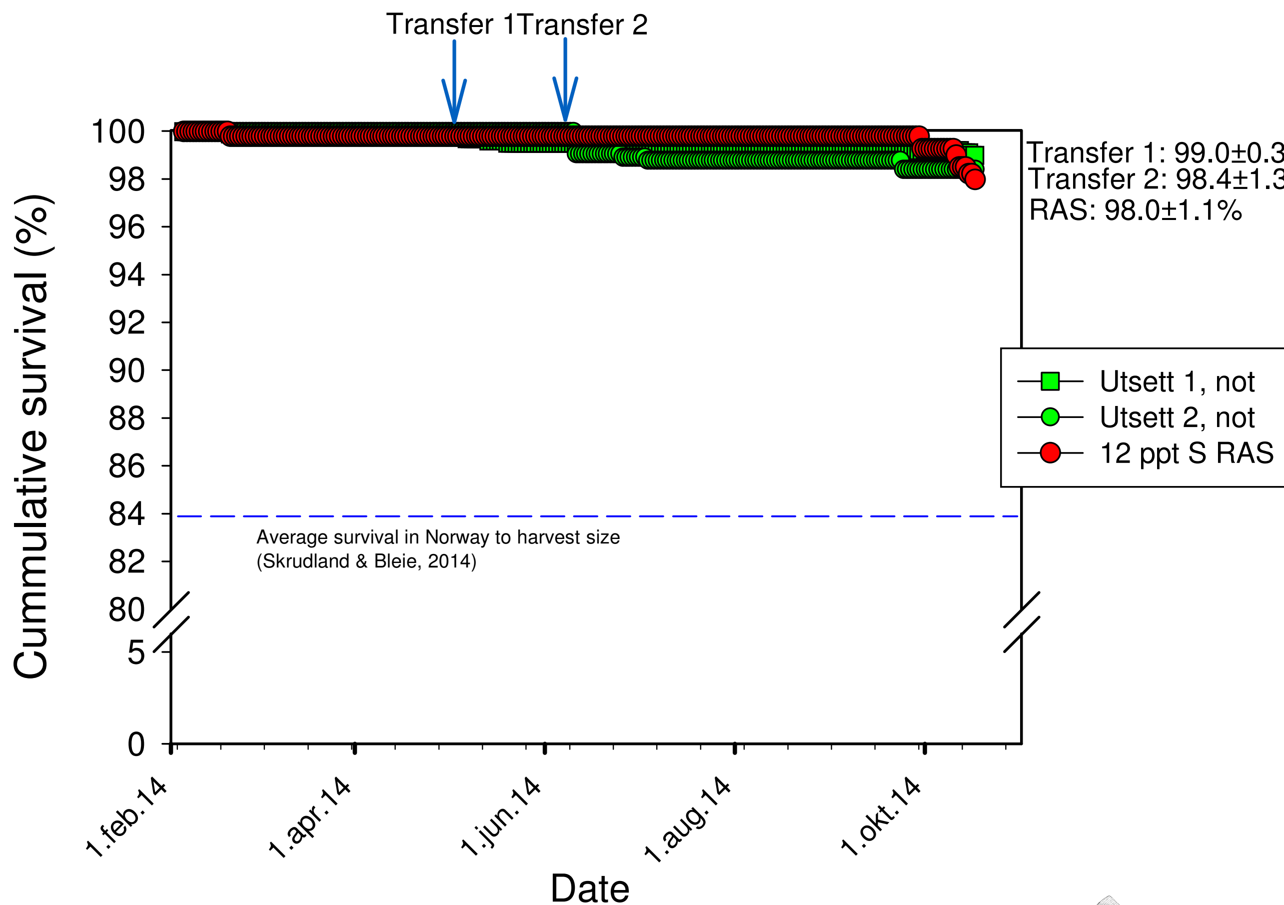


Ytrestøyl and Terjesen, unpubl. 2014

Exp. **3**: Survival



- ✓Very high survival, ~99%, calculated from smolt to 2.5 kg i cages, transfer 1
- ✓Despite transfer into RAS, out of RAS, on to truck, and into cages
- ✓Shows that postsmolt production in closed-containment has potential for virtually no mortality
- ✓<u>However</u>, focus must be on limited, and careful, handling of the fish



Ytrestøyl og Terjesen, upublisert, 2014

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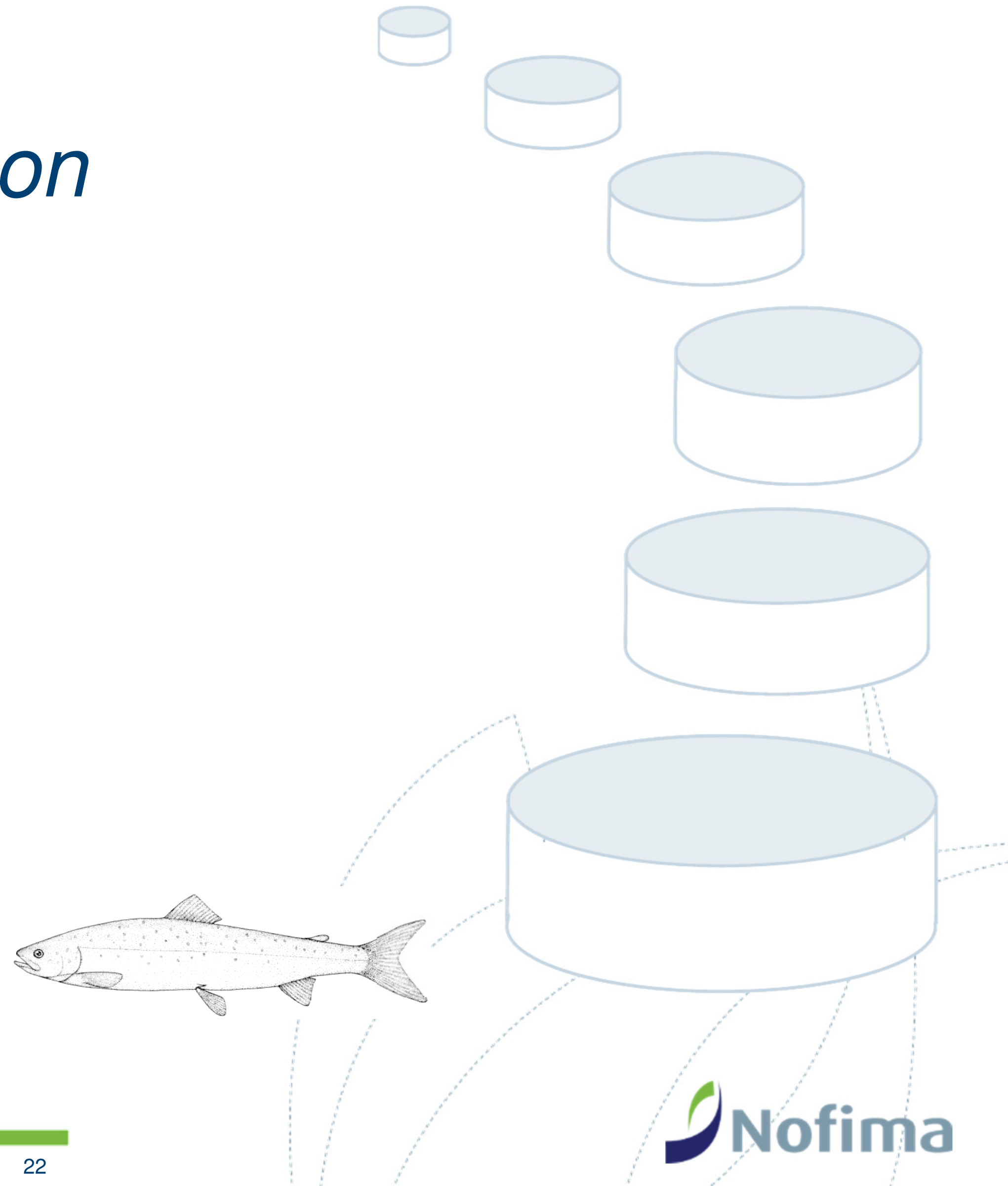
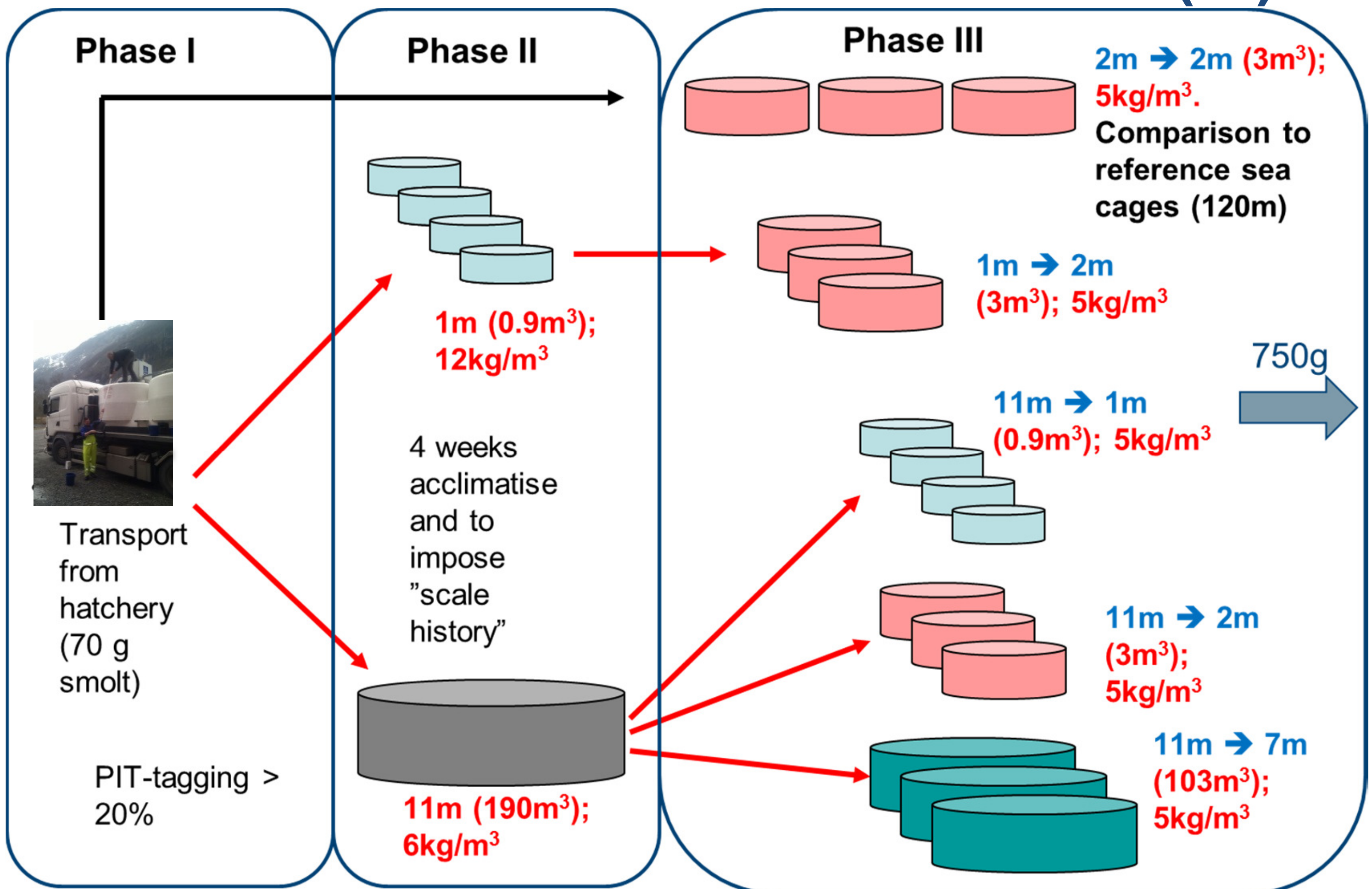
Effects of tank scale on postsmolt production



EU AquaExcel WP8: Up-scaling and validity of research results

- Scale is the size of fish containment units, i.e. tanks or cages, and biofilters
- There has been a tremendous increase in size of industrial tanks, cages, and biofilters
- Does the increasing gap in scale affect the relevance of scientific data?
- Information about scaling effects is also useful for industrial tank, bioreactor, unit design
- In AquaExcel we have modelled scale effects, and validated by experiments on sea bass, salmon, and bioreactors
- Effects on the fish (Nofima, SINTEF, NTNU, HCMR) and bioreactor nitrification rate (IMARES, Nofima, WUR)

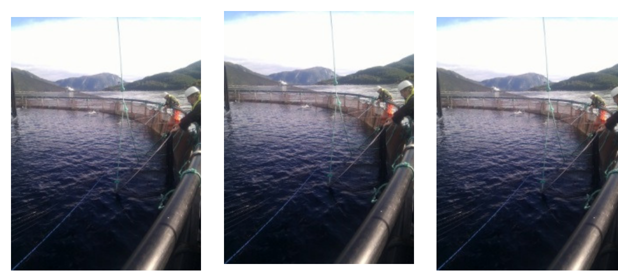
Experimental design: scale effects in salmon - all scales in tank diameter (m)



Espmark, Terjesen et al, unpubl.

Phase I

Triplicate 40 m cages, 16 000 m³ 200 000 smolts each



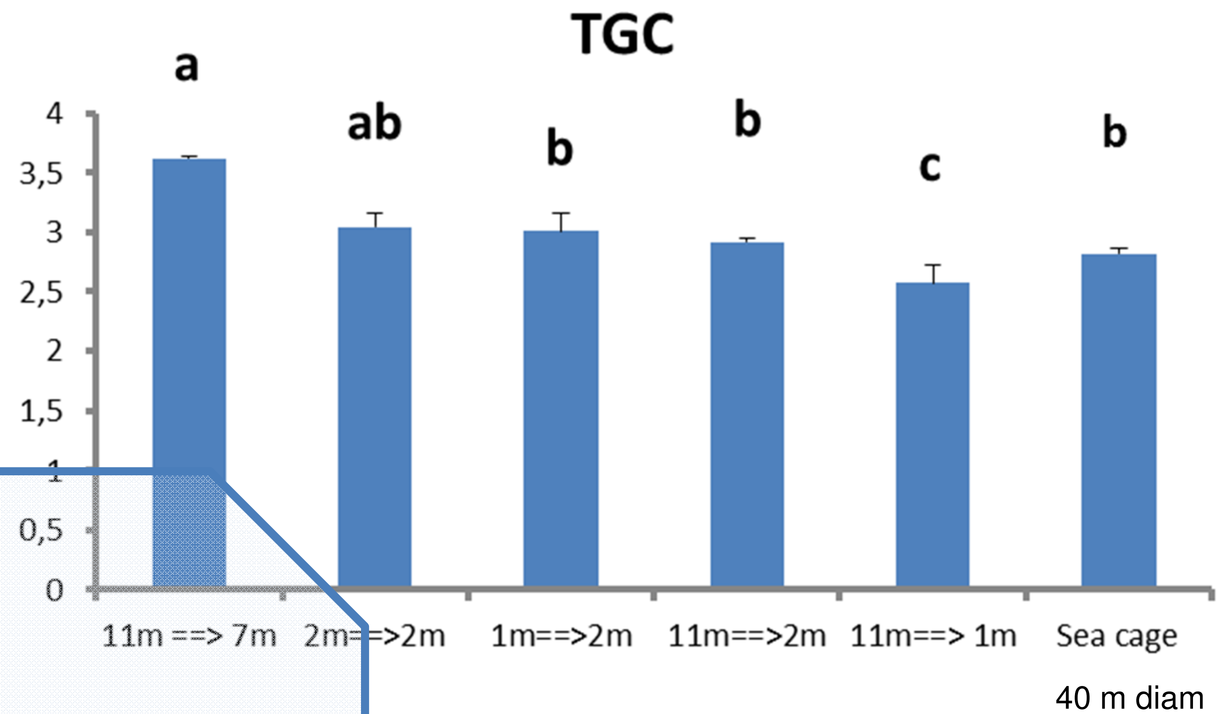
Material and Methods

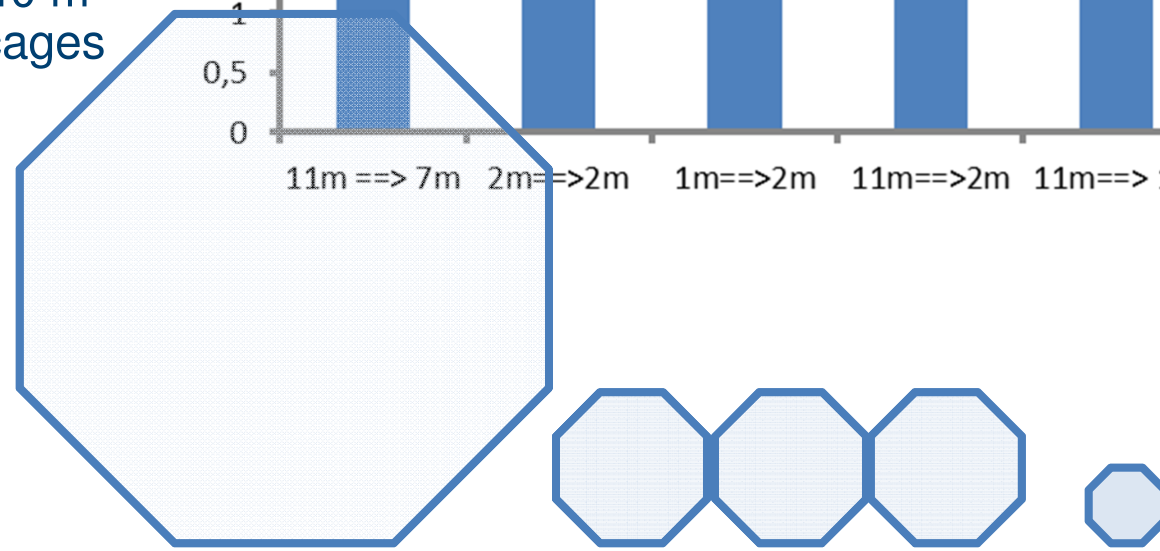
Variables that were standardized – between tank scales	**Variables that were not standardized – <u>but measured/monitored - tanks</u>**	**Variables that were standardized between cage and tank**
Tank geometry	Feed distribution angles	Fish genetic & batch origin
Fish genetic & batch origin	Tank water turnover	Feeding time regime adjusted in tanks
Initial fish density	Water velocity	Feed batch
Feed batch + feeding regime	Water quality parameters (except DO, controlled to 85% sat.)	Temperature adjusted in tanks, according to cage (5 to 14ºC)
Light (300-400 lux), and photoperiod (natural)		Photoperiod (natural)
Temperature (5 to 14ºC), oxygen saturation (85% sat.)		

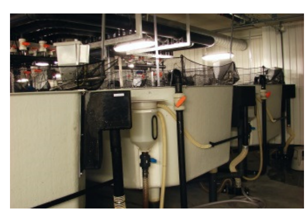
Growth rate in salmon postsmolts increases with scale (m diameter tank) and is affected by previous scale history

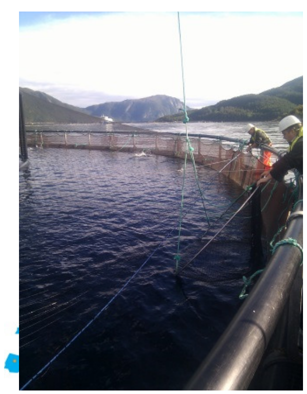
Design:

- Reared from 70g smolts to 1000g post-smolts
- Flow-through, temp as in sea
- Same fish and feed as in control triplicate, 40 m diameter cages





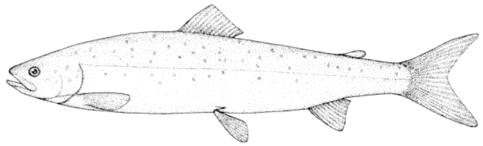




Espmark, Terjesen et al, unpubl. 2014

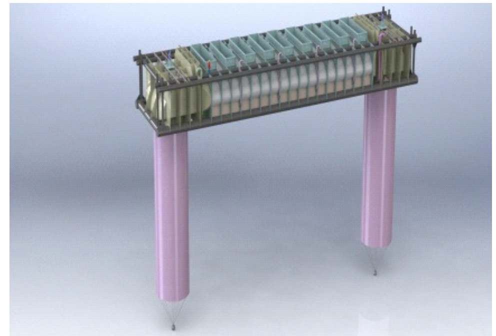
AIW#6

Research on postsmolt production in floating semi-closed containment systems in sea



Semi-closed containment systems for postsmolt production, taking water from below the sea lice belt

Photo: Aquafarm Equipment, 21 000 m³, 450 m³/min flow



Preline, 2 000 m³
Photo: Lerøy

HDN Flexibag: 1 600 m³. Photo Smøla KS

AquaDome. Photo: Cermaq, 5 700 m³

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OPP exp 5a: Industrial scale experiment, semi-closed system to 1 kg (Marine Harvest, UNI Research, Nofima)


Photo: Aquafarm Equipment


Photo: Bendik Fyhn Terjesen


Photo: Bjarte Sævareid

OPP5a: Industrial scale experiment, postsmolt production in semi-closed system: *Design*

Smolt producer

200 000, 0+ smolt transferred to each treatment 13/10 & 17/11

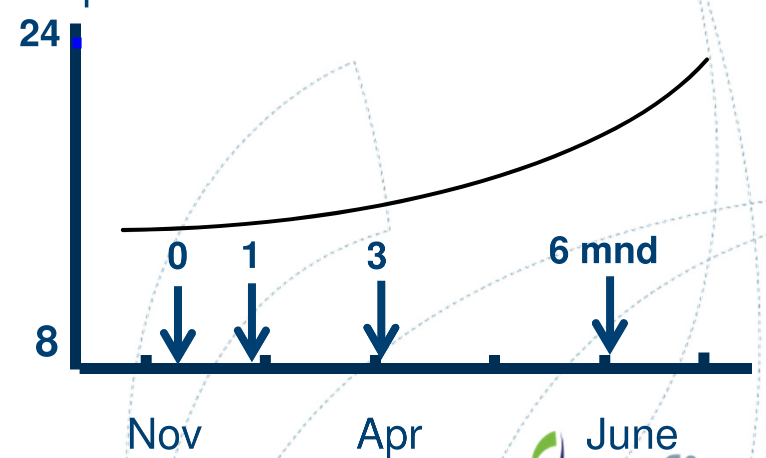
Semi-closed tank

Reference cages

<u>Sampling program to 1 kg:</u>

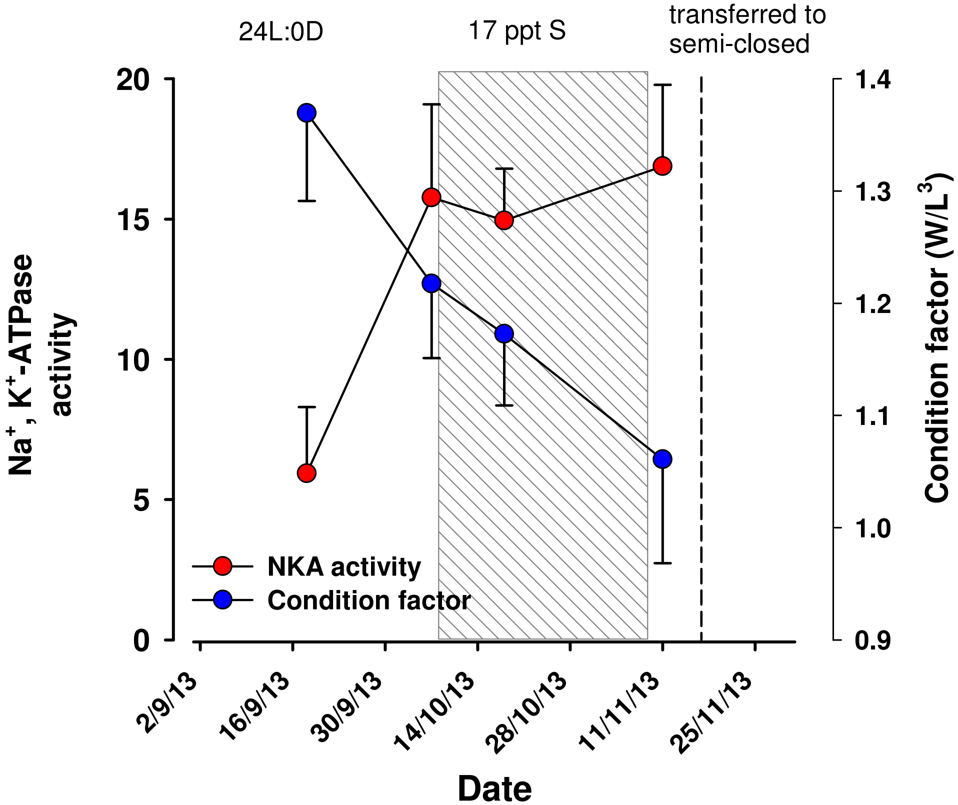
Weight, length, condition factor, TGC
Gill tissue, NKA, plasma
Samples for molecular and histopathology analyses of skin health
External welfare indicators (e.g. fins, cataract, skin)
Water quality (temp, CO2, TAN, O2, TSS, etc)
Fish health screening (Postsmolt E, NVI)

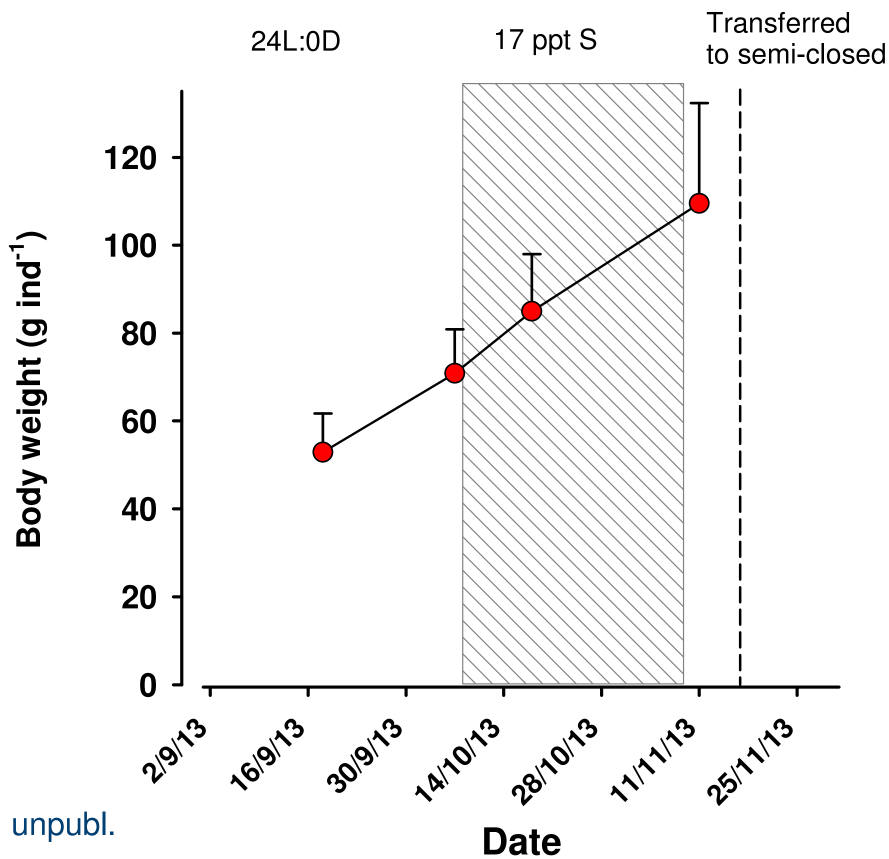
Photoperiod



Calabrese, Handeland, et al, unpubl.

OPP5a: *Status* experimental fish before transfer to semi-closed or reference cages

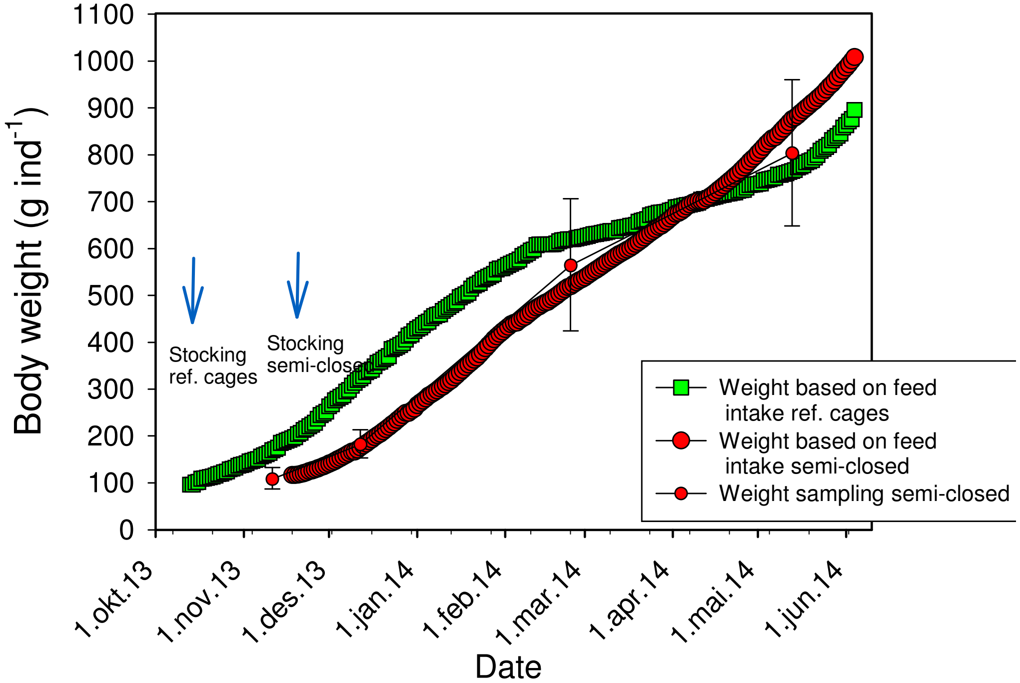




Calabrese, Handeland, et al, unpubl.

OPP5a: Industrial scale experiment, postsmolt prod. in semi-closed system: *Weight*

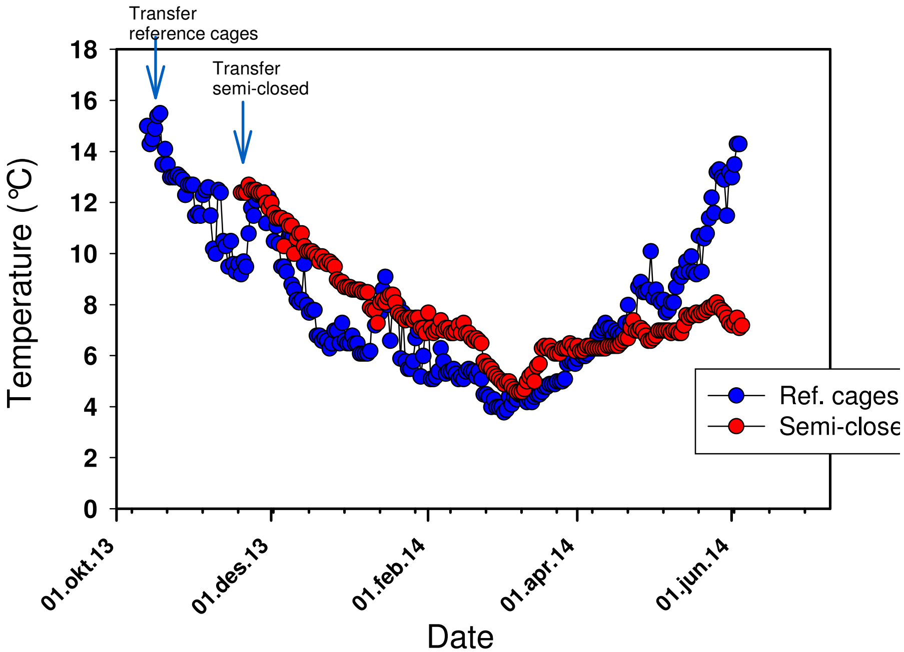
Comparable weight development in semi-closed



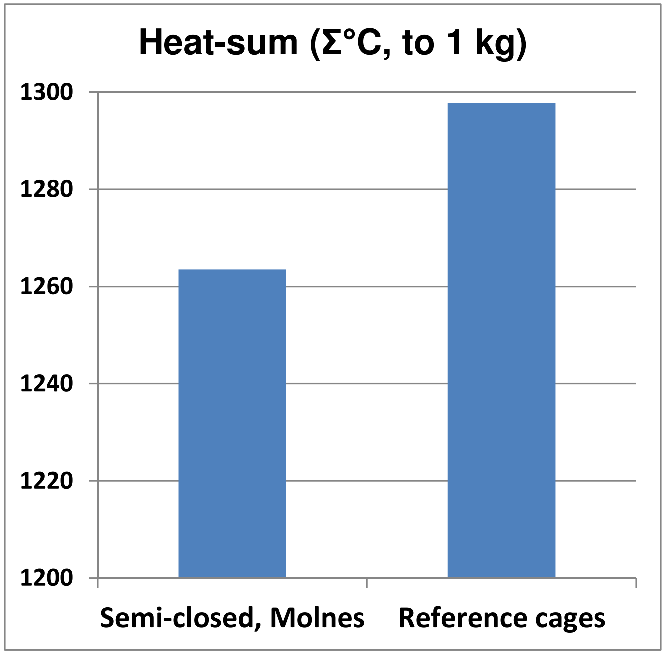
(Ref. cages based on fed amounts and FCR=1.0)

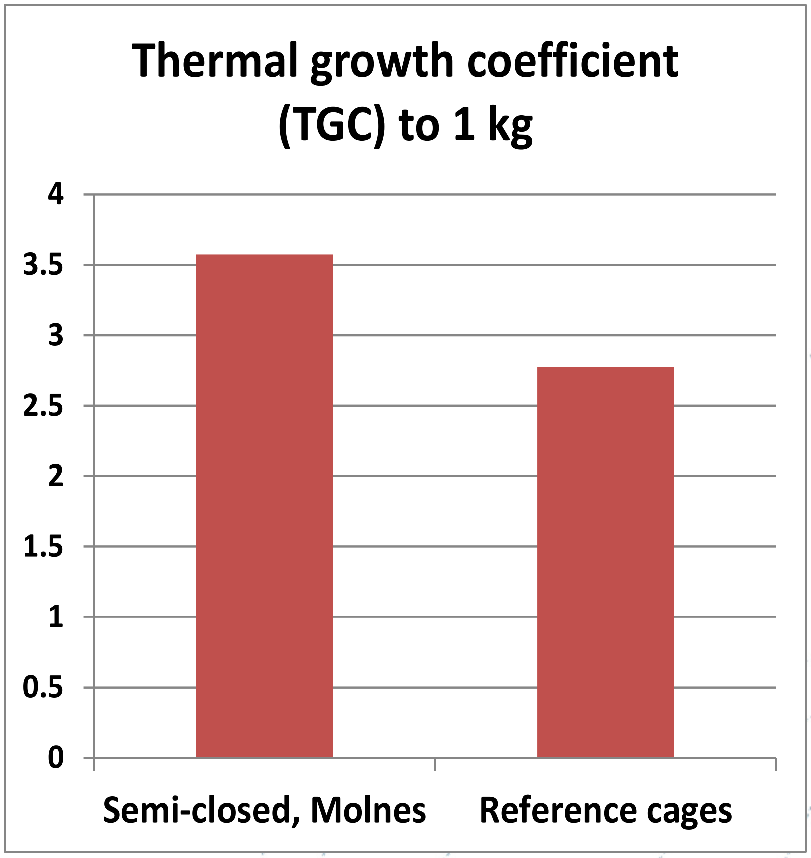
Calabrese, Handeland, et al, unpubl.

Water temperature



OPP5a: Industrial scale experiment, postsmolt prod. in semi-closed system: *Growth to 1 kg*





Calabrese, Handeland, et al, unpubl.

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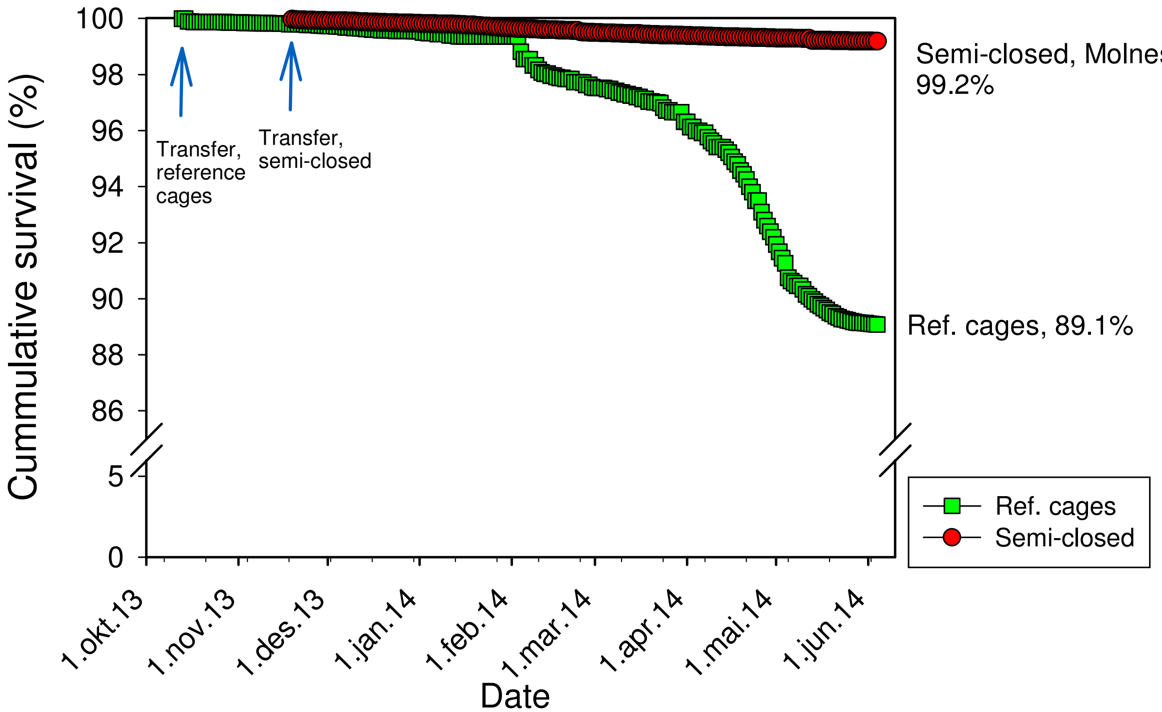
OPP5a: Industrial scale experiment, postsmolt prod. in semi-closed system: *Survival to 1 kg*

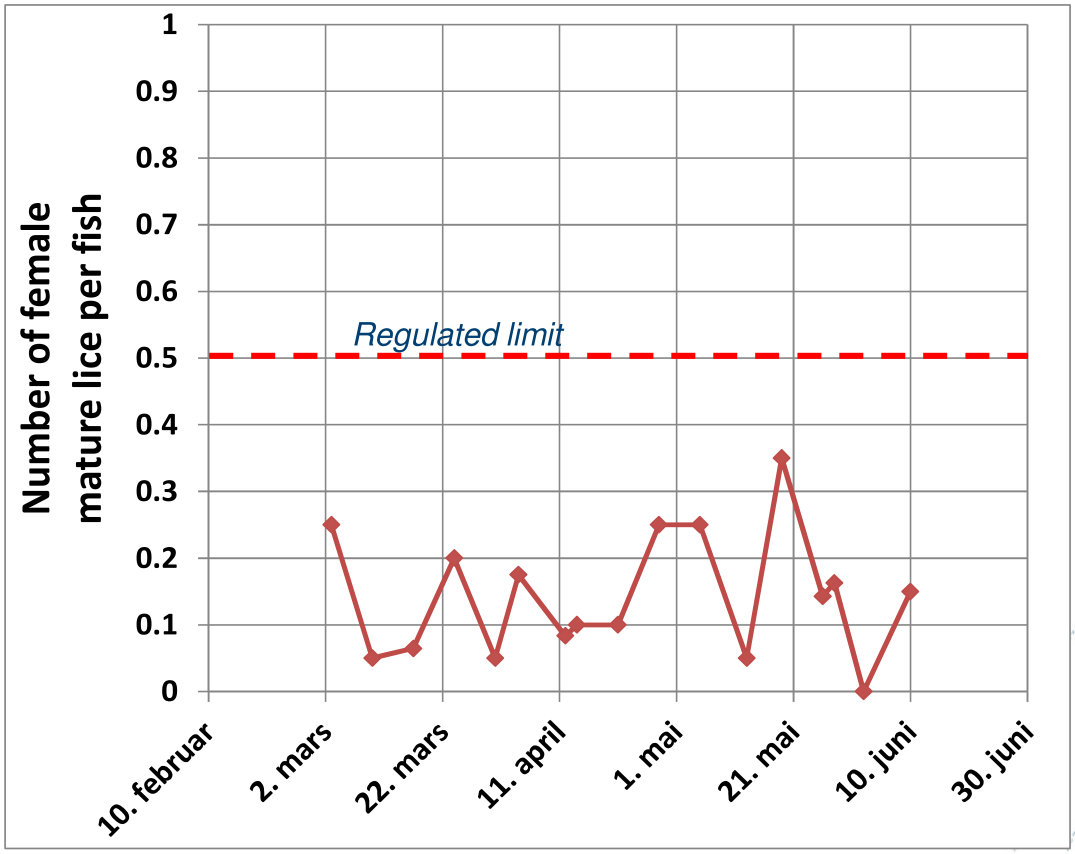


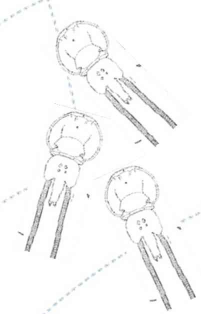
Calabrese, Handeland, et al, unpubl.

- ✓ Indicates that postsmolt production to 1 kg in semi-closed systems, has potential for very low mortality
- ✓ However, after this project, the fish were kept, and in September experienced toxic algae, and became infected with AGD, amoebic gill disease
- ✓ Marine Harvest therefore harvested the tank this Sunday

OPP5a: Industrial scale experiment, postsmolt prod. in semi-closed system: *Low, but not zero sea lice*

Mature sea lice per postsmolt





Calabrese, Handeland, et al, unpubl.

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OPP5a: Industrial scale experiment, postsmolt prod. in semi-closed system: *External welfare scores to 1 kg*

	Cataracts	Skin lesions	Operculum damage	fin damage
Before transfer	0,01±0,12	0,63±0,48	0,01±0,12	0,91±0,37
3 months	0,10±0,34	0,36±0,48	0,02±0,13	0,87±0,42
6 months	0,24±0,45	0,48±0,50	0,01±0,11	0,96±0,25

Means ± SD

N=60-80 fish. Each indicator is given a score between 0-2 based on condition (0=good, 2=bad). Values are given as means±SD

Kolarevic, Terjesen, et al, unpubl.

OPP5a: Industrial scale experiment, postsmolt prod. in semi-closed system: *Water quality to 1 kg*

Water sampling Molnes 12.05.14

Sampling location	Temp (oC)	pH	Conductivity (mS/cm)	Salinity (ppt)	Oxygen (%sat)	Turbidity (NTU)	CO2 (mg/l)
Inlet	7	8.08	50.7		101	0.39	
2m	7.28	7.8	50.8	32.2	82	0.28	4
10m	7	7.89	50.8	32.2	82	0.42	3.5
15m	6.9	7.9	50.9	32.2	83	0.5	3

Kolarevic, Terjesen, et al, unpubl.

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