NOFIMA Research to Optimize (RAS for) Atlantic Salmon Post-Smolt Production

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New strategies for post-smolt production in Norway

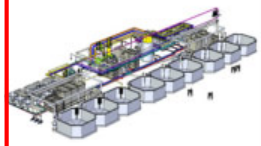
Today: 22 000 t produced in CCS

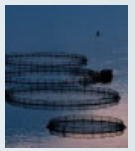
All production in CCS: 290 000 t, 13x increase!

Close-containment on land (CCS)

Smolt production in CCS in FW on land → Post-smolts in CCS on land → Short period in traditional cages/offshore

0-70 g | 70 g – 1 kg | 1 kg – 5 kg





Semi-closed containment in sea (SCC)

Smolt production in CCS in FW on land → Post.smolts in SCC in sea → Short period in traditional cages/offshore

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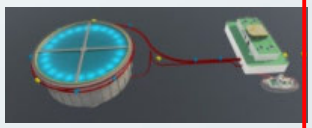

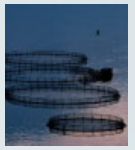

Slide prepared by Bendik Fyhn Terjesen

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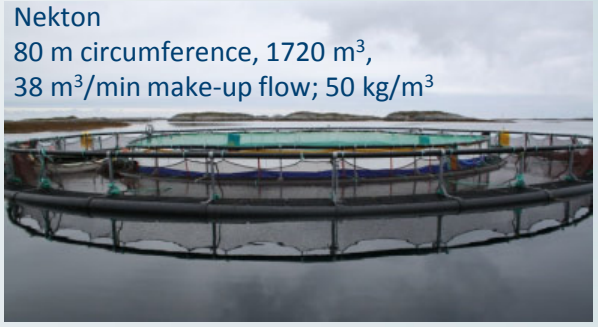
Why new strategies for post-smolt production in Norway?

- Directorate of Fisheries (2013) - increase of fish size on land from 250 g to 1 kg
- Possible solution is to reduce time fish spend in the sea
- Hypotheses: large post-smolts can
  - ✓Reduce problem with lice and escapees
  - ✓Give faster growth and better welfare
  - ✓Reduce losses in sea
  - ✓Reduce production time especially at low wither temperatures
- Lack of knowledge about the biological requirements of Atlantic salmon post smolts reared in semi-closed systems necessary for optimal performance, health and welfare


Grieg Seafood, Adamselv
2 200 m3 tank volume
2 t feed/dag


Foto: Aquafarm Equipment,
21 000 m^3, 450 m^3/min flow


Nekton
80 m circumference, 1720 m^3,
38 m^3/min make-up flow; 50 kg/m^3

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Selected research on post-smolt production in CCS & SCC

- **OPP**: Optimized post-smolt production (2012-2014)
  (PL: Marine Harvest)

- **SalmoFutura**: Welfare of Atlantic salmon postsmolts in closed-containment production systems, using a function-based approach (2014-2016)
  (PL: Bendik Fyhn Terjesen)

- **CtrlAQUA**: Centre for Research-based Innovation in Controlled-environment Aquaculture (2015-2023)
  (PL: Bendik Fyhn Terjesen)

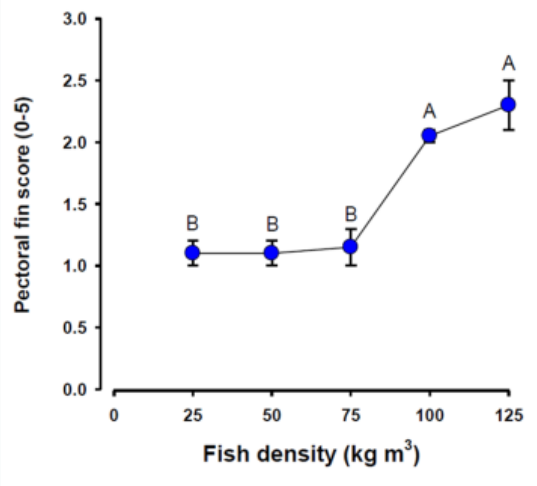
OPP: Optimized post-smolt production

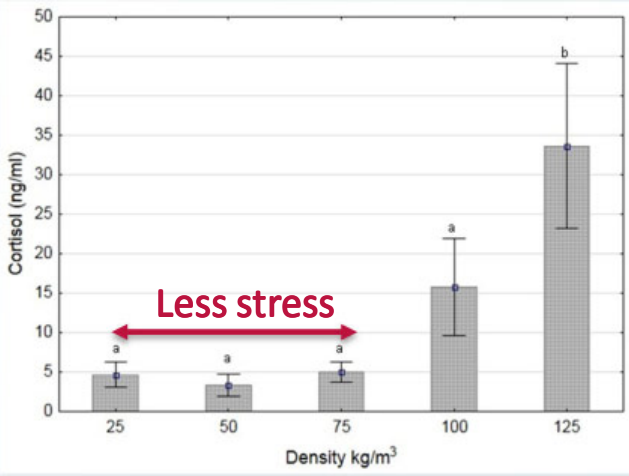
To Develop basic and applied knowledge on wheather the time in open sea cages can be reduced, and what the consequences may be in terms of performence, phisiology, health/welfare of Atlantic salmon post-smolt and production costs.

Optimized post-smolt production

- **OPP1** Optimal density and water flow for post-smolts in the sea (SCC)
- **OPP2** CO2 tolerance concentrations for post-smolts in the sea (SCC)
- **OPP3** Effect of salinity and training on growth, survival and health of post-smolts in RAS
- **OPP4** Timing of SW transfer, effects on growth, survival, welfare and quality of post-smolts
- **OPP5a** Production of post-smolts in proto-type SCC system @ Marine Harvest
- **OPP5b** Production of post-smolts in flexibag type of SCC system @ Smøla Klekkeri og Settefisk
- **OPP6** Welfare and performance of post-smolts produced @ commercial RAS @ different salinities

- Significantly lower SGR @ densities > 75kg/m^3
- 49% lower SGR @ 125 vs. 100kg/m^3
- Minimum specific water flow 0.3 l/kg fisk/min
- Increased fin erosion @ densities > 75kg/m^3



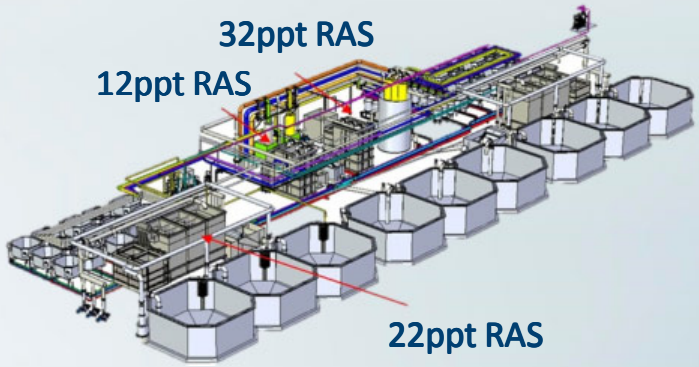


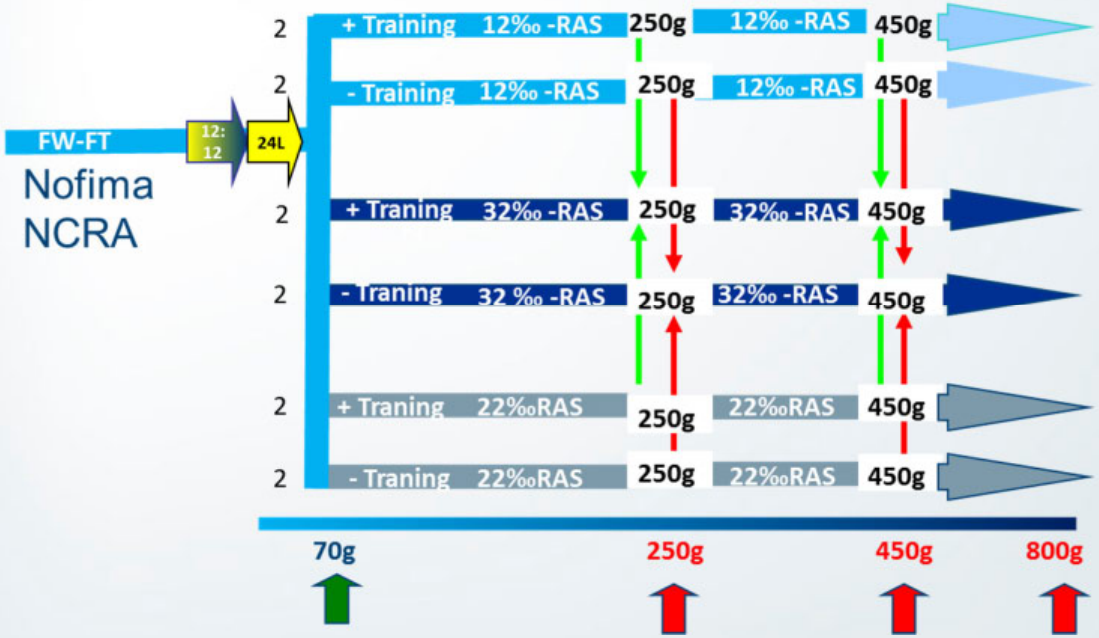
Calabrese et al. (submitted)

Optimized post-smolt production

OPP3 Effect of salinity and training on growth, survival and health of post-smolts in RAS

- What is the optimal salinity for growth, physiology, health and welfare of postsmolts in landbased RAS facilities?
- What is the effect of exercise on growth, physiology, health and welfare at different salinities?





- 70 g - 850 g post-smolt
- 7 months
- 3 salinities: 12-22-32 ppt S
- Vater welocities: 0.3 and 1 BL/s
- Light regime: 12L:12D
- 25% daily exchange rate
- 0.5 kg feed/m^3/day
- 12°C
- CO_2 < 10 mg/L
- TAN < 1.0 mg/L
- NO_2-N < 0.2 mg/L

Ytrestøyl et al, submitted, 2015

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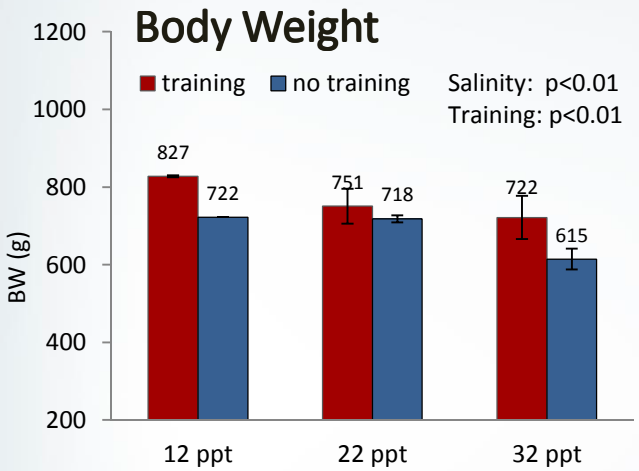
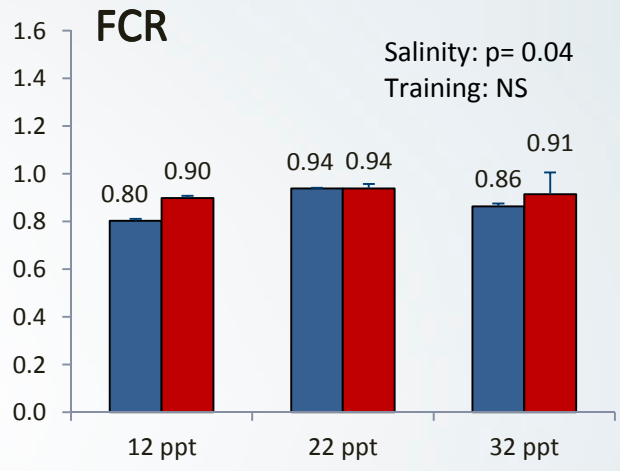
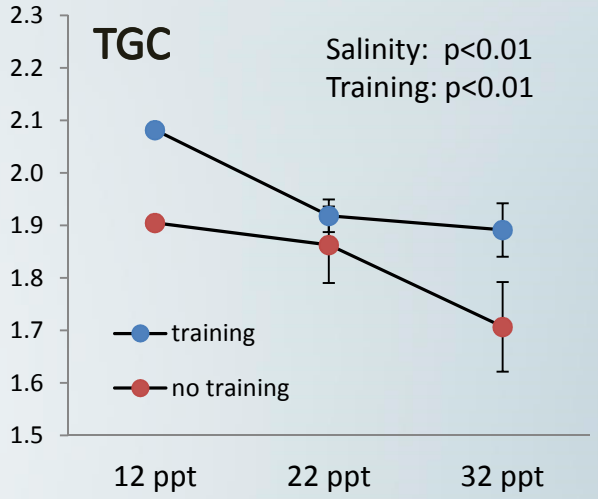
Optimized post-smolt production

OPP3

Effect of salinity and training on **growth**, survival and health of post-smolts in RAS







Salinity

Best growth @ lower salinty

Training improved growth @ all salinities

Improved feed utilisation @ lower salinity

Higher TGC@ lower salinity and in trained groups

No signs of sexual maturation observed

Ytrestøyl et al, submitted, 2015

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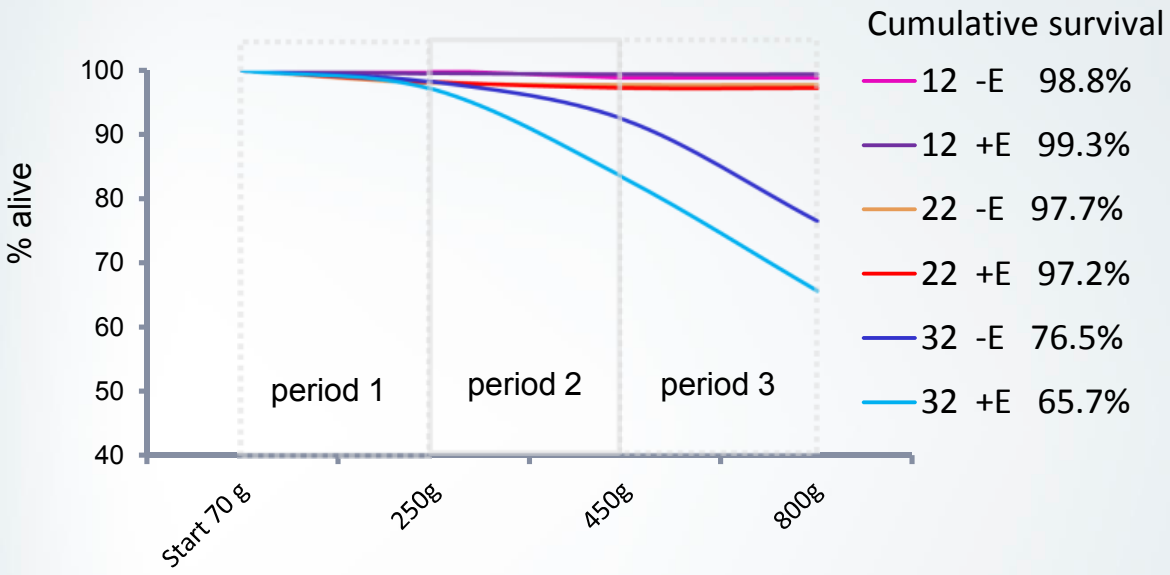
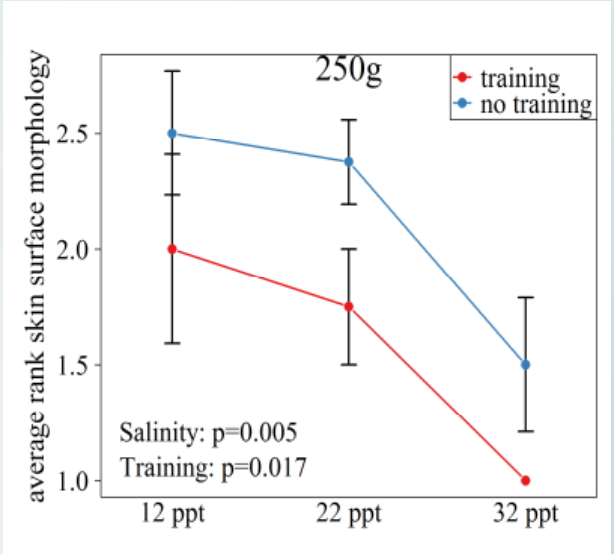
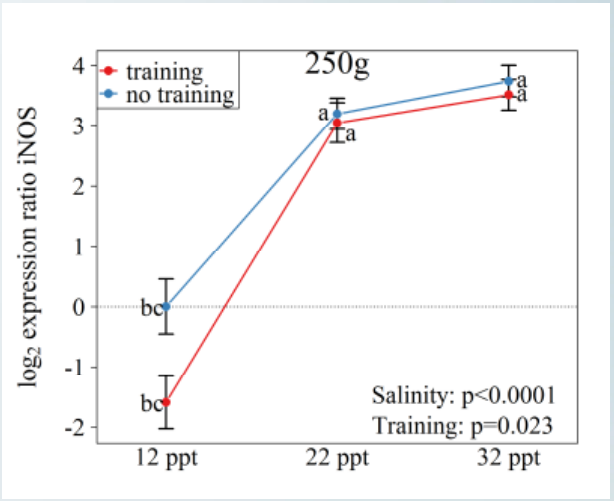
Optimized post-smolt production

OPP3

Effect of salinity and training on growth, **survival** and **health** of post-smolts in RAS







- Most of the mortality occured after weighing the fish
- Fish at 32 ppt had higher plasma cortisol
- Fish at 12 ppt had better skin quality
  - ✓ More mucus cells and thicker mucus layer
  - ✓ Lower expression of stress-induced genes

Ytrestøyl et al, submitted, 2015

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Optimized post-smolt production

OPP4 Timing of SW transfer, effects on growth, survival, welfare and quality of post-smolts

RAS 12 ppt 12°C, 1 BL/sek
NCRA Sunndalsøra

200-600 g

200-900 g

200-2000 g

600g

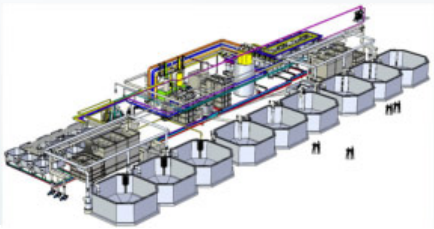
1000 g

Marine Harvest Averøy
(5x5x5 m net pens)

600-2000 g

1000-2000 g

SGR/TGC
FCR
GSI
Welfare
Quality



Ytrestøyl et al, submitted, 2015

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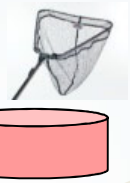
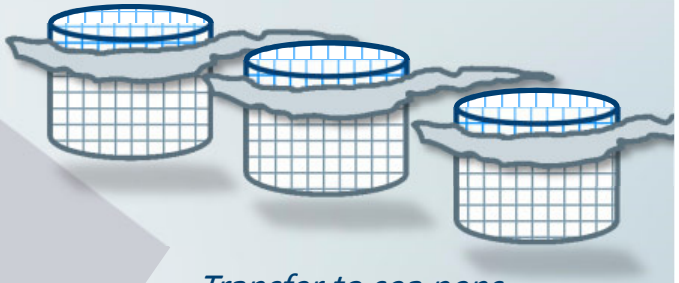
Optimized post-smolt production

OPP4 Timing of SW transfer, effects on growth, survival, welfare and quality of post-smolts

Protocol for seawater transfer





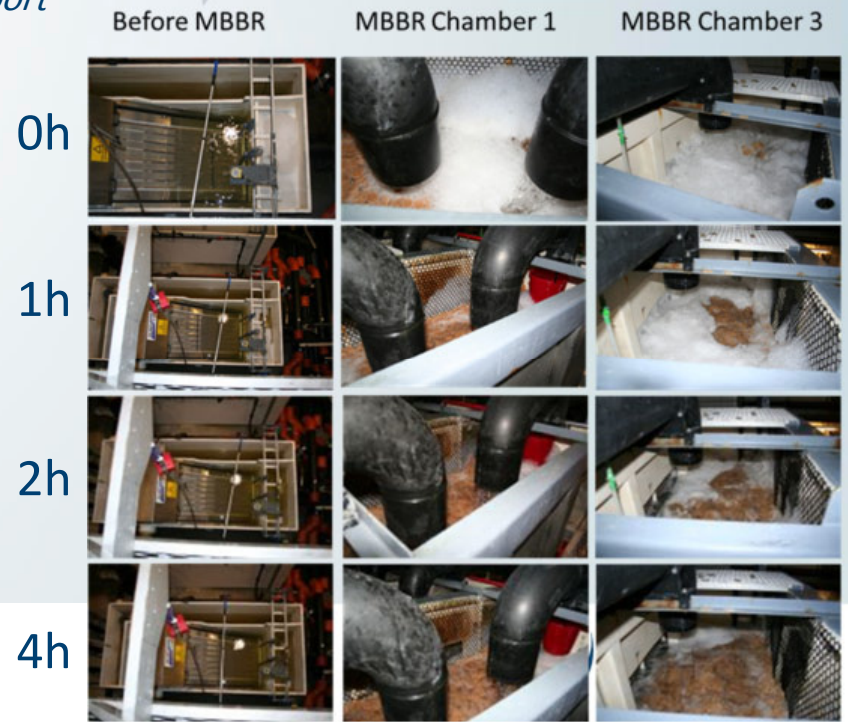
Transfer to sea pens without pumping

Sedation during transport (12 ppt S, iso-eugenol) 3.5 h trasport

Vidalife (PVP, 60 mg/l & EDTA) for netting

Used product with iso-eugenol for sedation (AQUI-S) (2.7 mg/l)

Temp in RAS (12-13ºC), 0-4ºC difference to seawater Stopped feeding 2 d before transfer



Ytrestøyl et al, submitted, 2015

Kolarevic &Terjesen, 2014

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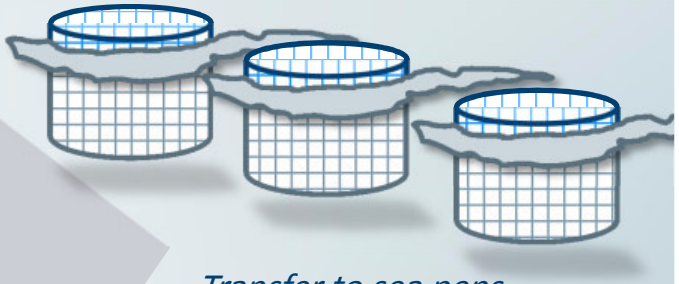

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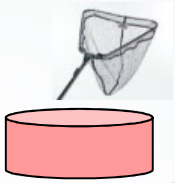

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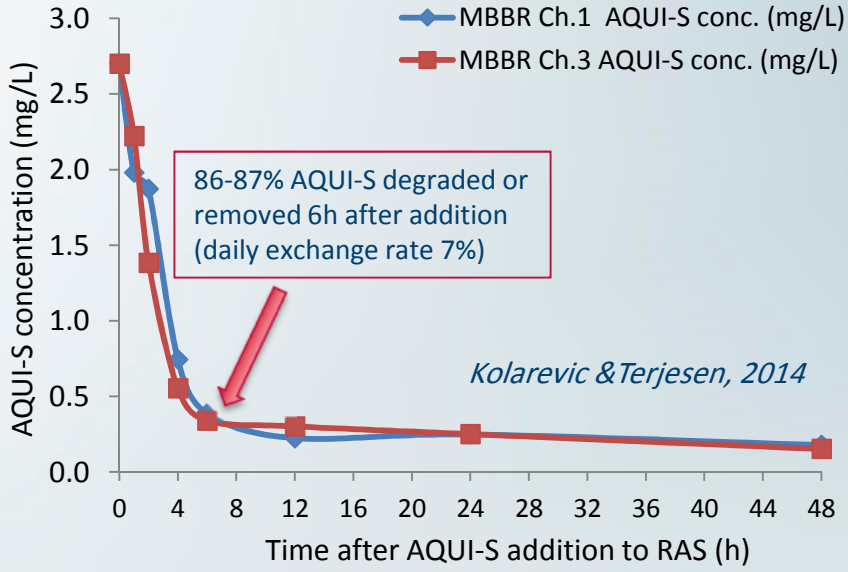

Ytrestøyl et al, submitted, 2015

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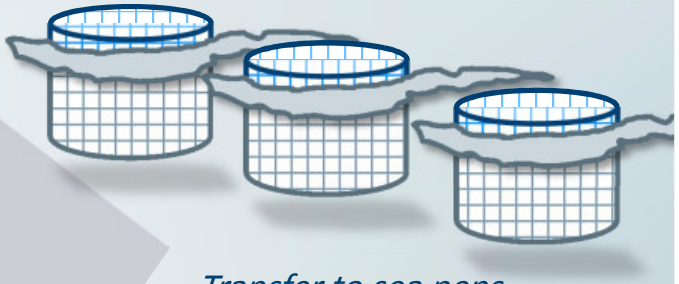

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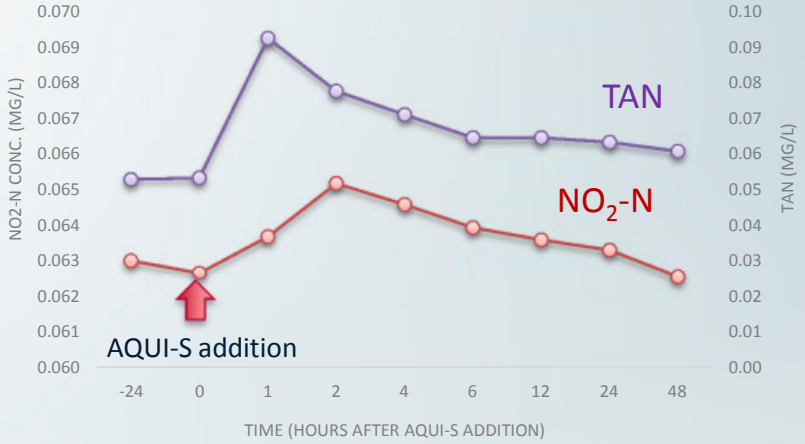

Kolarevic &Terjesen, 2014

Ytrestøyl et al, submitted, 2015

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Optimized post-smolt production

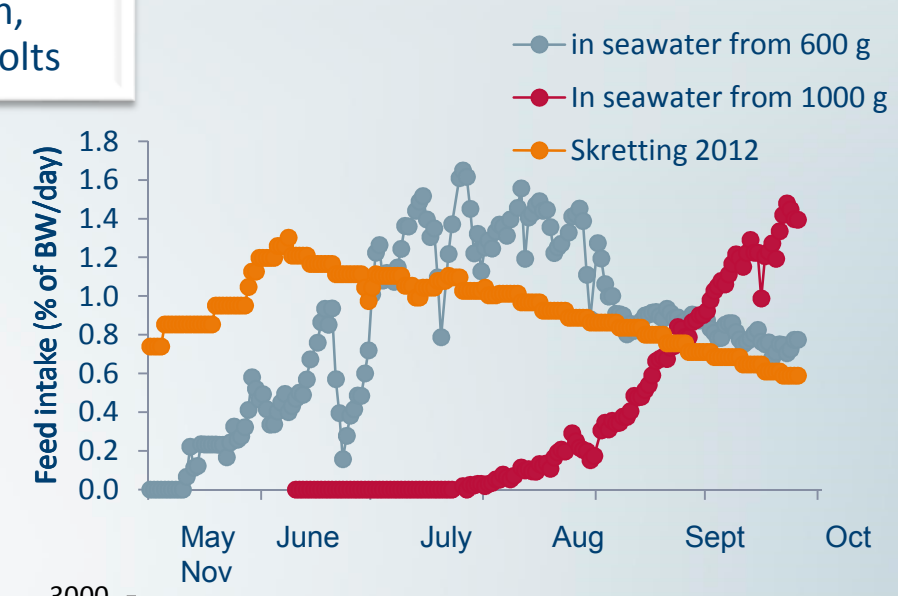
OPP4 Timing of SW transfer, effects on growth, survival, welfare and quality of post-smolts

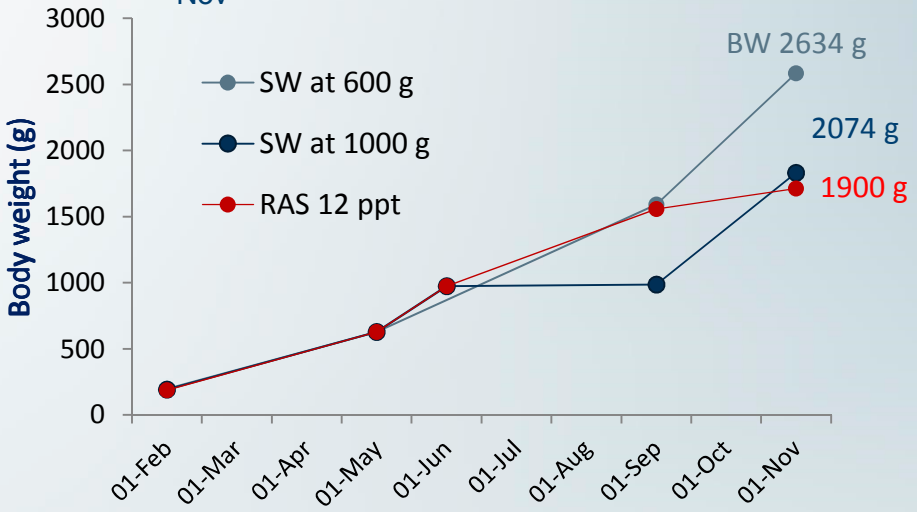
✓Transfer at 600 g:

Feed intake shortly after transfer and increase to above commercial tables in July-Sept.

✓Transfer at 1000 g:

~8 weeks without feed intake, gradual increase from late August, and above table from mid October-condition factor >@ 1000g transfer compared to transfer @ 600g





Ytrestøyl et al, submitted, 2015

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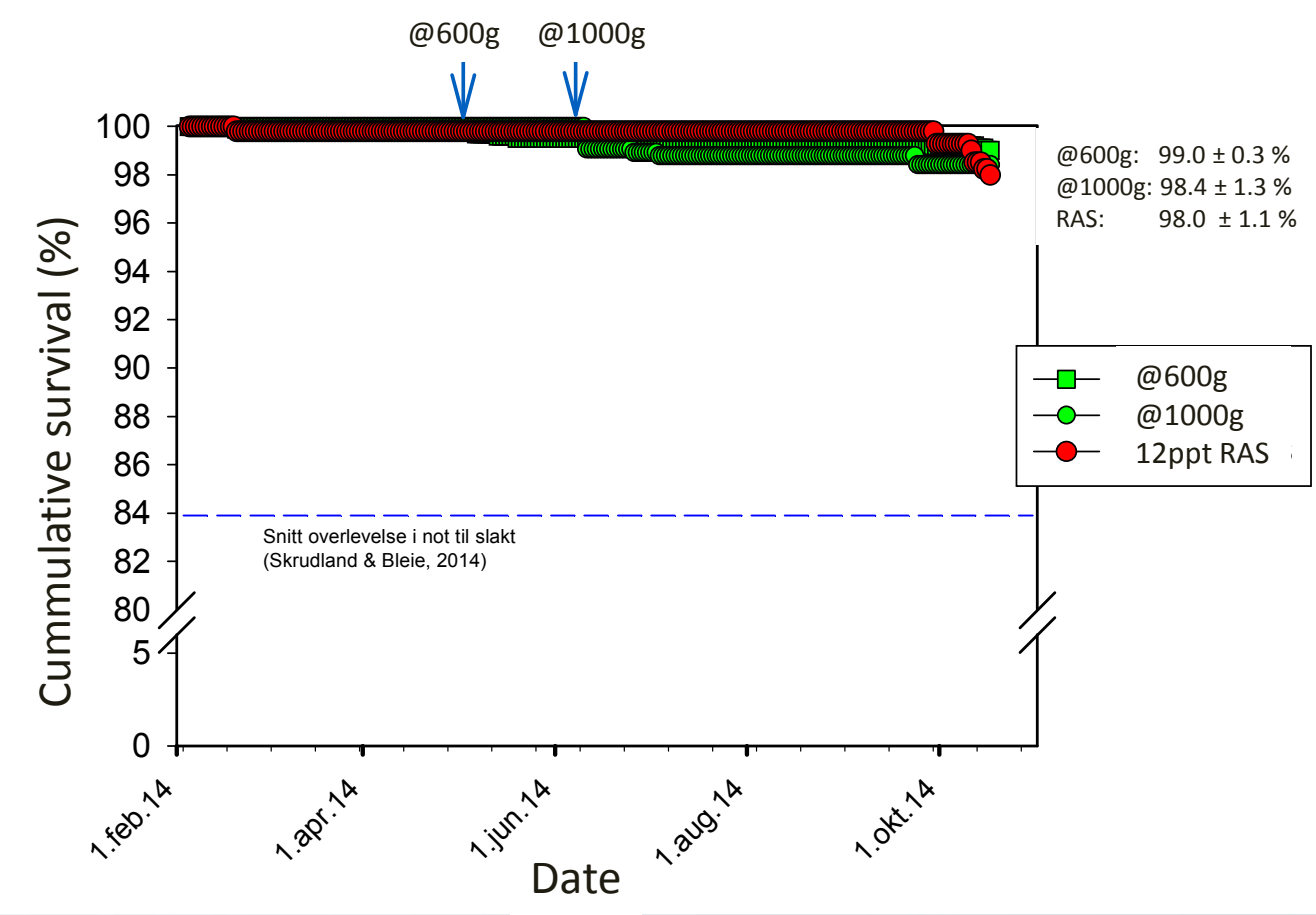
Optimized post-smolt production

OPP4 Timing of SW transfer, effects on growth, survival, welfare and quality of post-smolts

- ✓ High survival ~99%, from smolts 2.5 kg in net pens (transfer @600g)
- ✓ Inspite of several transfers and handling in the RAS and from RAS to net pens
- ✓ Post-smolt production in RAS has potential for virtually no mortality
- ✓ Handle with care!



Ytrestøyl et al, submitted, 2015

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Optimized post-smolt production

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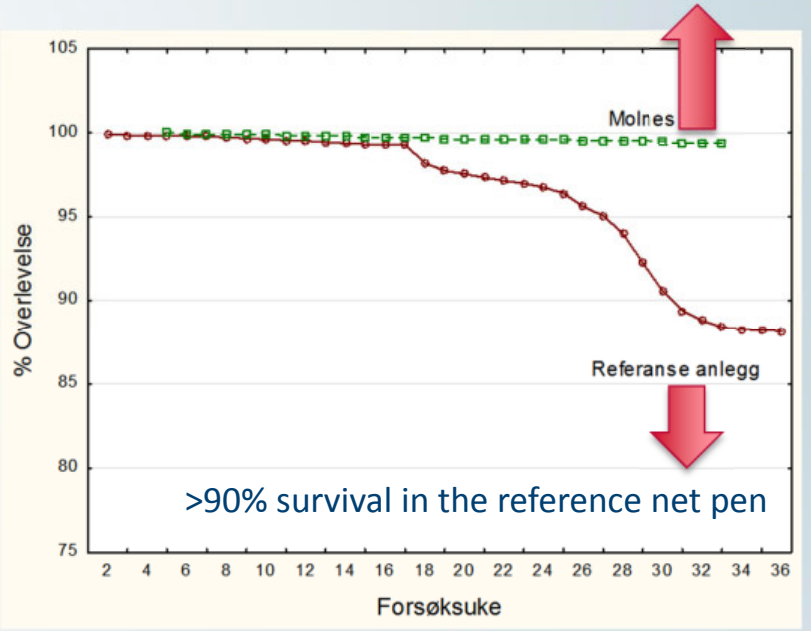
Foto: Aquafarm Equipment,
21 000 m³, 450 m³/min flow

99% survival after 6 month in SCC



>90% survival in the reference net pen

Handeland et al., 2015

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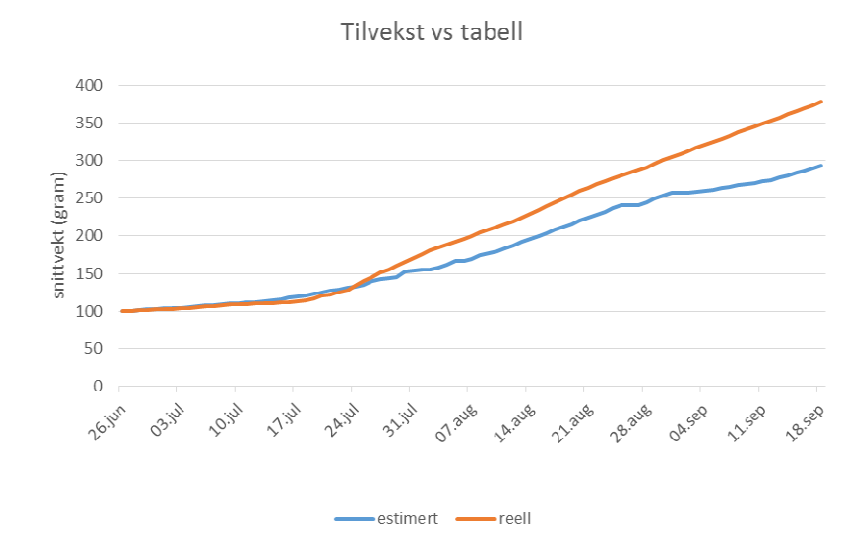
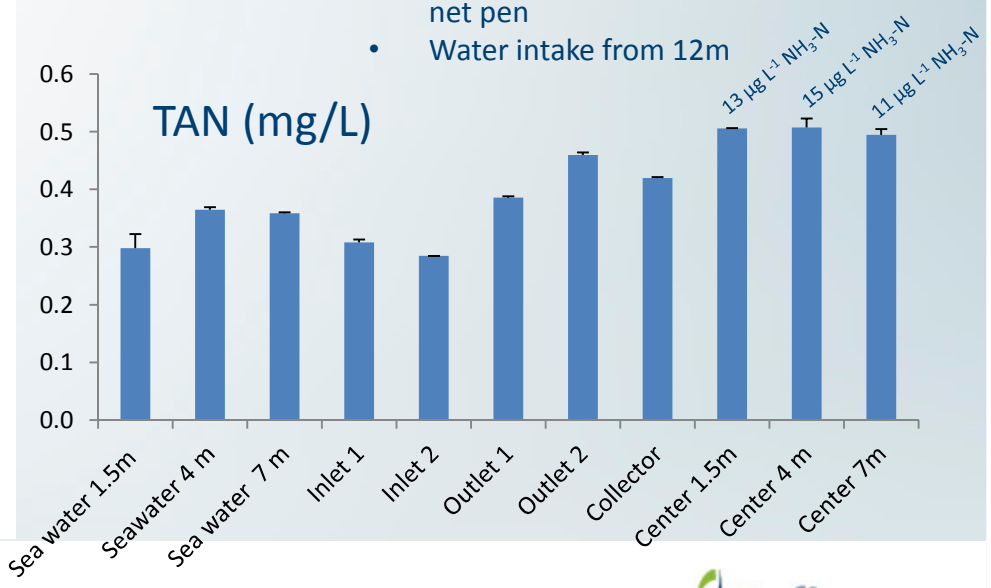
Optimized post-smolt production

OPP5b Production of post-smolts in flexibag type of SCC system @ Smøla Klekkeri og Settefisk

- 25.06.-18.09.2014
- 60 000 fish/start weight ~100g (max 15kg/m^3 density)
- Relatively high survival rate (92 %)
- Good specific growth rate of 2.2 % / day
- No lice!
- Water quality within "optimal" range of values
- Outbreak of AGD
- 2nd run in 2015 (2480m^3) – no lice & no AGD

- 1720 m3 volume & 10m deep
- Capacity: 86 ton @50kg/m3
- 38m3 intake flow four pumps
- 45 minutters retention time
- 90% exchange of water via 4 side oppenings and 10% via lift-up
- 60m diameter & 90m outer security net pen
- Water intake from 12m





Kolarevic et al. 2015

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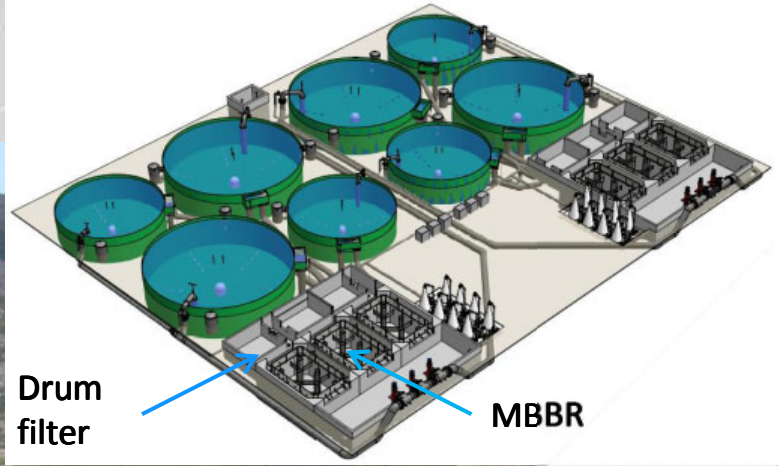
Optimized post-smolt production

OPP6 Welfare and performance of post-smolts produced @ commercial RAS @ different salinities

RAS facility

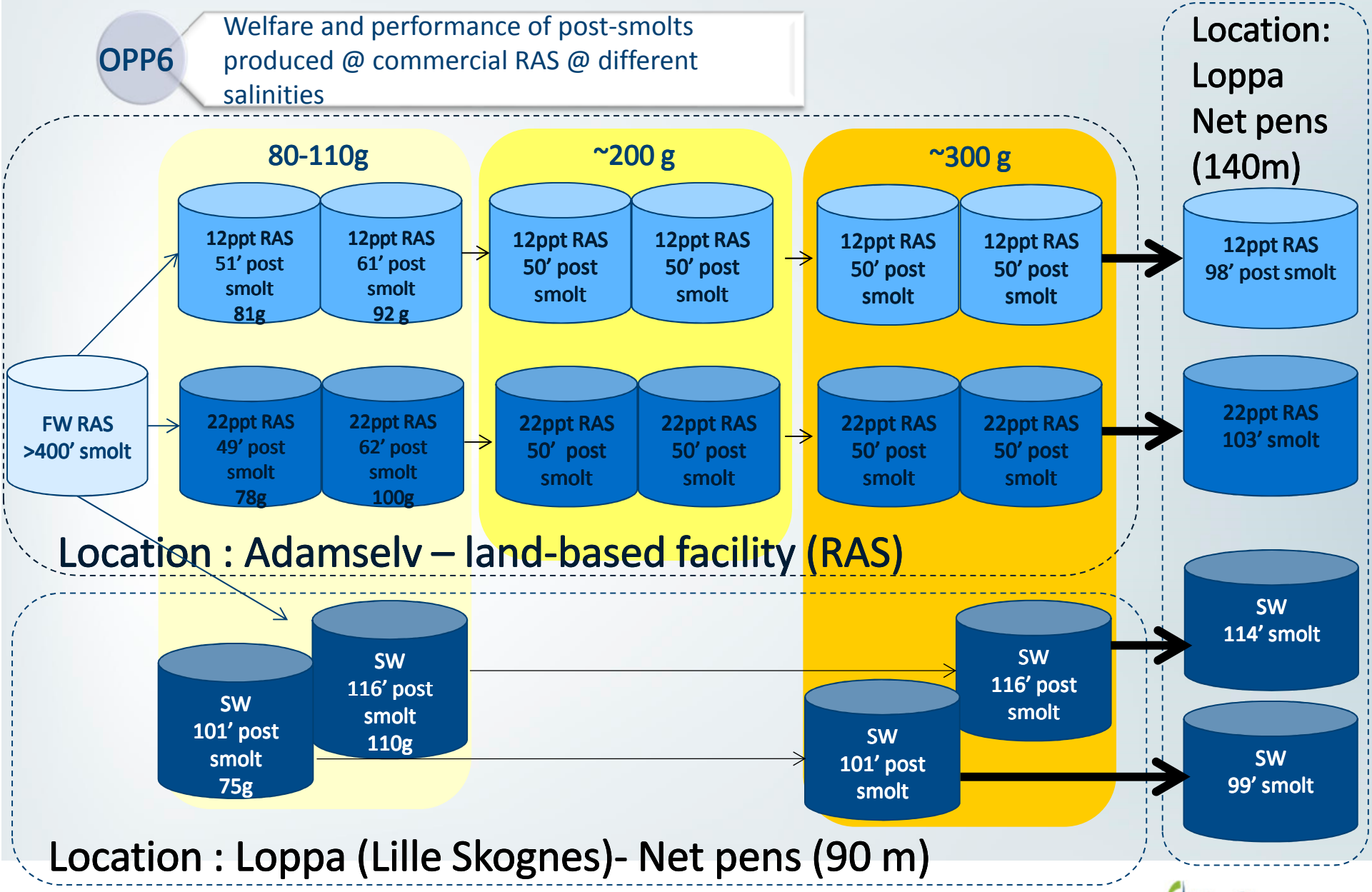
- Built in 2012/2013
- 2 200 m^3 tank volume
- 2 tons feed /day
- 30 min turn over time (55 min during the trial)
- Max flow 3600 m^3/h
- Hydrotech filters (40 µm screens)
- 3 bio reactors (volume of 500 m^3)



Optimized post-smolt production

OPP6

Welfare and performance of post-smolts produced @ commercial RAS @ different salinities



Kolarevic et al. 2015

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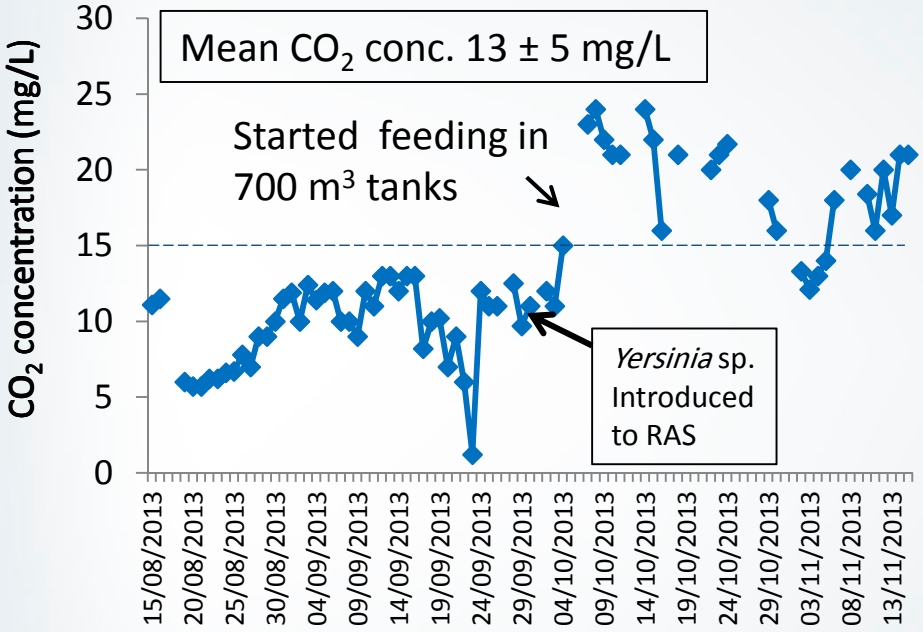

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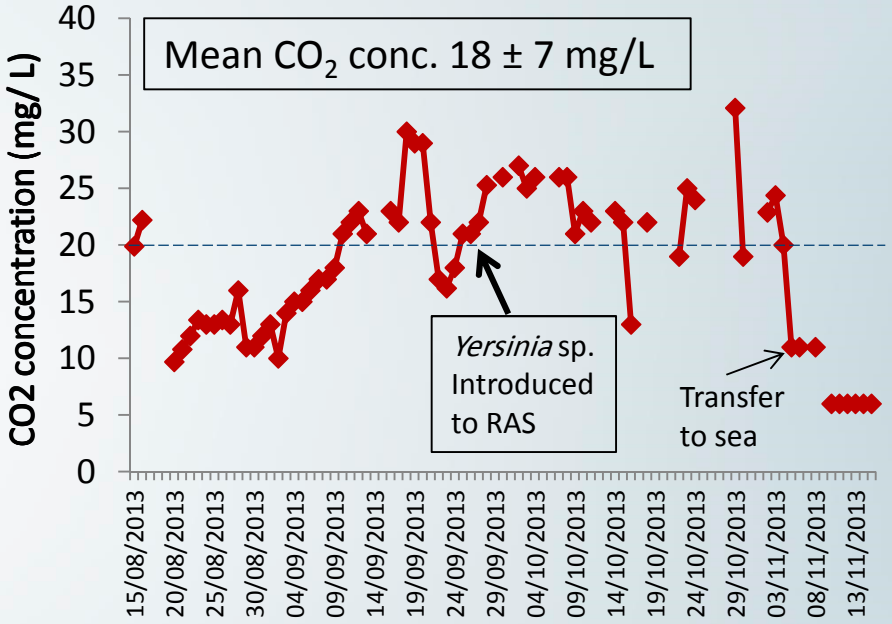

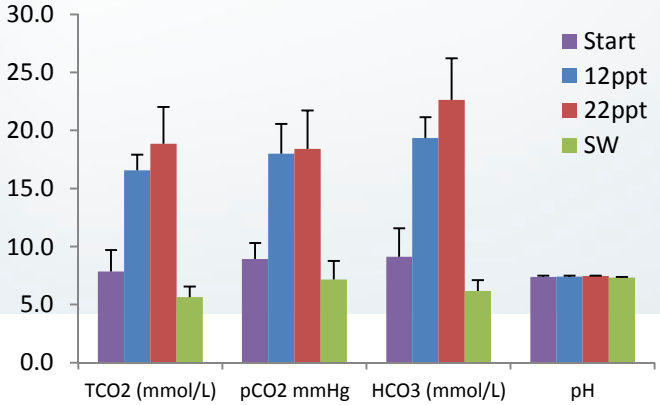

- Typical response to CO_2 in RAS treatments, with higher carbonate system conc., and lower Cl-
- Signs of Nephrocalcinosis
- Yersinia ruckeri & Tenacibaculum sp.

Kolarevic et al. 2015 & Medhus et al., 2015

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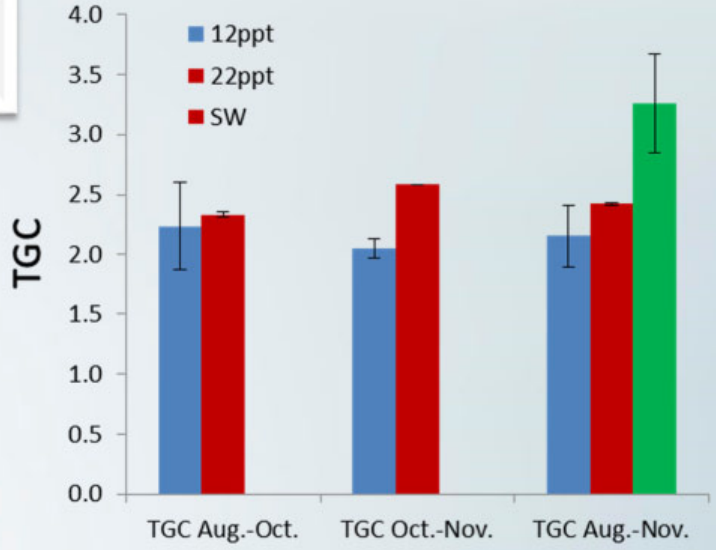
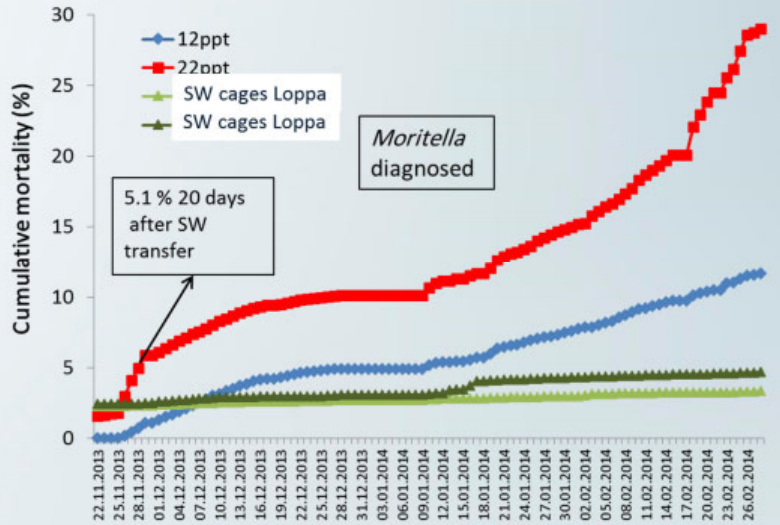
Optimized post-smolt production

OPP6 Welfare and performance of post-smolts produced @ commercial RAS @ different salinities

- Good growth rate in RAS, however Yersinia outbreak had a negative effect
- After transfer to sea higher mortality rate for RAS groups, because of sub-optimal WQ & Yersinia outbreak
- In RAS without disease 12 ppt S should be used due to better growth, health and water treatment
- In RAS with patohgens for example tipical FW-pathogens higher salinites shoud be used if adequate water treatment is in place
- Changes have been made to inprove water treatment and biosecurity and subsequent production of post-smolt was satisfactory





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SalmoFutura: Welfare of Atlantic salmon postsmolts in closed-containment production systems, using a function-based approach

Forskningsrådet

HAVBRUK 2014-2016

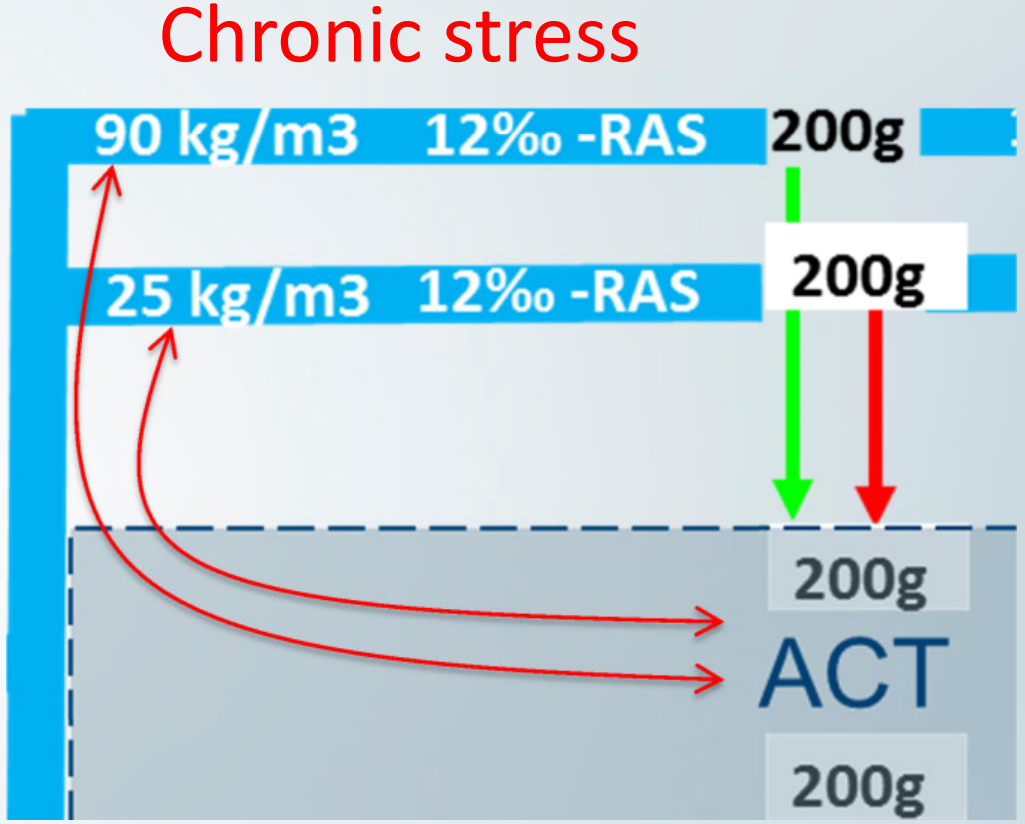
Characterize and develop new function-based tools for welfare documentation and assessment of post-smolts of Atlantic salmon in closed-containment systems, that will for the first time also include detection of chronic mild stressors using acute challenge tests (ACT)

Nofima uni Research Radboud University Nijmegen UNIVERSITY OF STIRLING PENNSTATE

Nofima

"Reverse engineering" of postsmolt:

- Identifying the indicators that when sampled during chronic mild stress can predict outcome of later ACTs, i.e. be used by farmers to identify good stocks and conditions
- Indicators that can be used to determine when a group of postsmolt for example should be transferred from a closed facility to sea cages



Slide prepared by Bendik Fyhn Terjesen

Nofima

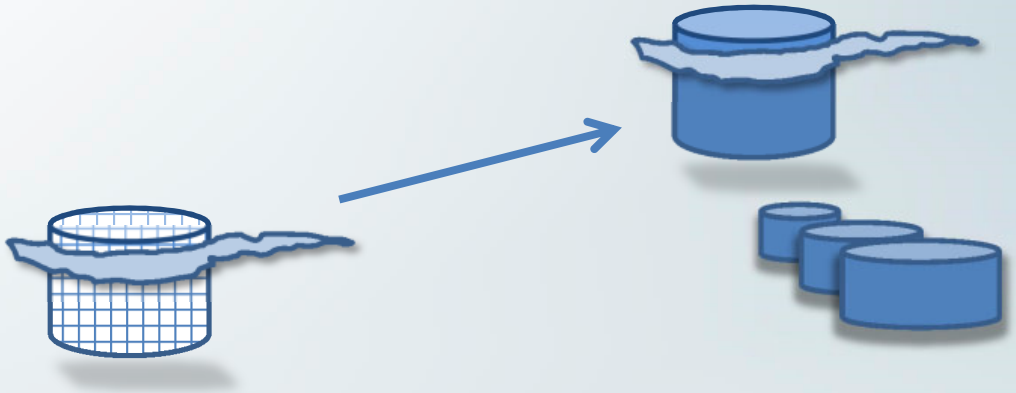
CtrlAQUA

Centre for Closed-Containment Aquaculture

Centre Director: Dr Bendik Fyhn Terjesen, Nofima

Chairman of the board: Frode Mathisen, Grieg SeaFood

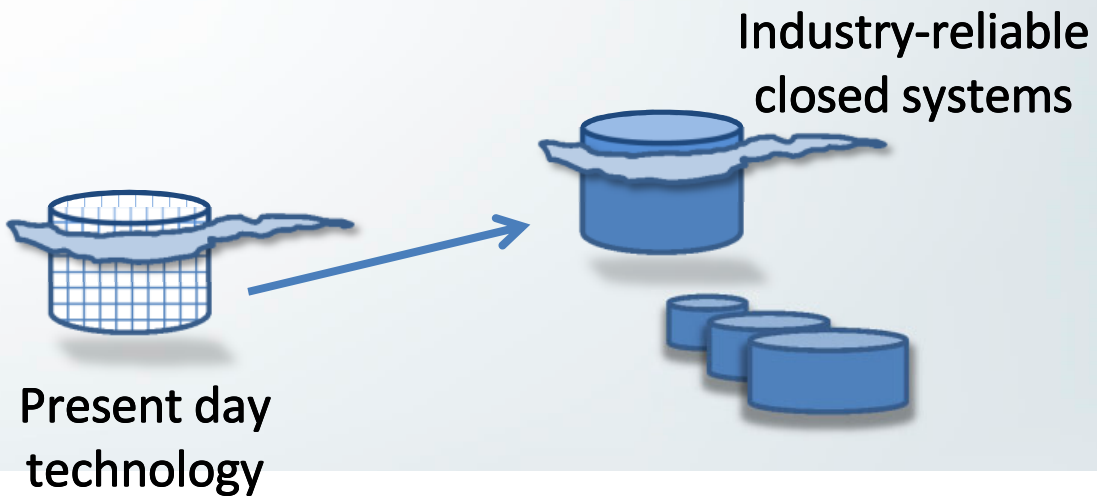
sfi Centre for Research-based Innovation



The goal of CtrlAQUA SFI

Develop technological and biological innovations to make closed-containment aquaculture systems a reliable and economically viable technology, for use in strategic parts of the Atlantic salmon production cycle-

- thus contributing to solving the challenges limiting the envisioned growth in aquaculture



19 CtrlAQUA SFI partners

Host institution:

- Nofima

Research partners:

- UNI Research
- University of Bergen
- Norwegian University of Science and Technology (NTNU)
- The Freshwater Institute
- University of Gothenburg

User partners:

Technology suppliers:

- Krüger Kaldnes
- Storvik Aqua
- Aquafarm Equipment
- Oslofjord Ressurspark
- FishGLOBE AS

Farming companies:

- Marine Harvest
- Cermaq
- Grieg SeaFood
- Lerøy SeaFood Group
- Bremnes Seashore
- Smøla Klekkeri&Settefisk

Pharmaceutical:

- Pharmaq
- Pharmaq Analytiq

Many challenges: reliability, biosecurity, technology, fish requirements, prod. costs.

Innovations for industry-reliable closed systems

Dept. **Preventive Fish Health**

Dept. **Production & Welfare**

Dept. **Technology & Environment**

Dept. **Training & recruitment**

Closed systems today

Status: 14 projects started in June 2015

Research & innovation departments

- **Dept. Technology & Environment**
  - ✓ To facilitate innovation of closed system technology, water treatment processes, and sensors, to achieve a high level of production control
- **Dept. Fish Production & Welfare**
  - ✓ To provide knowledge and innovations to determine environmental and biological requirements of salmon in closed containment systems
- **Dept. Preventive Fish Health**
  - ✓ To facilitate innovations to prevent, detect and control disease in closed-containment systems



Slide prepared by Bendik Fyhn Terjesen

CtrlAQUA Nofima

CtrlAQUA projects 2015

Leader: Bendik Fyhn Terjesen (Nofima)

SENSOR: Sensor protection & maintenance in CCS

- Stability and long-time reliability
- Optimised maintenance
- Protecting grids and/or stockings.

Department Technology & Environment

HYDRO: Hydrodynamic challenges in huge tanks >1000 m^3

- Control of water rotational and radial velocities and mixing
- Adjusting flow inlet and outlet structures @ tank exchange rate.

REMOVAL: New technologies for RAS sludge processing

BIOMASS: Machine vision for biomass in closed systems

- Camera machine vision technology for fish weight
- FI monitoring

INTAKE: Particle and pathogen removal from intake water from SCC systems

- Technology preventing pathogens entrence
- Manage the huge intake flows
- Review of available technologies.

CtrlAQUA projects 2015

Leader: Lars Ebbesson (UNI Research)

FLEXIBAG Water quality in Flexibag SCC for post-smolts

- Monitoring of water quality

DATABASE: Environmental and biological requirements & surveillance database for CCS

- Database of environmental and biological requirements
- Surveillance tool for CCS

Department Production & Welfare

ROBUST: Robustness evaluation parameters associated with biological requirements in CCS

- Neural response genes provide predictive power of robustness when testing limits of biological requirements
- Integrate the new neural data with other biological data and publish

PARTICLE: Particle tolerance in post-smolts reared in RAS

- Effects of RAS particle concentration on post-smolt performance, welfare and health.

PRELINE: Post smolt welfare and performance in large scale Preline SCC

- Preline post-smolts vs post-smolt from open net pens

CtrlAQUA projects 2015

Leader: Sven Martin Jørgensen (Nofima)

BARRIER: Osmoregulatory barrier function in post-smolts reared in CCS

- Evaluate to what extent barrier function relates to the osmoregulatory capacity of skin in Atlantic salmon at different smolt-postsmolt stages exposed to different CCS strategies, stress levels and salinities.

Department Preventive Fish Health

RISK: Review of pathogens representing a particular risk in closed containment systems

- Review of the microparasites that could represent a future problem for production of salmonids in CCS or SCC

MICROPARASITES: Characterization of microparasites in CCS

- Identify and characterize microparasites in CCS
- Develop methods and technology for identification, diagnostics and for differentiation between high and low virulent strains.

Thank you for your attention!

..and to my colleagues in Nofima:
Trine Ytrestøy,Roger Selset, Yuriy Marchenko, Britt Kristin Reiten, Dag Egil Bundgaard, Kristin Skei Nerdal and others

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Follow us on:
www.ctrlaqua.no

Norges Forskningsråd, Havbruk, FHF and industri have financed projects:
Optimalisert Postsmoltproduksjon (OPP) og Postsmolt A,D,E (2012-14)
SalmoFutura (2014-16)
CtrlAQUA SFI (2015-23)

FHF The Research Council of Norway CtrlAQUA Nofima


Nofima