CtrlAQUA – New Knowledge About Closed and Semi-closed Containments

MIAMI 5. DECEMBER 2018

AQUACULTURE INNOVATION WORK-WHOP

CtrlAQUA

www.ctrlaqua.no

Åsa Maria Espmark
Senior researcher and CtrlAQUA Center leader

Nofima

New alternative ways of producing salmon increase the need for knowledge – new conditions and challenges

RAS og FT on land


Photo: Bremnes Seashore


Photo: Grieg Seafood


Photo: Grieg

S-CCS in sea


Photo: FishFarming

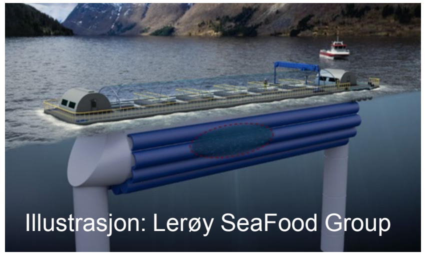
Illustrasjon: Lerøy SeaFood Group


Photo: Aquafarm Equipment

Off-shore


Foto: SalMar

Cages in sea


Foto: Åsa Espmark

Land-based to slaughter


Foto: Kyst.no

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CtrlAQUA – Center for closed containment aquaculture (2015 – 2023)

Senter for forskningsdrevet innovasjon

Norges forskningsråd

CtrlAQUA aim

CtrlAQUA shall develop technological and biological ***innovations*** *to make closed containments to a* ***reliable and economic sustainable*** *technology. Main focus are on innovations for the strategic important periods in the salmon live cycle, such as* ***post-smolt***

RAS on land

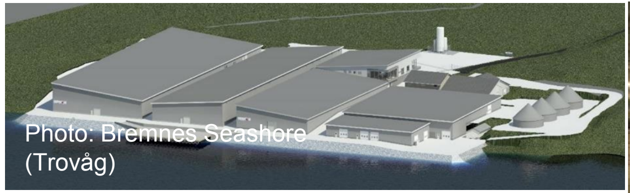


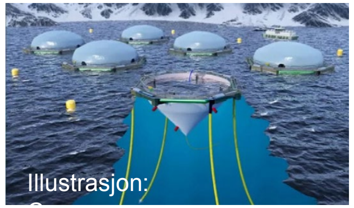
Photo: Bremnes Seashore (Trovåg)

Photo: Grieg Seafood

Photo: Grieg Seafood

S-CCS in sea

Photo: FishFarming



Illustrasjon:

Foto: FishGlobe

Photo: Aquafarm Equipment

Illustrasjon: Lerøy SeaFood

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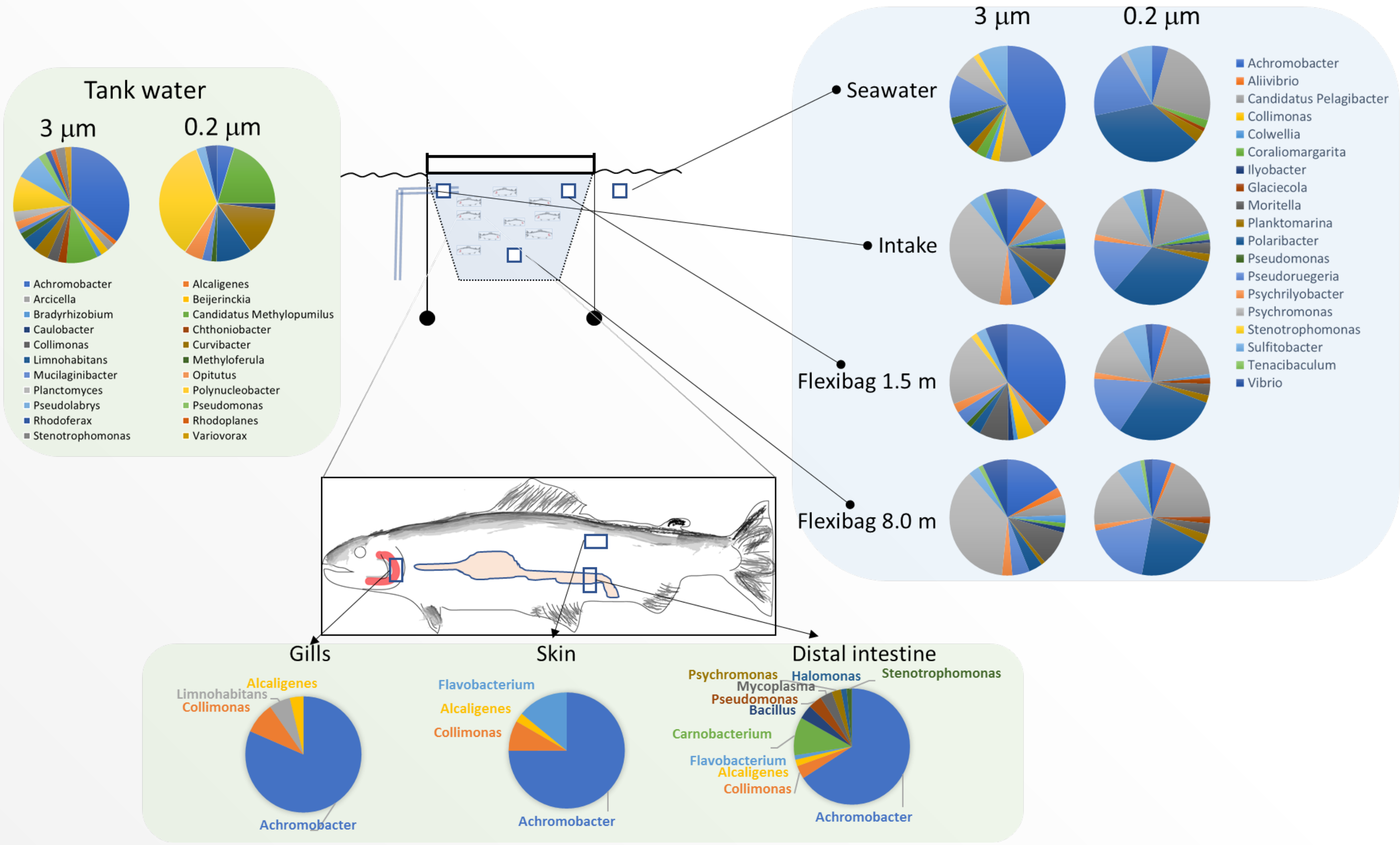
Key issues describing CtrlAQUA

1. Ensure the health and welfare status of the fish
2. Ensure robust fish
   - E.g. by identify gene markers for robustness
3. Ensure that the fish is well trained
4. Minimize the risk for pathogen entrance to fish and system
5. Find the optimal environmental conditions for rearing and transfer
6. Ensure optimal systems

Ensure the health and welfare status of the fish
Characterizing the microbiota

Christian Karlsen
(Nofima)



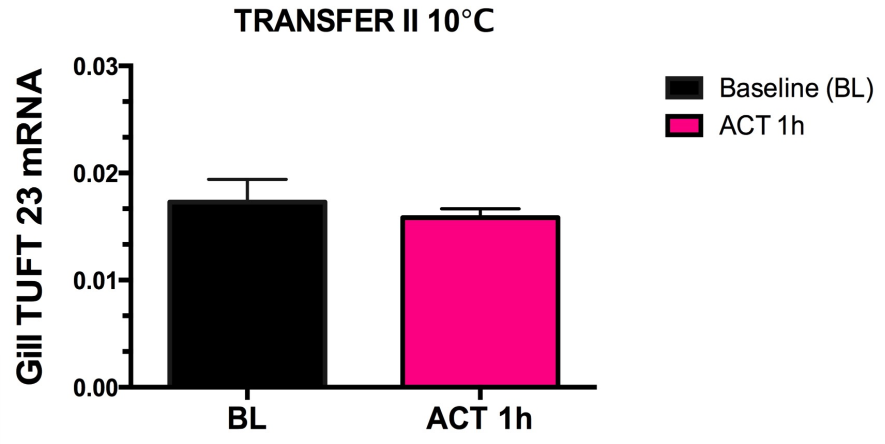
Identifying bacteria associated to the rearing environment and the surfaces of Atlantic salmon

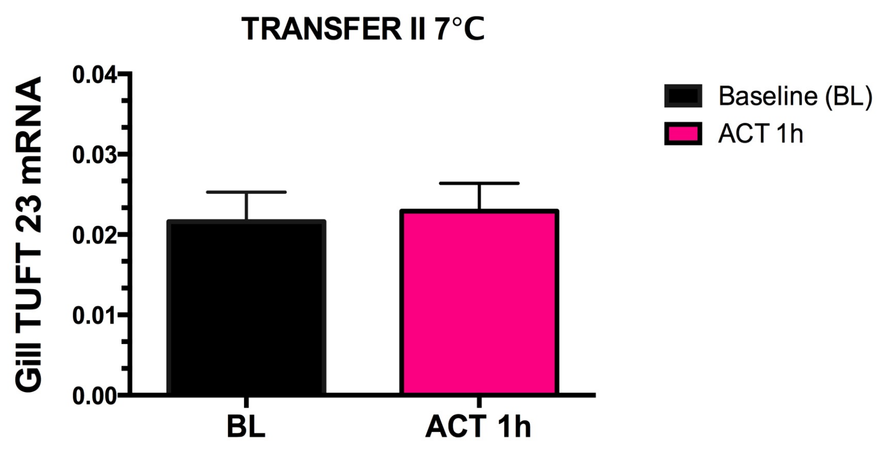
- What types of bacteria are entering systems and where
- Are certain bacteria enriched in the rearing environment
- Bacteria associated to specific tissue types

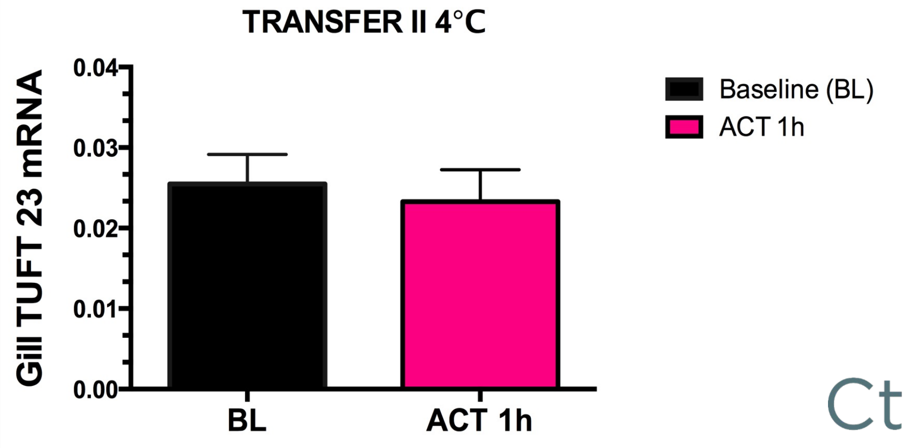
Tom-Ole Nilsen
(NORCE)

Identify gene markers for robustness

Direct transfer of post-smolts to different temperatures – gene markers







- **Velocities**
- **Particle load**
- **CO_2**
- **S-CCS**
- **Temperatures at transfer**

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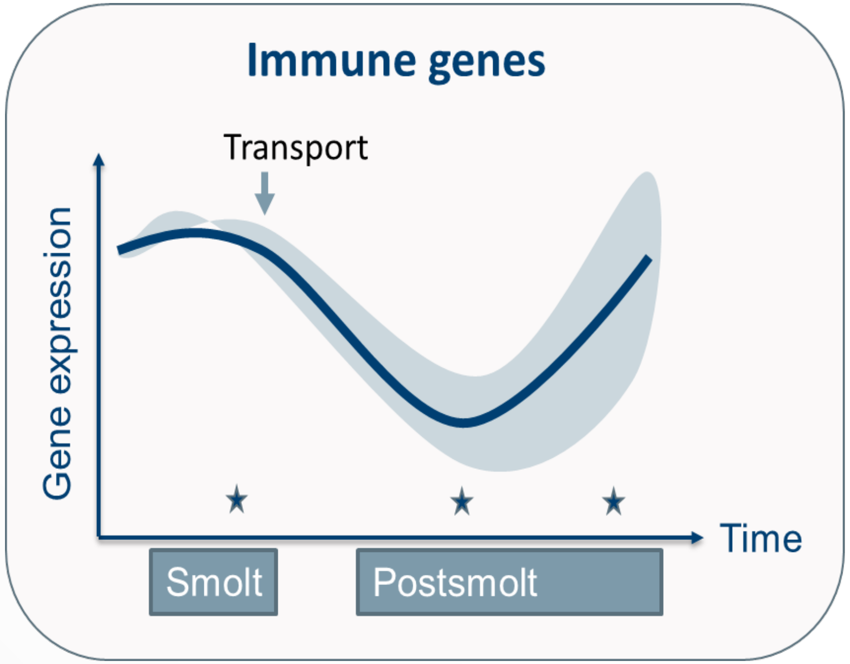
Identify gene markers for robustness

Christian Karlsen
(Nofima)

Skin gene transcription

Immune gene expression
- reduced 1 month post SW transfer
- increased after 4 months

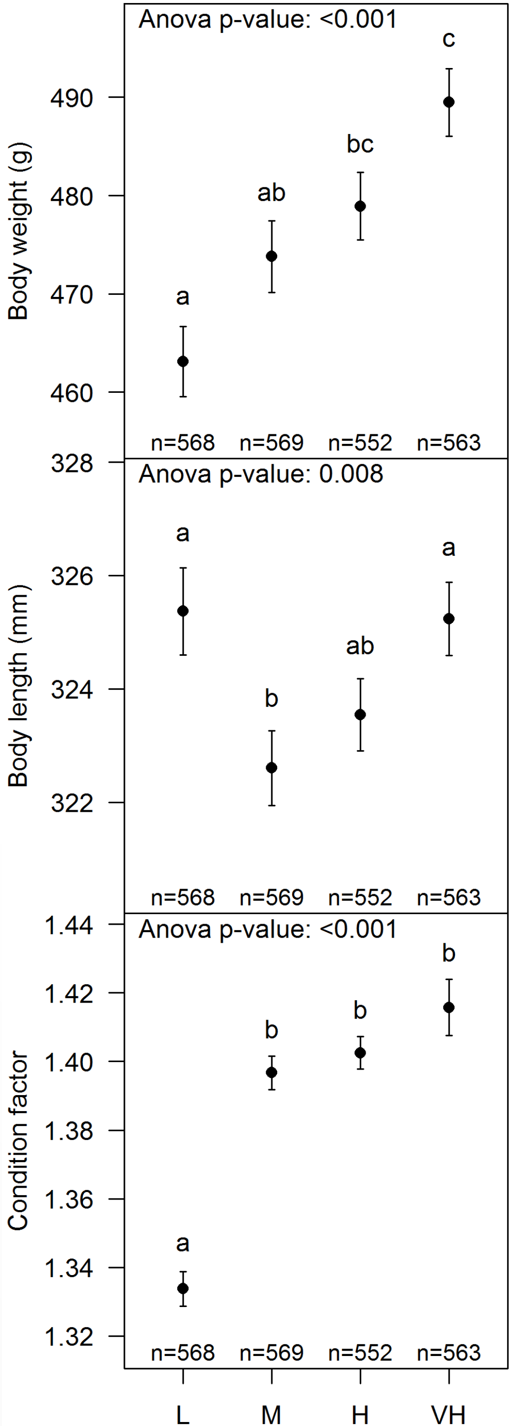


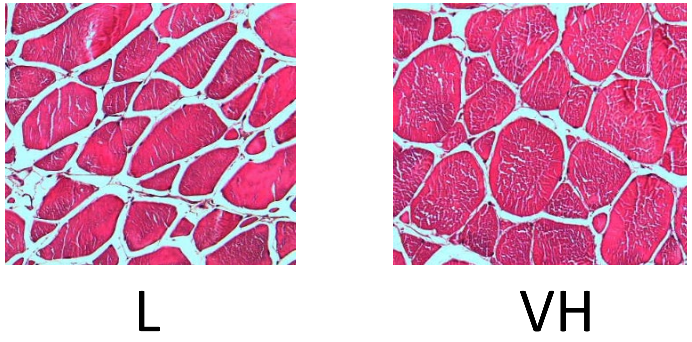
Results indicate why increased susceptibility to pathogens associated to welfare problems and losses of postsmolts occur

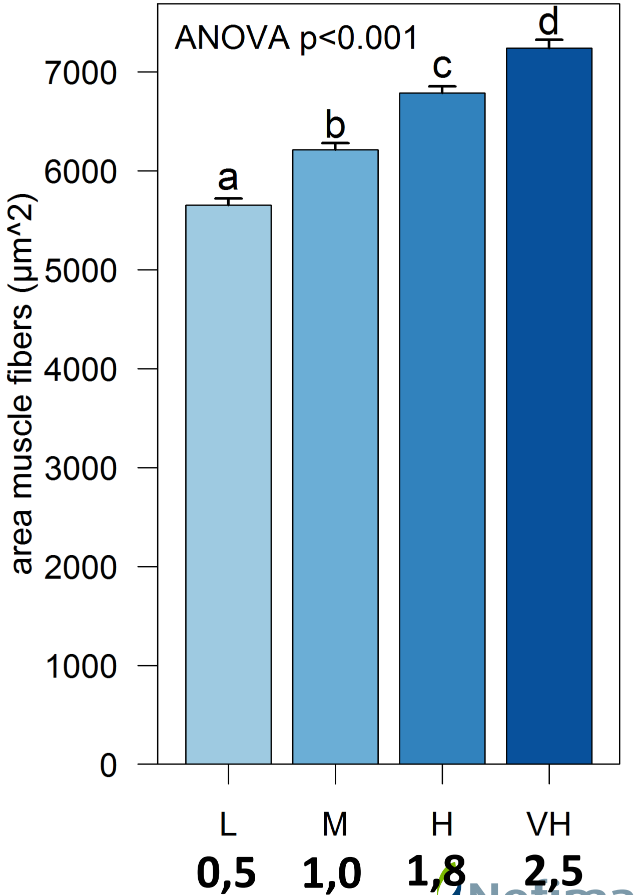
Ensure that the fish is well trained
Gerrit Timmerhaus (Nofima)

After three month training:

- Linear growth rate increase with higher water velocities
- Length increase of L group, resulting in lower condition factors
- Increase in body mass mainly due to muscle growth
- Behavior observation: schooling at high velocities



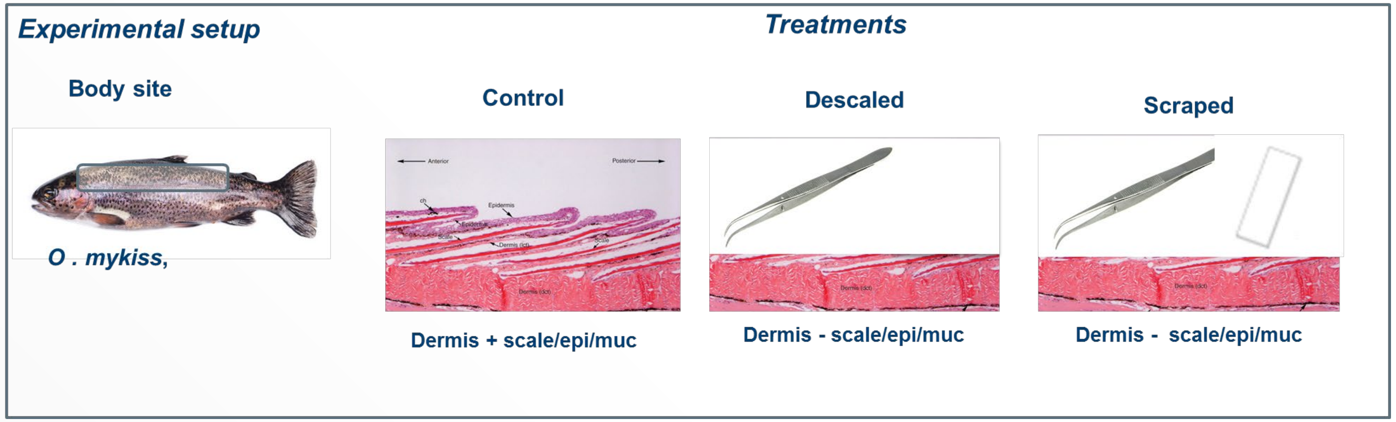


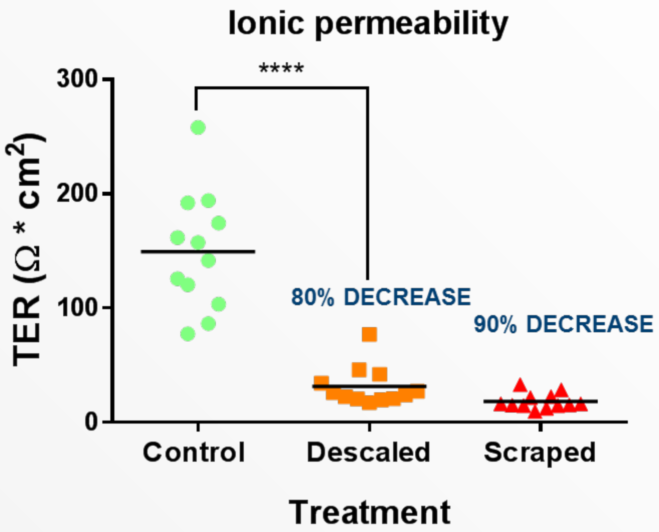


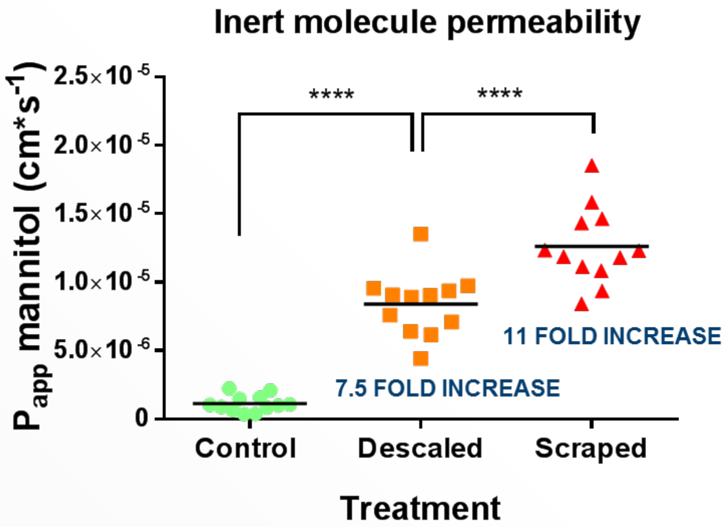
Minimize the risk for pathogen entrance to fish and system

(Christian René Karlsen, Nofima)

Scale loss and skin barrier function in CCS







University of Gothenburg

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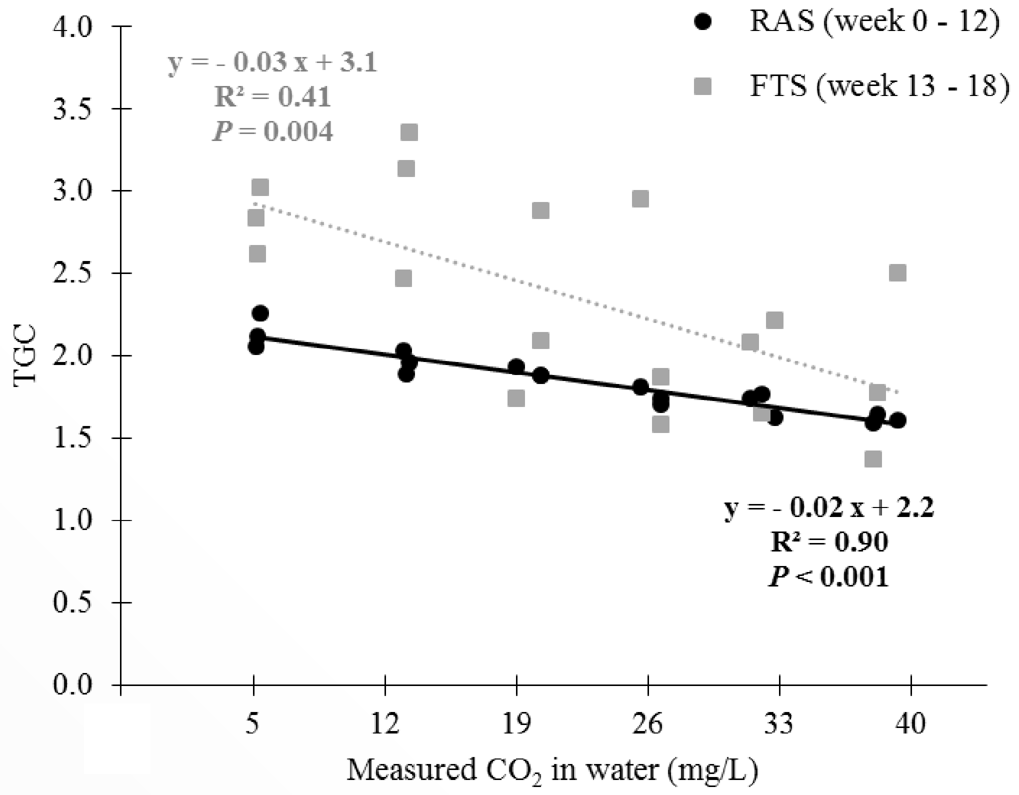
Optimal environmental conditions – example water quality and CO_2

Vasco Mota/
Kevin Stiller
(Nofima)

Challenge: many of the recommendations on water quality limits come from flow through

- Approx. 10% of growth reduction was observed for every 10 mg/L increase in CO_2, over the range of CO_2 concentrations studied (5–40 mg/L).
- Negative effects of CO_2 exposure on growth in the RAS phase persisted following transfer to seawater
- No mortalities, cataracts, nephrocalcinosis or poor external welfare observed in fish exposed to CO_2 from 5 – 40 mg/L



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Impacts of ozon on the performance and health of Atlantic salmon post-smolts in RAS

Kevin Stiller
(Nofima)

Total residual oxidants (TRO) in Atlantic salmon post-smolt in brackish water

Experimental setup:

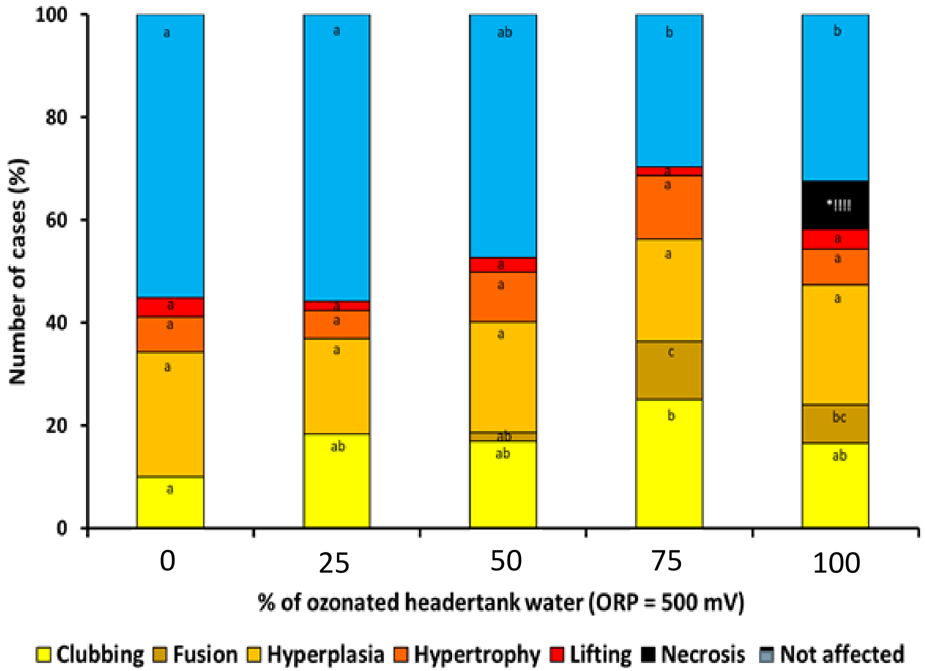
very high
500 mV; 44 µg as l^{-1} as Cl_2

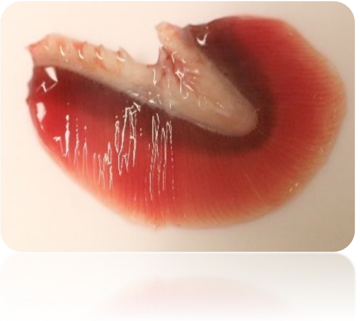
high
425 mV; 16 µg as l^{-1} as Cl_2

medium
350 mV; ~10 µg as l^{-1} as Cl_2

low
280 mV; ~10 µg as l^{-1} as Cl_2

control
230 mV; 0 µg as l^{-1} as Cl_2





Gene markers for inflammation, oxidative stress and apoptosis were significantly upregulated in VERY HIGH group.

Gill health was significantly affected in HIGH and VERY HIGH groups. Pathological alterations such as necrosis, hypertropy, hyperplasia and lifting were significantly high in these groups.

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Impacts of water quality on the performance and health of Atlantic salmon post-smolts and biofilsm in RAS (Chris Good, FI)

Effects of Ozone on Post-Smolt Atlantic Salmon Growth, Performance, and Maturation in Freshwater Recirculation Aquaculture Systems

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Experimental Design

3 RAS Operated with Ozone
- ORP setpoint = 320 mV

3 RAS Operated without Ozone

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	Ozone	No Ozone
True Color (Pt-Co Units)	2 ± 1	48 ± 2
Ultraviolet Transmittance (%)	86 ± 1	62 ± 1
Heterotrophic Bacteria (counts/mL)	33 ± 9	119 ± 14
Dissolved Copper (mg/L)	0.008 ± 0.001	0.028 ± 0.002
Dissolved Iron (mg/L)	0.014 ± 0.002	0.025 ± 0.003
Dissolved Zinc (mg/L)	0.052 ± 0.003	0.062 ± 0.002

	Ozone	No Ozone
Means Salmon Weight (g)	1051 ± 36	928 ± 4
Fish Density (kg/m^3)	96.5 ± 3.2	84.6 ± 0.3
FCR	0.98 ± 0.10	0.92 ± 0.01
Fish Survival (%)	98.9 ± 0.4	98.9 ± 0.2
% Mature Fish (GSI $\geq$ 1.0%)	29 ± 3	19 ± 6

- Ozone significantly improved water clarity, diminished bacteria counts, and reduced dissolved metals concentrations in the culture water.

- Ozone does not appear to be interrupting early salmon maturation; however, growth/feed intake advantages are evident.
- Nearly all mature fish were males.

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Finding the optimal rearing protocols - Benchmark

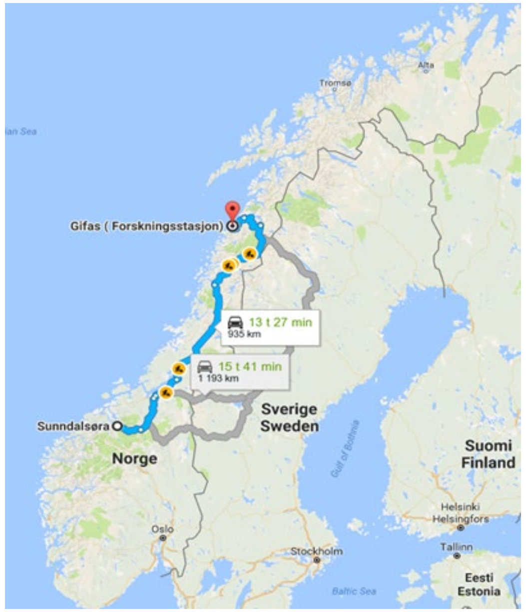
Trine Ytrestøyl (Nofima)

Objective: Evaluate the effect of different post-smolt production protocols in RAS on fish performance, health and welfare in the seawater grow-out phase

2x2 factorial design, variables:

1) **Photoperiod**: 6w 12:12 vs 24:0 light entire period in RAS
2) **Salinity**: FW entire period in RAS vs 12 ppt in RAS from 100 g to transfer
3) **Size at transfer**: Transfer to sea at 200 and 600 g

Control group: Traditional 100 smolt, 6 weeks with 12:12 L:D and FW



Light \ Salinity	FW	12 ppt SW
12:12	FW x 12:12	12 ppt x 12:12
24:00	FW x 24:0	12 ppt x 24:0

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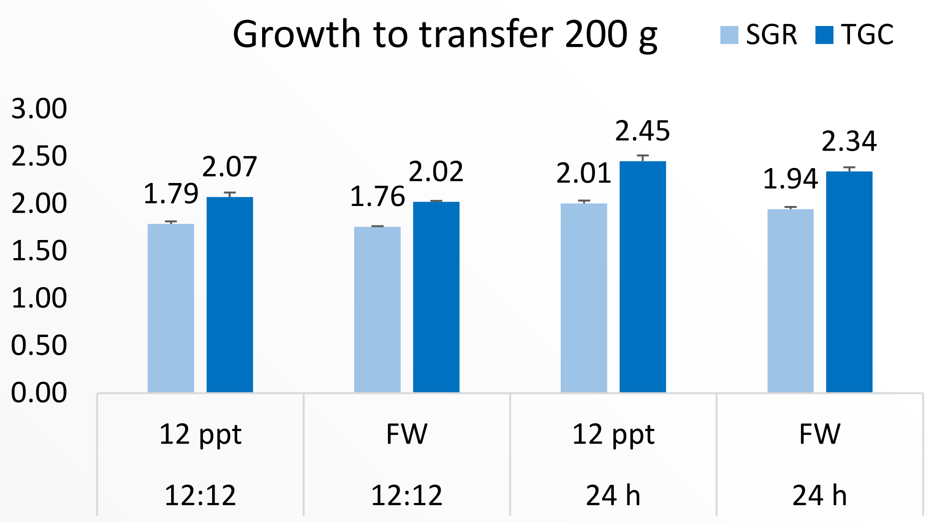
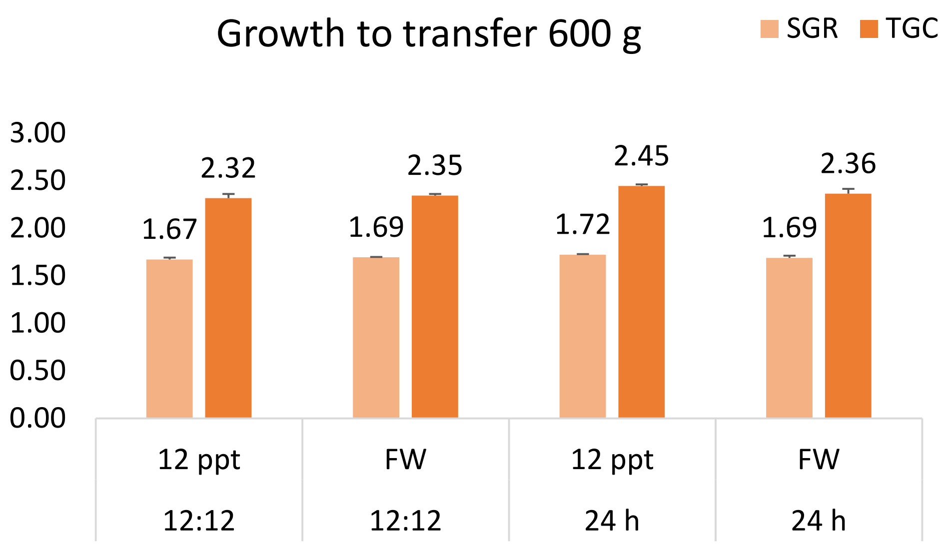
Benchmark- Performance in RAS





- **Light: 24:0 h** light improved growth in RAS
- **Salinity:**
  - 12 ppt improved growth up to 200g
  - No sign. effect of salinity at 600 g
- Low mortality (>0.5 %)
- Gonadosomatic index (GSI) higher in 600 g

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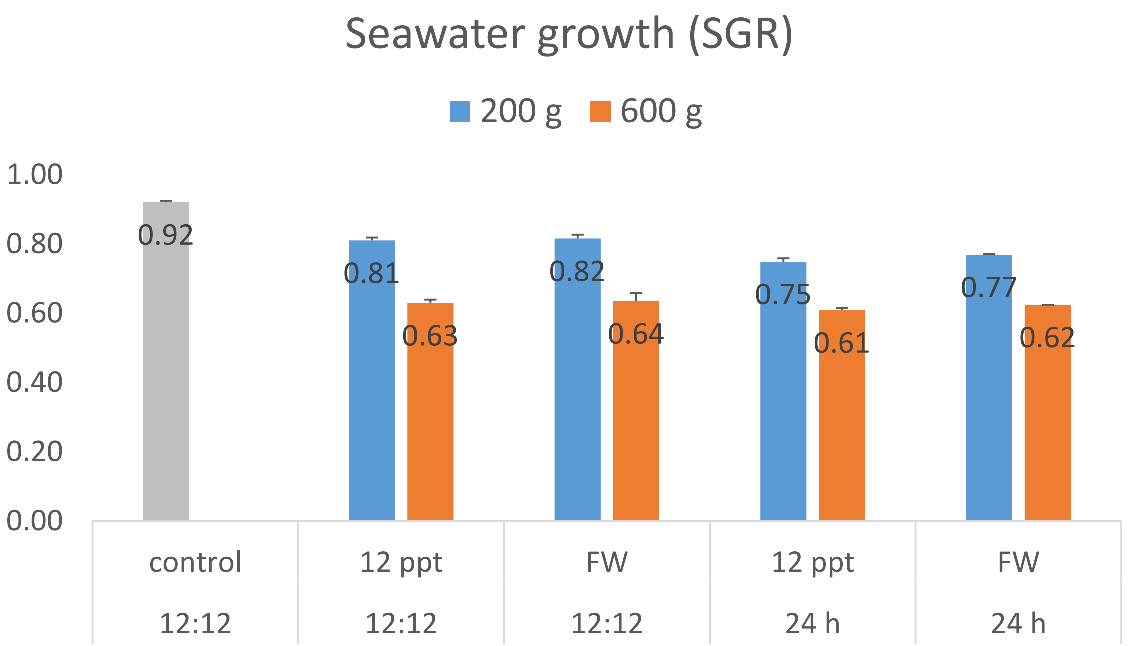
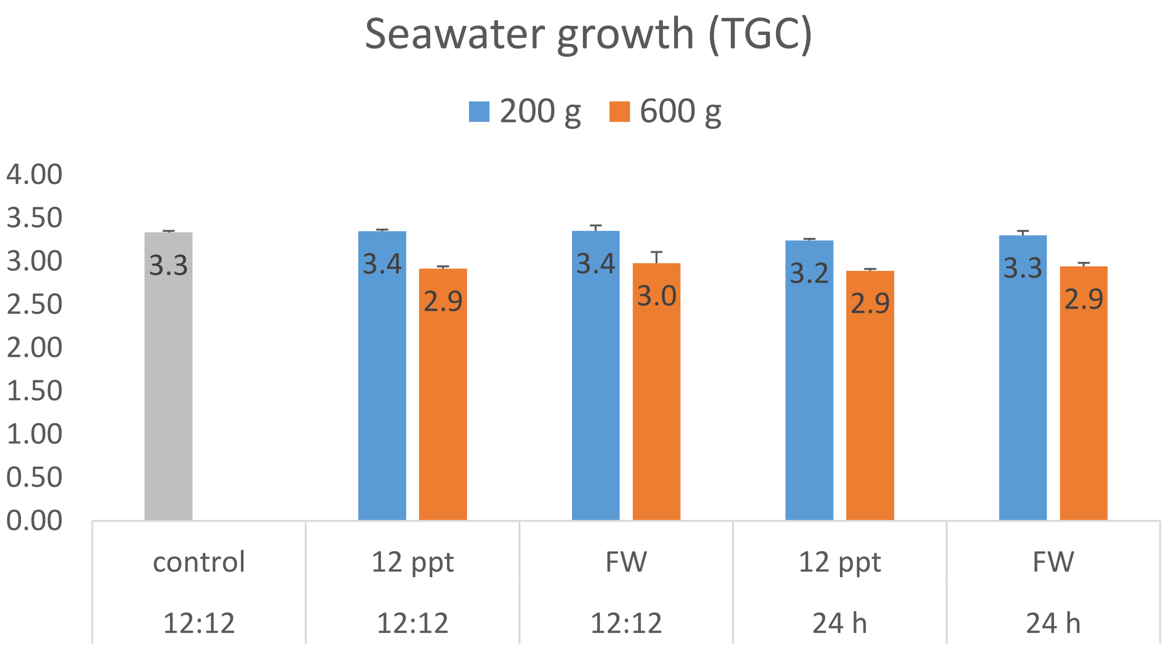
Benchmark- Performance in sea





- control > 200 g > 600 g
- Salinity : NS
- Light: 12:12 > 24h

- control = 200 g > 600 g
- Salinity : NS
- Light: 12:12 > 24h

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Ensure optimal systems

Water velocity in commercial RAS culture tanks for Atlantic salmon smolt production

Jagan Gorle (former Nofima)


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Water velocity in commercial RAS culture tanks for Atlantic salmon smolt production

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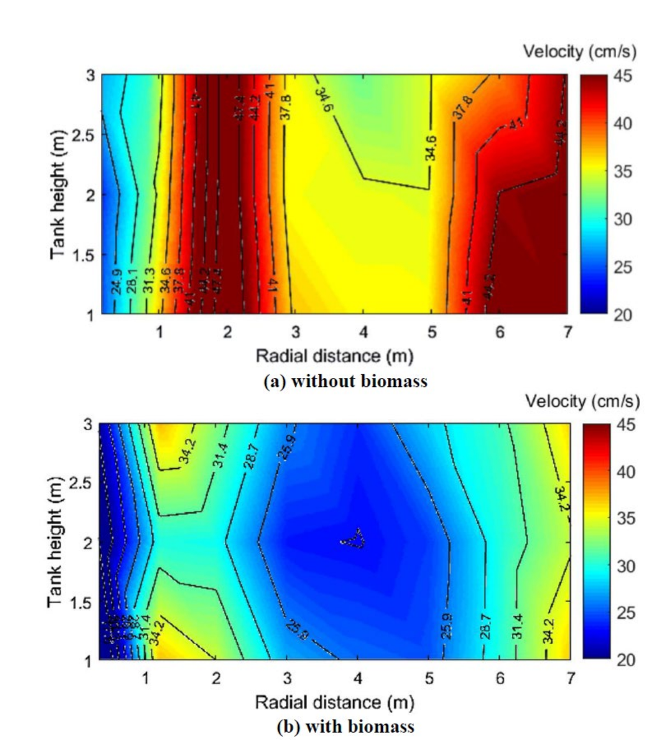
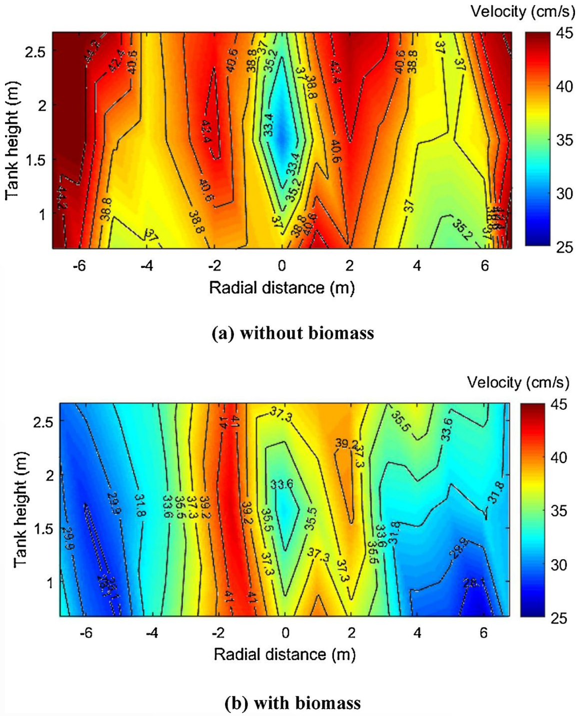
[a] Nofima AS, Sjølsengvegen 22, 6600 Sunndalsøra, Norway
[b] The Conservation Fund Freshwater Institute, 1098 Turner Road, Shepherdstown, WV, 25443, USA

Without biomass

With biomass



Circular tanks 653m^3



Octangular tanks 788m^3

Fish are a major source of turbulence at 35 to 64 kg/m^3

- Fish increase mixing & reduce water rotational velocities by 25%

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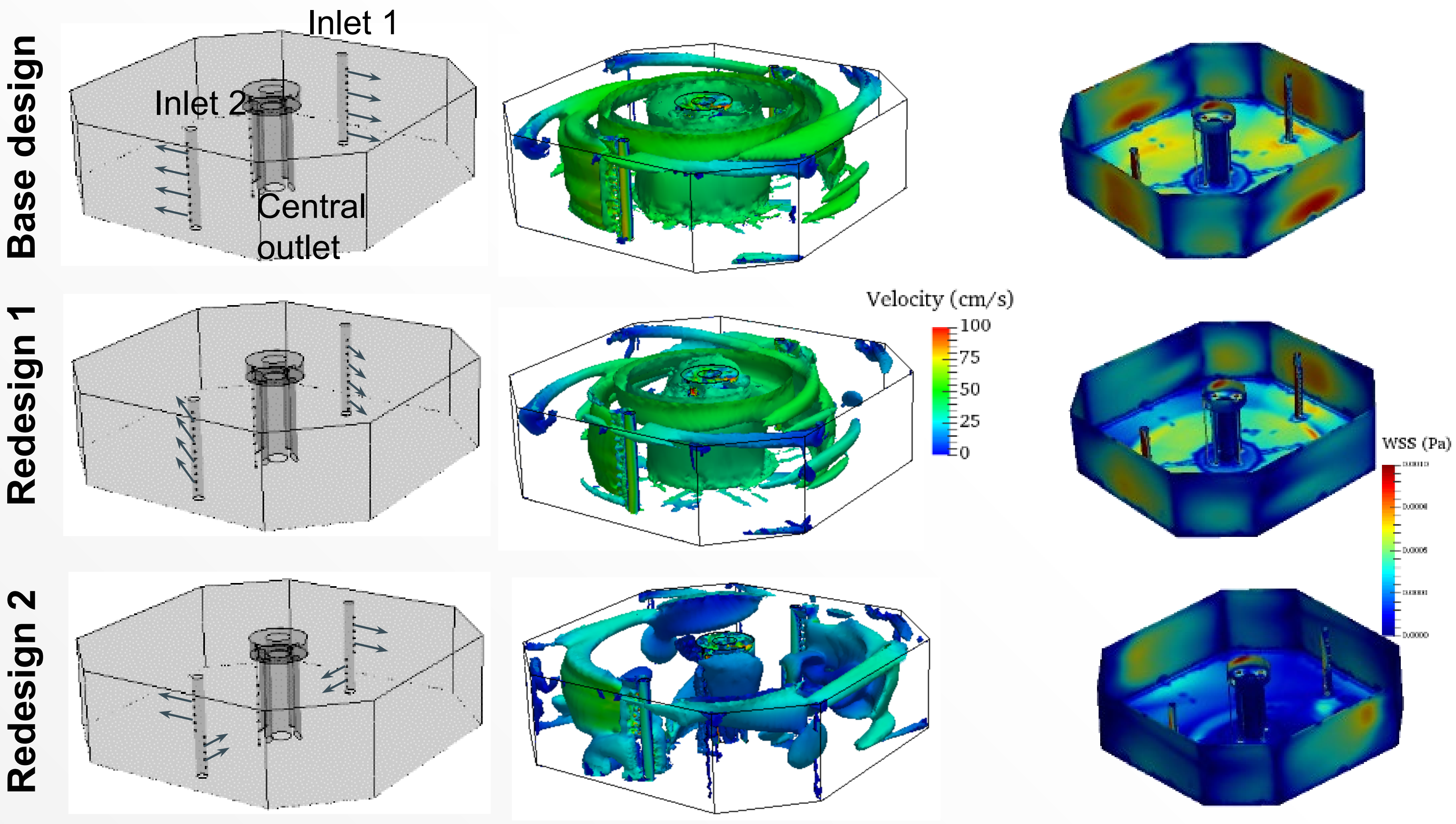
Hydrodynamic challenges - Effect of nozzle angles

(CFD by Jagan Gorle, Nofima, Steve Summerfelt; TCFFI)

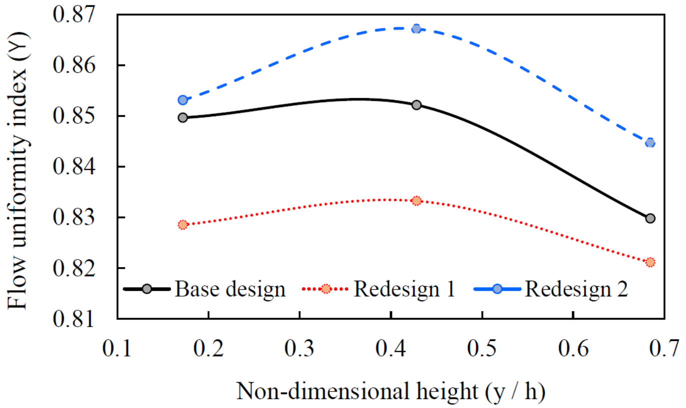


Gorle et al., 2016

Distributed vorticity, Tea-cup effect & self-cleaning retained

Reduced wall stresses. Energy is used in the flow

Possible to further optimize the tank environment, improve technology efficiency and water quality (fish welfare and performance)



Redesign 2 creates more uniform flow; we hypothesize this is more optimal for the fish

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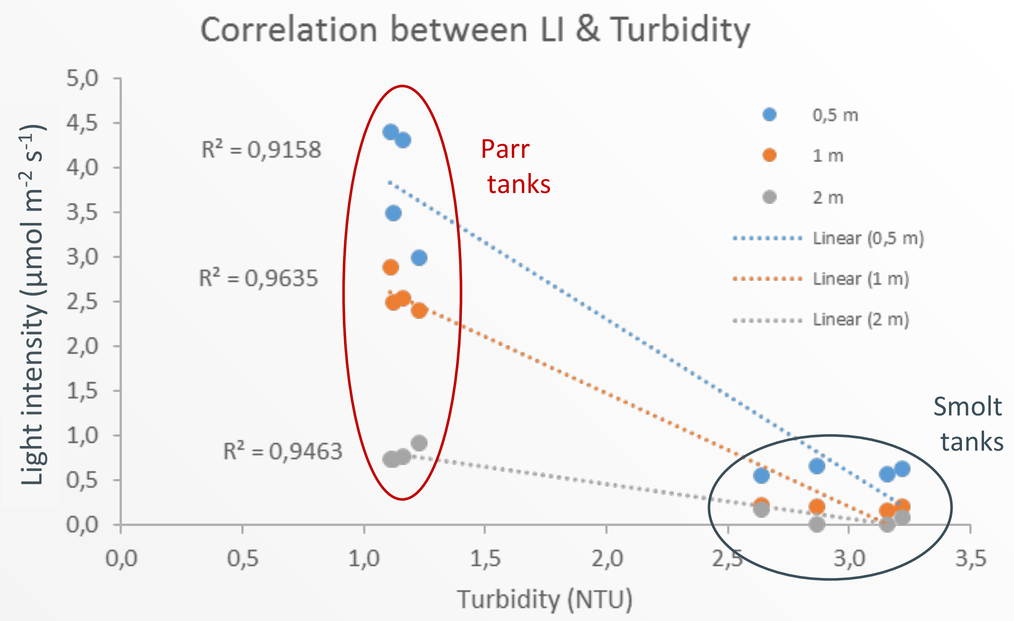
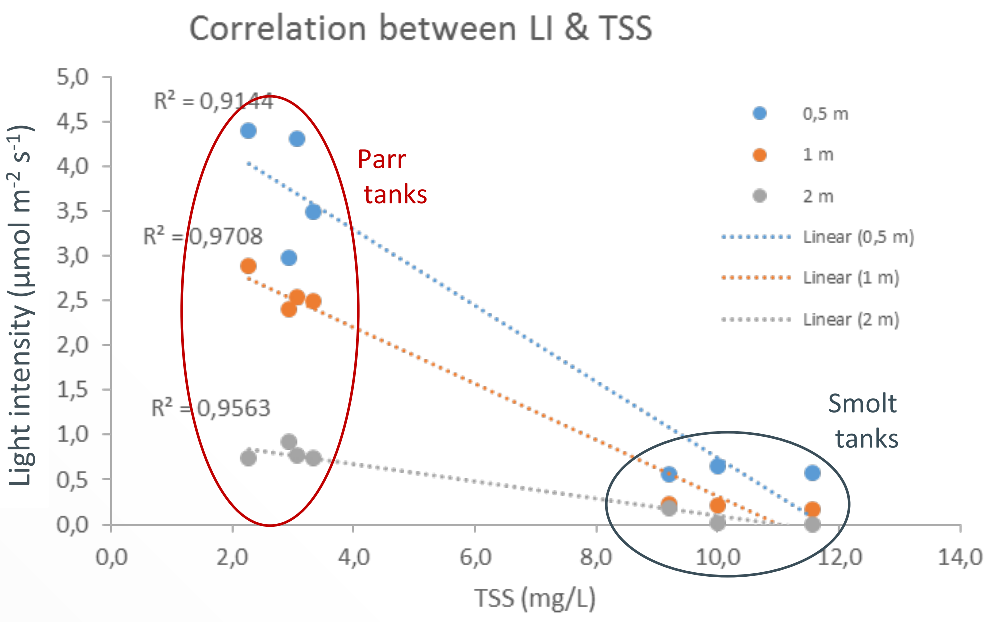
Light intensity vs turbidity and TSS

- General observation: Reduction in light intensity with increased turbidity/TSS





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Performance in semi-closed containment

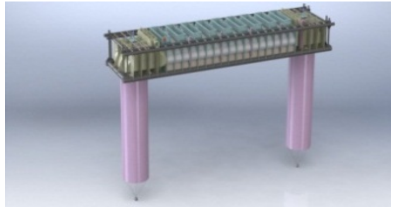
Sigurd Handeland (NORCE)

Semi closed facility

+

Control (open pen)

Neptun;
Three production cycles



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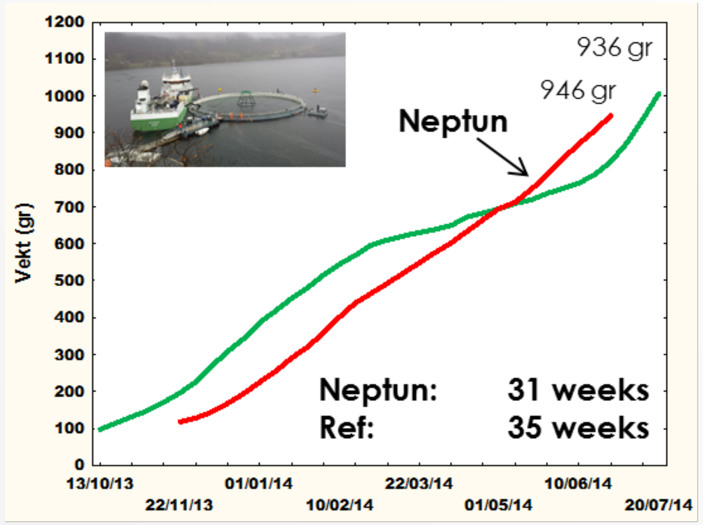
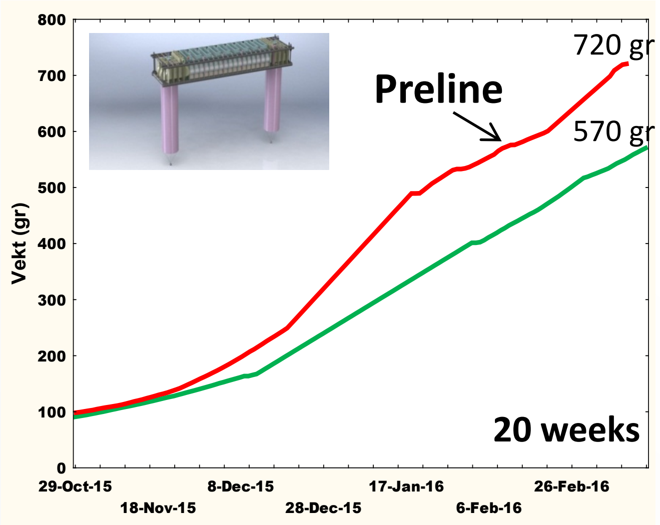
Preline;
Six production cycles





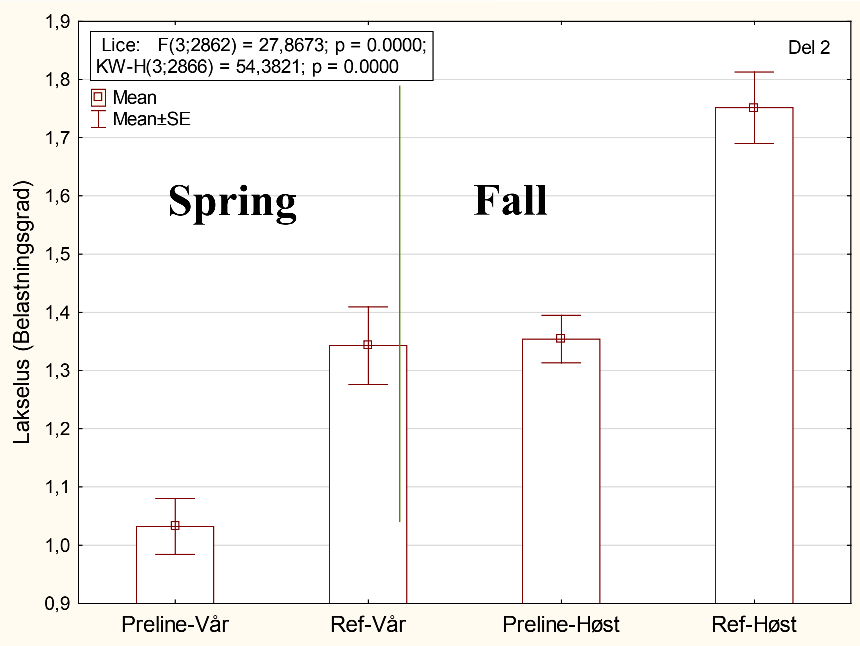
Food conversion ratio (FCR):

Neptun	: 0,95
Ref	: 1,17
Preline	:1.07
Ref.	:1,24

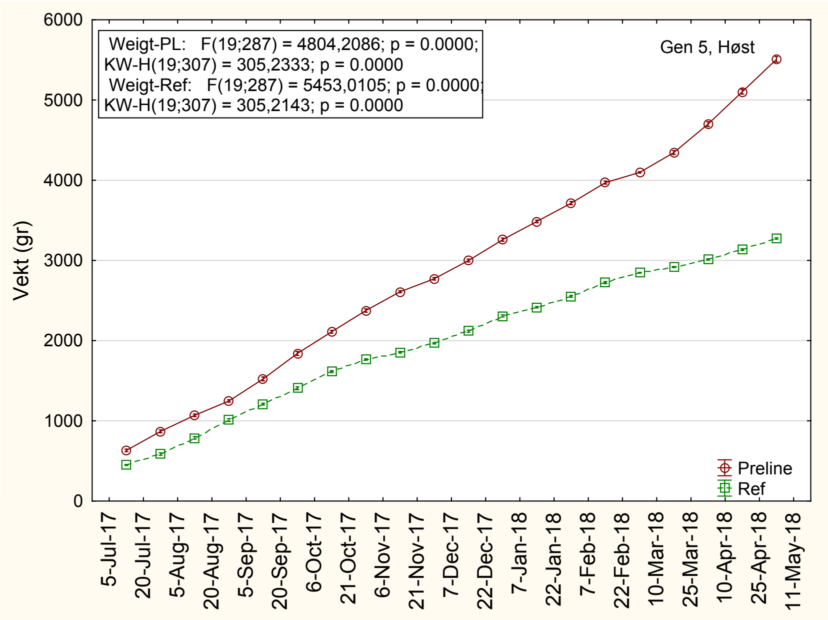
11-14 % improved FCR in closed system

S-CCS Performance after transfer from S-CCS to open cage

Sea lice



Growth in one generation



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Sensors

1st Antifouling material : Graphene oxide / silver nanocomposites (GO/Ag) - Antifouling property of GO/Ag nanocomposites against H.Pacific and marine algae

Xiaoxue Zhang (NTNU)

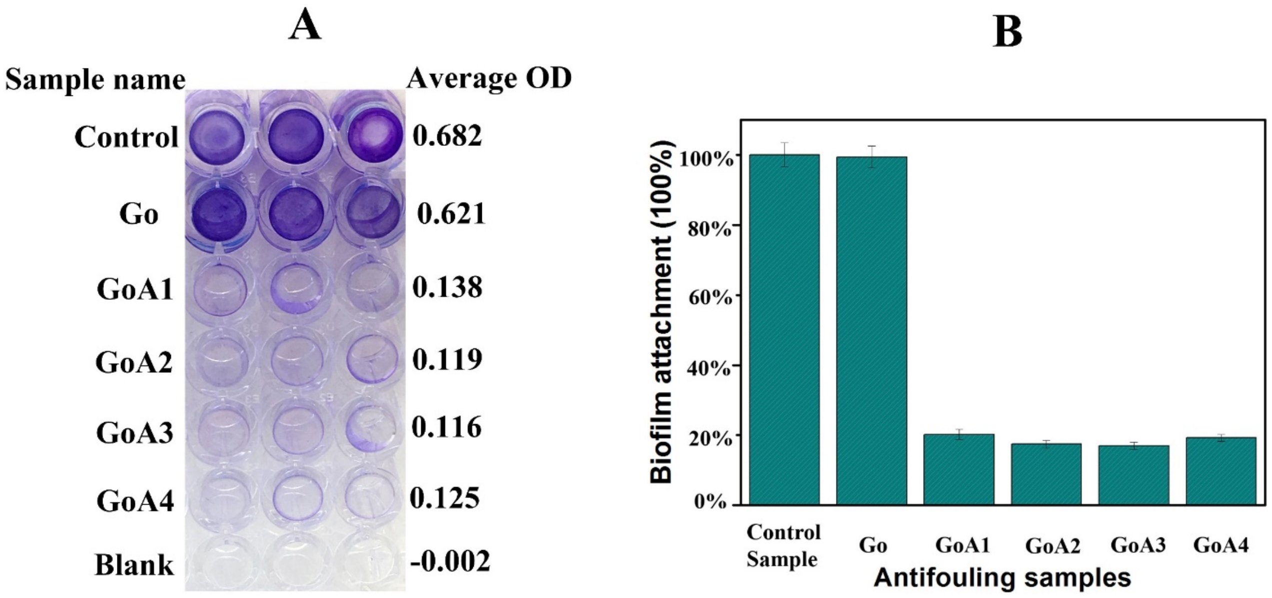

Fig. 4. (A) Biofilm staining with crystal violet and average OD of control sample, GO, GO/Ag nanocomposites at 0.1 mg/ml; (B) Quantification of antifouling activity of control sample, Go, GO/Ag nanocomposites. Bars represent mean ± s.d. of three independent experiments. ($P<0.05$, student's t-test)

21CtrlAQUA SFI partners!

Host institution:

- Nofima

R&D-partners:

- UNI Research
- University of Bergen
- Norwegian University of Science and Technology
- The Freshwater Institute, WV, U.S.
- University of Gothenburg, Sverige
- University of South-East

User partners:

Suppliers of Technology:

- Krüger Kaldnes
- Vard Sunndal
- Aquafarm Equipment
- Oslofjord Ressurspark
- FishGLOBE
- Botngaard

Farmers:

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

Biotechnology companies:

- Pharmaq
- Pharmaq Analytiq