Optimizing Light in Closed Containment Systems

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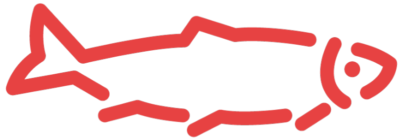
Why work with light in CtrlAQUA?

- Artificial light used in production
- Knowledge gaps on optimal light conditions in close containment forAtlantic salmon post-smolt
- Effect on fish and system operation
- Different aspects need to be considered:

  - Light characteristics

  - Light placement

  - Investment



Light characteristics and sources

- 3 characteristics:

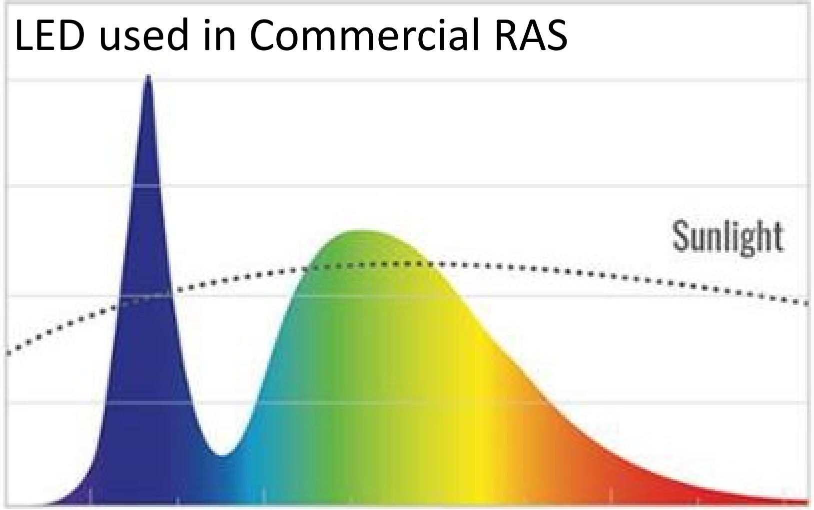
1. Intensity or quantity of illumination

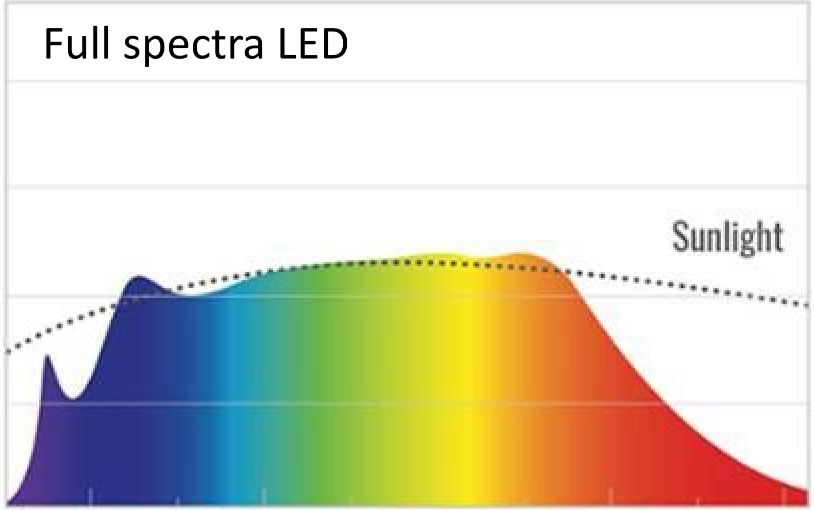
2. Wavelength or colour or spectral output

3. Photoperiod or duration of the light

- ***Traditional lighting sources***: incandescent, fluorescent, and high-pressure sodium (HPS) are fixed in respect to intensity and colour

- ***Light emitting diode (LED) technology*** provides controllable light intensity, wavelengths and photoperiod all in one system and are more in use lately





Light intensity

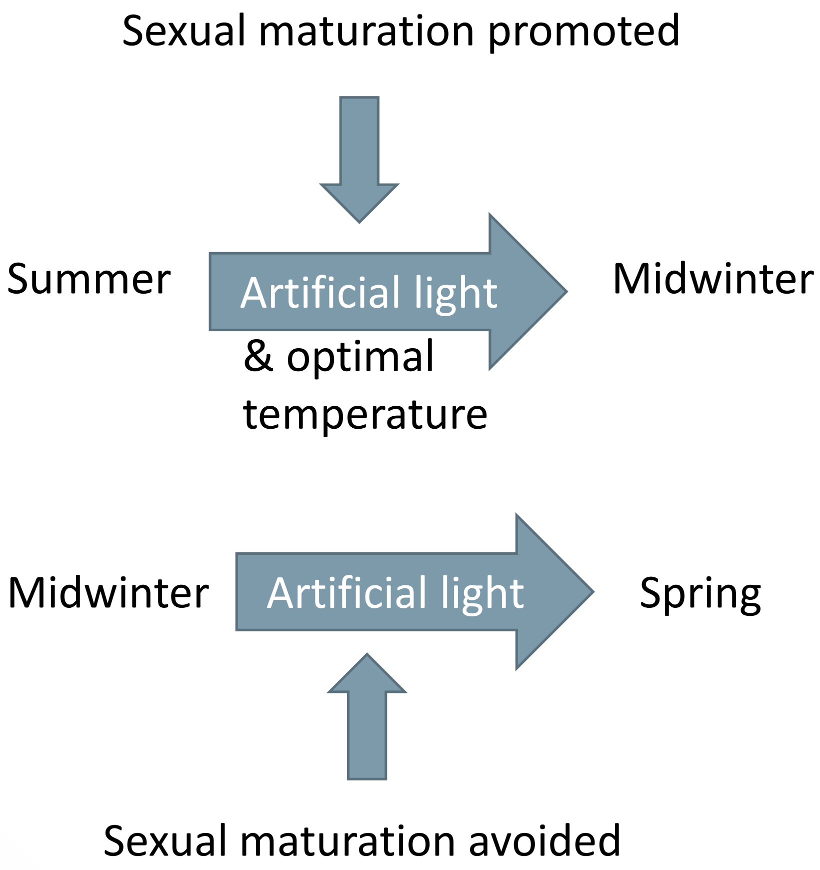
A minimum intensity detected by salmon eye over a wide spectral range:
0. 037 µmol m^{-2} s^{-1}
(Bui et al.,2013)

Light intensity: Effect on smoltification

- **Minimum light intensity for optimal smolt** development and growth of Atlantic salmon smolts: **43 lx** (Handeland et al., 2013)
- The **minimum irradiance suppressing plasma melatonin** to basal day-time level: **0,08 µE** (Migaud et al., 2006)

Light intensity: Effect on maturation

- High intensity artificial light in cages can **reduce incidence of sexual maturation** and can **promote sexual maturation** (FISHWELL handbook)
- A mean-irradiance of **~0.06 µE** can be considered as a safe threshold to **suppress sexual maturation** of 1+ Atlantic salmon to basal levels (Leclercq et al., 2011)
- Intensity more important for maturation control than light composition or light technology (Leclercq et al., 2011)



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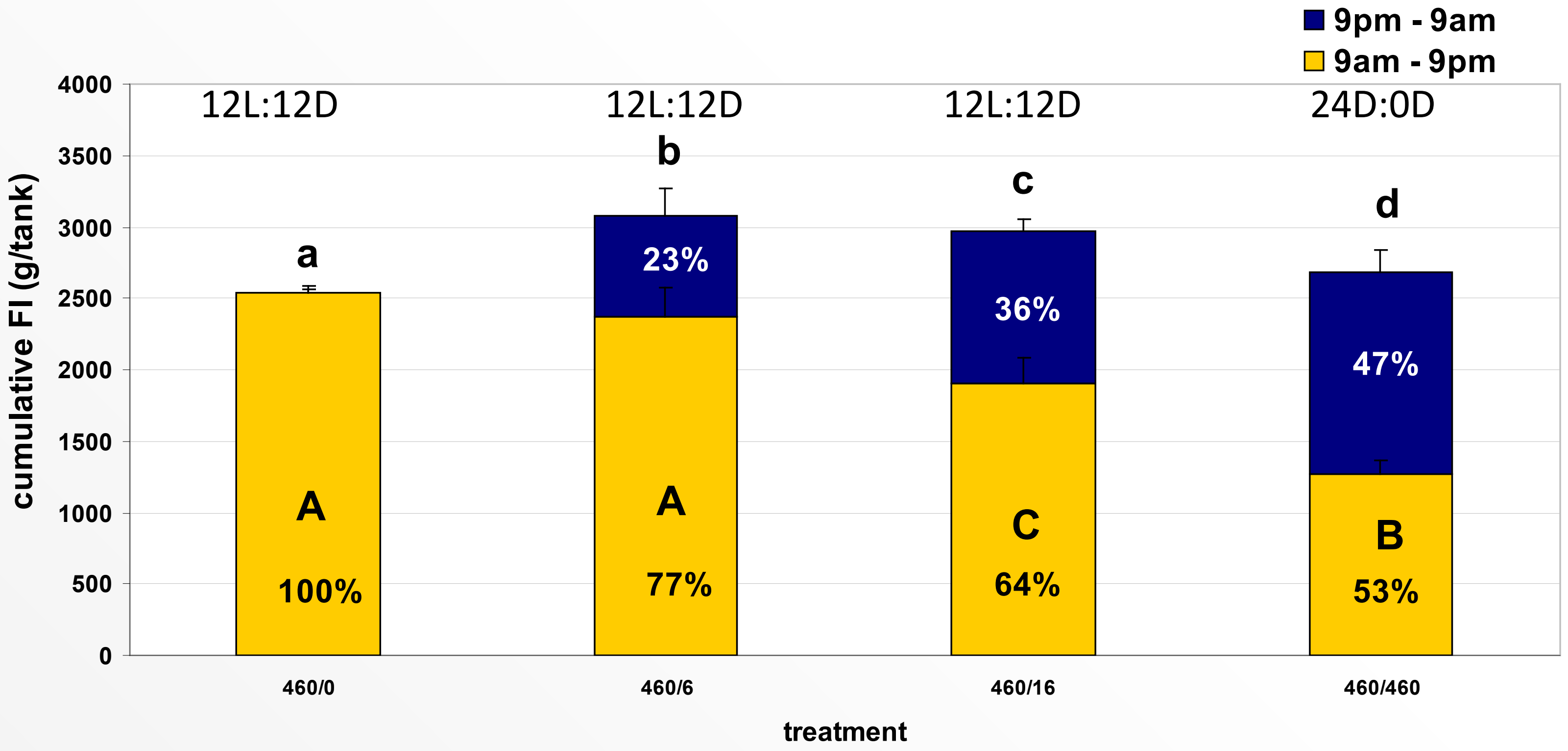
Light intensity: Growth, welfare & behaviour

- **Increase growth rate** with increased intensity (Handeland et al., 2013; Hansen et al., 2017; Leclercq, 2011; Oppedal et al., 1997, 1999)
- Affects **vertical position** of salmon in the cages even @ intensity of 0.1µE and the effect increases with increase in intensity (Stien et al., 2014)
- Attracting fish **away from** areas of potentially high **lice** intensity (Wright et al., 2015)

Light intensity: Feed intake

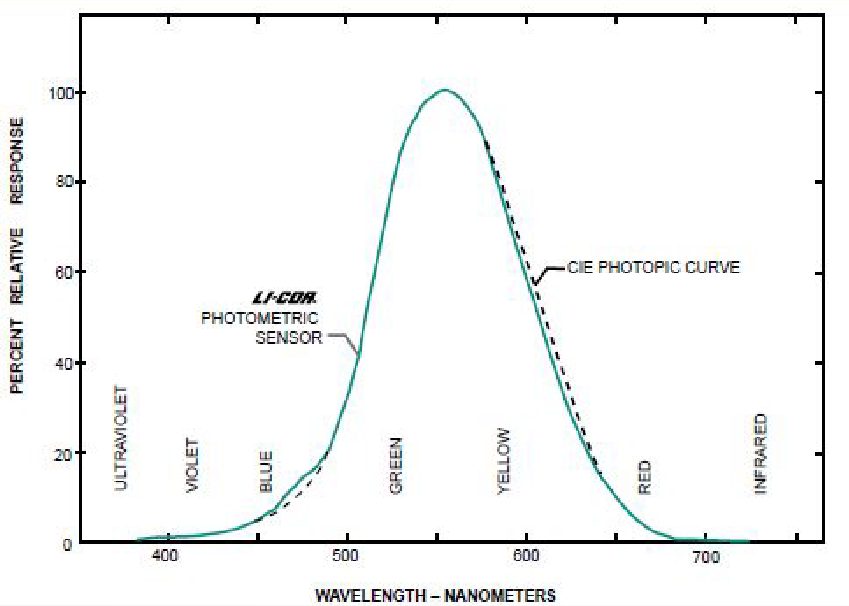
- **Feed intake** increases with light intensity
- Minimum 0.03-0.04 lx necessary to maintain **feeding ability** (Elliott, 2011)



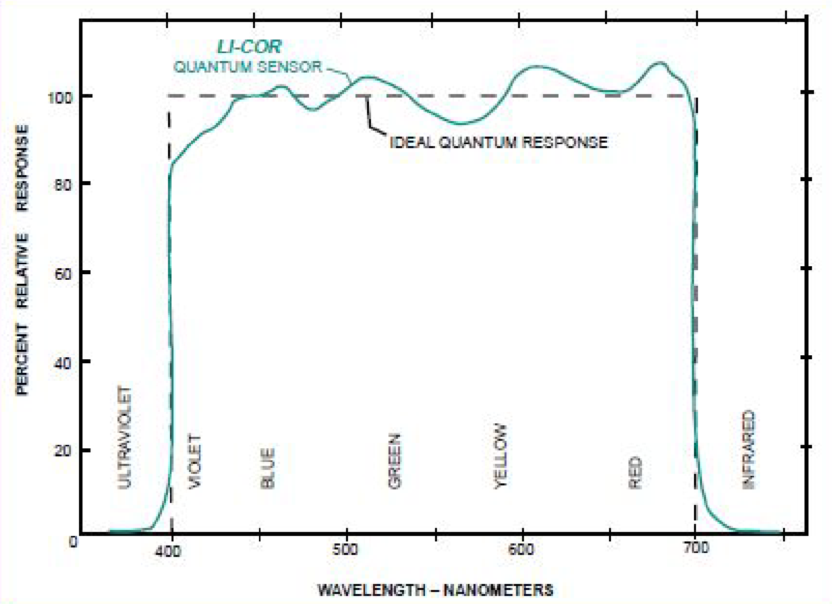
Kolarevic et al., unpublished

Light intensity measurements and units

- Lux and Lux meters (photometric sensors) not appropriate to use in aquaculture
- In order to avoid spectral bias of photometric sensors, quantum sensors are used
- Quantum sensors measure photon flux (light energy) for the wavelengths between 400-700 nm expressed as µmoles $m^{-2} s^{-1}$ where 1 mole of photons = 6.022 x 1023 photons



Spectral response of LI-COR photometric sensors vs. Photopic response curve (from licor.com)



Spectral response of LI-COR Quantum sensors vs. Wavelength and ideal quantum response (from licor.com)

Light intensity survey in commercial RAS facilities

Objective of survey:

*To document **light intensity conditions** and how **water quality and biomass** affect light intensity at commercial RAS facilities for Atlantic salmon.*

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Locations

- 29 tanks (Max 750m^3; 4m deep)
- Tank profiles (15 measurements)
- Density: 4-65 kg/m^3
- Fish size: 2-209 g

- 4 Regions of Grieg Seafood ASA:
  - Grieg Seafood Finmark (Adamselv)
  - Grieg Seafood Rogaland (Trosnavåg)
  - Grieg Seafood Shetland (Girlsta)
  - Grieg Seafood BC (Golden River)
- Marine Harvest @ Steinsvik

Figure Grieg Seafood.no

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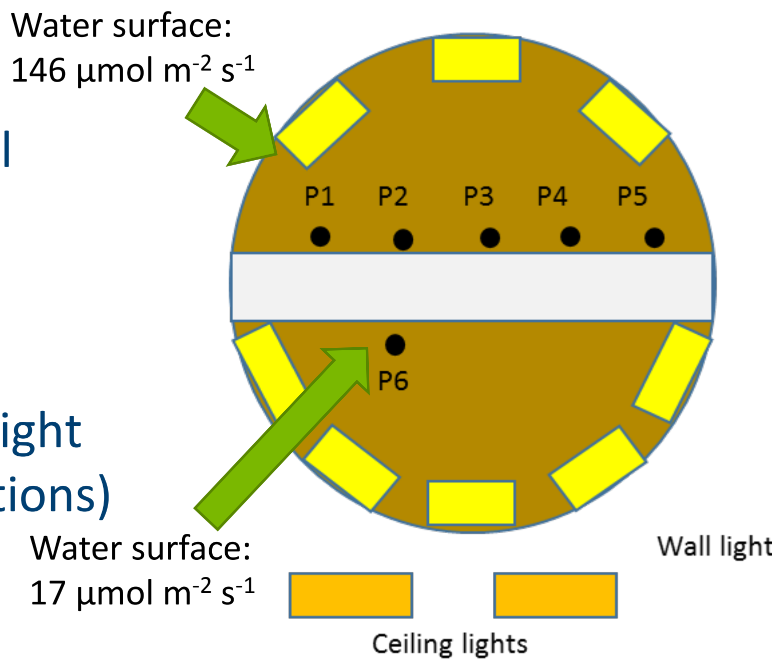
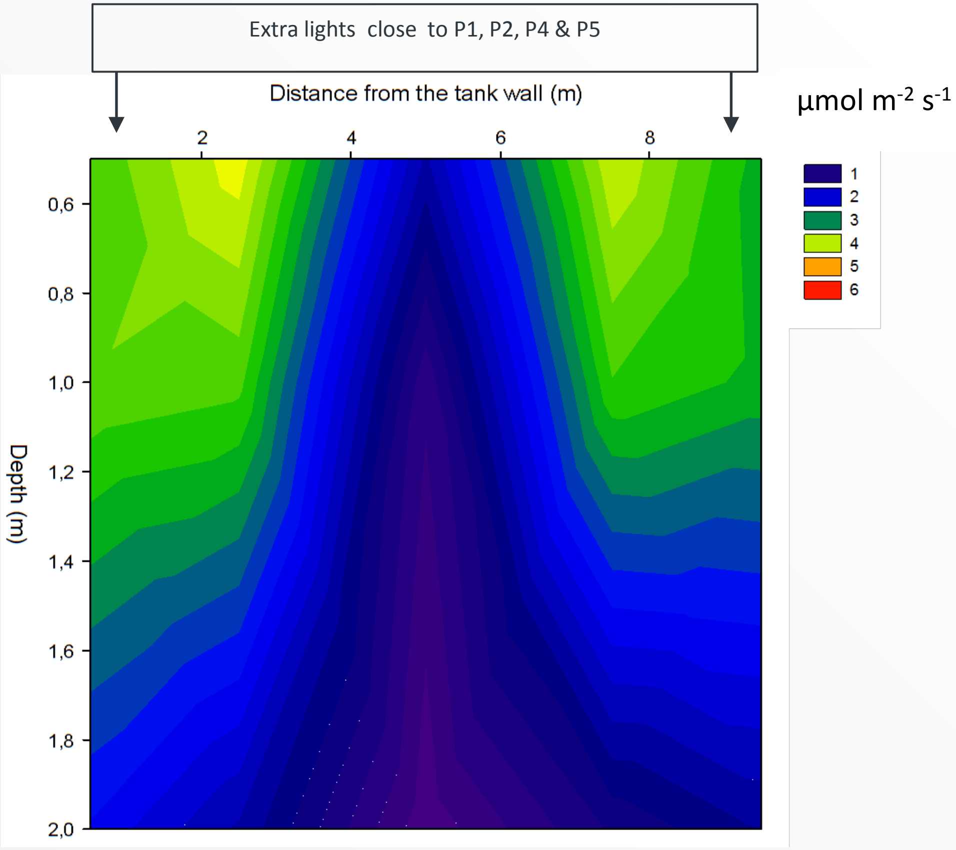
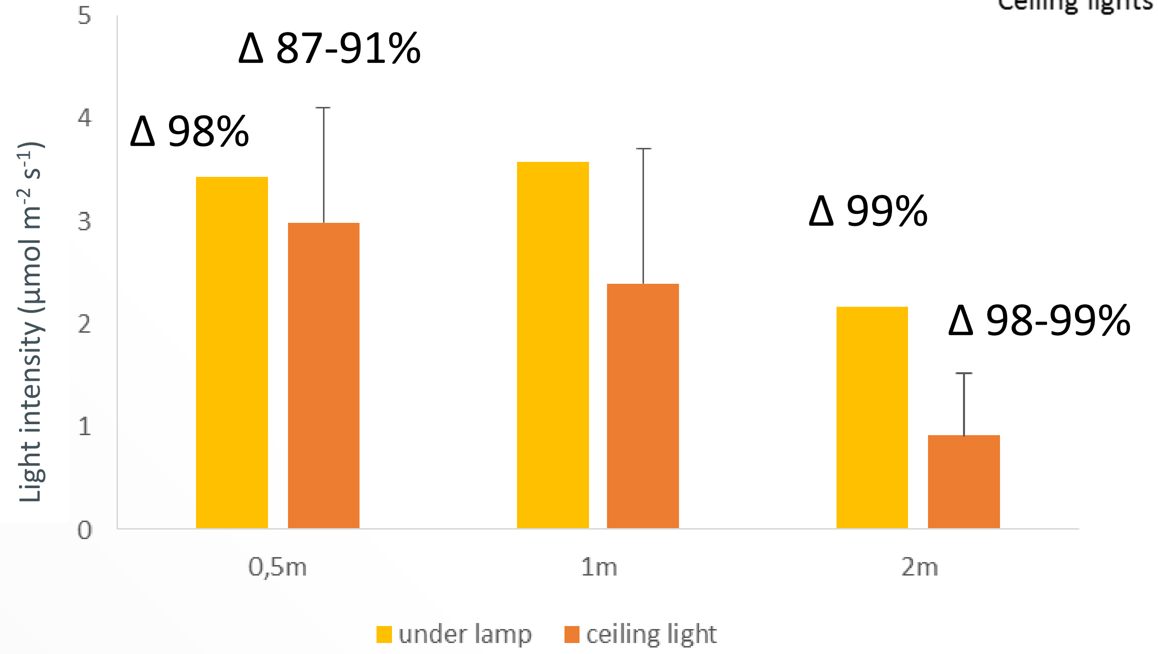
Light intensity profile in RAS tank

Department: Parr
Tank volume (m^3): 230
Fish in the tank (#): 244000
Fish size (g): 4
Stocking density (kg/m^3): 4
Turbidity (NTU): 1,2
TSS (mg/L): 2,9
Light: 100W white LED

- Highest light intensity @ all depths directly under additional lighting
- Reduction in LI with depth
- Minimum & maximum LI measured: 0.3 & 4.1 µmol m^{-2} s^{-1}
- 2 times higher average LI @ 2m depth directly under extra light compared to the rest of the tank (heterogenous light conditions)



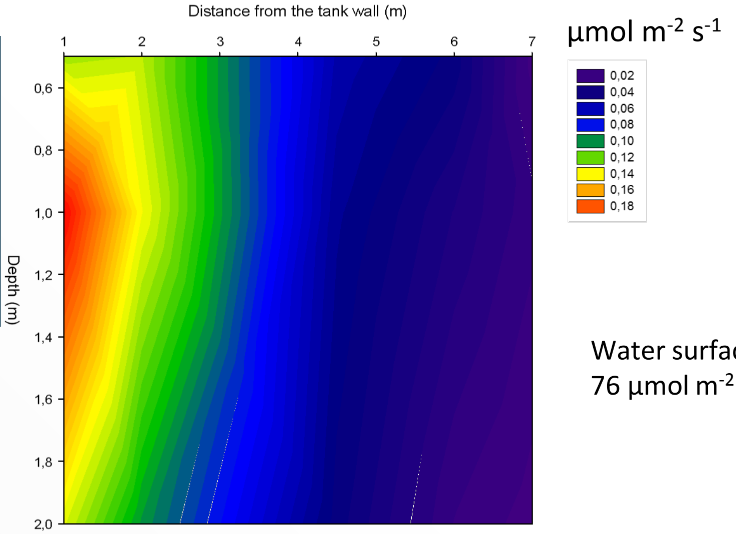


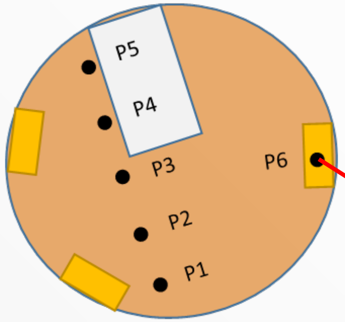


FT vs RAS tank

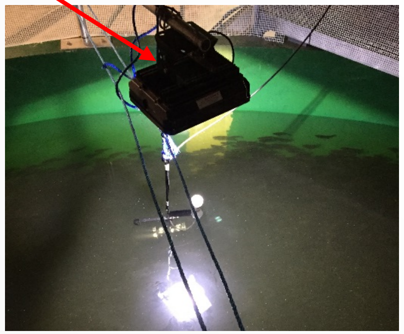
Extra light close to P4 & P5

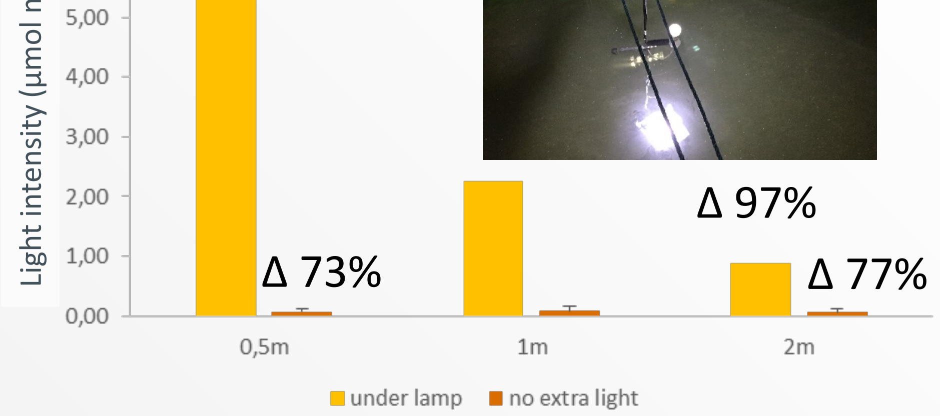
System: FT tank
Tank volume (m³): 96
Fish in the tank (#): 132055
Fish size (g): 27g
Stocking density (kg/m³): 37
Turbidity (NTU): 1,5
TSS (mg/L): 2,7





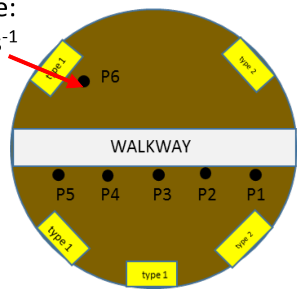
Water surface: 33,5 $\mu mol\ m^{-2}\ s^{-1}$

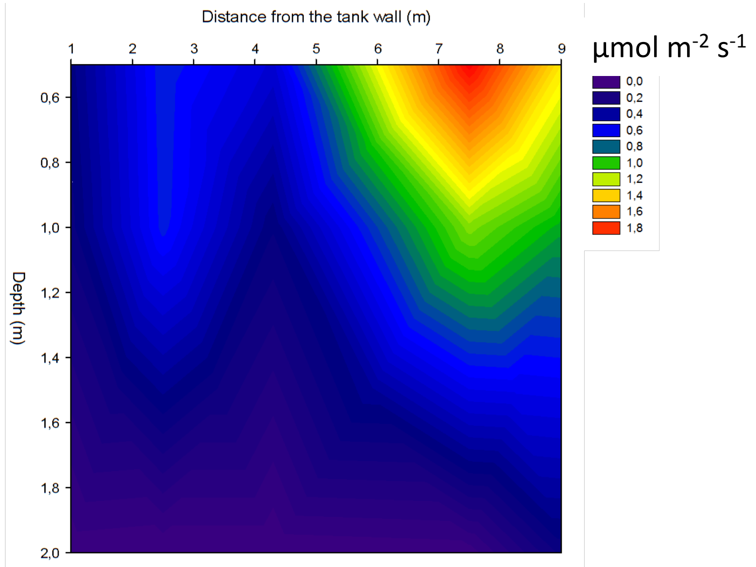


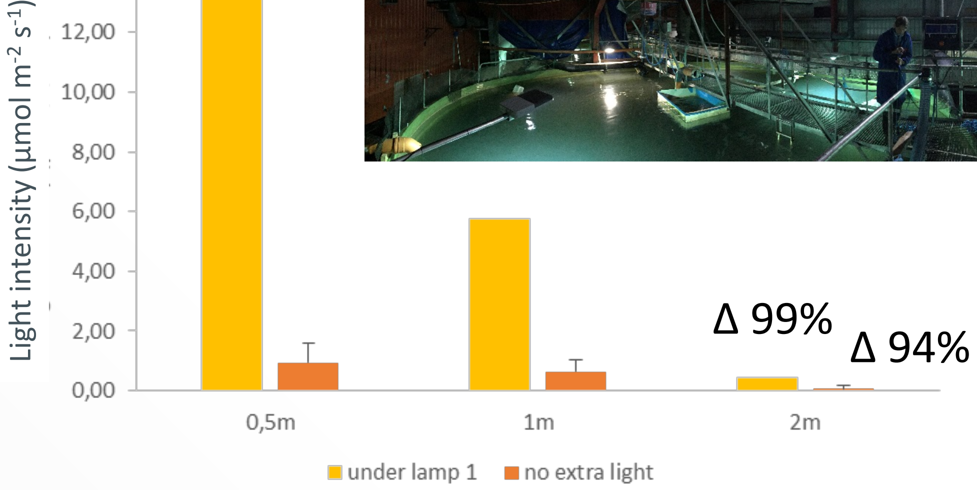


System: RAS
Tank volume (m³): 181
Fish in the tank (#): 240290
Fish size (g): 41,6 g
Stocking density (kg/m³): 55
Turbidity (NTU): 2,9
TSS (mg/L): 7,3

Water surface: 76 $\mu mol\ m^{-2}\ s^{-1}$



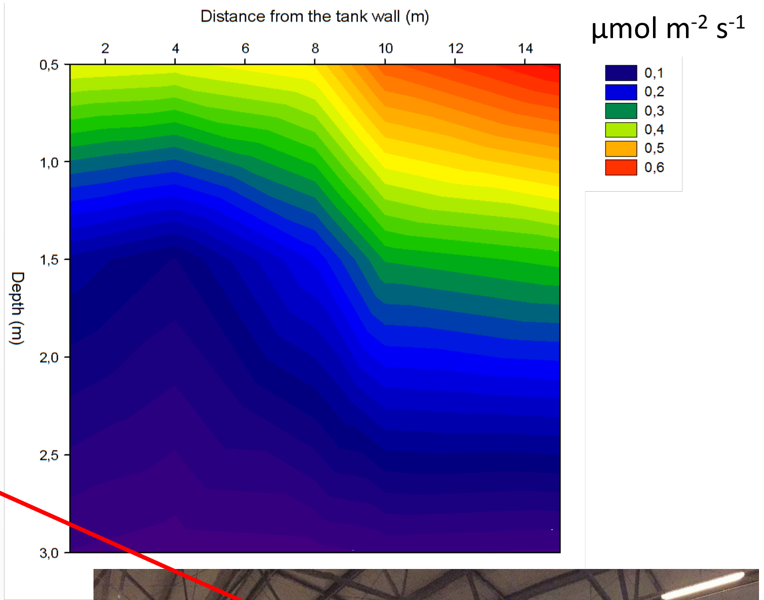


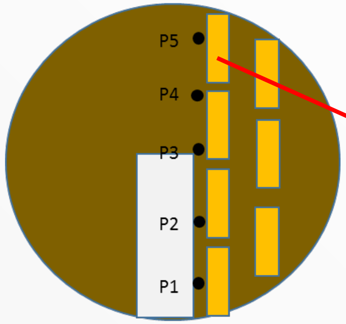


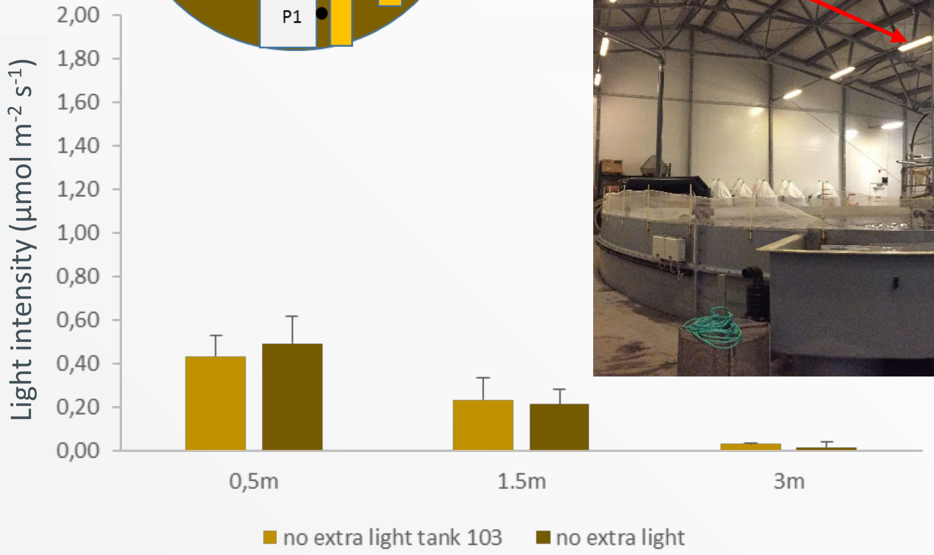
Effect of light placement

Extra light close to P4 & P5

System: RAS
Tank volume (m³): 704
Fish in the tank (#): 137066
Fish size (g): 197,4 g
Stocking density (kg/m³): 38
Turbidity (NTU): 1,4
TSS (mg/L): 3,4







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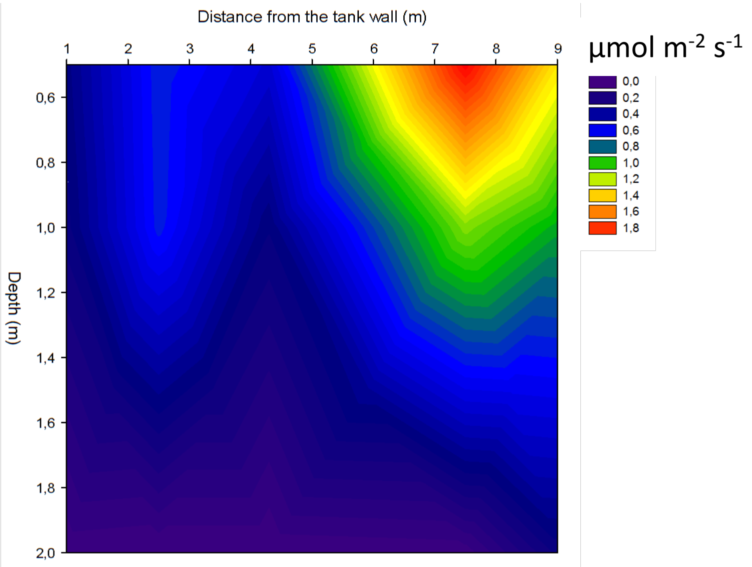
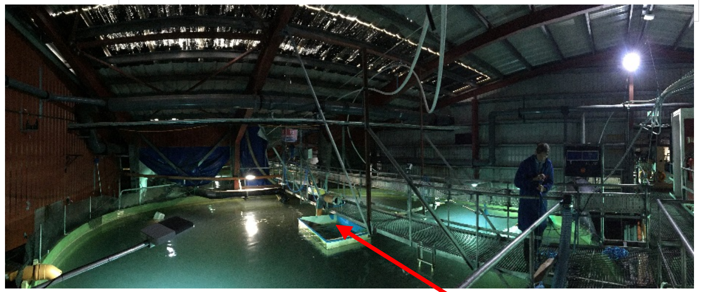
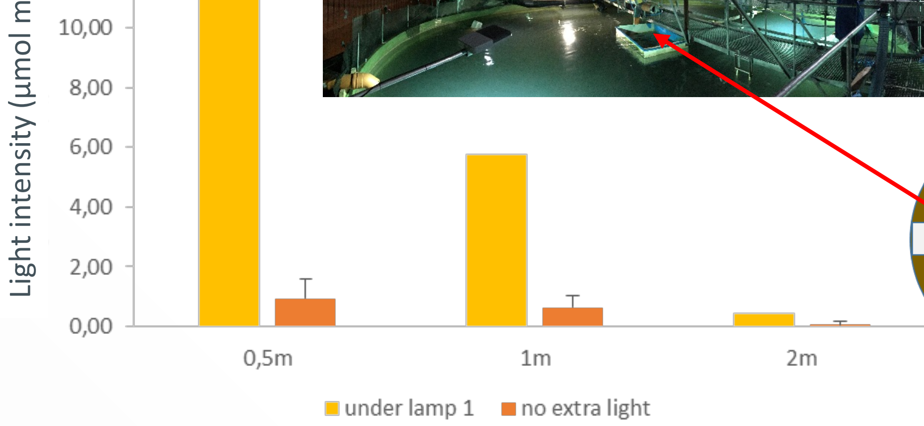
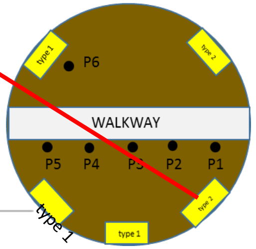
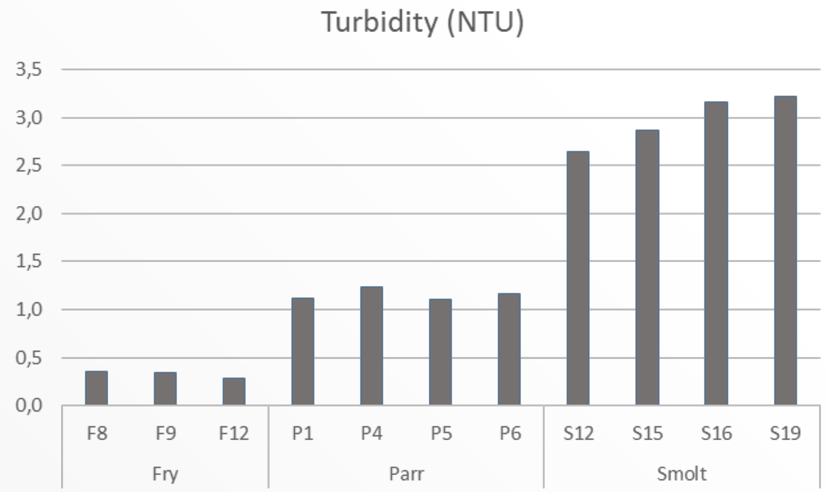


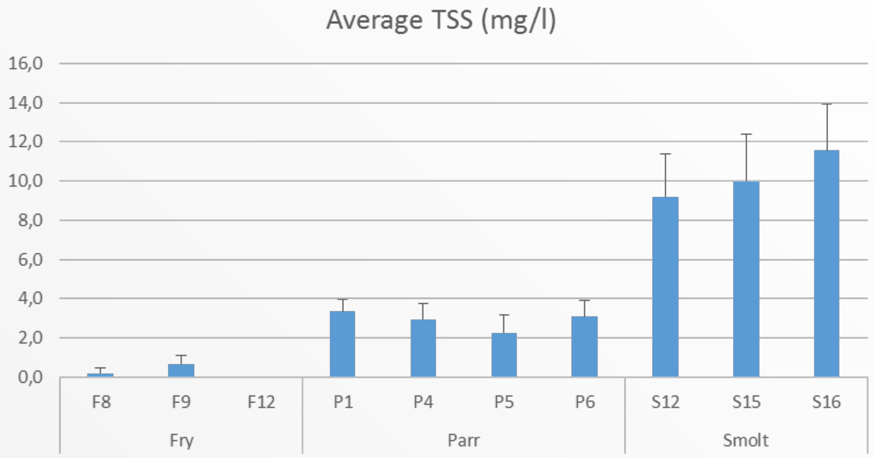


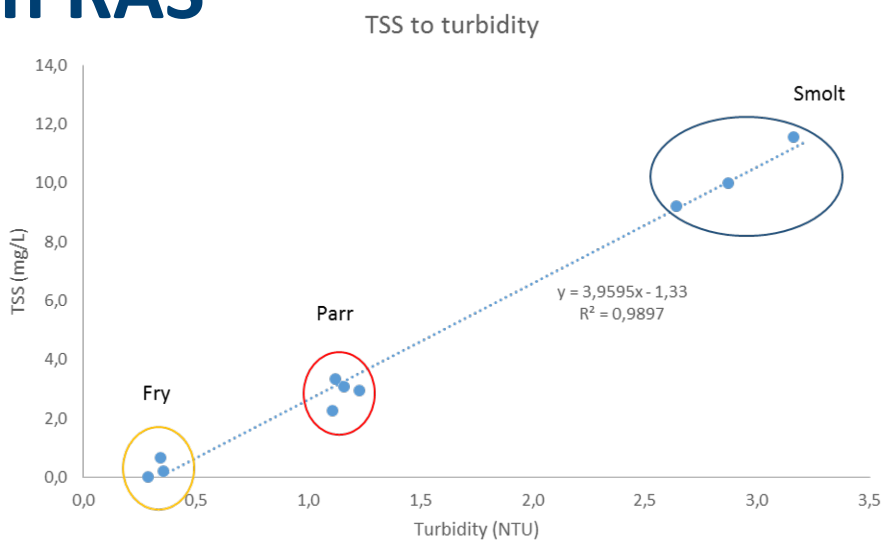




Effect of turbidity/TSS on light intensity in RAS







Linear correlation between turbidity and TSS across departments (R=0,9897)

Fry Parr Smolt

- Significantly different TSS and turbidity between departments ($p<0,05$)
- Turbidity and TSS increasing : fry<parr<smolt (3x ↑ turbidity and 4 x ↑ TSS in smolt vs parr tanks)

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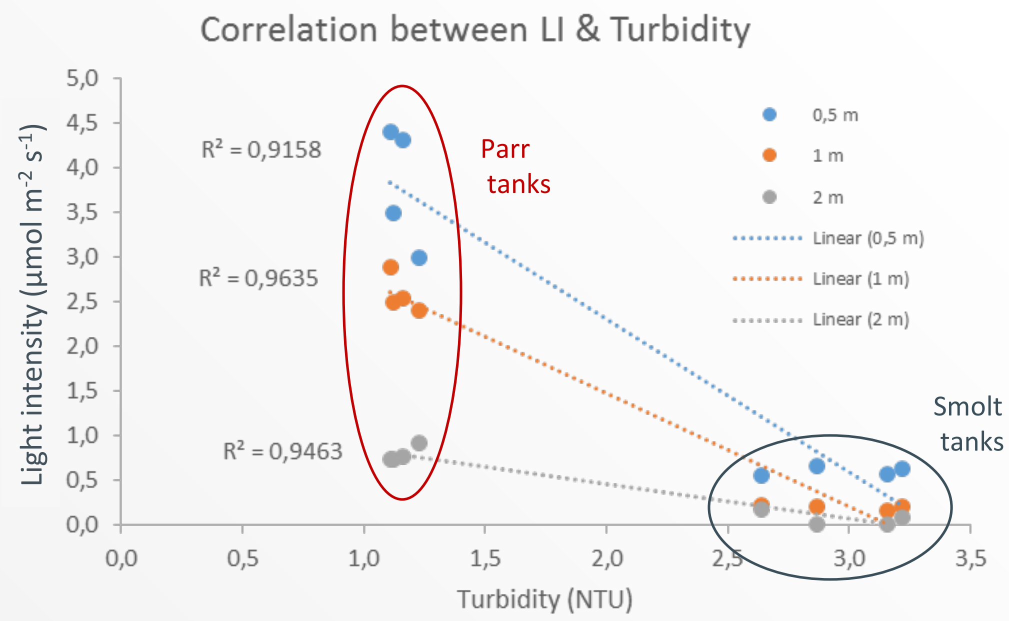
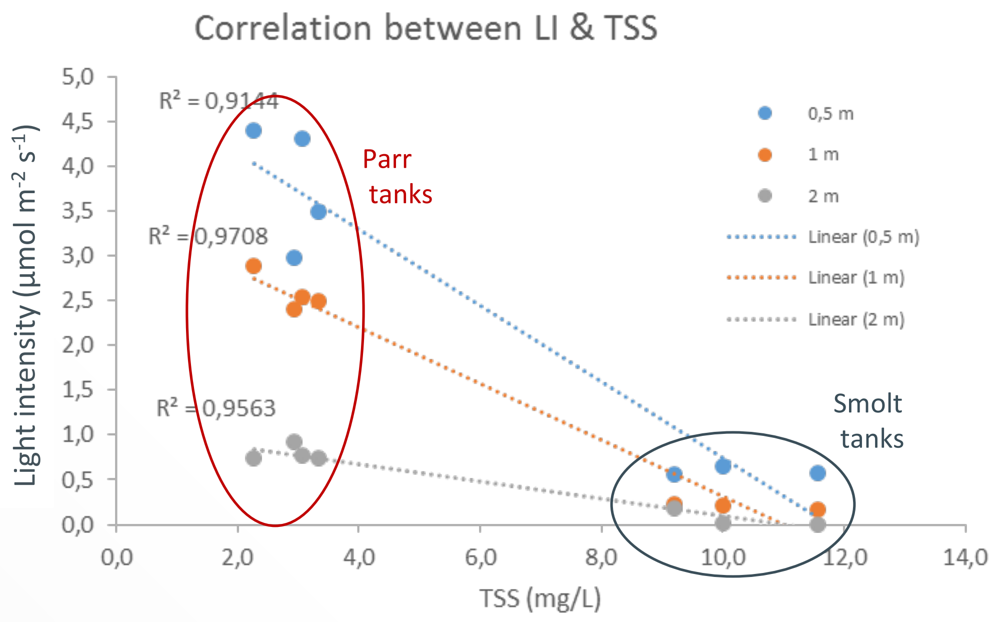
Light intensity vs turbidity and TSS

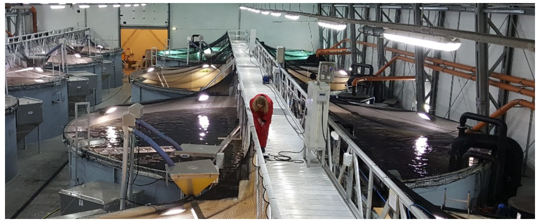
- Linear corellation between light intensinity and turbidity/TSS in parr and smolt department
- Light intensity decreased with increased turbidity

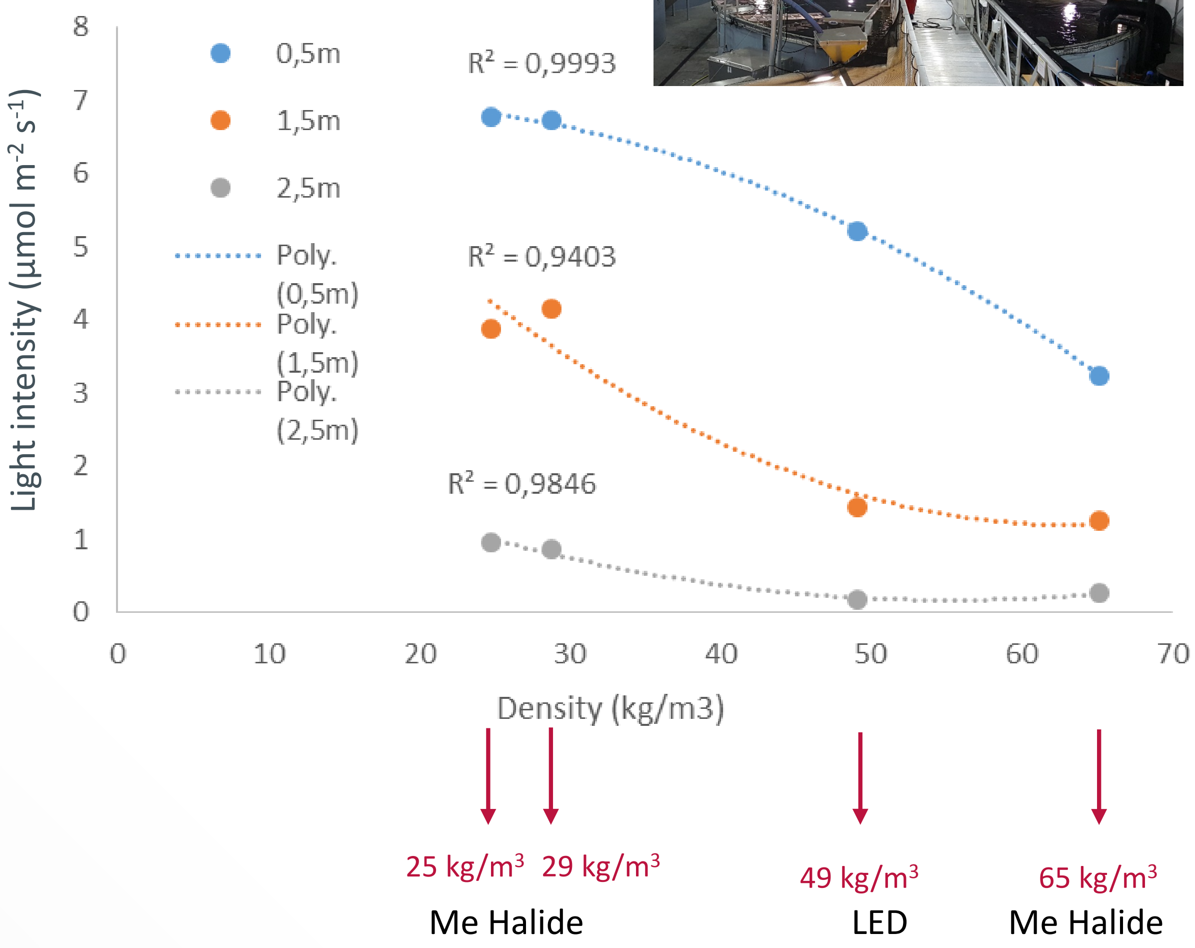




Relationship between fish density and light intensity

- All measured tanks received water from the same RAS and had similar turbidity and TSS (1,7-1,9 NTU & 2,2 – 25 mg/L as $CaCO_3$)
- Tanks with silimar density and same light set-up had similar light intensity @ all measured depths
- Tanks with higher density had the lowest average light intensity regardless of light set-up (LED vs Me Halide)





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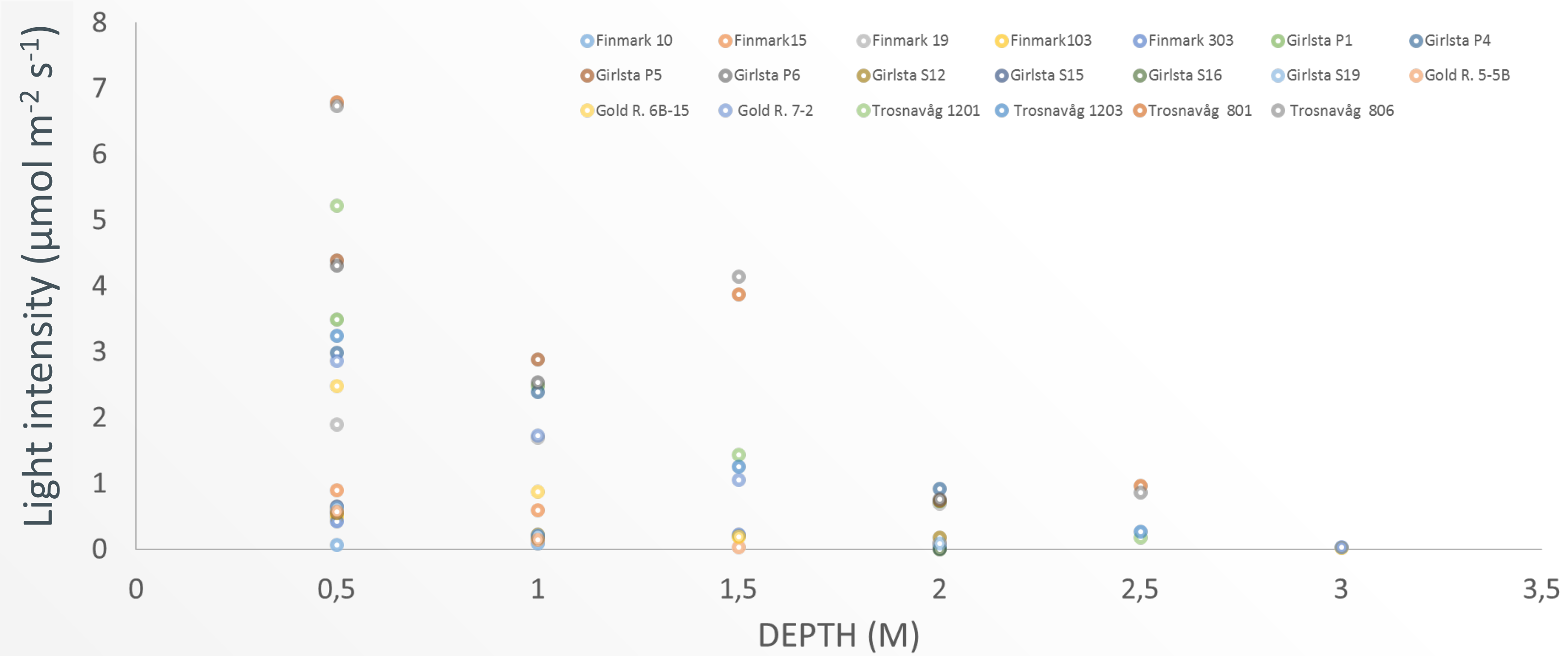
Summary

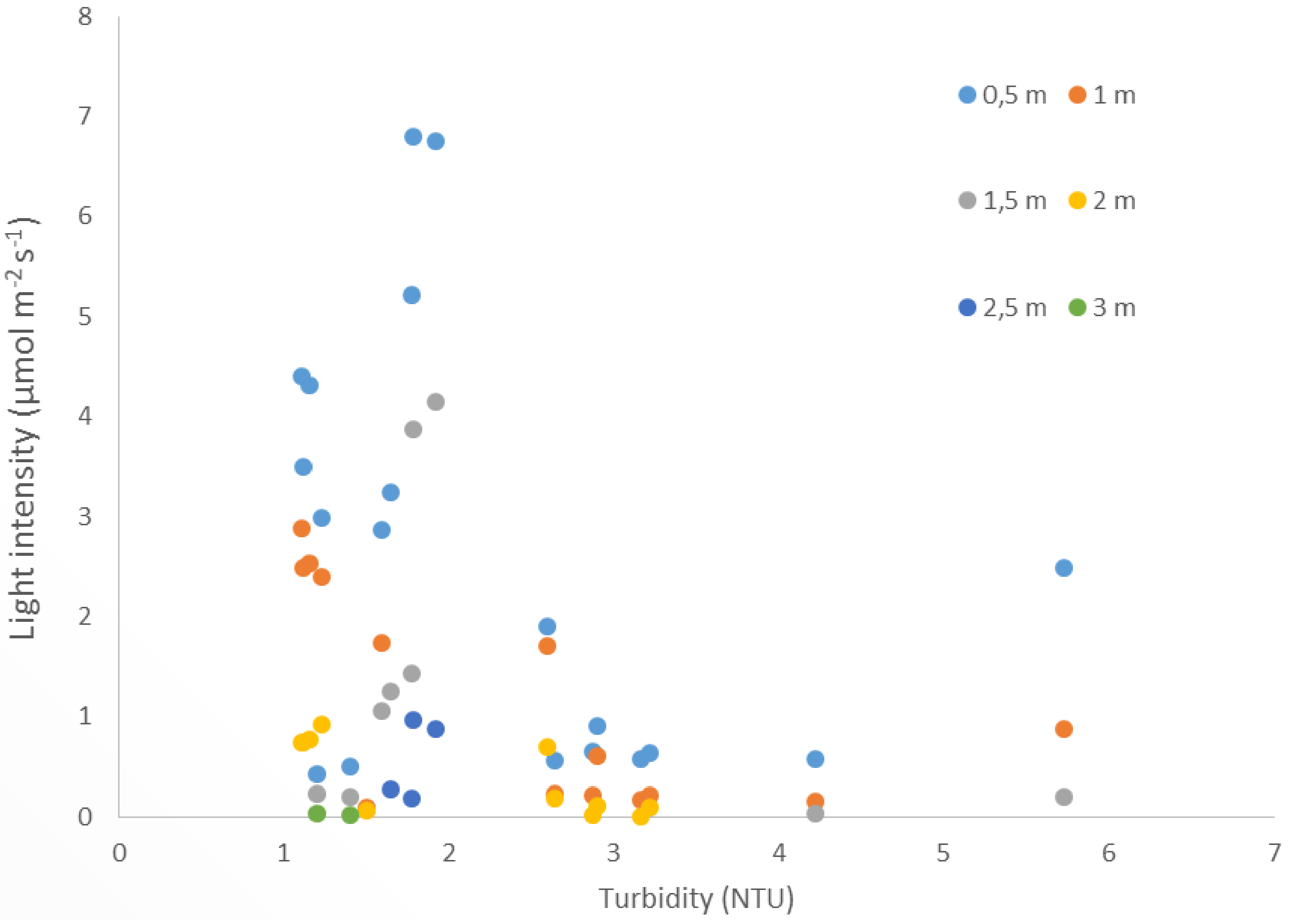
- Light intensity in all tanks decreased with depth: 93-100% light intensity reduction @ tank bottom
- Light placement effects light intensity profiles in the tanks – how does this affect fish?
- Fish density affects light intensity
- Faster light intensity reduction in RAS vs FT



Parameter/value	Minimum	Maximum
Fish size (g)	4	209
Fish density (kg/m^3)	4	65
Turbidity (NTU)	1	6
TSS (mg/l $CaCO_3$)	2	12

Summary

- Increased turbidity @ each location caused decrease in light intensity
- Tanks with similar turbidities from different locations had wide range of average light intensities which can be caused by difference in intake water quality, system management, particle size distribution, fish size and density



Average light intensity measured in the tanks (points under extra lighting excluded) at different depths (0,5m, 1m, 1,5m, 2m, 2,5m and 3m) and different tubidities

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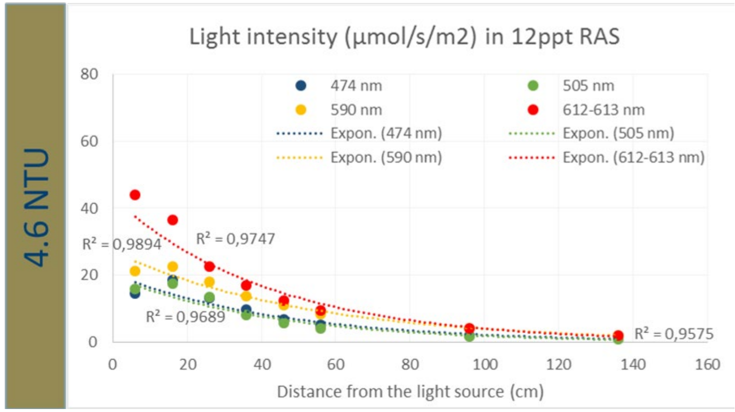
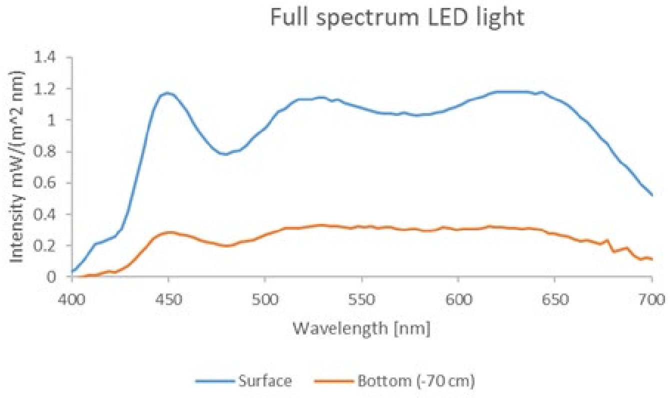
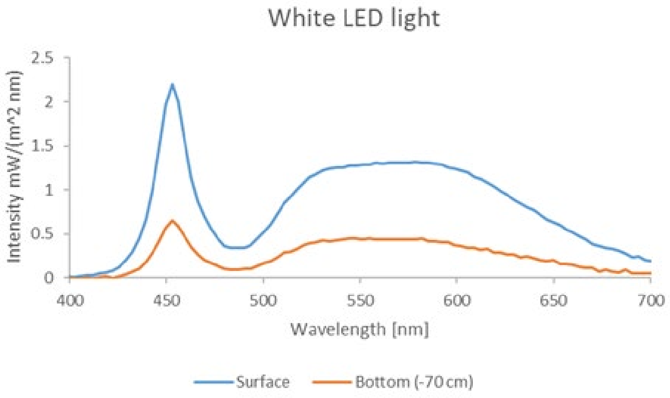
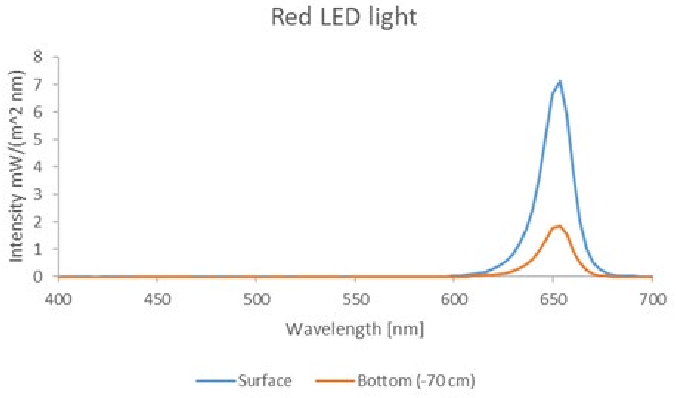
Way forward: optimizing light in RAS



- What is optimal light intensity for post-smolt production in RAS?
- Indications that different light spectra affects physiological processes differently in post-smolts (Ebbesson et al., unpublished)
- Turbidity affects spectral composition of the light in addition to light intensity - important to determine the spectral composition of light in tanks with RAS water
- Experiment will be done at a part of CtrlAQUA to look into optimal light condition for post-smolt production; FARMWELL- effect on eye histology







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Thank you for your attention

..and to Frode Mathisen from Grieg Seafood, my Nofima colleague Britt Kristin Reiten and staff of Grieg Seafood and Marine Harvest facilities

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