Post-smolt welfare, performance, and water quality in commercial scale, floating, semi-closed containment systems: CtrlAQUA Flexibag and concrete

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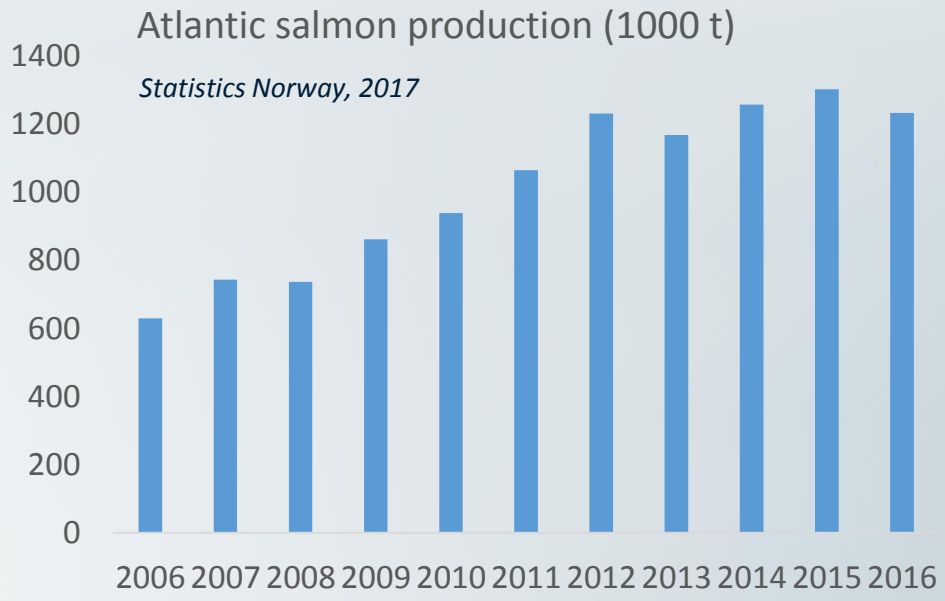
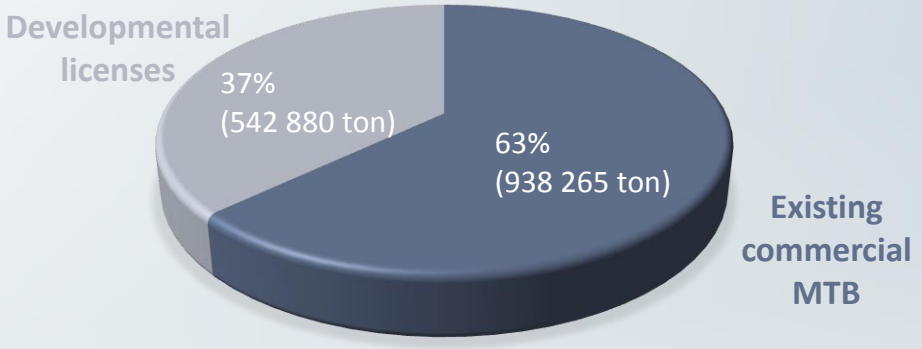
Norwegian Atlantic salmon production in 2050

- 5 mill. ton salmon in 2050 (Olafsen et al., 2012)?
- **P**rice**w**aterhouse**C**oopers: max 3.5 mill. ton
  - ✓ «green traffic light» all the way (lice issues resolved)
  - ✓ Production of large post-smolts
  - ✓ Use and development of new technologies
  - ✓ Solve feed sustainability issue
  - ✓ High demand for Norwegian salmon
  - ✓ Max production from Developmental Licenses
  - ✓ 1 mill t production on land

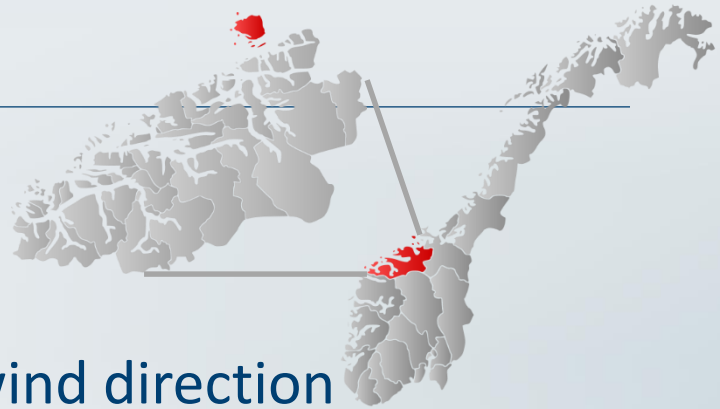


Total maximum allowed biomass (MTB)



Fiskeridirektoratet, 2017

S-CCS testing and development @ Smøla



- Mid Norway, Møre og Romsdal
- At Flatøy/Gullklakken north of Hopen on Smøla
- In a sheltered area for wind and waves except south-easterly wind direction
- Water quality and welfare and performance of Atlantic salmon post-smolts

Testing period: 2016-ongoing
2 production cycles so far
(3rd ongoing)

Testing period: 2014-2016
4 production cycles

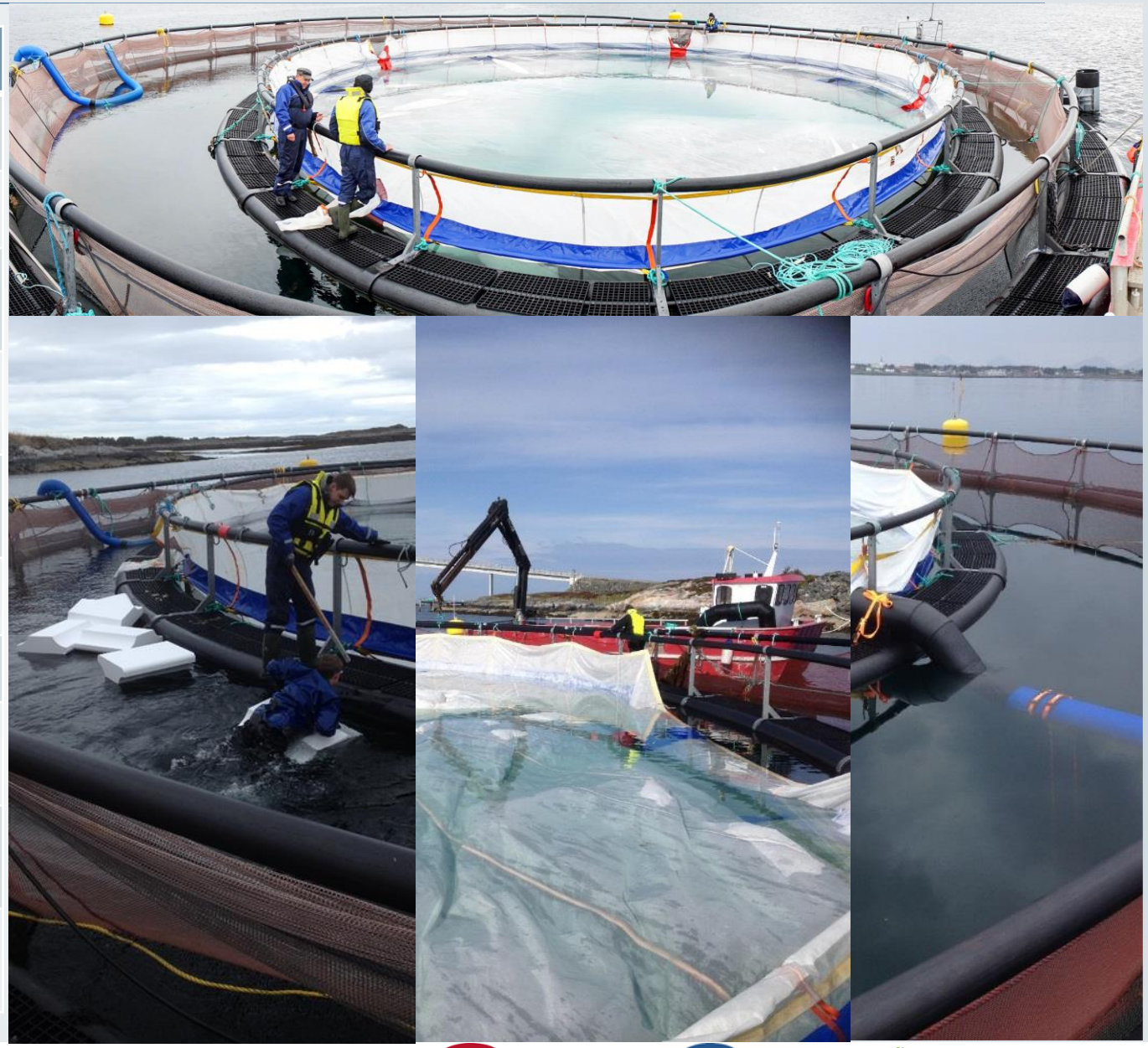
Why SCCS:

- ✓ Louse barrier
- ✓ Nutrient collection
- ✓ More controlled environment

Flexibag: SCCS with flexible walls

93% polyamid, 7% Dyneema (HPPF)

Parameters	1st generation	2nd generation
Water volume	1720 m^3	2484 m^3
Water exchange	38 m^3/min	38 m^3/min
Specific pump capacity (4 pumps in total)	158 l/sec per pump	158 l/sec per pump
Hydraulic retention time (HRT)	45 minutes	66 minutes
Minimum specific water flow	0.44 l/min/kg	0.29 l/min/kg
Maximum fish density	52 kg/m^3	52 kg/m^3
Maximum biomass	86 000kg	130 910 kg
Maximum oxygen added	663 kg/day	663 kg/day
Maximum CO2 in the outlet water	8 mg/L	8 mg/L
Water intake (600 mm) depth (m)	12	12



Flexibag: Four production cycles 2014-2016

Production cycle	Flexibag system volume (m^3)	Start date	End date	# days of production	Start weight (g)	End weight (g)	Start density (kg/m3)	End density (kg/m^3)
1st	1720	25.06.2014	18.09.2014	85	130	**360**	5	15
2nd	2484	16.06.2015	29.07.2015	43	98	152	4	7
3rd	2484	02.12.2015	07.04.2016	127	**58**	193	**2**	7
4th	2484	26.05.2016	17.08.2016	83	127	245	10	**19**

- Profiling of water quality in the bag :

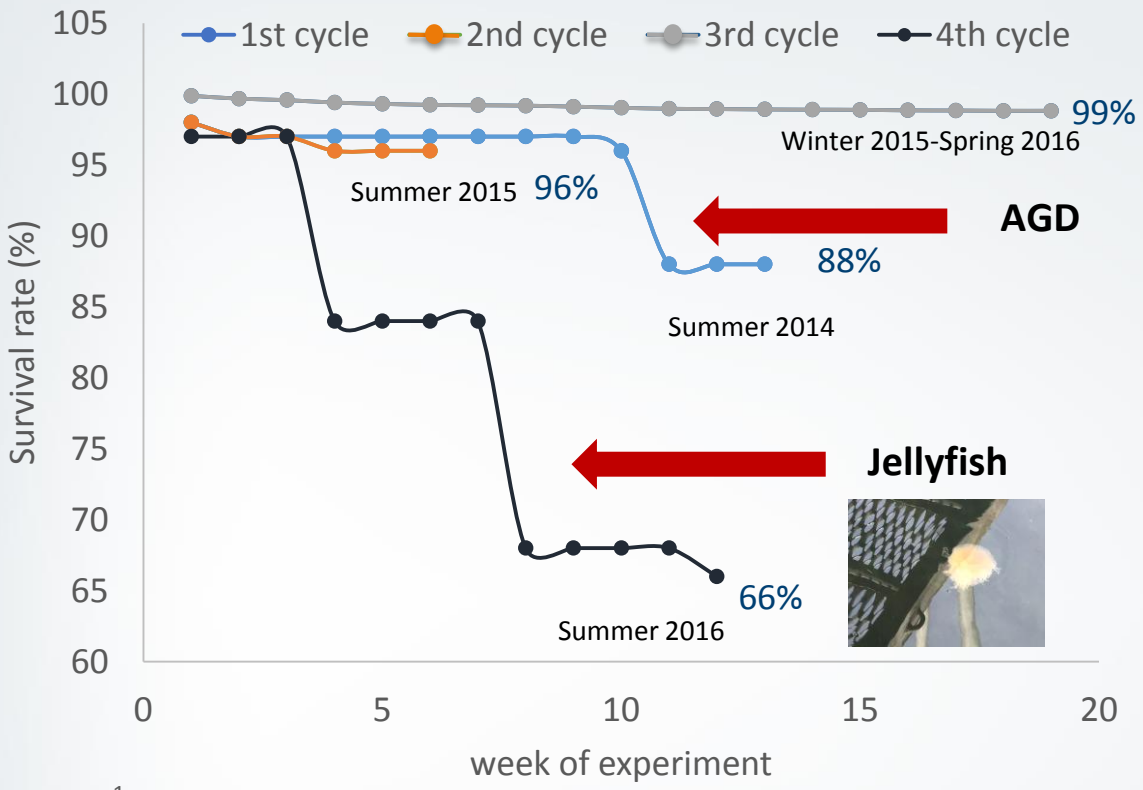
✓ Vertical @ 3 depths : 1.5, 4 & 8 m

✓ Horisontal in the centre (all) & 1m from the edge (2nd-4th cycle)

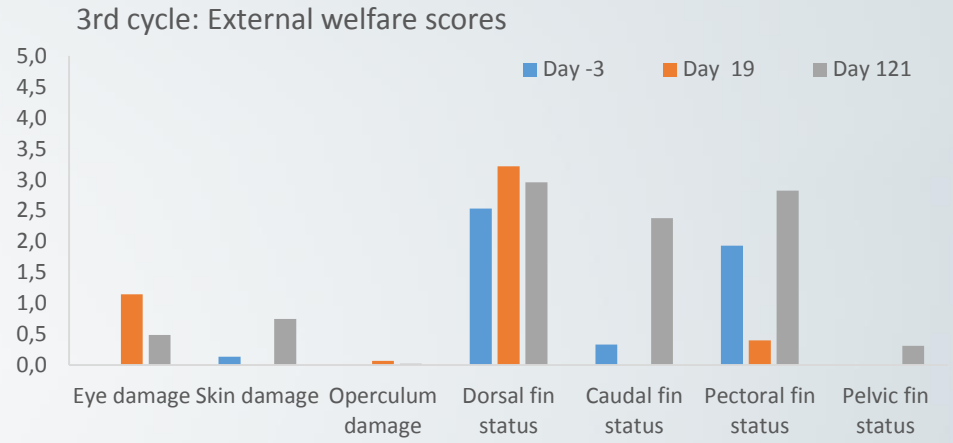
- Water velocity (4th cycle)
- Salmon performance (all) & external welfare (1st, 3rd & 4th)

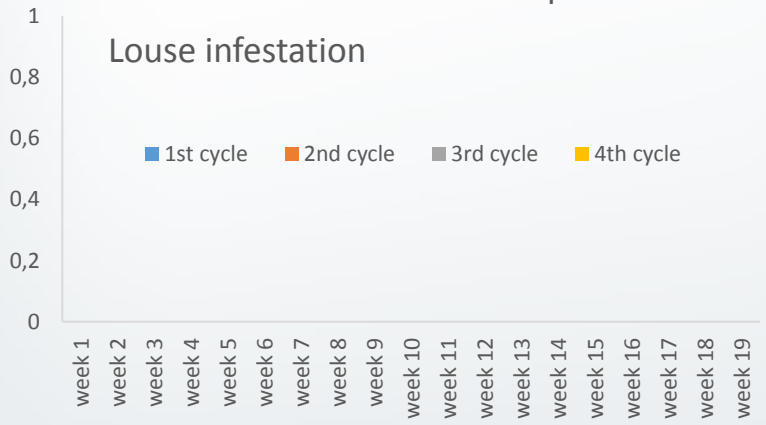
NO CONTROL GROUP!

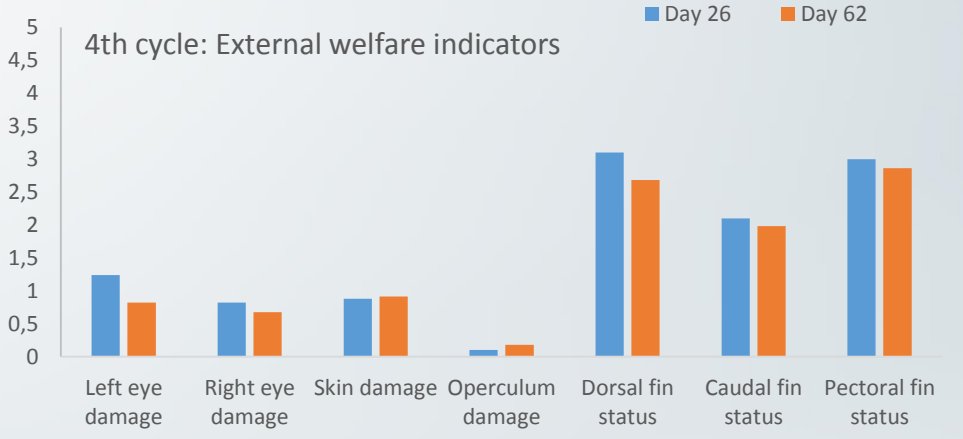
Flexibag: Post-smolt performance & welfare



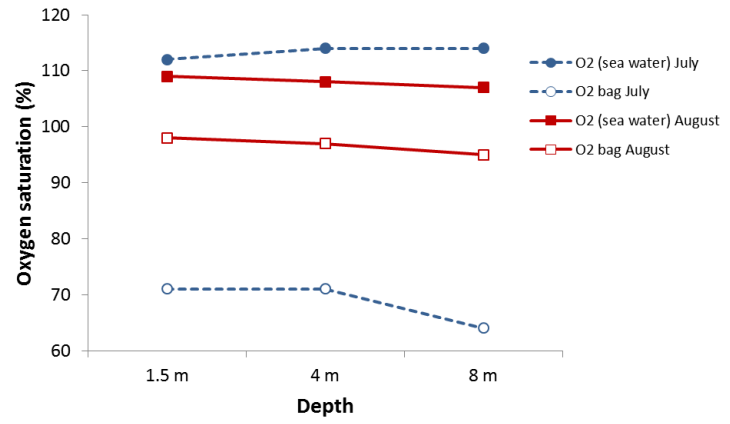
Production cycle	start date	end date	# days	Start W	End W	# days	SGR	TGC
1st	25.06.2014	18.09.2014	85	103	371	85	1,50	2,47
2nd	16.06.2015	29.07.2015	43	98	152	43	1,02	1,42
3rd	02.12.2015	07.04.2016	127	58	193	127	0,95	2,56
4th	26.05.2016	17.08.2016	83	127	245	83	0,79	1,24

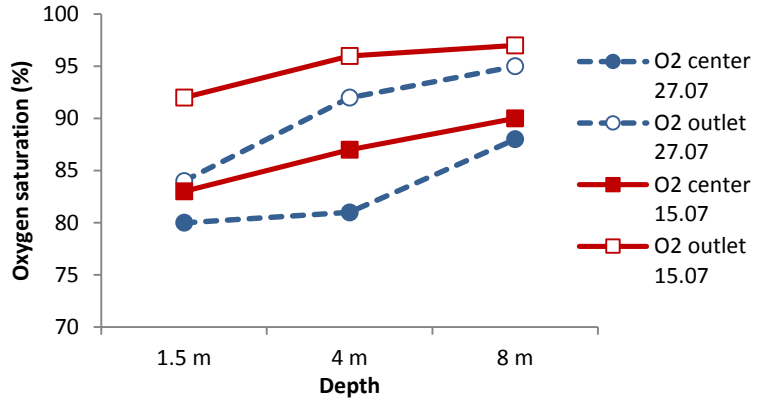


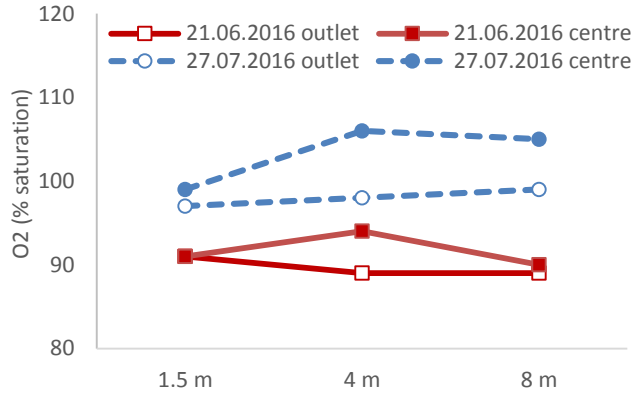


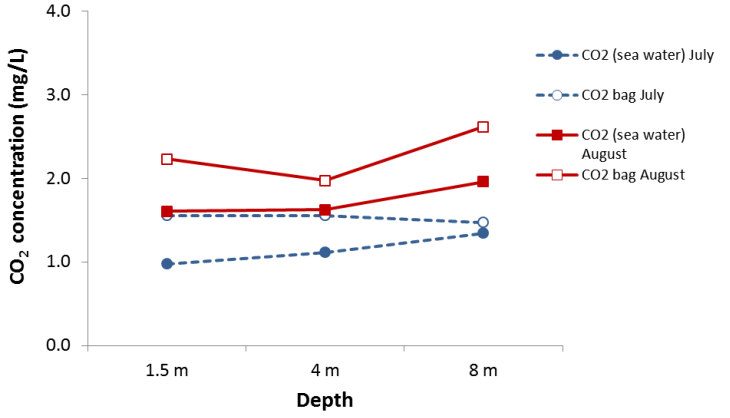


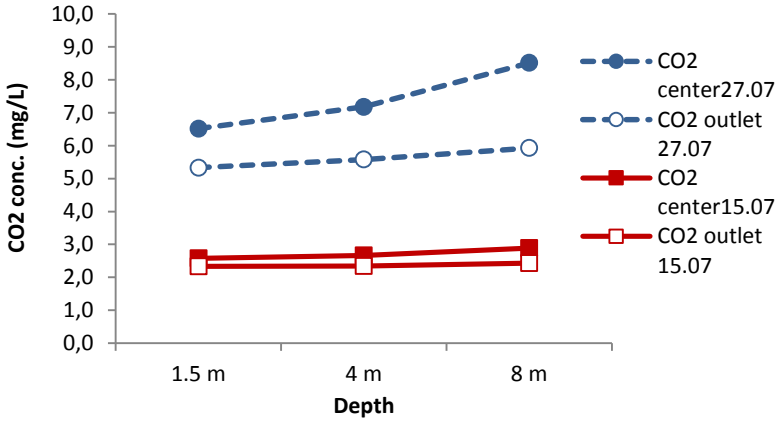
Flexibag: Water quality within recommendation

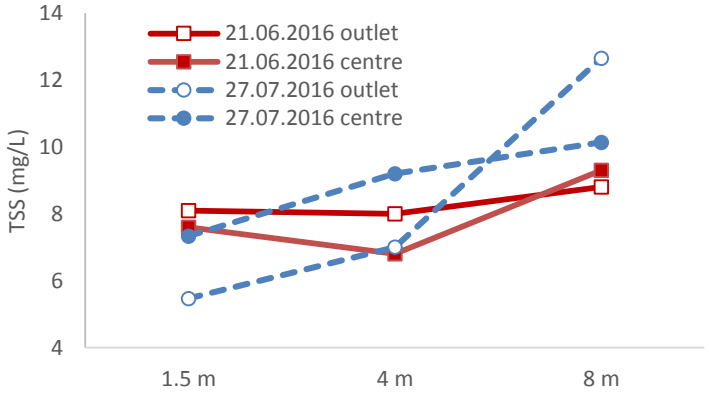










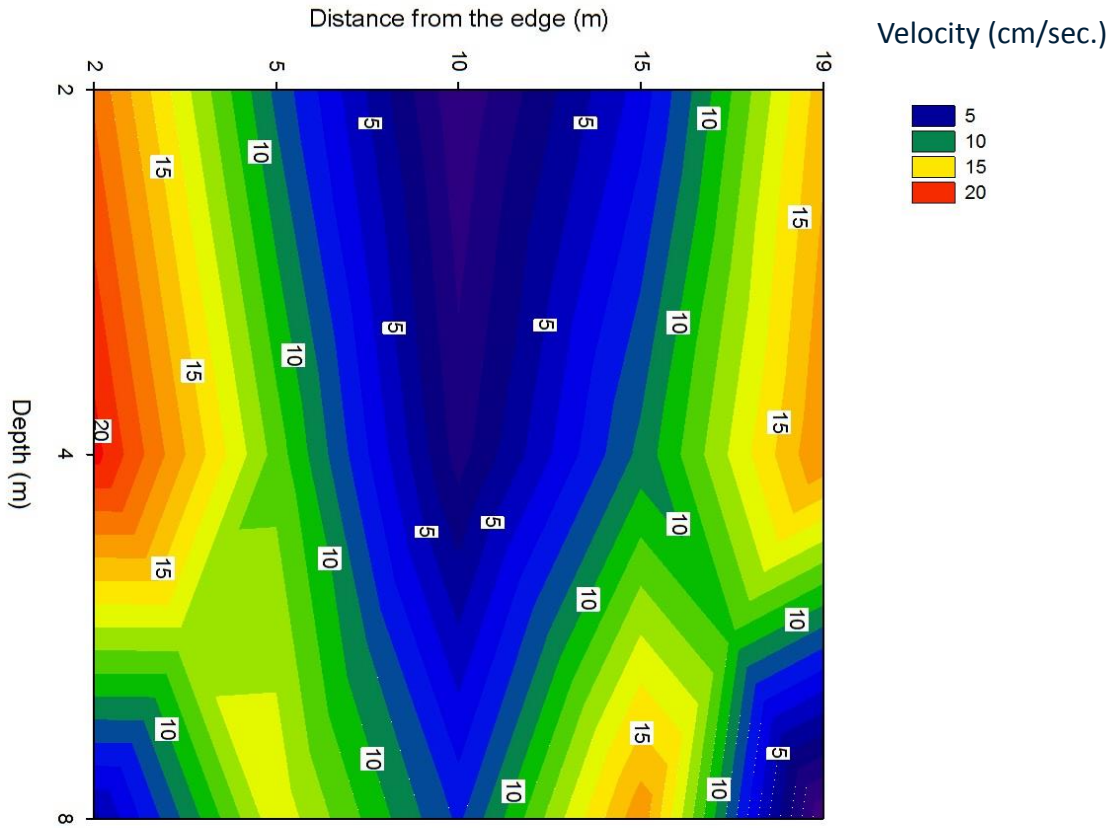


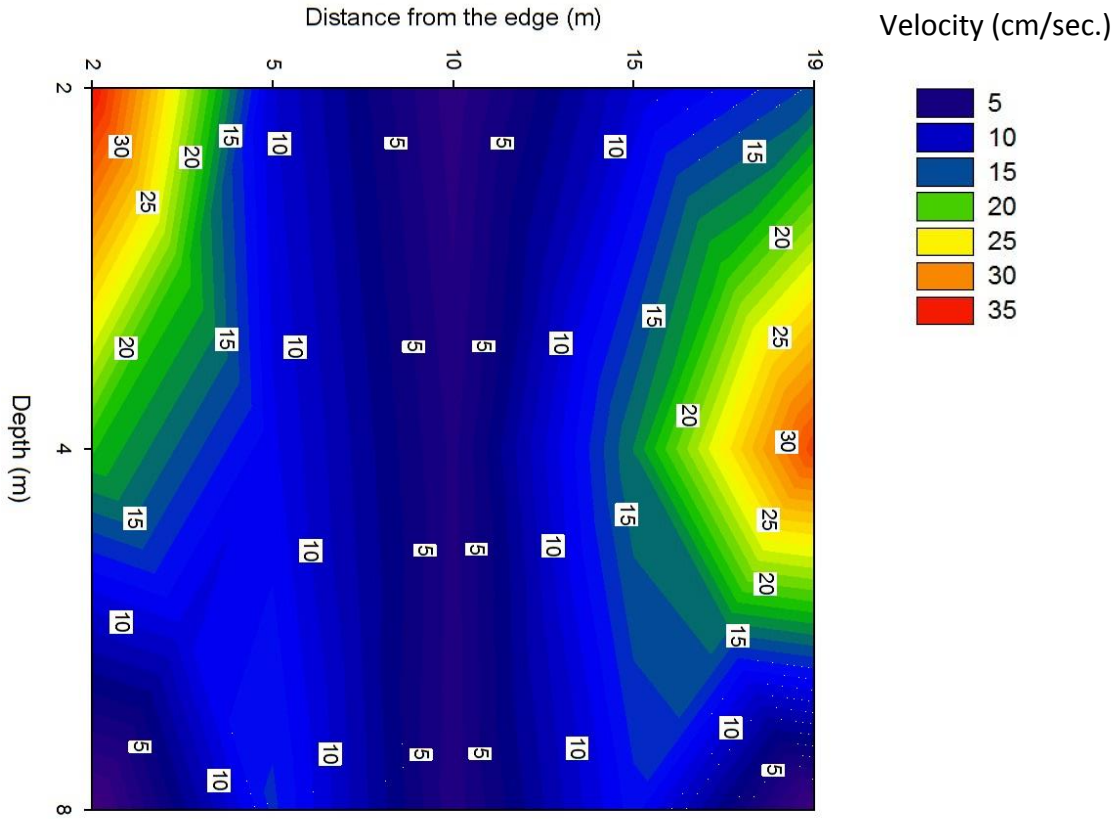
2014: Max. Pumping was only 50% of maximum pump capacity due to ondersized outlet

2015: Improved design; Problems with self-cleaning; differences were found in the horizontal & vertical profile of the water quality

2016: Oxygen control and monitoring; persistent difference in water quality profile

Flexibag: Water velocity (4th cycle)





Day 26: 0.4 ± 0.3 BL/sec
Max 0.9 BL/sec

Day 62: 0.5 ± 0.4 BL/sec
Max 1.4 BL/sec

Flexibag: Conclusions

Positives:

- ✓ Choice of material
- ✓ Robust system
- ✓ No lice
- ✓ Good growth
- ✓ Investment cost
- ✓ Water quality

Challanges:

- ✓ Fouling
- ✓ Outer net pen
- ✓ Sampling of fish
- ✓ Collecting dead fish
- ✓ Biosecurity (AGD & jellyfish)
- ✓ Harvesting fish
- ✓ Suboptimal hydraulics
- ✓ Particle removal

Foto: Rune Iversen, Nekton Havbruk AS

Salmon Home #1: concrete floating tank in the sea

- 1000 m^3 pilot; 14m diameter; 267 t
- Concrete (2x10cm walls; 70 cm isopor)
- Pipes inside walls
- 3 Propeller pumps (2 inlet & 1 outlet)
- Oxygenation
- Intake water from 10-12 m depth
- Drum filter
- Investment cost: 20 mil NOK (3.1 $ CAD)

Photos: Fishfarming Innovation, Nekton Havbruk & Jelena Kolarevic

Salmon Home #1: Two production cycles (2016-ongoing)

Production system S-CCS	November 2016- March 2017		May 2017- August 2017	
	Start ind. Weight	Density @ start	Start ind. Weight	Density @ start
	96g	6 kg/m³	118 g	8 kg/m³

Atlantic salmon post-smolt in S-CCS
11/9/2016

Sampling 1
1/17/2017

Sampling 2
3/23/2017

nov | des | 2017 | feb | mar | apr | mai | jun | jul | aug

2017

11/9/2016 **Production cycle 1 S-CCS (136 days)** 3/24/2017

5/29/2017
Sampling 1

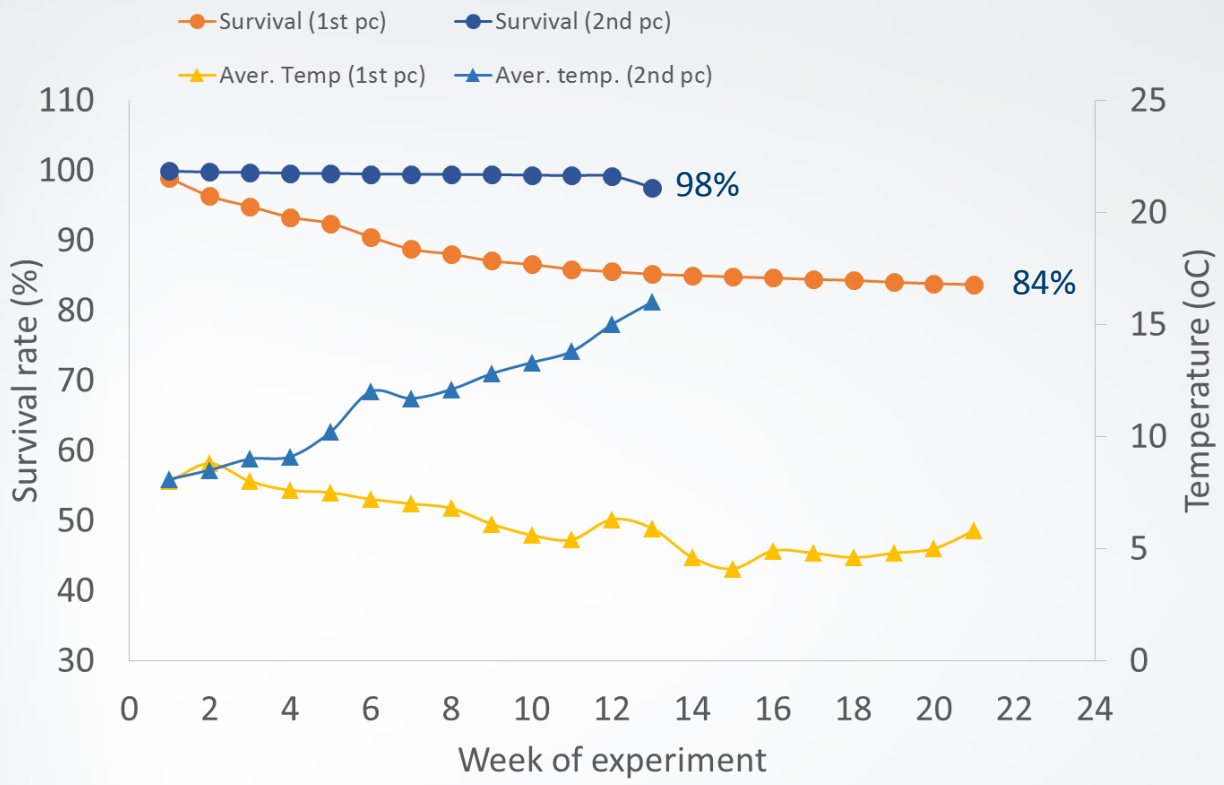
7/31/2017
Sampling 2

5/10/2017
Atlantic salmon post-smolt in S-CCS

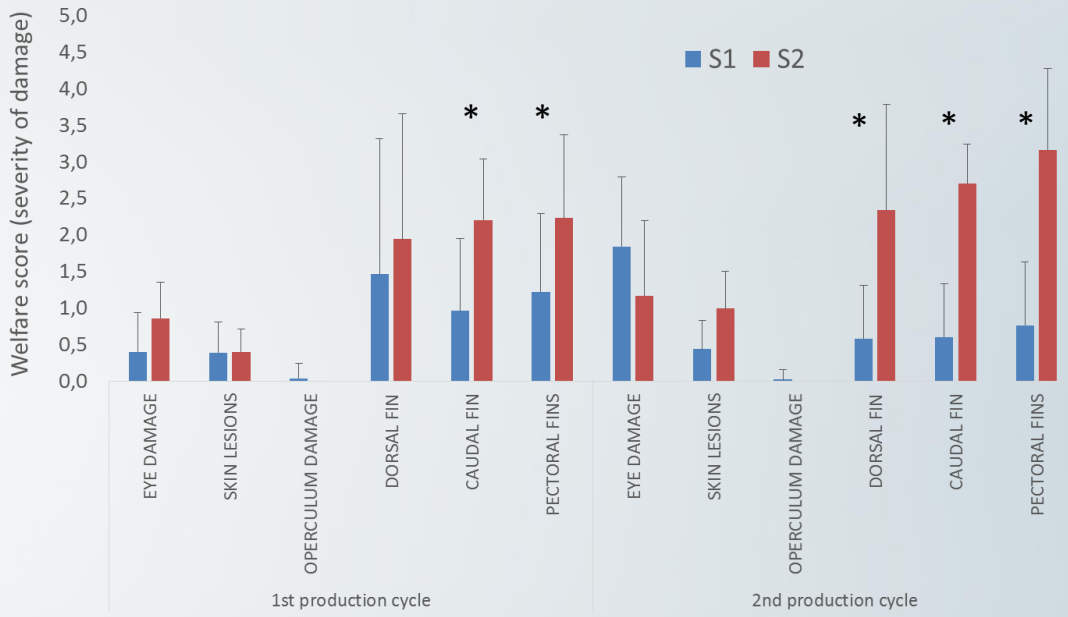
5/10/2017 **Production cycle S-CCS (86 days)** 8/3/2017

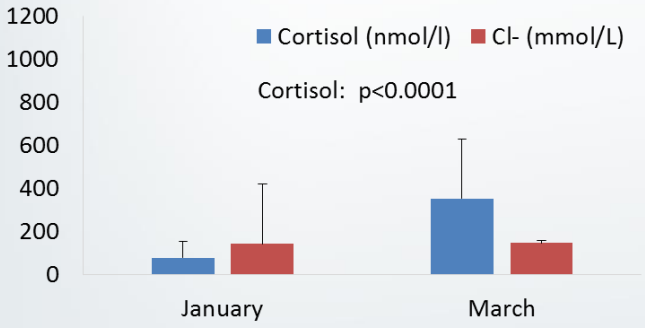
- Performance (survival & growth)
- Blood chemistry (ions, lactate and cortisol)
- External welfare indicators
- Organe indexes
- Water quality profiling of the system
- Water velocity profiling of the systems
- «Control group»: Cage with lice skirt

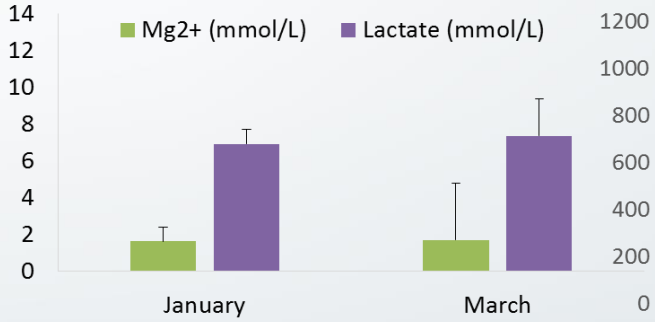
Salmon Home #1: Post-smolt performance & welfare

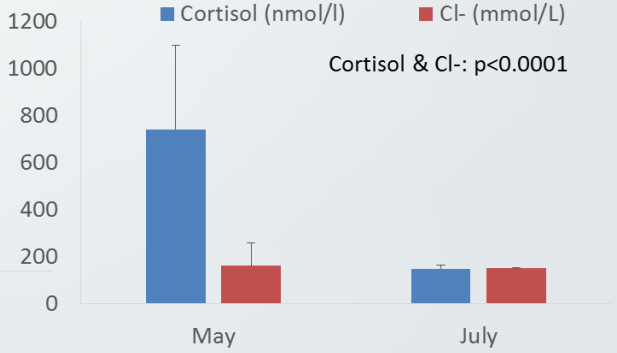


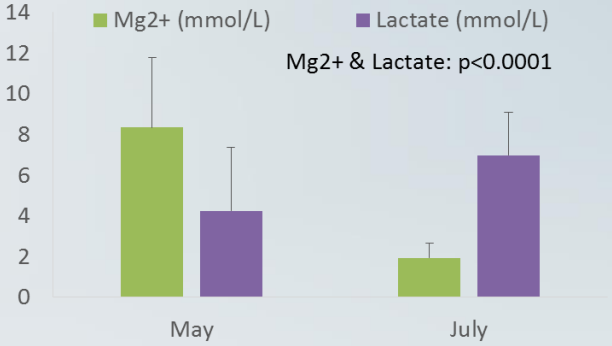
Production period	SGR (%)	TGC
1st production cycle	0,87	2,7
2nd production cycle	1,36	2,3



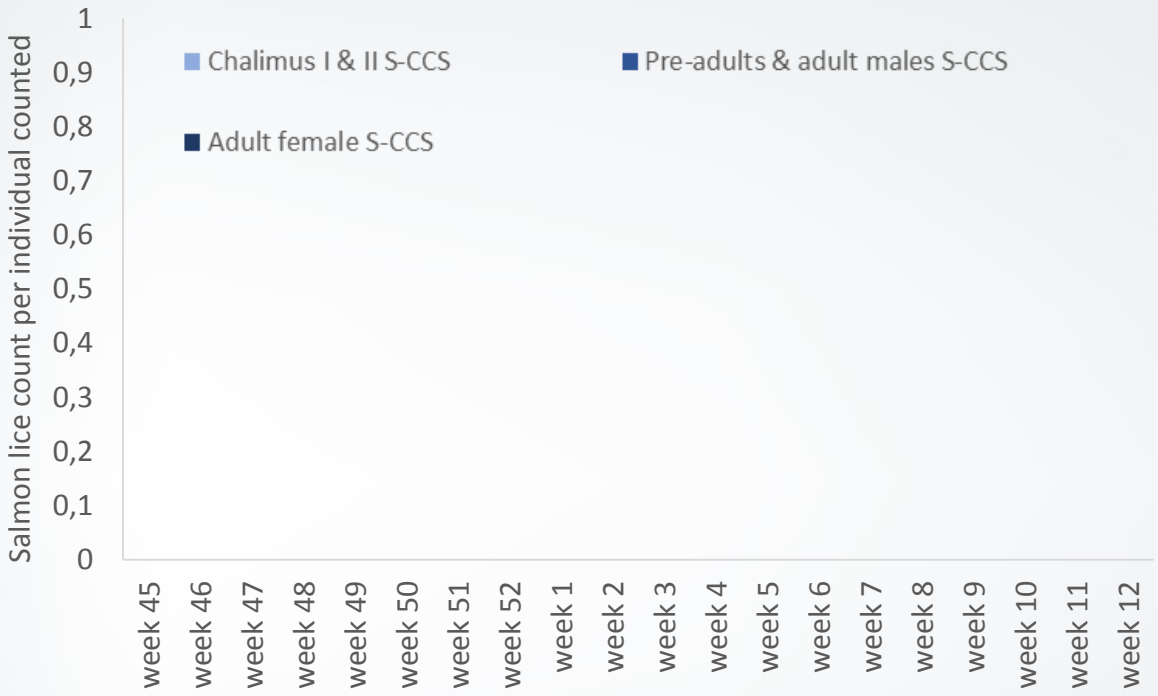


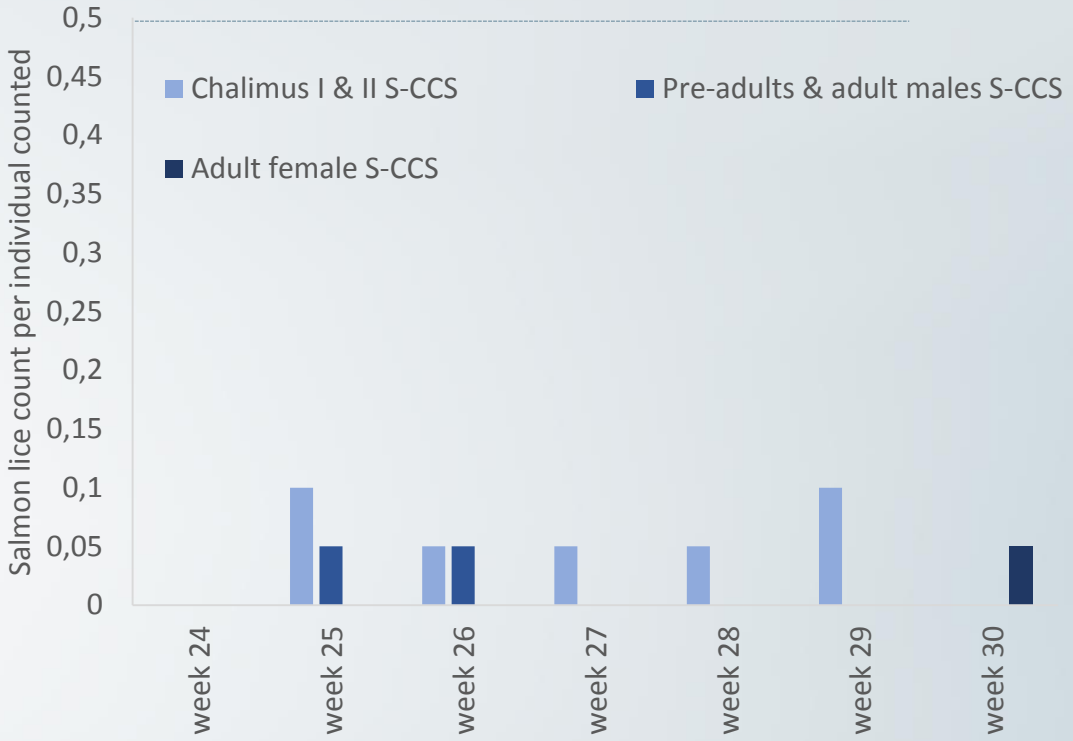






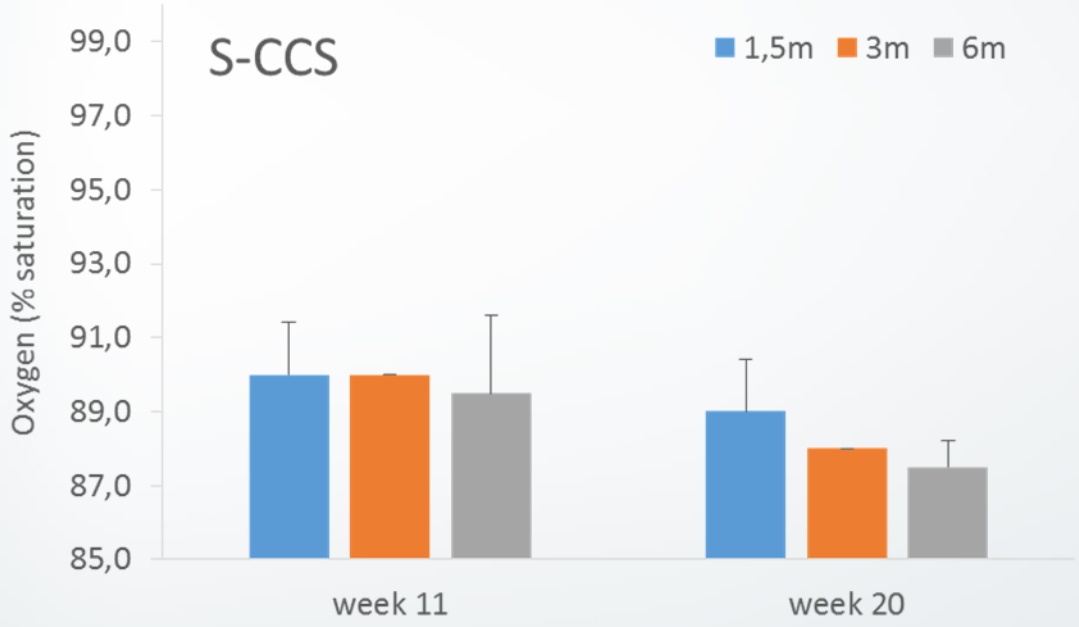
Salmon Home #1: Salmon Louse (*Lepeophtheirus salmonis*) infestation





Salmon Home #1: Water quality (1st prod. cycle)

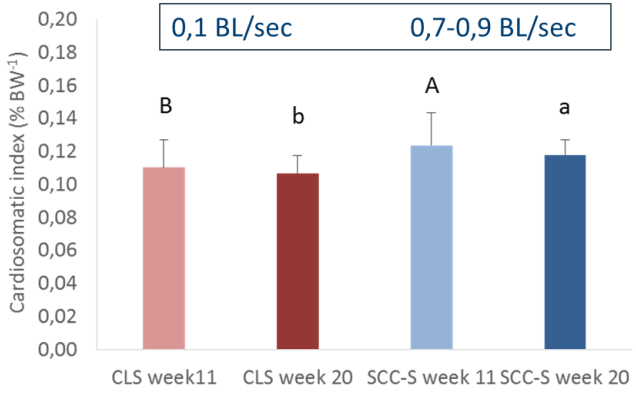
Week of experiment	Values	Temperature (oC)	pH	Salinity (ppt)	Oxygen (% saturation)	CO2 (mg/L)	TAN (mg/L)	TSS (mg/L)	Turbidity (NTU)	Conductivity (mS/cm)
Week 11	Average	5,4 ± 0,1	8,0 ± 0,0	33,5 ± 0,1	89,8 ± 1,2	1,5 ± 0,1	0,5 ± 0,1	9,3 ± 2,3	0,0 ± 0,0	53,1 ± 0,3
	Min	5,3	8,0	33,4	88,0	1,5	0,3	7,2	0,0	52,8
	MAX	5,5	8,0	33,5	91,0	1,6	0,6	13,0	0,0	53,4
Week 20	Average	5,4 ± 0,1	8,1 ± 0,0	33,9 ± 0,0	88,2 ± 1,0		0,6 ± 0,1	8,0 ± 1,1	0,0 ± 0,0	53,4 ± 0,1
	Min	5,3	8,0	33,9	87,0		0,4	6,8	0,0	53,3
	MAX	5,4	8,1	33,9	90,0		0,7	9,6	0,0	53,4

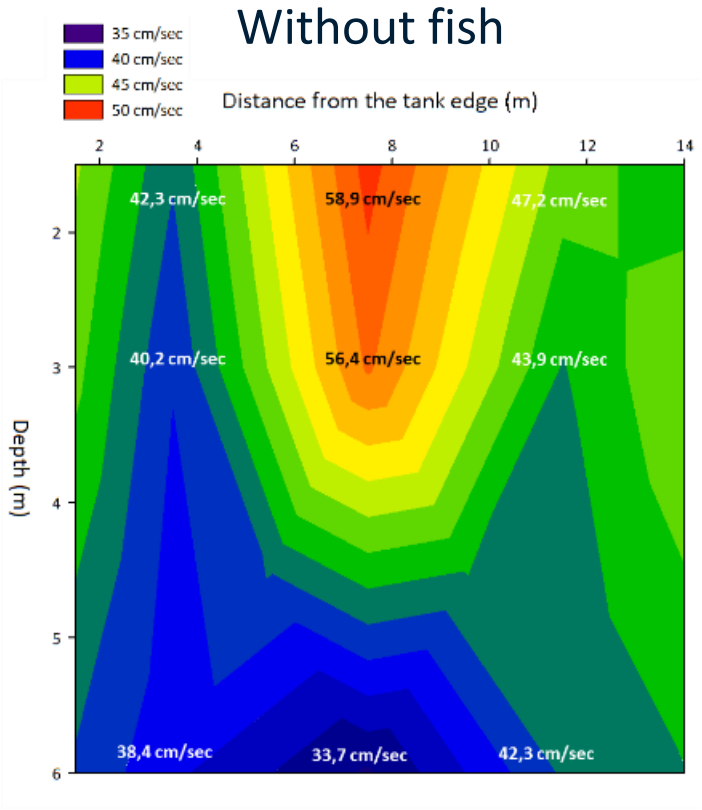


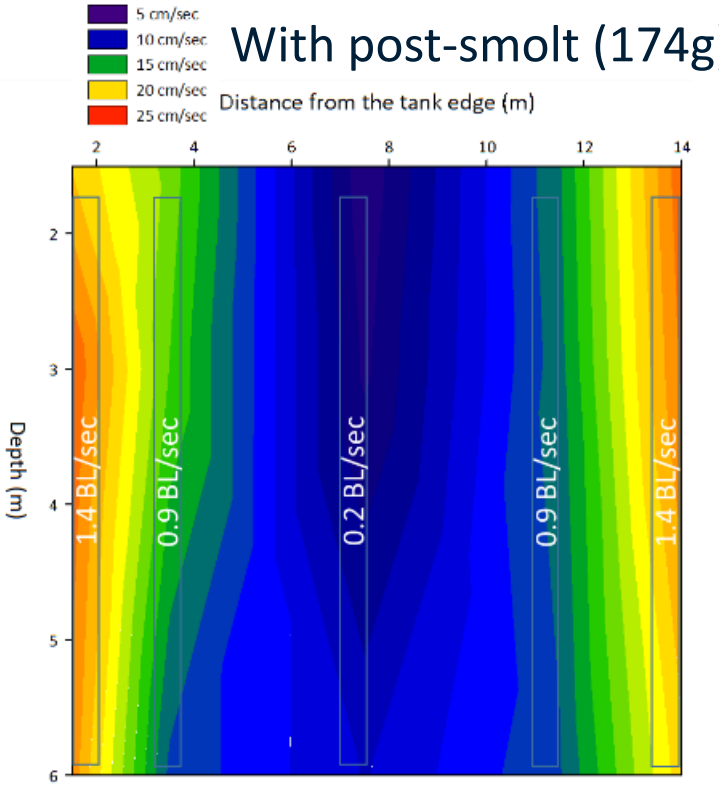
- Measured @ 3 depths & 5 horisontal points within the system (15 point measurements in total)
- Good water quality
- No large differences between point measurements

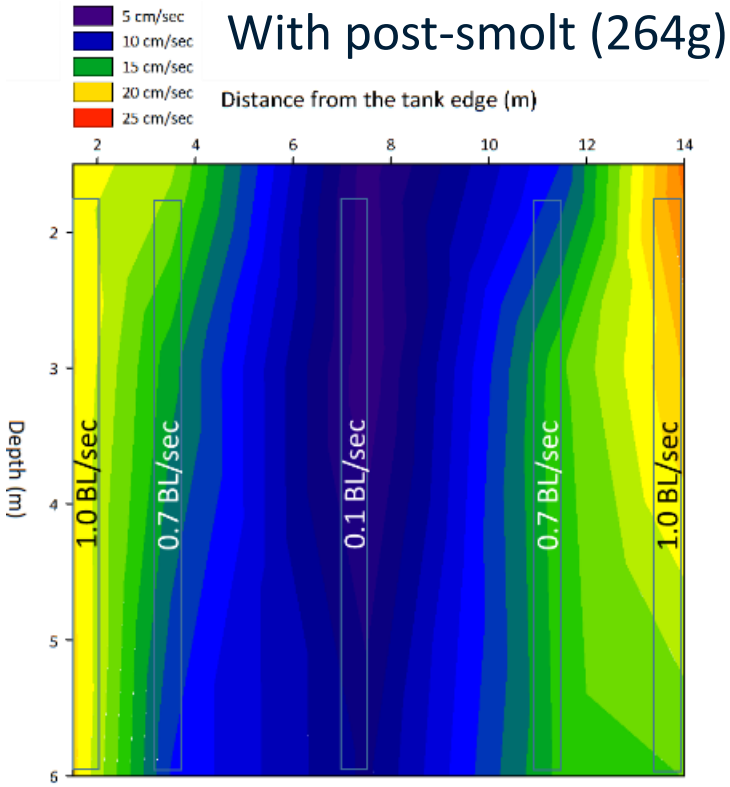
Salmon Home #1: Water velocity

- Water velocity close to 60 cm/s in empty tank
- Potential to maintain good training conditions and self-cleaning









@ 3 depths & @ 5 horisontal points within system

0,9 ± 0,5 BL/sec

0,7 ± 0,4 BL/sec

Salmon Home #1: Conclusions so far

Positives:

- ✓ Strength & durability
- ✓ Good tank hydraulics
- ✓ Good particle removal
- ✓ Daily management
- ✓ Cleaning of tank (raise/lower tank)
- ✓ Louse
- ✓ Good growth
- ✓ Water quality
- ✓ Harvesting fish
- ✓ HMS

Challanges:

- ✓ Biosecurity (AGD)
- ✓ Investment cost
- ✓ Back-up solutions
- ✓ Smaller size (pilot)

Photo: Nekton havbruk

Photos: Fishfarming Innovation

Photo: Nekton havbruk

Atlantic salmon Operational Welfare Handbook: Assessing and documenting fish welfare out on the farm (Noble at al., 2017)

- **Part A:** Collation of knowledge on the welfare of Atlantic salmon
- **Part B:** Fit for purpose welfare indicators for different production systems
- **Part C:** Fit for purpose welfare indicators during handling operations

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Thank you for your attention

CtrlAQUA

..and to our colleagues in Nofima:
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