Developments in Recirculating Aquaculture Systems for Salmon Grow-out in Europe and Asia.

Aquaculture Innovation Workshop #6, Vancouver, 27th of October, 2014
Presentation by Bjarne Hald Olsen, CEO at Billund Aquaculture, Denmark

Agenda

1. An Introduction to Billund Aquaculture
2. An introduction to RAS technology (Recirculated Aquaculture Systems)
3. Developments in RAS for Salmon Grow-out in Europe and Asia
4. Vision for the Future

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An introduction to Billund Aquaculture

- Billund Aquaculture is a Danish company located in Billund, Denmark and in addition we have offices in Norway and Chile. In total we are 78 employees.
- We have a large and well documented reference list which document more than 28 years of experience in design, installations, operation and service of intensive re-circulation fish farms.
- Worldwide Billund Aquaculture has built more than 122 projects (> 508 RAS) for 25 different salt- and freshwater species in 28 different countries.
- Billund Aquaculture has technical and biological experience in planning and construction of intensive production of all kind of warm and cold fresh- and saltwater fishes for example;

Freshwater species:

- **Salmon (Egg → smolt)**
- **Sturgeon**
- Trout
- Barramundi
- Pike Perch
- Perch
- Eel
- Tilapia
- Arctic Shar
- Pike
- Carp
- Catfish
- Tench

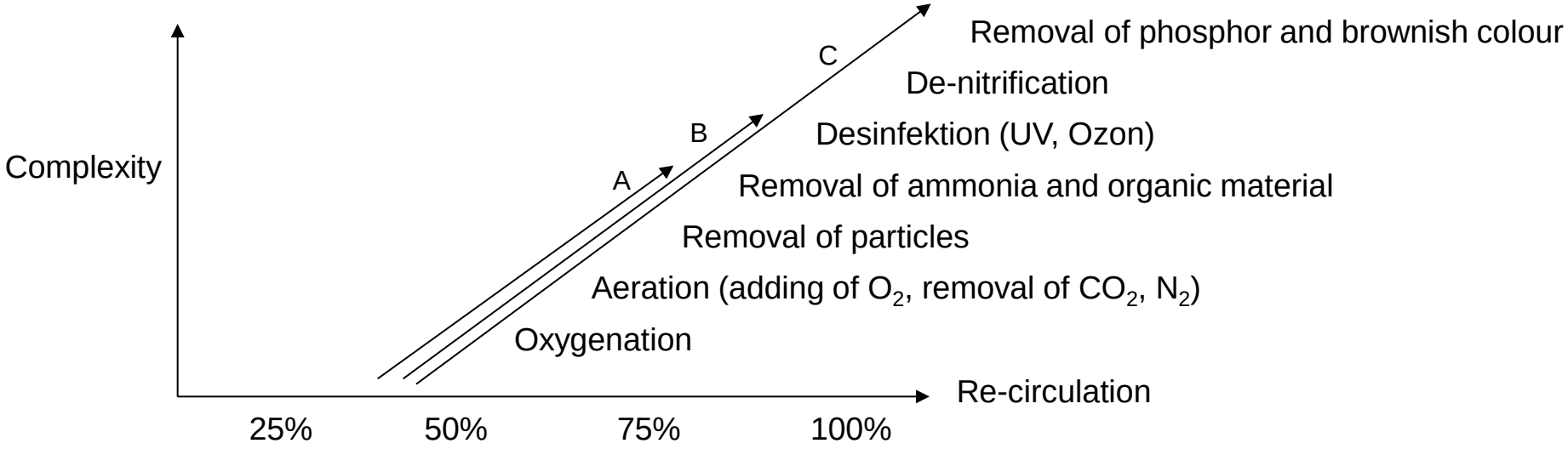
Saltwater species:

- **Salmon** (Post-smolt → Grow-out)
- Atlantic Lumpus (fish for eating sealice)
- Sea Bass
- Sea Bream
- Cod
- Turbot
- Halibut
- Cobia
- Grouper
- Snapper
- Sole
- Yellowtail Kingfish
- Coral fish

An introduction to Billund Aquaculture

In general, there is often confusion about what is meant by recycling and what is meant by reuse.
Recycling is when the water quality is in control of the water treatment system, **NOT** by the inlet water.

RAS (Re-circulated Aquaculture System): Exchange less than 10% of total water volume per day



Flow through systems	40.000 - 50.000	Liter of new water/day/kg fish produced
Semi RAS (A)	2.000 - 5.000	Liter of new water/day/kg fish produced
Moderate RAS (B)	300 - 500	Liter of new water/day/kg fish produced
Intensive RAS (C)	50 - 300	Liter of new water/day/kg fish produced

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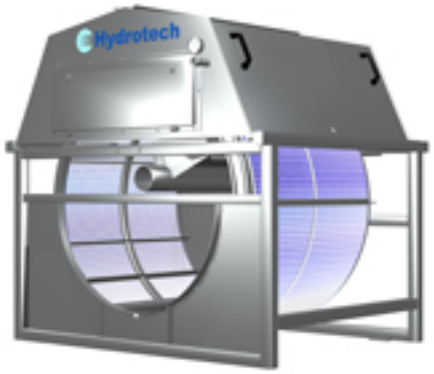
An introduction to RAS

Water consumption between 300 - 500 litre new water per day per kg feed

Fish tanks

An introduction to RAS

Water consumption between 300 - 500 litre new water per day per kg feed



Mechanical filter

Removal of particles

Biological filter – fixed bed filter – cleaning of filter

Transformation of ammonia (NH_4^+) to nitrite (NO_2^-) and nitrate (NO_3^-) (end product!!)

Removal of organic material to carbon dioxide (CO_2) and water

Biological filter – moving bed filter – no cleaning

Transformation of ammonia (NH_4^+) to nitrite (NO_2^-) and nitrate (NO_3^-)

Removal of organic material to carbon dioxide (CO_2) and water

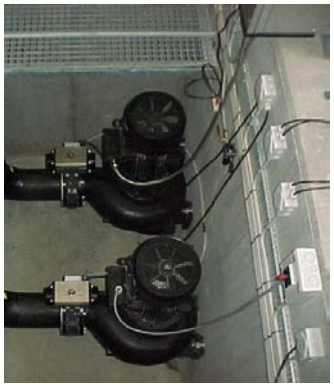
Trickling filter / Vacuum Degassing

Removal of Carbon dioxide (CO_2) and Nitrogen gas (N_2)

Aerating of water to approx. 100 % oxygen (O_2)

An introduction to RAS

Water consumption between 300 - 500 litre new water per day per kg feed



Pumps (Centrifugal or propeller pumps)

Oksygen-cones or deep-shaft

Oksygen supply

UV disinfection (Reactor or channel)

Fish tanks

An introduction to RAS

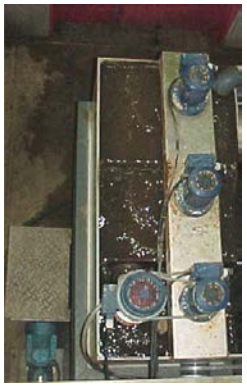
Water consumption between 300 - 500 litre new water per day per kg feed

Temperature regulation by heat-pumps

Energy savings by use of
Frequency converters

Water consumption between 50 - 300 litre new water per day per kg feed

Nitrate removal by
use of de-nitrification



Phosphor removal by addition of coagulants

Removal of brownish colour
by use of ozone

An introduction to RAS

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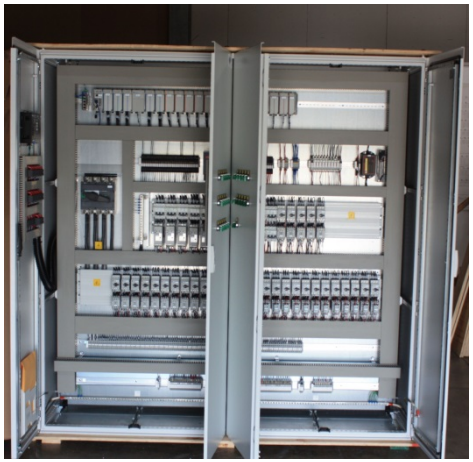
Automation & Monitoring/Control System

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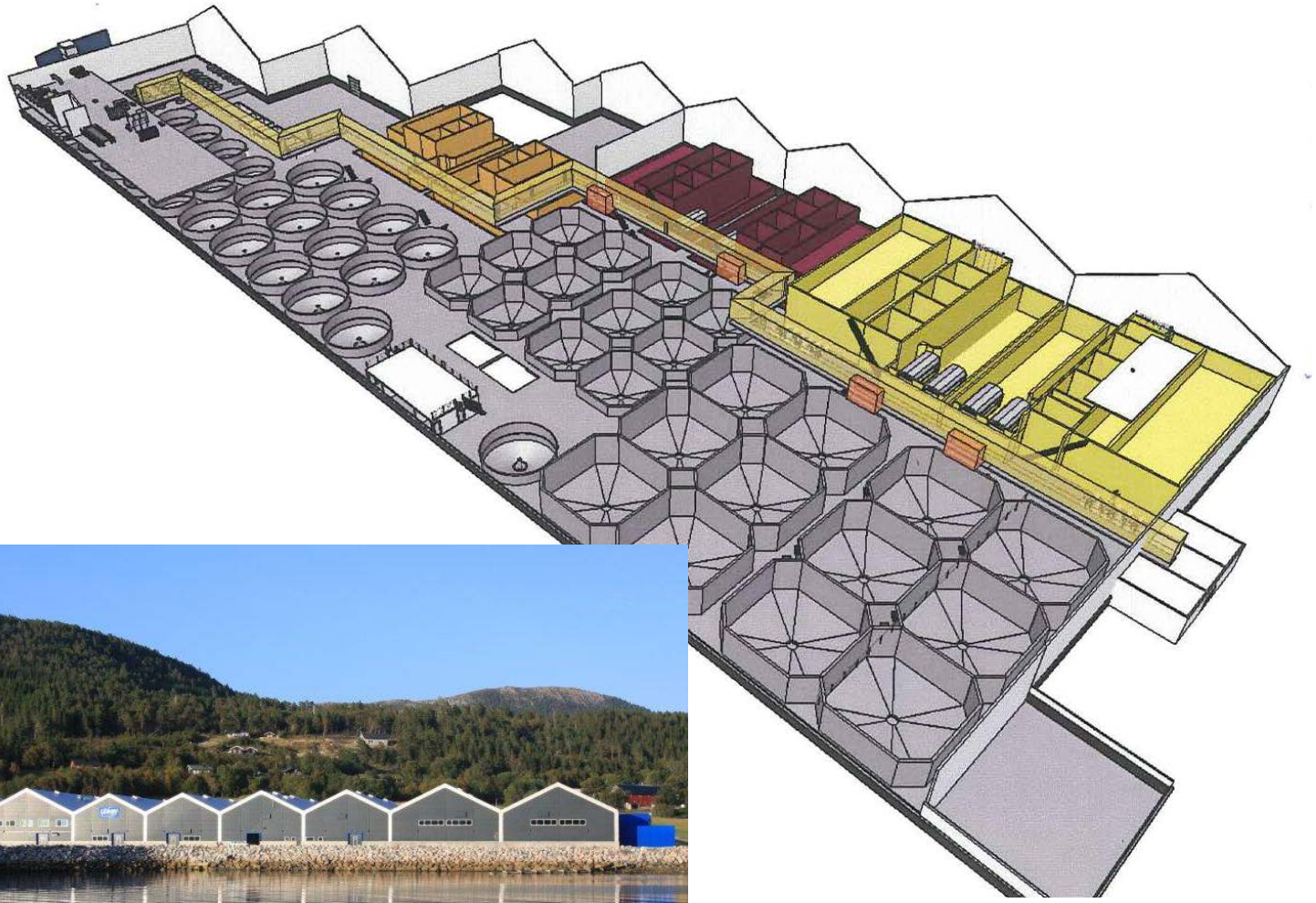
Developments in RAS for Salmon Grow-out

Lerøy Group, Belsvik: Capacity 14 -18 million smolt per year, 11.000 m^2, biological filter 9 tons feed per day



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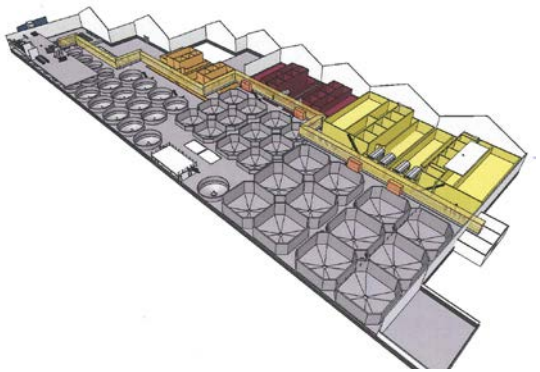
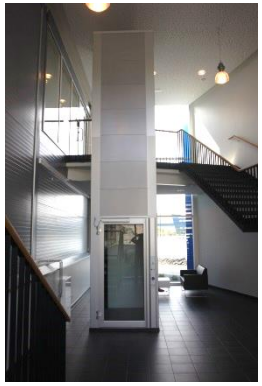
Developments in RAS for Salmon Grow-out





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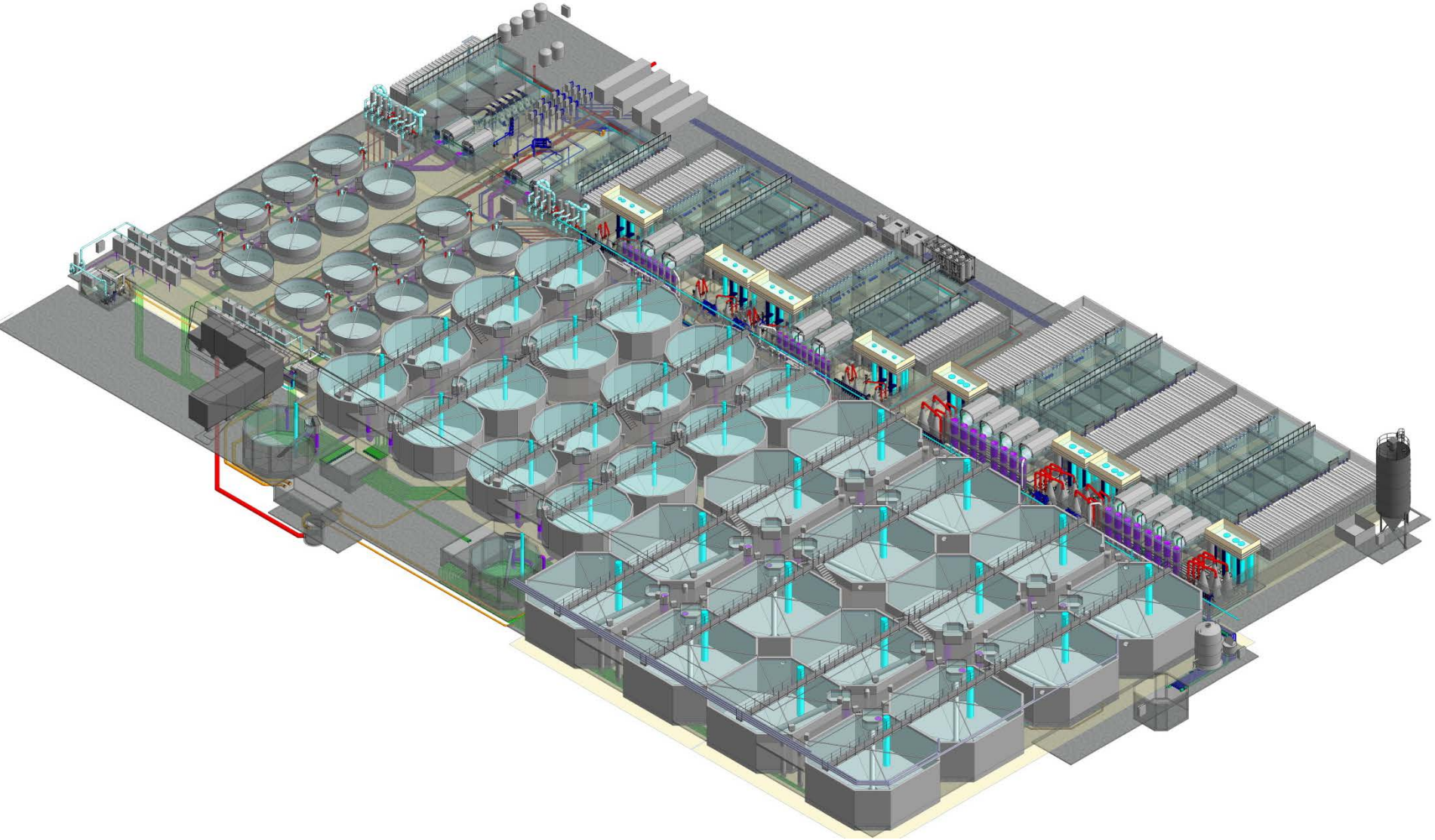
Developments in RAS for Salmon Grow-out

SalMar – Norway: Capacity 15 million smolt per year, 12.300 m^2, biological filter 11 tons feed per day



Developments in RAS for Salmon Grow-out

Atlantic Salmon Grow-out:

1. Langsand Salmon, Denmark – capacity 1.000 tons per year – Billund Aquaculture
2. XinJiang, China - capacity 1.000 tons per year – Billund Aquaculture
3. Jurassic Salmon, Poland - capacity 1.000 tons per year – Billund Aquaculture
4. Danish Salmon, Denmark – capacity 2.000 tons per year
5. Namgis First Nation, Canada – capacity 4-500 tons per year
6. Yantao Salmon Farm, China – capacity < 1.000 tons per year

Developments in RAS for Salmon Grow-out

Background for Grow-out Salmon production in 2011 in Denmark:

Billund Aquaculture has been working with the Grow-Out concept for 5 years (2005 – 2011)

Conducted two Grow-Out test for Salmo Salar in our own RAS

Focused on the following issues:

- Handling & Logistic
- Fish densities versus fish size
- Fish densities versus tanks size
- Growth rates
- Feed Conversion Rates (FCR)
- Temperature regimes
- Salinities
- Feed composition
- Maturation (light, temperature etc.)
- Off-flavor
- Fish quality (condition, fillet yield etc.)

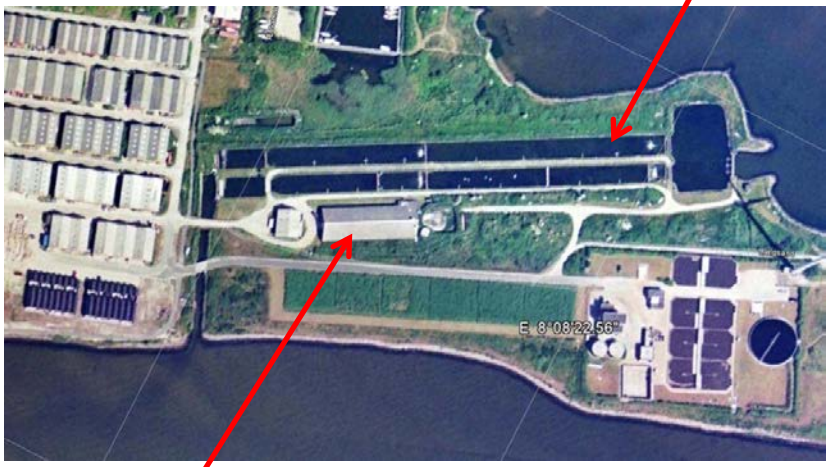
In 2011”Langsand Laks” was establish in the centre of Scandinavia, in a town called “Hvide Sande” in Denmark.

Developments in RAS for Salmon Grow-out

Langsand Salmon, Denmark – 1.000 tons, 4-5 kg Salmon - Total area 4.000 m^2

- At the location there was a former Eel farm and flow-through Trout farm
- The Eel-farm are now being used as for Hatchery, Startfeeding and Smolt Production.
- The Trout-farm has been demolished and the Salmon Grow-out production has been established using the existing permits for discharge.
- Dimensioning criteria was 4 batches per year
- First batch July 2011
- First harvest Q4 2013

Trout farm

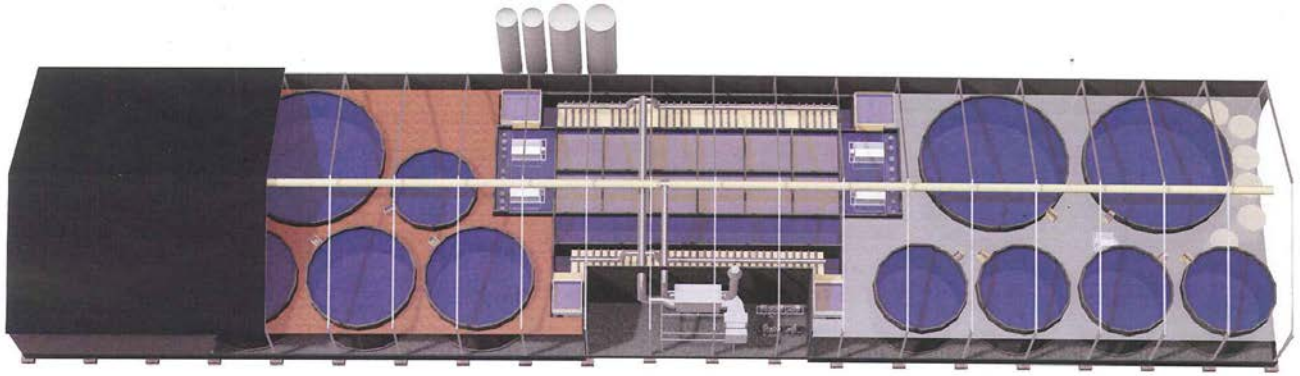


Eel farm

Developments in RAS for Salmon Grow-out

Langsand Salmon, Denmark – 1.000 tons, 5 kg Salmon - Total area 4.000 m^2

Dimension criteria:



Total building area:

- Incubation, Hatchery, Parr and Smolt-system: ~ 700 m^2
- On-Growing system ~ 3.300 m^2 (120 m x 27,5 m)
- 4.000 m^2 ~ 4 m^2/ton produced salmon

On-Growing System:

Total tank volume: 6.100 m^3

- 4 pcs. Ø 7,8 m – water level 5,5 m – 260 m^3 (off flavour)
- 4 pcs. Ø 8,5 m – water level 4,6 m – 260 m^3
- 3 pcs. Ø 10,2 m – water level 5,5 m – 450 m^3
- 3 pcs. Ø 14,2 m – water level 5,5 m – 870 m^3

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Developments in RAS for Salmon Grow-out

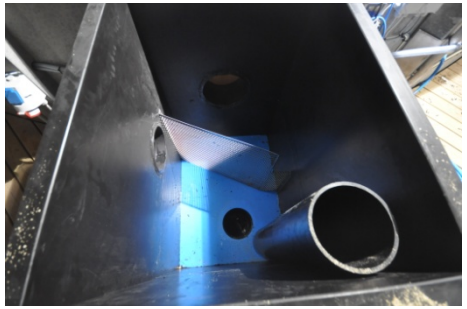
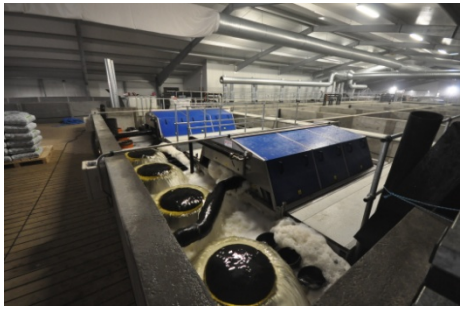
Langsand Salmon, Denmark – 1.000 tons, 5 kg Salmon - Total area 4.000 m^2









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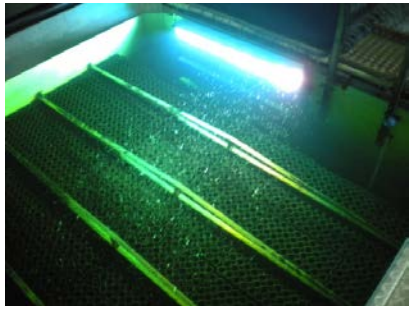
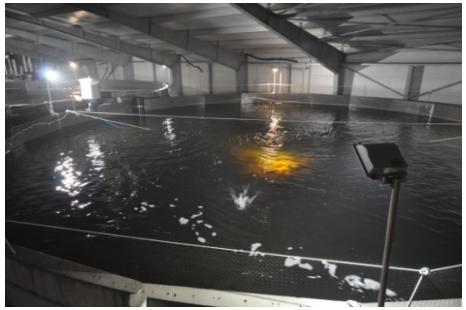
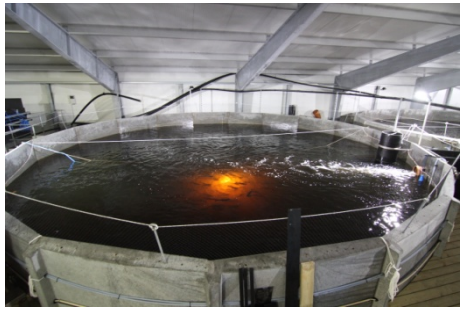
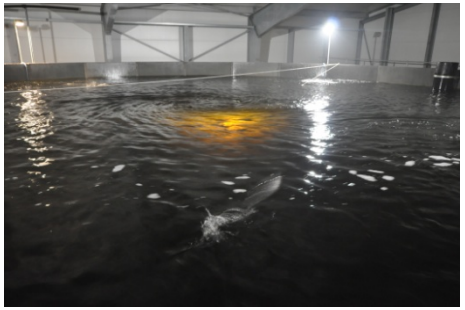
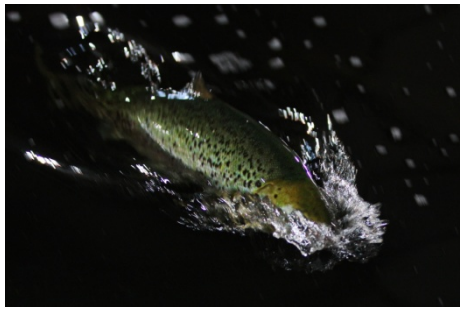
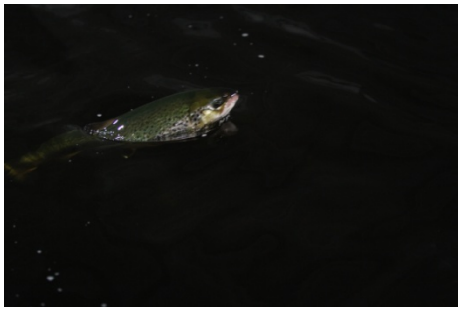
Langsand Salmon, Denmark – 1.000 tons, 5 kg Salmon - Total area 4.000 m^2






Developments in RAS for Salmon Grow-out

Langsand Salmon, Denmark – 1.000 tons, 5 kg Salmon - Total area 4.000 m^2

Developments in RAS for Salmon Grow-out

Langsand Salmon, Denmark – 1.000 tons, 5 kg Salmon - Total area 4.000 m^2

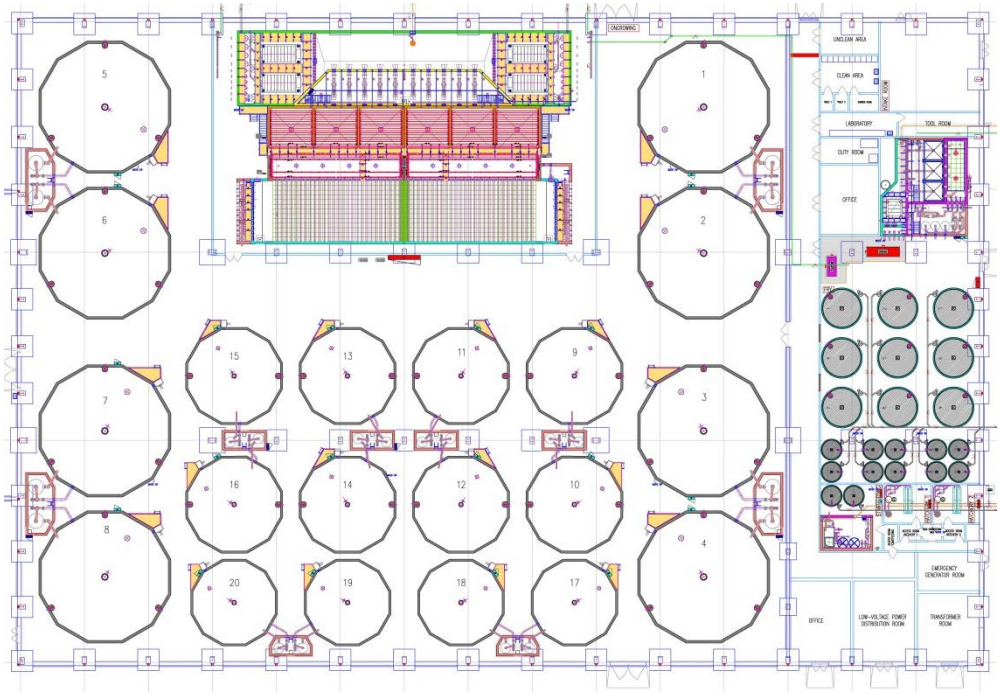
On-Growing system: (input: approx. 210 gram, output 4-5 kg salmon):

- Water flow to fish tanks: 7.400 m^3/h equal 48 minutes of retention time
- Biological filter capacity (maximum): 3.000 kg feed per day
- FCR: ~1,0
- Water consumption: 250 litre water per kg feed applied to the system
- Oxygen consumption: 0,4 kg oxygen/kg produced salmon
- Lime consumption: 0,1 kg $Ca(OH)_2$/kg produced salmon

- Coagulant & Polymer: 100 ml/litre sludgewater & 3 gram polymer per kg DM
- Energy consumption:
  - Main pumps to fish tanks: 1,1 kW/prod. salmon
  - Mechanical filters, various pumps etc.: 0,3 kW/prod. salmon
  - Cooling/heating, ventilation, wells, light, phosphor removal, de-nitrification etc: 1,3 kW/kg prod. salmon
  - GRAND TOTAL: 2,7-3 kW/kg produced salmon
  - Windmill capacity: 850 kW
- Production costs from egg to 4-5 kg salmon (all inclusive): 5,4 USD per kg HOG
- Sludge used for biogas in the future

Developments in RAS for Salmon Grow-out

XinJiang, China – 1.000 tons, 5 kg Salmon - Total area 9.500 m^2



On-Growing System:

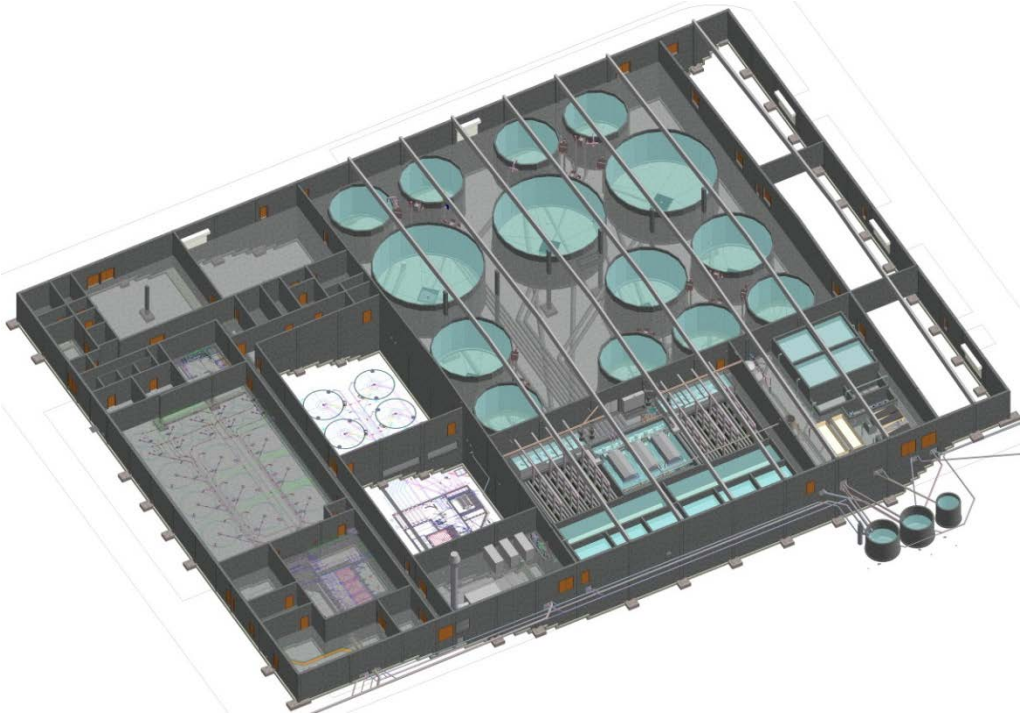
Total tank volume: 9.000 m^3

- 8 pcs. Ø 11,0 m – water level 3,2 m – 300 m^3
- 8 pcs. Ø 15,0 m – water level 4,0 m – 710 m^3
- 4 pcs. Ø 10,0 m – water level 3,0 m – 225 m^3 (off flavour)

The facility will receive eggs in December 2014

Developments in RAS for Salmon Grow-out

Jurassic Salmon, Poland – 1.000 tons, 5 kg Salmon - Total area 7.725 m^2



On-Growing System:

Total tank volume: 6.100 m^3

- 4 pcs. Ø 8,5 m – water level 4,5 m – 260 m^3
- 3 pcs. Ø 10,2 m – water level 5,5 m – 450 m^3
- 3 pcs. Ø 14,2 m – water level 5,5 m – 870 m^3
- 4 pcs. Ø 7,8 m – water level 5,7 m – 275 m^3 (off flavour)

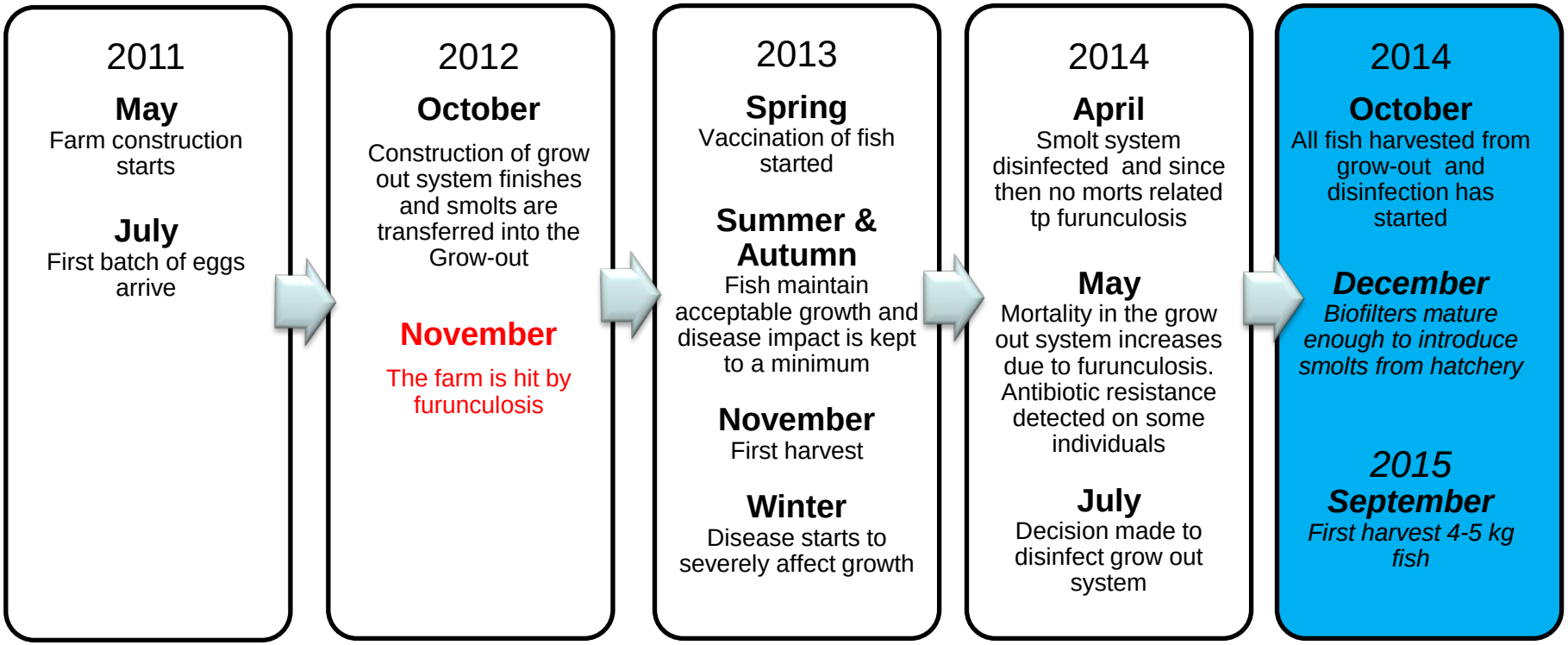
The facility will start feed the first batch 1st week of November 2014

Developments in RAS for Salmon Grow-out

Langsand Salmon, Denmark – 1.000 tons, 5 kg Salmon - Total area 4.000 m^2

Status October 2014:

Langsand Salmon has been through an interesting but challenging process where a lot has been learned about the farming methods required for growing salmon on land in RAS.



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Developments in RAS for Salmon Grow-out

Langsand Salmon, Denmark – 1.000 tons, 5 kg Salmon - Total area 4.000 m^2

Key Learning's & Challenges:

Premium Quality
Atlantic salmon produced in landbased RAS develops in another way than fish grown in net pen farming systems. The water flow in the RAS have them actively swimming their whole life which creates a firmer flesh structure, low fat content (14%) and good taste, which is seen as premium quality by top Chefs in the US.

Disease Outbreaks
Landbased RAS offer a barrier to protect the environment from the damaging affects seen in traditional salmon farming methods.
Furunculosis entered our system through the intake water and a new investment in advanced filtering technology will protect our farm from pathogens.

Off-Flavoring
Fish produced in recirculating aquaculture systems are known to suffer from "off-flavoring". We have now successfully implemented methods to overcome this issue.

Early Maturation
In initial batches, Langsand experienced early maturation around 35%. Today, our farming methods have reduced this figure to around 5%.

Economic Profile
We have collected comprehensive data on capex, opex and production and have a clear insight on the economy of landbased Atlantic salmon farming.

Developments in RAS for Salmon Grow-out

Langsand Salmon, Denmark – 1.000 tons, 5 kg Salmon - Total area 4.000 m^2

Future focus points:

EARLY MATURATION:
Experience so far shows maturation rates from 5 - 35%

- Stable salinity
- Stable temperature
- Fish density
- Grading
- Light / photoperiod
- Post-smolts

VISION FOR THE FUTURE:

- Next harvest November 2015
- Increase production from 1.000 tons to 4.000 tons

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Thanks for your attention