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Survey - Use of large Circular Tanks in Norwegian Salmon Smolt and Post-Smolt Facilities

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Centre for Closed-Containment Aquaculture

HYDRO – Hydrodynamic challenges in huge tanks (1000 m^3)

- Part 1 – Survey culture tanks at industry partners
- Part 2 – Sample water rotational velocities and tank mixing data from tanks identified in Part 1
- Part 3 – Use computational fluid dynamics (CFD) to model and optimize culture tank hydrodynamics

- Surveyed six major Norwegian Atlantic salmon production companies
  - All CtrlAQUA participants.
- Circular or octagonal culture tanks > 400 m^3
- Determine geometry, operating parameters, and key features

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55 Tanks at 7 Land-Based Facilities

- 7.9 (range of 4-12) large tanks per site
- One site with octagonal tanks, others w/ circular
- 500 to 1300 m^3 per tank
- 14.5 to 20 m diameter
- 3.5 to 4.5 m tank depths
- 3.6:1 to 5.5:1 m:m diameter:depth

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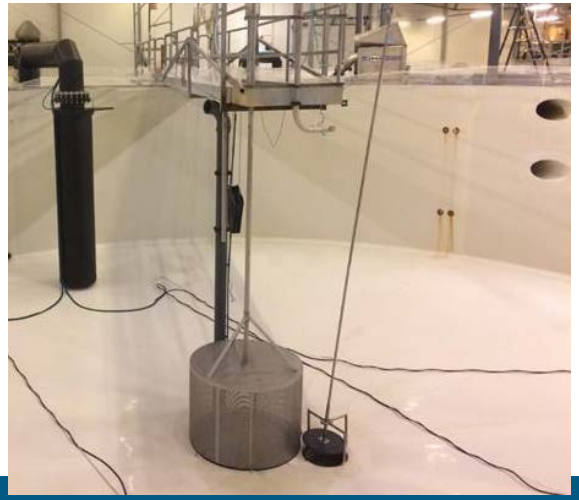
- Over-tank walkways for all tanks
- Pipes penetrate culture tank at tank center
- 4.0 to 6.5% floor slope
- Pipes and sloping floors used to reduce labor when removing dead fish and harvesting fish



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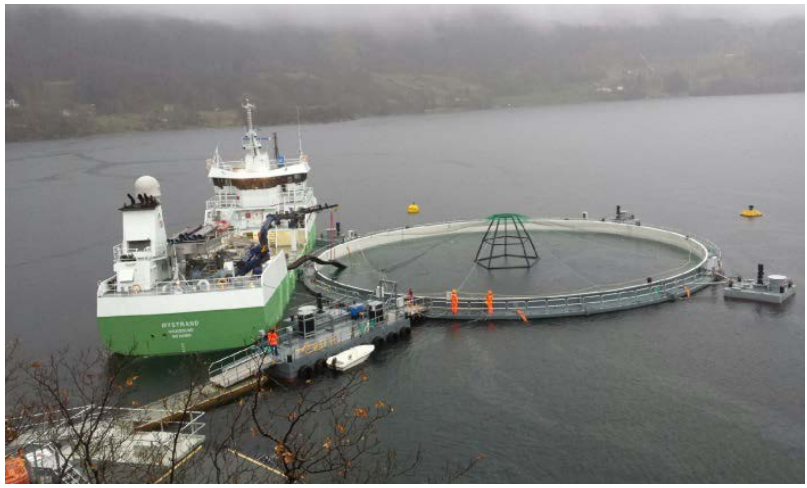
One Floating Fiberglass Tank

- 21,000 m^3
- 40 m diameter
- 20 m tank max depth
- 2.4:1 m:m diameter:depth
- 30% floor slope



Marine Harvest Molnes

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- Less than half of L-B tanks operate dual drains
  - Majority of flow discharged through the bottom-center drain of the dual-drain tank
- Floating tank
  - ~20% flow through the bottom-center drain
  - ~80% of flow exited side-wall drains located almost at the bottom of the tank
  - More similar to L-B tanks operated in North America

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Flow & Hydraulic Retention Time

- 3 to 19 m^3/min max flow per land-based tank
  - 400 m^3/min at the floating tank
- 35 to 170 min HRT
- Half of tanks installed-renovated since 2013
  - Includes 3 tank systems with the highest flow rate per tank (greater than 17.6 m^3/min)

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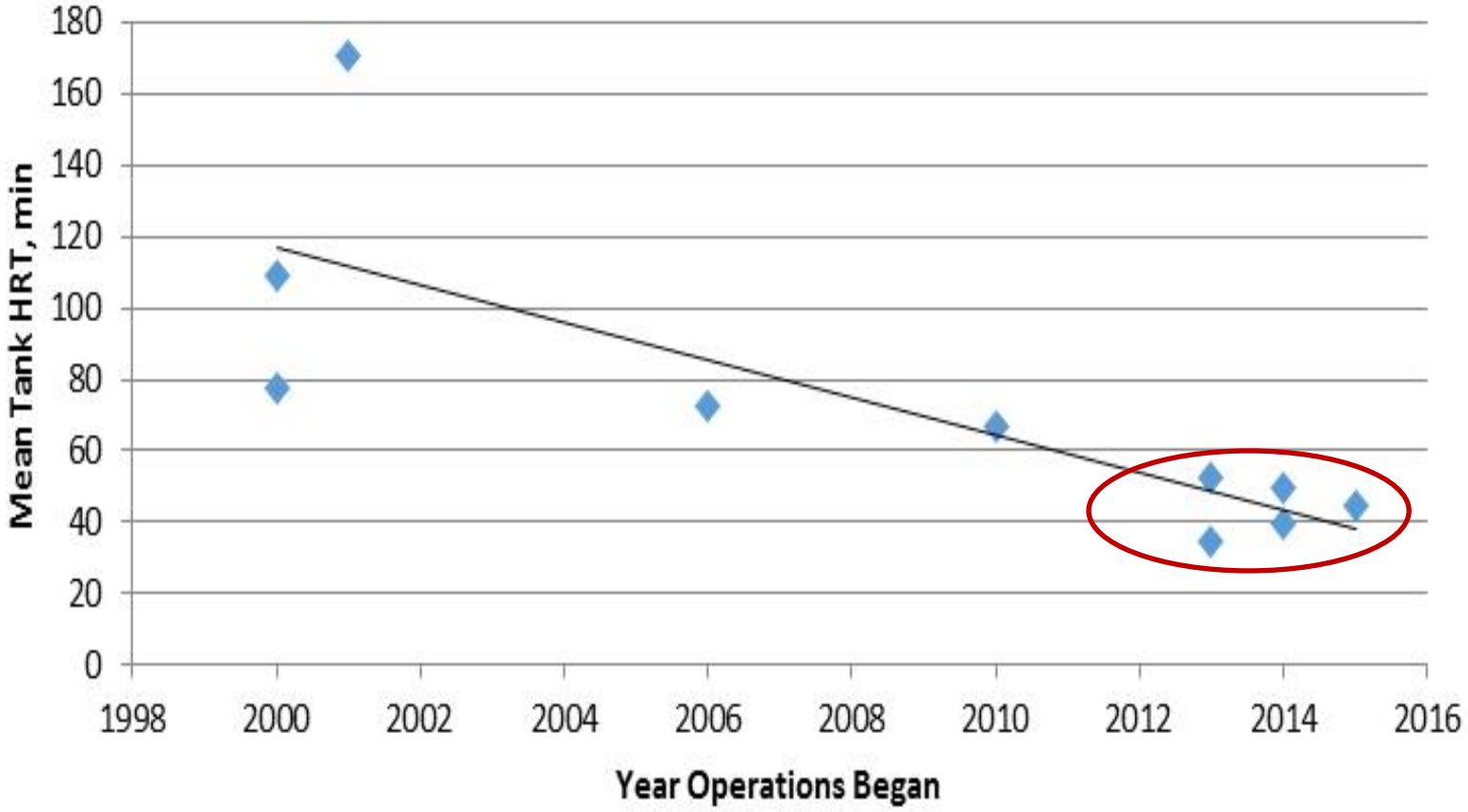
HRT versus Year Operation Began

- Since 2013, more rapid tank HRT's (35 to 53 min)



Maximum Feed Load & Density

- Land-based tanks
  - 525 to 850 kg/day
  - 40 to 70 kg/m^3
- Floating tank
  - 3700 kg/day
  - 20 kg/m^3

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Flow per Unit of Feed Load (max.)

	Flow per Feed (m^3 flow/kg feed)
Before 2010 (land-based)	19-30
2010 – 2015 (land-based)	33-40
Floating Tank	160

- Tanks built-renovated from 2010-2015 used more flow per unit of feed load than tank built previously
- Floating tank used much more flow per unit feed
  - Increasing flow is cheap with low lift pumping & no treatment requirement

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Metabolic Loading Per Unit Flow

	Theoretical Max. O_2 Consump. Each Pass (mg/L)
Before 2010 (land-based)	12-21
2010 – 2015 (land-based)	8.8-12
Floating Tank	2.2-2.5

- Compared to previous practices, recently built-renovated tanks are operated
  - at reduced metabolic loading per unit of flow
    - improves water quality throughout the culture tank

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Part 1 – Conclusions

- Trends in large smolt & post-smolt tanks:
  - Increasing use of large culture tanks in land-based RAS
  - Increasing awareness of general fish welfare and limits on metabolic waste accumulation and
  - Tanks are operated at a lower intensity per unit of flow to optimize water quality throughout the culture tank
    - counter to practices reported just a decade earlier
    - possible because of increased use of RAS technology
  - Multiple drain outlets provide more operating options
  - Impact of in-tank pipes on hydrodynamics is yet unknown

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Survey of large circular and octagonal tanks operated at Norwegian commercial smolt and post-smolt sites.

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