AQUACULTURE STRUCTURES
CURRENT DEVELOPMENT TRENDS

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Source: Salmar
Outline

• Introduction to fish farming
• Salmon farming in Norway
• Aquaculture structures in exposed areas
• Closed cage aquaculture
• Future prospects
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World population increases

Source: UN Population division, «World population prospects, The 2012 revision»
Food gap challenge towards 2050

69% increase in food production needed

- Change in diets
- Population growth

UN’s sustainable development goals
World capture fisheries and aquaculture production

Source: FAO (2016), «The State of World Fisheries and Aquaculture»
Aquaculture – Which species?

Atlantic salmon production

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Production cycle of Atlantic Salmon

1. Spawn
2. Brood – Parr - Smolt
3. Transfer to sea
4. Growth phase in sea
5. Slaughtering
6. Processing

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The largest/best salmon sites in Norway

Present Norwegian fish-farms
15 000 metric tonnes salmon per cycle
10 – 16 cages Ø 50 meter
40,000 m³ volume per cage and max. 200 000 fish per cage
1 000-1 500 metric tonnes/man year
Exposed but not offshore/open ocean

Photo: SINTEF/ACE
Modern fish farming
Norwegian aquaculture and sustainable growth

**Challenges:**
- Diseases and parasites
- Use of coastal areas
- Feed and feed resources
- Escaped fish/genetic interaction
- Pollution and discharges

**Consequence:**
- No new ordinary licenses
Development licenses

• Political ambitions of growth

• Development licenses (from November 2015) - for development of new technology which contributes to:
  • solving environmental challenges
  • improving the utilization of the coastal zone

• Free licenses for up to 15 years, can be converted to commercial licenses

• Huge interest – innovation boost in the industry

• Low oil price – transfer of knowledge
A very special period with a rare innovation rate

- Development licenses, low oil prices and high salmon prices leads to investments and a high innovation rate
- Both closed, semi-closed and open systems under development
- Two main trends:
  - Structures for exposed locations
  - Closed cage farming
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Why farm at exposed coastal areas?

There has been a gradual move towards using more exposed coastal areas

- Need for more space and less area conflicts
- Improved production environment with stable conditions and greater dispersal of wastes
- Located at a greater distance to wild salmonids in coastal waters
Challenges

• Much more expensive than traditional structures
• Need to perform a more thorough design process
• Current standards and regulations do not fit new concepts
  • New Norwegian standard for fish farms under development
• Description of marine environment
  • Not offshore (yet)
  • Waves and current in coastal regions
• Fish welfare
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Closed cage aquaculture

• Improve fish health and welfare (avoid sea-lice)
• Reduce emissions to the environment
• Reduce impact on wild salmon
• Can be grouped into rigid, semi-rigid and flexible structures
• Traditional grid moorings often used
• Intended for less exposed locations
From a marine technological perspective

• Less explored type of structure
• Two important properties (compared to net cages):
  1. Large mass
  2. Enclosed volume of water with free surface
Sloshing

• Resonant motion of contained water
• Coupled with global cage motions
• Can cause large structural loads
• Local structural loads (fatigue)
• Natural frequencies depend on cage dimensions
Effect of enclosed water on cage response

- Tests with and without water in the cage
- Dry weights corresponding to weight of water

Dimensions:
- Diameter $D=1.5$ m
- Draught $h = 0.375$ m
- $h/D = 0.25$
Surge response

- Large effect of the enclosed water
- Cancellation of motion at the dry models resonance period
- Amplification of the response at lower periods
- Important for design of mooring system
- Sloshing must be accounted for
Challenges

• **Structure:**
  - Large volume structure (diffraction effects matter)
  - Large displacement (inertia forces)
  - Sloshing
  - Traditional grid moorings often used

• **Systems:**
  - Water exchange system (critical component)
  - Power system (pumps and feeding)
  - Additional oxygenation needed
  - Waste removal (and storage)

• Fish welfare
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Future prospects

• New times for the fish farming industry
• What will happen with the development licenses?
• Will today's structures survive in the future?
• Fundamental shifts
• Technology meets biology!

• Many exciting multidisciplinary challenges to be solved!
Technology for a better society