Safety of fish farms with well boat in operation

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Outline

1. Introduction to offshore aquaculture and its operation;
2. Safe fish farming and typical causes for fish escaping;
3. The effect of well boat on responses of gravity cage:
   - Hydrodynamic coupling between floating collar and well boat;
   - Dynamic response of gravity cage with well boat in operation
4. Summary and conclusions
1. Introduction to aquaculture and its operation
Site Classification for Aquaculture

Conventional system based on geography

Norwegian system based on wave energy

<table>
<thead>
<tr>
<th>Site class</th>
<th>Significant Wave Height (Hs)(Meters)</th>
<th>Degree of Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;0.5</td>
<td>Small</td>
</tr>
<tr>
<td>2</td>
<td>0.5-1.0</td>
<td>Moderate</td>
</tr>
<tr>
<td>3</td>
<td>1.0-2.0</td>
<td>Medium</td>
</tr>
<tr>
<td>4</td>
<td>2.0-3.0</td>
<td>High</td>
</tr>
<tr>
<td>5</td>
<td>&gt;3.0</td>
<td>Extreme</td>
</tr>
</tbody>
</table>

(Ryan 2005)
Containment Systems

- **Gravity cages**
  - Force of gravity to maintain net shape
- **Anchor tension cages**
  - Tensioned mooring system to maintain net shape
- **Semi rigid cage**
  - Combination of ropes and rigid steel components
- **Rigid cages**
  - Rigid structure to which net is attached
- **Other cages designs**
  - Tension leg cage
  - Ocean drifter

(Ryan, 2005)
Gravity cage structure

- Floating collar of HDPE/plastic
- Bracket
- Railing
- Jump net
- Weights
- Dead fish removal system
- Netting mounted to frame of ropes
- Mooring line
- Anchor
- Grid
- Buoy
- Bridle line
Fish transport from hatchery to slaughterhouse:

Høiseth et al. 2009
Typical well boat operations:

- Loading/ offloading;
- Feeding;
- Sorting;
- Net lifting etc.
The largest well boat in the world, Ro Fjord

LOA: 72.17 meter
Breadth: 15 meter
Depth: 6.9 meter
Gross tonnage: 2310
2. Safe fish farming and typical causes for fish escaping
Safety of fish farming: key areas where aquaculture may potentially have a negative impact on environment:

- Escaped fish / genetic interaction;
- Pollution and discharges;
- Diseases and parasites;
- Feed and feed resources;
Typical causes for fish escaping

Moan (2006)
Main causes for fish escaping

Data is based on reports by fish farming companies to the Norwegian Fisheries Directorate from 1 September 2006 to 31 December 2009.

(Jensen et al. 2010)
The number of Atlantic salmon escaped by the size of the escape event.

Jensen et al. (2010)
Main causes for structure failure leading to escapes

Progressive mooring failure:
  Storm;

Breakdown and sinking of steel fish farms:
  Fatigue and crack in hinges;
  Storm

Abrasion and tearing of the net
  Net failure and the subsequent formation of a hole.

How will the well boat affect mooring line tension?

Jensen et al. (2010)
3. The effect of well boat on responses of gravity cage
3.1 Coupling between gravity cage and well boat

- During well boat operation, the cage is coupled with the well boat in several ways:

  • Hydrodynamic coupling;
    
    *Hydrodynamic coefficients;*
    
    *Wave field, thus excitation forces;*
  
  • Well boat is moored to the cage by ropes;
  
  • Contact.
3.2 Hydrodynamic coupling
- The effect of well boat on added mass of floating collar

![Graphs showing the effect of well boat on added mass in sway and heave](image-url)
- Wave field at the leeward side of the well boat

Long wave

Short wave
3.3 Dynamic response of gravity cage with well boat in operation
3.3 Dynamic response of gravity cage with well boat in operation

- Effect of well boat mean drift force on mooring tension of the gravity cage
• Single cage vs cage with well boat in operation – mooring line

![Graph showing maximum and minimum tension of mooring line No.6](image)

- Coupled; Maxima
- Coupled; Minima
- Cage; Maxima
- Cage; Minima

\[ \gamma = \frac{1}{48}, \frac{1}{24} \]
- Single cage vs cage with well boat in operation – bridle line
- Cage with well boat in operation – connecting line
4. Summary and conclusions
- Preventing fish escape is one key aspect for environmentally sustainable aquaculture;

- Structural integrity is crucial to prevent large scale fish escaping, and boat operation is one of main causes for large number of small scale escapes;

- Dynamic responses of gravity cage with well boat in operation is investigated, and found that:
  
  • Maximum mooring line tension is increased by 30~120% in waves with slope 1/48, and even more in steeper waves;
  
  • Maximum bridle line tension is increased by more than 100% in waves with slope 1/48 and even more in steeper waves;
  
  • Connecting line can slack during operation, thus there is sudden peak when tensioned again;
References:

Thank you for your attention!

Safety is a myth. Risk is reality. Fear is the mind killer. Seize the day. Take the road less travelled. Dare to be different. Nothing ventured, nothing gained. The adventure is within. Boldness has no cape. Take the first step.