Operation Regularity, Exposed Locality

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Abstract

The growth of farmed fish farming will require moving into shallower more exposed wind, current and wave zones than has been the case so far.

When establishing fish farms in exposed areas, one needs to consider the following two aspects:

- Regularity of operation sufficient to maintain a profitable economics of the site.

A serious attempt to establish a fish farm in exposed waters was made at Gullmar offshore community in northern Norway in 1982. The water depth below the fish farm was about 50 m.

The estimated maximum wind speed (2-year return period) was about 24 m/s. Current 1.5 m/s and wave at 1.2 m/s was significant wave height. The net enclosures were mounted on Poly-Crel disposable masts.

An automatic feeding plant was installed in the doctor on a Poly-Crel service platform. A hydraulically operated platform with power 15 m/s and depth 3.5 m. The dry feed

This paper describes the operation regularity analysis carried out by MAINEQEX in close cooperation with the staff of the operation of the fish farm, GINAS. The project was

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Introduction

Important requirements for successful fish farming are that:

- the locality offers good growth conditions with respect to water quality, temperature, etc.
- the technical installations are able to withstand the occurring weather
- the actual combination of environmental, technical installations, equipment and staff allows safe and profitable operation.

The goal of the project presented in this paper was to develop a method for checking the given technology versus a selected locality, and to see if it was possible to achieve a satisfactory percentage of operation time, here called regularity. Checking of regularity becomes the technical installation consists of a number of cages and a separate moved service platform with an automatic border on board. The preprogrammed amount of polsters was thrown through plastic pipes between the platform and the cages, one pipe per cage. See Figure 1.

Figure 1. Layout of cages and service platform
increasingly important as one moves the fish farms out to more exposed waters.

**Locality and technical installation**

The position of the service platforms measured by DGPS was 67° 03' 710 North and 13° 55' 342 East. The most critical wind direction is from South West which leaves the fish farm totally unsheltered.

**Description of method**

For a regularity analysis one needs:

- long-term statistics of the weather parameters
- water dynamic response or behavior of the technical installation
- operation plan, i.e., a list of all activities, the frequency of start activity and the consequence of postponement or cancellation
- available staff, i.e., number and skills
- available equipment such as boats, cranes, etc.

**Long-term weather statistics**

The long-term weather statistics were acquired by two methods:

1. Measurements of wind, current, and waves on board the service platforms for about three months, and with these analyses extrapolation to long-term data. These data were used for the regularity analysis presented in Table 2.
2. Calculations based on standard wind statistics from the Norwegian Meteorological Institute (DNMI) at the nearest location, Bodø airport. Regularity analysis using wind and wave data based on these data is given in Table 5.

**Wind and waves based on standard meteorological data**

The DNMI wind statistics give the distribution of wind force in Bodø (BF) for every 10 degrees based on measurements every 6 hours. Tables are given as monthly and whole year statistics.

A method for prediction of long-term statistics for wind is suggested by Hau Aske Barrecow at DNMI assuming a Weibull distribution and with the Weibull parameters form factor, c, and scale factor, k, derived from the mean value, and standard deviation, \(\sigma \). \(U_0\) is wind velocity from the standard data.

\[
\mu = \bar{U} = \frac{1}{n} \sum_{i=1}^{n} U_i
\]

\[
\sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (U_i - \mu)^2}
\]

\[
k = \frac{\mu}{\sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (U_i - \mu)^2}}
\]

\[
V_r = \frac{\sigma}{\mu} = \frac{\sqrt{c^2 + 2c}}{c}
\]

\[
V_r = \frac{\sigma}{\mu} = \frac{1}{\sqrt{\frac{c^2 + 2c}{c^2}}}
\]

*Figure 2* Vr k relation
Once the Weibull parameters are determined the regularity can be calculated:

\[ P_X(X > x) = 1 - e^{-\frac{x}{\lambda}} \]

\[ P_X(X \geq x) = e^{-\frac{x}{\lambda}} \]

\( P_X(X \geq x) \) gives the cumulative distribution of \( X \) (in our case \( X = U \)).

\( P_X(X \geq x) \) is the probability for \( X \) to exceed the value \( x \). Multiplying by \( 100 \) gives the probability in \%. 

Wind is measured by DNMI every six hours, i.e. four times a day. The return period \( R \) calculated in years has to include the number of observations (obs) per year.

\[ N = 4 \times 365 = 1460 \text{ obs/year} \]

The return period is found by

\[ R = \frac{N}{P_X(X \geq x)} \]

\[ E(x) = \frac{1}{N} \int_{x}^{\infty} x f(x) \, dx \]

\[ E(x) = \frac{1}{N} \int_{x}^{\infty} x \left( 1 - e^{-\frac{x}{\lambda}} \right) \lambda e^{-\frac{x}{\lambda}} \, dx \]

\[ E(x) = \frac{1}{N} \left[ -\lambda x e^{-\frac{x}{\lambda}} \right]_{x}^{\infty} - \frac{1}{N} \left[ \frac{\lambda}{\lambda} e^{-\frac{x}{\lambda}} \right]_{x}^{\infty} \]

\[ E(x) = \frac{1}{N} \left[ 0 - 0 - \left( -e^{-\frac{x}{\lambda}} \right) \right] \]

\[ E(x) = \frac{1}{N} \left( e^{-\frac{x}{\lambda}} \right) \]

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where \( U \) is wind velocity in \( \text{m/s} \), \( F \) is fetch length in \( \text{m} \), \( H_s \) is significant wave height in \( \text{m} \) and \( T_p \) is the wave dominant peak period.

The fetch length for every 30 degrees is taken from the map. The long-term statistics for waves is derived by combining the above formulae with the wind statistics from DNMI and the fetch length.

The method for calculation based on standard wind statistics (DNMI) at the given location was programmed in a spreadsheet. For our location this method gave good correspondence between measured
and observed wind and wave data, which are the most critical parameters for regularity of the factors. An example of disagreement is given in Table 3.

**Operation criteria**

GIFAS made a list of all activities, frequency of each activity, required time and resources, and a judgment of criticality. This is listed in Table 1.

The GIFAS personnel made plans for carrying out the activities and they logged deviations from the plan and the cause of deviation. After some months of experience with the plans, the staff of GIFAS and MARIOTEC met and tested what was considered realistic weather criteria for the activities.

For each operation, a short description of the actual operation was given. Then the following factors were considered:

**Importance of operation**

- Frequency of operation
- Duration
- Complexity
- Costs
- Consequence of delay: 1 day, 1 week, 1 month
- Consequence of dropping the operation

**Weather limitations**

- Maximum wind, waves, and current dependence on resources, i.e., boat size, crane, number of people
- Agreement with observed deviation from operation plans
- Reason for possible disagreement.

An example:

**Net Change**

**Importance**

- Normally four times in the period April-September
- Duration about five hours
- Complexity is relatively high; GIFAS has worked out instructions procedures
- Cost: new net and main haws = boat
- Consequence of postponement:
  - 1 day = no consequence
  - 1 week = probably less growth and stress
  - 1 month = not acceptable

**Weather limit**

Net change requires supply of a large boat with crane, and access to the site. Difficult weather conditions in the site can both alongside the cage and carry out the operation. The maximum R8 is connected to the vessel movements.

**Weather parameters**

- Waves: $H_w$ = 0.3 m
- Wind: fresh breeze (8.0–10.7 m/s)
- Current: $U_{cruise}$ = 0.2–0.3 m/s

**Necessary crew**

- Minimum three if experienced
- Otherwise four or five

- Boat: large
- Equipment: crane, lifting device
Calculated regularity

The activities listed in Table 1 were then averaged into daily, weekly, monthly, etc., operations. The frequency criteria of the different operations were compared with the long-term weather patterns based on the extrapolated weather data in [Reference]. The probability or percentage of time of non-existence was calculated as follows:

<table>
<thead>
<tr>
<th>Operation</th>
<th>Frequency</th>
<th>Daily</th>
<th>Weekly</th>
<th>Monthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading</td>
<td>Daily</td>
<td>26</td>
<td>62</td>
<td>96</td>
</tr>
<tr>
<td>Unloading</td>
<td>Daily</td>
<td>25</td>
<td>95</td>
<td>96</td>
</tr>
<tr>
<td>Feeding</td>
<td>Daily</td>
<td>26</td>
<td>95</td>
<td>96</td>
</tr>
</tbody>
</table>

Experienced regularity

The conclusion of the theoretical evaluation was that the operation of the fish farm with the given technical installation could be made with satisfactory regularity. Little damage, however, revealed weaknesses in the design that made operation at satisfactory regularity level impossible. The nature of the problems, however, did not result in the equipment of a very bad weather which in turn affected the operation regularity, especially feeding, in a negative way.

The problems regarding technical defects and the fact that the project funding did not allow for improvements and modifications of the concept forced GENAS to move the cages with about 200 tons of salmon into sheltered water. The most important reason for
this was damages to the cages on Oct. 2, 1994. The wind speed this day was about 26 meters with gusts above 32 meters, and the significant wave height was around three meters.

The inspection of the farm this day revealed that the buoys on the anchors towards the incoming waves were fully submerged and there was no consistancy left. This meant that all the cages must be well-submerged. The buoys on the outgoing waves were also affected but had some consistancy left in the anchor lines.

The other problem was that the PEH food pipes broke near the platform and in bad weather. The distance between the platform and the nearest cages was approximately 100 m. Due to the fact that the cages and the platform had separate mooring systems and also different weather-induced effects, the food pipes had to be longer than the distance between them in calm water. GIPAS installed a guiding rope from the platform to the cage frame via a roller and down to a weight. The guiding rope was connected to the food pipes in order to get suitable heights and not too large of付费. This worked out satisfactorily and there were few problems with the food pipes 10 meters out from the platform and out to the cages.

As mentioned, the food pipes broke in bad weather at the outlet through the platform side. GIPAS installed the pipes by attaching them together with plastic pipe-to-pipe connectors. This system worked well for wind speeds up to 20 meters and significant wave heights up to 2.5 m. The result is found in Table 2.

The final conclusion, however, is that the food pipes should be kept out of the platform above the wave zone and perhaps set from the roof of the deck house. With use of guiding ropes as described above and reinforcement of the pipes from the platform down to the sea level about 10 m out from the platform, the pipes should withstand any weather conditions on this site.

In general, it is GIPAS's opinion that relatively small improvements could have made the farm concept able to get through the worst weather conditions expected on this site.

The next issue to consider is how to produce salmon of acceptable quality at competitive costs in exposed waters. This requires detailed solutions of the whole farming concept from the sea transfer of smolt to delivering of adult ready for slaughter. This project has given us valuable knowledge that should form the foundation to develop such a tool concept.

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