Designing to optimize costs and minimize environmental effects

Anton Edwards
*University of the Highlands and Islands*

Colin Griffiths
*SAMS*
Structures in the Sea
Structures in the Sea

Over-Engineered

£££ High Capital Cost
£££ High Running Cost

→ High environmental effect of running
→ High environmental effect of manufacture
→ Low Risk of catastrophic environmental effect
Structures in the Sea

Under-Engineered

£ Low Capital
£ Low Running

- Low environmental effect of running
- Low environmental effect of manufacture
- High Risk of catastrophic environmental effect
Structures in the Sea

Optimally Engineered?

- Modest Capital
- Modest Running

- Modest environmental effect of running
- Modest environmental effect of manufacture
- Low Risk of catastrophic environmental effect
Three Types of Environmental Costs

- Environmental Costs
  - Optimal Design
  - Manufacture
  - Running
  - Catastrophic

£ Cost
Searching for the Optimum among

Waves,

Tides,

& Currents
Mooring Forces Associated with Currents

Currents are:
- Tidal
- Wind
- Turbulent

![Graph showing mooring forces vs. speed squared over days](image-url)

Speed²
Modelling Extreme Currents

Tidal - Predictable
Wind & Eddies - Quasi-predictable

Deterministic Prediction

OR
Lumped Statistical Prediction

Statistical Prediction
Statistical Distribution of Lumped Speeds
(30,000 measurements from Sound of Sleat)

A Weibull Distribution

\[ P = 0.04 \cdot S \cdot e^{-0.02 \cdot S^2} \]
Statistical Distribution of Lumped Speeds (30,000 measurements from Sound of Sleat)

Probability of Speed $S$ or less

Cumulative Weibull Distribution

Speed $S$ (cm/s)
The Chance of less than a Particular Speed

Median Speed

50% chance < Median

0% chance < 0

Not easy to predict chance at higher speeds
The Chance of less than a Particular Speed (after a bit of fancy log-log manipulation!)

Chance of less than Speed S (Gareloch, 13000 x 10 minute data)

Measurements

Predictions

50 yr: 60 cm/s
5 yr: 50 cm/s
1 yr: 43 cm/s
...
...
Return Periods
## Return Periods in the Gareloch

<table>
<thead>
<tr>
<th>Years</th>
<th>&gt; Speed cm/s</th>
<th>Factor above measured maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>0.25</td>
<td>35</td>
</tr>
<tr>
<td>Predicted</td>
<td>1</td>
<td>43</td>
</tr>
<tr>
<td>5</td>
<td>50</td>
<td>1.7</td>
</tr>
<tr>
<td>50</td>
<td>60</td>
<td>1.8</td>
</tr>
</tbody>
</table>
Caution! Are Measurements Independent?

Speed vs. Time graph showing a parabolic curve.
How many independent measurements?

Number of independent measurements from a Weibull Distribution

50% chance of unsampled by 1 measurement

50% chance of unsampled by 10 measurements
How many independent measurements?

Weibull (2,2): Number of measurements needed for 50% chance of sampling the tail at speeds above the median

=> Diminishing returns from longer sampling
Reservations and Cautions

• Weibull parameters need estimation

• Check independence of measurements

• Tidal and Random: separate or together?

• Spring-neap cycles

• Seasonal effects
Thank you


Mooring Forces Associated with Currents

Currents are:

- Tidal
- Wind
- Turbulence
The chance of exceeding a particular speed (after a bit of fancy log-log manipulation)

Log-Log Transformation of Exceedance Probability

Logarithm of Speed

Measurements

Easier prediction of chance of exceeding higher speeds
How many independent measurements?

1 Sample:
50% chance of not being sampled

2 Samples:
50% chance of not being sampled

10 Samples:
50% chance of not being sampled
The chance of exceeding a particular speed

- 100% chance of > 0 cm/s
- 50% chance of > 8 cm/s

Not easy to predict chance at higher speeds
How many independent measurements?

Weibull(2,2): Number of samples (N) needed for a 50% chance of sampling the tail above the Median speed

Diminishing returns from longer sampling
## Return Periods in the Gareloch

<table>
<thead>
<tr>
<th>Measured</th>
<th>Years</th>
<th>Speed cm/s</th>
<th>Factor above measured maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured</td>
<td>0.25</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>Predicted</td>
<td>1</td>
<td>43</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>50</td>
<td>1.7</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>60</td>
<td>1.8</td>
</tr>
</tbody>
</table>
How many independent measurements?

50% chance of not being sampled by 1 measurement