ASSESSING THE IMPACT OF MAN-MADE UNDERWATER NOISE FROM MARINE RENEWABLES IN THE OUTER HEBRIDES

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Presentation to EIMR 2014
Overview of presentation

• Underwater noise measurements
• Acoustic propagation modelling
• Acoustic impact modelling
Underwater noise measurement

Kongsberg seabed recorder (RUNES) – autonomous underwater noise recorder.

- Seabed located.
- Frequency range 20 Hz to 250 kHz.
- Sampling schedules – variable.
  In this case, it sampled for 2 minutes every 30 seconds every hour over a total period of around 6 weeks.
Aug 2011 - 2 x RUNES units were deployed in the Project Areas. Deployment depths were around 25 - 30 m. They were on-site for a total of 2 weeks. On recovery, there was around 500 GBytes of acoustic data available for processing.
Background noise results

Frequency spectrum of the background noise.

Total noise level  
R5 - 119 ± 6 dB re. 1 μPa (Peak)
R6 - 117 ± 4 dB re. 1 μPa (Peak)
Acoustic propagation modelling

Time of year
Location
Water depth
Sound speed
Attenuation
Duty cycle

Cause and Effect modelling

Cause Model
- Sound Source Level
- Sound spectrum
- Sound Pulse Shape Type and Duration
- Sound Directivity

Effect Model
- Diver/Swimmer
- Marine Mammals
- Commercial Fish
- Marine Flora and Fauna

Oceanographic and Acoustic Models

Oceanographic and Acoustic Databases
Underwater acoustic propagation model

Need to model the propagation of underwater sound from the point of origin to a given receptor location

\[
\nabla^2 g(x, y, z, t) - \{c(x, y, z)\}^{-2} \frac{\partial^2 g(x, y, z, t)}{\partial t^2} = -s(t)\delta(x - x')\delta(y - y')\delta(z - z'),
\]

\[
\frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial G(r, z)}{\partial r} \right) + \frac{\partial^2 G(r, z)}{\partial z^2} + \frac{\omega^2}{c^2(z)} G(r, z) = -\frac{1}{\pi r} \delta(r)\delta(z - z'),
\]

Models based on
1. Ray theory
2. Parabolic equation
3. Normal modes
4. Full field or Wavenumber integration
Modelling input parameters – Site-specific data

Key data inputs

1. Bathymetry – ETOPO1 – Global database, 1 minute resolution
2. Oceanography – WOA09 - Global database, 1 degree resolution
3. Seabed geoacoustics – BGS charts and geophysical/geological surveys
Acoustic propagation modelling
Results

Drilling noise downslope and upslope during the month of February
Acoustic impact thresholds are taken from the peer-reviewed international literature. They are subject to change from time to time as our knowledge of the effects of sound on marine life improves.

<table>
<thead>
<tr>
<th>Exposure limit</th>
<th>Effect</th>
<th>Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>240 dB re 1 µPa (Peak)</td>
<td>Lethality</td>
<td>Yelverton and Richmond (1981)</td>
</tr>
<tr>
<td>230 dB re 1 µPa (Peak)</td>
<td>PTS Auditory injury onset in cetaceans</td>
<td>Southall et al. (2007)</td>
</tr>
<tr>
<td>218 dB re 1 µPa (Peak)</td>
<td>PTS Auditory injury onset in pinnipeds</td>
<td>Southall et al. (2007)</td>
</tr>
<tr>
<td>215 dB re.1µPa²s SEL M-Weighted</td>
<td>PTS Auditory injury onset in cetaceans</td>
<td>Southall et al. (2007)</td>
</tr>
<tr>
<td>203 dB re.1µPa²s SEL M-Weighted</td>
<td>PTS Auditory injury onset in pinnipeds</td>
<td>Southall et al. (2007)</td>
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<tr>
<td>224 dB re 1 µPa (Peak)</td>
<td>TTS onset in cetaceans</td>
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</tr>
<tr>
<td>212 dB re 1 µPa (Peak)</td>
<td>TTS onset in pinnipeds</td>
<td>Southall et al. (2007)</td>
</tr>
<tr>
<td>193.7 dB re 1 µPa (Peak)</td>
<td>TTS onset in harbour porpoise</td>
<td>Lucke et al. (2009)</td>
</tr>
<tr>
<td>195 dB re.1µPa²s SEL M-Weighted</td>
<td>TTS onset in cetaceans</td>
<td>Southall et al. (2007)</td>
</tr>
<tr>
<td>183 dB re.1µPa²s SEL M-Weighted</td>
<td>TTS onset in pinnipeds</td>
<td>Southall et al. (2007)</td>
</tr>
<tr>
<td>164.3 dB re 1 µPa²s SEL</td>
<td>TTS onset in harbour porpoise</td>
<td>Lucke et al. (2009)</td>
</tr>
<tr>
<td>190 dB re 1 µPa (RMS)</td>
<td>Auditory injury criteria – pinnipeds</td>
<td>NMFS, (1995)</td>
</tr>
<tr>
<td>174 dB re 1 µPa (Peak)</td>
<td>Aversive behavioural reaction in harbour porpoise</td>
<td>Lucke et al. (2009)</td>
</tr>
<tr>
<td>145 dB re 1 µPa²s SEL</td>
<td>Aversive behavioural reaction in harbour porpoise</td>
<td>Lucke et al. (2009)</td>
</tr>
<tr>
<td>120 dB re 1 µPa (RMS)</td>
<td>Level B - Harassment in cetaceans and pinnipeds exposed to continuous sounds</td>
<td>NMFS, (1995)</td>
</tr>
</tbody>
</table>
# Acoustic propagation modelling Results

<table>
<thead>
<tr>
<th></th>
<th>Lethality</th>
<th>PTS</th>
<th>TTS</th>
<th>Level B –Harassment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>0 – 97 m *</td>
</tr>
<tr>
<td>Operational noise</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>0 – 65 m *</td>
</tr>
</tbody>
</table>

* dependent on background noise levels
Conclusions

Summary
1. No significant impacts – fatalities, permanent or temporary deafness
2. Behavioural impacts possible – but dependent on background noise
   Deemed minimal and manageable
3. Consent awarded to Oyster project May 2013!!!

What I left out
1. Characterisation of sound sources
   • Construction noise
     Drilling noise
     Vessel noise
   • Operational noise
2. Temporal / spatial variability of acoustic propagation
3. Cumulative impacts ...