

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

Peter D Ward¹

Kongsberg Maritime Ltd

14 Compass Point, Ensign Way, Hamble, Southampton SO31 4RA, UK

ABSTRACT

Offshore construction developments may lead to the generation of man-made underwater noise as a by-product of the activities followed and this has the potential to impact on marine life. Marine renewables projects, although often cited as "environmentally friendly" are no different in this regard. As part of the consenting process, the regulatory authorities require that such projects undergo a programme of assessment in order to determine the scale and significance of any environmental impact that may occur.

Aquamarine Power Ltd is involved in the development of a site off the west coast of the Isle of Lewis, Outer Hebrides for the installation of a number of their Oyster 800 wave energy converters. During the consenting requirement and as part of the baselining process prior to any development taking place, seagoing surveys were undertaken. The surveys indicated that a number of species of marine mammals, including harbour seal, common dolphin, harbour porpoise and minke whale were often found in and around the project area. It is noted that these are all classified as European Protected Species and are thus legally protected from harassment including that which may arise from man-made underwater noise. Such animals make use of sound to hunt and to communicate and are thus sensitive to disturbance when this capability becomes compromised.

The construction process is likely to involve the drilling of sockets in the seabed in which foundation piles are located while the installation process will require the use of specialist vessels equipped with lifting gear and dredging units in order to prepare the seabed in the project area. In the absence of more relevant data, the operational characteristics of the wave energy devices were based on data extrapolated from other underwater devices of similar power output. This paper outlines the procedures followed by Kongsberg Maritime Ltd when they were tasked to produce an acoustic impact assessment on behalf of the developer. It describes the tasks and equipment used in terms of their likely acoustic source levels and frequency spectra. The paper goes on to show how through the modelling of underwater sound and the application of acoustic impact models, the potential impacts on environmentally sensitive sites close to the wave energy development were quantified.

The ensuing analysis indicated that the acoustic impacts likely to occur from the installation and operation of the wave energy development were deemed to be relatively insignificant. As a result, the project received full consent from the Scottish Government in 2013.

INTRODUCTION

The construction and installation of a marine renewables project often involves, as a by-product, the generation and emission of considerable levels of man-made noise. The regulatory authorities require an assessment of the potential acoustic impacts that may arise during such processes. Consent for a given project is often therefore dependent on the project engineers demonstrating that the potential impacts are either insignificant or manageable.

An overview is given below of the processes followed by Kongsberg Maritime Ltd (KML) when they were tasked by Aquamarine Power Ltd (APL) to produce an underwater acoustic impact assessment in connection with the proposed installation and operation of an Oyster Wave Energy converter (WEC) development. The case study commences with a discussion of the background noise levels recorded off the Isle of Lewis. This is followed by an examination of the acoustical sources and an analysis of the propagation of underwater sound arising from each. The acoustic impact on species of marine life local to the project area is assessed using sound level thresholds known to be associated with the onset of deafness and behavioural effects.

For the interested reader, the underwater acoustic impact assessment as submitted to the consenting authority Marine Scotland, is available on-line [1].

METHODOLOGY

Background noise

The significance of an acoustic impact is assessed through determining the level of a man-made sound relative to prevailing noise levels in the absence of the perturbing noise. The first task was therefore to measure background underwater noise levels in the defined project area. For this task, KML used its autonomous seabed noise recorder RUNES (Remote Underwater Noise Evaluation System) as shown in Figure 1. RUNES is designed to be located on the seabed for extended periods of

¹ Corresponding author: peter.ward@kongsberg.com

time while sampling the noise field and recording the results to an on-board data storage unit.



Figure 1: Kongsberg RUNES

A total of 2 x RUNES units were deployed over a 12-day period during August 2011, one in each of the project areas indicated in Figure 2. The locations were recorded as 58° 25' 39.73" N, 006° 28' 17.30"W and 58° 21' 7.140"N, 006° 40' 38.36"W. The water depths lay between 25 m and 30 m.

Upon recovery and subsequent data analysis, it was found that noise levels recorded at the two sites over a frequency range of 20 Hz to 200 kHz were found to be slightly different. At the northern-most deployment site, levels were 119 ± 6 dB re. 1 μ Pa (Peak), while those at the southern site were 117 ± 4 dB re. 1 μ Pa (Peak). Such levels were considered to be consistent with measurements made in similar shallow water locations around the UK. The differences in noise levels between the two sites were not considered to be significant but may nevertheless be attributed to local differences in wind, wave and bathymetry conditions.



Figure 2: Project areas off Isle of Lewis

Sound sources

The main sound sources of concern with regards to potential acoustic impact were considered to be

noise generated during the drilling of the foundation sockets in the seabed; and noise generated during the operation of the Oyster WEC itself.

Drilling noise was recorded by KML during activity at the European Marine Energy Centre (EMEC) wave test site at Billia Croo, Orkney during July 2011. Noise levels were found to be 153.8 ± 12.1 dB re. 1 μ Pa (Peak) at 1 m over the frequency range 50 Hz to 200 kHz. This was subsequently taken forward to be a representative value for drilling noise at Isle of Lewis. It is acknowledged that noise levels generated during seabed drilling are at least partly dependent on the nature of the sediments. Differences in seabed type between those at Isle of Lewis and Orkney could account for differences in drilling noise between the two sites. However, without a comparative geophysical survey of the two areas, any differences in seabed type and hence noise levels remain unknown.

Operational noise data from an Oyster WEC installed at the EMEC site was unavailable in time for the acoustic impact analysis. However, anecdotal evidence from divers working on the EMEC range suggested that the highest levels of noise arising may be attributed to the noise of the hydraulic fluid running through the pipelines. In order to complete the acoustic assessment, it was decided to generate a synthetic spectrum based loosely on drilling noise with its overall noise level reduced by an arbitrary 3 dB.

Frequency spectra for both drilling noise and notional operational noise are given in Figure 3.

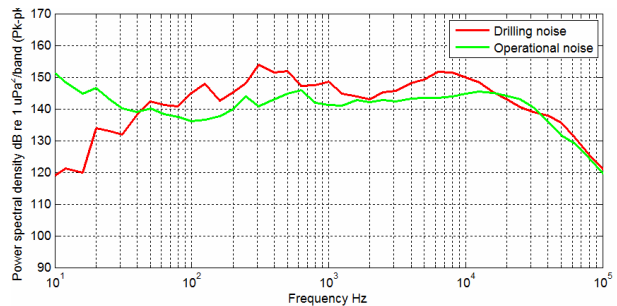


Figure 3: Frequency spectra of drilling noise and operational noise in 1/3 octave bands

Propagation models

In order to assess the impact of underwater sound on marine life, it is necessary to model its propagation from the source location to a point in the far field. For accuracy, the process invariably requires the use of sophisticated modelling techniques and site-specific data. A number of techniques are available and these are discussed by Jensen *et al.* [2]; and Etter [3]. The selection of the most appropriate model depends on a number of parameters including water depth, signal frequency, and the beam pattern of the outgoing noise. In any event, the ensuing computer programs are based on mature and rigorous scientific methodologies that have been reviewed extensively in the international literature over a number of years. It is considered of

fundamental importance that acoustic modelling is not based on “in-house” solutions using non peer-reviewed techniques as this could put the project in a vulnerable position in the event that the resulting environmental impact assessment documents become subject to external scrutiny.

For the analysis undertaken in the current work, the propagation models chosen were RAM [4] covering low frequencies in the range 10 Hz to 1 kHz; and BELLHOP [5] for propagating higher frequencies from 1 kHz to 160 kHz.

Modelling data

The key to generating reliable acoustic propagation data is to use, as far as possible, site-specific data. The input data for the acoustic models discussed above falls into three groups: bathymetry; oceanography and seabed geoacoustics.

(i) The bathymetry data was derived from ETOPO1 [6]. This is a database of water depths having global coverage and a resolution of 1 minute of arc - corresponding to a spatial separation of around 1.8 km around the Isle of Lewis.

(ii) Sound speed profiles relevant to the project area were derived from oceanographic data, specifically gridded monthly samples of temperature, salinity and depth, contained in the World Ocean Atlas [7].

(iii) Previously commissioned surveys in the area determined that seabed type was variable ranging from sand through to gravel with grain sizes varying from pebble through cobble to boulder. Inshore, the predominant sediment type was coarse sand overlying a metamorphic bedrock. Hamilton [8, 9, 10] provides advice on deriving suitable values of compressional wave velocity, density and attenuation for each sedimentary layer.

Acoustic propagation results

Underwater drilling was found to generate relatively low levels of noise. As a result, the noise from such a source was found to propagate only relatively short distances before falling below the background noise level and hence becoming inaudible. Figure 4 shows a typical example of drilling noise propagating inshore where the water depths are seen to decrease with range. It will be seen that the sound pressure level (SPL) falls to minimum background noise levels (113 dB re. 1 µPa (Peak) – see above) at a range of approximately 2 km.

Operational Oyster WECs are expected to give rise to slightly lower levels of underwater noise compared with drilling activities. The background noise levels in the project area were found to lie in the range 113 – 125 dB re. 1 µPa (Peak) and therefore have the potential to drown out the operational noise from time to time even at relatively short distances from the Oyster WECs. Figure 5 indicates that when background levels are at their highest, operational noise may fall to

background levels as close as 50 m from the Oysters. This distance may increase to 250 m when background noise levels are at their lowest.

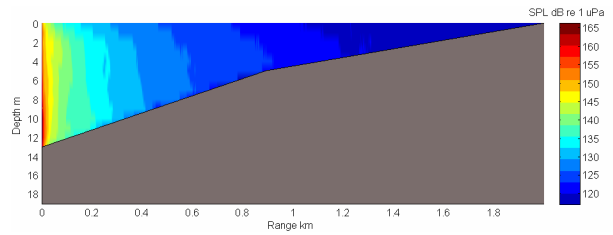


Figure 4: Drilling noise as a function of range and depth heading inshore (note the part coloured grey indicates the seabed)

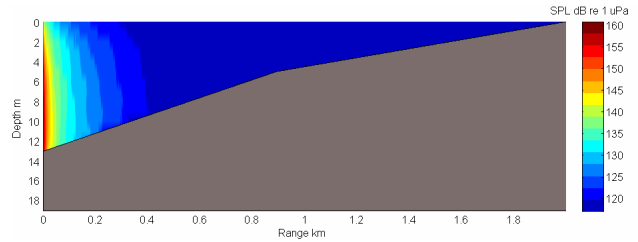


Figure 5: Operational noise as a function of range and depth heading inshore for the month of February

Acoustic impacts

During surveys previously commissioned by APL, a number of marine species were identified as being vulnerable to acoustic disturbance. These include harbour seal, common dolphin, harbour porpoise and minke whale. For these species, it was important to determine sound pressure levels that could give rise to various acoustic impacts.

Southall *et al.* [11] reviews a considerable corpus of research covering acoustic impacts on marine mammals. A number of these relevant to the sources considered above are given in Table 1.

Table 1: Summary of underwater noise impact criteria

Exposure limit	Effect
240 dB re. 1 µPa (Peak)	Lethality
230 dB re. 1 µPa (Peak)	Permanent hearing damage in cetaceans
218 dB re. 1 µPa (Peak)	Permanent hearing damage in pinnipeds
224 dB re. 1 µPa (Peak)	Temporary hearing damage in cetaceans
212 dB re. 1 µPa (Peak)	Temporary hearing damage in pinnipeds
193.7 dB re. 1 µPa (Peak)	Temporary hearing damage in harbour porpoise
190 dB re. 1 µPa (RMS)	Auditory injury criteria – pinnipeds
180 dB re. 1 µPa (RMS)	Auditory injury criteria – cetaceans
174 dB re. 1 µPa (Peak)	Aversive behavioural reaction in harbour porpoise
120 dB re. 1 µPa (RMS)	Level B - Harassment in cetaceans exposed to continuous sounds

OBSERVATIONS

The maximum ranges at which each acoustic impact identified in Table 1 might occur are found by comparing the corresponding threshold levels with the propagated sound data as shown in Figures 4 and 5.

The analysis indicated that sound levels generated by foundation drilling or else Oyster WECs in operational mode were not likely to give rise to fatality or hearing damage i.e. either permanent or temporary, in any of the marine mammal species found in the project area. Aversive behaviour in harbour porpoises is unlikely to be observed when exposed to drilling or operational noise.

The likelihood of Level B – Harassment occurring in cetaceans is dependent on the levels of background noise extant at the time. When background levels are as high as 125 dB re. 1 μ Pa (Peak), Harassment reactions may not occur to either drilling noise or operational noise i.e. the sound from either of these activities is likely to be drowned out by the prevailing background noise levels. By contrast, when background levels are as low as 113 dB re. 1 μ Pa (Peak), reactions to drilling noise and operational noise may be seen out to distances of 97 m and 65 m respectively. In either case, the impact was deemed to be negligible.

CONCLUSIONS

Full consent for the Isle of Lewis Wave Energy Converter Development was awarded by Marine Scotland in May 2013.

ACKNOWLEDGEMENTS

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