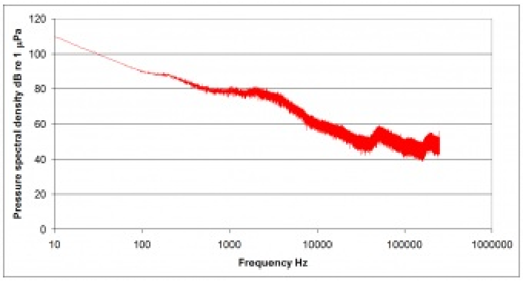
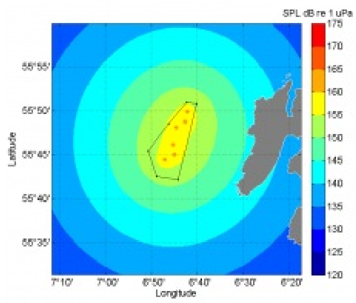
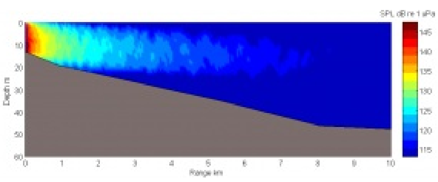
MAN-MADE SOUND AND MARINE LIFE

Measuring Potential Acoustic Impact of Marine Renewables Development





Over the past decade the United Kingdom has seen a significant increase in the number of marine-based construction projects - led principally by the offshore-renewables sector. The construction and operation of an offshore development is likely to involve tasks that generate underwater noise. Such tasks may include hammering foundation piles into the subsea sediments, drilling foundation sockets into the basement rock, increased shipping for support activities and, of course, the noise generated by each and all of the turbines. As a result of these activities, there has been an increasing awareness that the man-made noise thus generated has the potential to produce acoustic impacts on marine life found in and around the vicinity of the development.



In general, for marine-based projects it is necessary for the developer to gain approval for the project from various regulatory bodies: in the UK this duty often falls to the Department of Environment and Climate Change (DECC). In common with planning application procedures throughout Europe, the regulatory body has to be satisfied that a number of conditions are met before consent is granted including compliance with various European Commission directives on environmental regulations. These require consenting authorities to have all the necessary information available so that they are able to determine whether or not a development is likely to have a significant impact on the environment. As a result, the developer undertakes an EIA that considers environmental impacts from all phases of the development from construction and installation through to final decommissioning. Subsequently this is submitted for review by the regulatory bodies.

In the context of an offshore project, two specific studies are identified: the measurement of baseline underwater noise levels in the project area before any development has taken place and an assessment of the potential acoustic impact on marine life likely to arise during various stages of the project.

Wind, Wave and Tidal Projects in the UK

The measurement of underwater noise is often a pre-requisite in the early planning and development stages of marine projects and in this regard KONGSBERG has been working closely with Aquamarine Power Ltd (APL). Specifically, APL proposes to develop a wave-energy converter park based on the Oyster 800 off the north-west coast of the Isle of Lewis, Outer Hebrides, Scotland. The Oyster 800 is a large hinged device that uses the to-and-fro motion from waves to pump hydraulic fluid at high pressure through a turbine which is connected to an electric generator. As part of the consenting process, it was necessary for APL to commission measurements of underwater noise in order to establish baseline acoustic conditions off Lewis prior to subsequent development.

Measuring Underwater Noise

The key to quantifying the acoustic impact of a man-made noise is to determine its loudness relative to the prevailing background noise levels. To assist in this, KONGSBERG has created the Remote Undersea Noise Evaluation System (RUNES).

RUNES (Figure 1) is an underwater noise recorder that consists of two hydrophones between them covering the frequency range 10Hz to 250kHz, a high-quality sound card, noise data-acquisition software and a PC flash drive on which the digitised noise data is written. RUNES is around 1m diameter, weighs 100kg in air and sits on the seabed for periods up to 6 weeks at a time sampling the prevailing noise levels. At the end of the deployment period, the unit is recovered and returned to the laboratory where the data is downloaded and processed according to the client's requirement.

A variant of RUNES known as Acoustic Monitoring Buoy System (AMBS) has been developed specifically for monitoring underwater noise levels generated during offshore construction tasks when stringent noise limits may be in operation. AMBS (Figure 2) consists of a topside unit which contains a PC running the processing software and a remote unit which is attached to the client's own mooring buoy. AMBS is deployed at a given range from the noise source and measures instantaneous sound pressure levels as well as the build-up of sound exposure over time. The levels are compared with pre-set noise thresholds specified by a regulatory authority. Warning signals are issued by the controlling software when the levels are approached or breached thus prompting the project engineer to implement mitigation actions such as reducing the power levels to the activity or even ceasing the activity altogether if necessary.

Processing Underwater Noise

The data collected by RUNES is processed using software developed by the KONGSBERG engineers. A typical example output (Figure 3) shows background noise levels over the frequency range 20Hz to 250kHz recorded off the Isle of Lewis coast. The significance of this frequency range is that it encompasses nearly all the sounds generated by natural processes like

- wave noise
- rain noise
- surf noise
- biological sources (whales, dolphins, seals and fish) and
- man-made activities (underwater piling, drilling, dredging, etc.).

The noise data may be further manipulated using specially designed signal-processing filters that represent the hearing of species of marine mammals. These allow certain frequency components in the noise data to be enhanced or suppressed according to the animal's hearing capability thus giving an indication of how the target species may perceive the underwater sound. One such filter representing the hearing capability of the harbour porpoise, suppresses frequencies below around 300Hz as it is understood that such creatures are relatively insensitive to sound below this limit. It reveals that the harbour porpoise will tend not to hear the low frequency wave and rain noise or most of the seismic airgun and shipping noise.

Acoustic Propagation Modelling Techniques

The EIA Directive discussed above requires that a developer must assess the acoustic impact on the environment likely to arise from the proposed development. In the early stages of project planning and development the precise numbers and locations of marine renewables devices may not have been decided upon. It is necessary, however, to provide an estimate of the underwater sound levels and potential impacts for each constructional and operational scenario being considered. A full acoustic analysis for all scenarios may take many weeks to achieve and this often does not fit in with project timescales.

The planning authorities allow for a degree of flexibility in the plans that are eventually submitted to the Consenting process but they must, however, incorporate the worst possible case from an environmental impact perspective. To address this, the project team, including marine ecologists, underwater noise modellers and members of the regulatory bodies may come together to agree a project design that satisfies all necessary requirements and constraints. To assist in this process and to help define the worst case scenario in respect of man-made noise, KONGSBERG has developed a 'Quick-Look' tool. This is an acoustic propagation computer program that provides a 'first-draft' estimate to the spatial distribution of sound pressure arising from each sound source in the development. The results are plotted on a geographical map of the region in which the sound source is located (Figure 4) and the levels of sound pressure are compared with threshold levels that are known to give rise to acoustic impacts in whales, dolphins and seals. The threshold data was first compiled by a team of US-based researchers who published their findings in 2007. Their work showed that if a seal experiences a sound level in excess of 140dB re 1mPa it may cause changes in the animal's behaviour. As an example, the animal may cease feeding and leave the area – with potential consequences on the viability of the local population. Sound levels in excess of 190dB re 1 mPa may render the seal temporarily deaf and this could impair the animal's ability to communicate.

The Quick-Look programme is based on a simplified approach to sound propagation and, with its very short execution times, is ideally suited to providing immediate acoustic advice during such interactive meetings. Various construction and operation scenarios may thus be ruled-in or ruled-out of the need for more detailed analysis. For example, it may be established that piling foundations into the subsea sediments generates levels of noise that produce an unacceptable acoustic impact. Equally it may be found that drilling a foundation socket in the seabed has a much smaller acoustic footprint and may be used relatively close to a seal haul-out site without producing any discernible changes in behaviour by the seals themselves.

Acoustic Analysis

The alternative approach to Quick-Look involves a fully comprehensive acoustic analysis which is time-consuming and requires detailed information about both the noise source and the marine environment in which it is operating. Each noise source must be defined in terms of its source level and its frequency spectrum over a given bandwidth while the environmental data must describe the bathymetry, oceanography and seabed geoacoustics of the site in which the noise sources are located.

The acoustic propagation programs themselves are technically complex and generate mathematical solutions to the Elastic Wave equations. In order to achieve this the programs make use of mature and rigorous mathematic and scientific methodologies that have been reviewed extensively in 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 compromise the developer in the event that EIA documents become subject to scrutiny.

The underwater sound levels thus computed can be displayed in a 2D plot showing a slice through the ocean (Figure 5). For the example shown, the sound is seen to propagate at mid water depths producing low sound levels close to the sea surface and the seabed. The sound levels may be compared with threshold levels that are known to give rise to specific acoustic impacts in whales, seals and dolphins and as discussed briefly above. The example shows therefore that deafness is unlikely to arise in the seals but they may show behavioural reactions up to 100m from the noise source.

Growing Demand for Acoustic Impact Assessment

Governments and the energy industry must look increasingly towards opportunities to exploit wind and tides to meet the on-going demand for energy. It is essential that these bodies rise to the challenge yet all the while remain compliant with regards to the regulatory environment. This article has shown how the application of expert technical services and the best available science may be applied in order to quantify the impact of developments on the marine environment and hence to minimise any potential disruption that may ensue.

Underwater acoustics and marine impacts specialist at Kongsberg Maritime Ltd, **Peter Ward**, has worked in underwater acoustics for over 25 years. He started at the Institute of Sound & Vibration Research, University of Southampton as a Research Fellow subsequently joining the Scientific Civil Service where he advised the MoD on the impacts of underwater sound on marine life. When marine renewables took off in the UK, Peter found his skills and experience were in demand by developers who wanted to remain compliant with environmental and planning regulations. Since then he has rarely been idle, providing advice on underwater noise and acoustic impacts to industries involved in offshore renewables, oil and gas exploration and production, marine aggregate dredging and platform decommissioning. Peter has been with Kongsberg Maritime for 18 months.