

## 9 UNDERWATER NOISE & VIBRATION

### Summary of previous survey results

This section of the annual FEPA report has previously presented published data on the construction noise measured from the NHOWF during piling and other activities in 2003. The latest section now includes up to date research and operational noise monitoring for the first time.

### 9.1 INTRODUCTION

Measurement of underwater noise has been undertaken by Subacoustech Ltd, the contractor carrying out the COWRIE studies on subsea noise and vibration. Baseline and during construction monitoring has been undertaken at the NHOWF and other offshore wind farms and is reported in previous Annual FEPA reports. The latest COWRIE noise report (Nedwell et.al (2007) presents the monitoring results for these, and includes operational noise monitoring results for the first time.

The conditions of the Food and Environment Protection Act (FEPA) 1985: Part II, licence 31579/02/0 (as amended) to NWP Offshore Ltd. for the NHOWF specify:

“The Licence Holder must make provision during the construction phase of the wind farm to install facilities to enable subsea noise and vibration from the turbines to be assessed and monitored during the operational phase of the wind farm. Before completion of the construction phase the Licence Holder must supply specification to the Licensing Authority of how it proposes to measure subsea noise and vibration. Collaborative studies, e.g. research funded by COWRIE in this respect, would be an acceptable means of fulfilling this condition.”

“Detailed post construction data must be collected on the frequencies and magnitudes of underwater noise produced by the North Hoyle offshore wind farm.”

NWP Offshore Ltd has formally agreed with the Licensing Authority that it would utilise the transect monitoring method for subsea noise monitoring and hence fixed structures were not deemed necessary. NWP Offshore Ltd appointed Subacoustech Ltd in 2003 to write a detailed specification for a post-construction monitoring programme which was submitted to the Licensing Authority for approval. Further discussion with the Crown Estate indicated that the results of the COWRIE study may be used to discharge this monitoring condition, provided they became available within the North Hoyle FEPA monitoring period. The COWRIE report (Nedwell et.al., 2007) has now been released with the salient findings reported below.

An interpretation of the monitoring data throughout the three phases of development at North Hoyle against perceived effects on marine mammals and fish is also presented.

## 9.2 BACKGROUND

In order to determine the impact of noise from piling on marine mammals and fish, consideration must be given to the level of noise generated, the receiving environment, noise propagation and to the sensitivity of the species in question to such noise.

Previous reports (Nedwell (2003a)) have established that piling during wind farm construction creates high levels of underwater noise. Injury of marine species could be caused by the noise in the immediate vicinity of the piling, at distances of the order of 100 metres, and potential behavioural effects at ranges of the order of 10 kilometres or more.

Two previous reports have been provided under this programme to COWRIE; the first, by Nedwell et.al. (2003) dealt with an assessment of underwater noise arising from offshore wind turbines and its impact on marine life. The second, by Nedwell and Howell (2004), contained a review of offshore wind farm-related underwater noise sources. The latest submission; Nedwell et.al. (2007), incorporates a précis of the salient findings of these earlier reports together with new findings from further monitoring.

A detailed analysis of the measurements has been made in the COWRIE report which indicates the properties of the noise. An estimation of the likely behavioural and physical effects on a selection of the most common species of fish and marine mammals is also presented, using both conventional analysis and the dBht (Species) scale.

The effects of noise on underwater animals may range from injury to behavioural effects such as avoidance; the measurements presented below have consequently been interpreted to indicate what effects the noise may have, and the range within which each effect may occur.

The previous studies provided estimates of the likely levels of noise using metrics that may be applied either to predict injury (peak pressure level and impulse) or to estimate behavioural effects (dBht). The following impact ranges are defined:

- Lethal range
- Physical injury range
- Auditory injury range
- Behavioural impact range

### 9.2.1 Survey Methods

Sound measurements were taken using Bruel & Kjaer hydrophones. For the measurements close to a pile being driven a Type 8105 hydrophone was used, while for the measurements at greater distances, and for measurements at operational wind farms, a Type 8106 hydrophone was used. The latter type has a higher sensitivity than the former, and could overload if the sound level is high, as it is in the close vicinity to a pile being driven. The calibrations of the hydrophones are traceable to the Danish Primary Laboratory of Acoustics (DPLA) and the American National Institute of Standards and Technology (NIST) International calibration standards. The Type 8105 hydrophone was connected to a Bruel & Kjaer Type 2635 charge amplifier for conditioning of the signal before it was applied to a National

Instruments Type 6062E A-to-D converter card. The Type 8106 hydrophone was connected to a Subacoustech Type 02 power supply/precision amplifier, the output of which was connected to the National Instruments DAQCard.

The hydrophone being used was hung from an anti-heave buoy, at depths of 5 and 10 m. The hydrophone was weighted at its lower end with a small diver weight attached to its protective grid to keep it close to vertical. The hydrophone and buoy were deployed over the side of the vessel being used such that it tended to drift away from the vessel. The vessel's engines, depth sounder, and other equipment which might have contaminated the sound signal, were all shut off just prior to the hydrophone being deployed, and the vessel drifted freely. Additional small pellet buoys were attached at intervals to the hydrophone lead as it was fed out to support the lead and keep it at the surface. After a suitable length of cable had been fed out (up to 100 m) the hydrophone was pulled back to the side of the vessel and either retrieved back on board or allowed to drift away again as another set of measurements was taken.

The vessels position was obtained from a Garmin e-Trex GPS receiver. At intervals during data acquisition wind speed measurements were taken using a small hand-held anemometer and noted. Also, usually at the start and end of a series of acquisitions, measurements were taken of the sea's temperature and the water depth using a Valeport conductivity, temperature and depth (CTD) meter. The signals from this instrument were applied to the National Instruments DAQCard and acquired by the notebook computer as for the hydrophone signals. In use the sensing head of the instrument was steadily lowered into, and retrieved from, the water at a rate that allowed it to adjust to the water's temperature. The sound recordings were acquired at a sample rate of 350,000 samples/sec. After software de-emphasis the recordings had a wide frequency range, from 1 Hz to 175 kHz, thus covering the full audiometric frequency range of fish, human divers and marine mammals. The CTD probe's signals were sampled every second.

### 9.3 INTERPRETATION AND ASSESSMENT

Nedwell et.al. (2007) determines that criteria for lethal and physical injury can be applied as follows:

- death, or injuries of sufficient severity that may lead to death in a short period of time, occur where the incident peak pressure sound level typically exceeds 240 dB re. 1 $\mu$ Pa, and the impulse 700 Pa.s;
- physical injury to organs such as the lungs, liver, intestines, and other soft tissues surrounding gas-containing structures of the body may occur where the incident peak pressure sound level exceeds 220 dB re. 1 $\mu$ Pa, and the impulse 14 Pa.s

The criterion that has been developed to determine the likelihood of auditory injury is based on the concept of Noise Dose.

As a consequence of the close analogy between the dB(A) and the dBht, an equivalent criterion for marine animals may be adopted, that an allowable species noise dose is that equivalent to 90 dBht (Species) for 8 hours. A similar weighting is allowed for shorter time

exposures. In practice, the level of sound that an animal is exposed to may vary considerably, but if the level is known or can be estimated the equivalent noise dose may be calculated. The level may be termed the continuous equivalent level or dBht Leq.

Exposure Level (dBht)	Exposure duration
90	8 hours
92	5 hours
99	1 hour
110	Approx 5 minutes
120	Approx 30 seconds
130	Approx 3 seconds

**Table 9.1: Comparison of noise exposure level and duration for the same cumulative 90 LEP,D Noise Dose.**

It is reasonable to assume that, at the high perceived sound levels associated with an exposure at 90 dBht (Species) or above, animals will move rapidly out of the vicinity of the sound. Nedwell (2007) argues that the fleeing animal model indicates that for a typical piling operation, provided marine animals are moved out of the immediate vicinity of the piling prior to its inception, say to over one or two hundred metres, animals will not accumulate enough noise dose to cause injury.

In respect of piling, therefore, unless a marine animal is within the immediate vicinity of the impact piling operation, and receives an unacceptable noise during the first few strikes, fleeing animal analysis indicates that it is unlikely that it will receive a noise dose causing auditory injury. The loudness of the transient pressure wave is likely to cause an aversive behavioural response with the animal fleeing the area before auditory injury occurs.

At greater range the underwater sound wave may not directly injure animals, but has the potential to cause behavioural disturbance. The dBht (Species) metric is probably the only metric which offers to quantify the risk of behavioural effect across a wide range of species having varying hearing ability. It gives a species-specific noise level referenced to an animal's hearing ability, and therefore a measure of the potential of the noise to cause an effect. The measure that is obtained represents the "loudness" of the sound for that animal.

An audiogram of an animal shows, as a function of frequency, the lowest level of sound that the animal can perceive. Nedwell et.al. (2007) presents audiograms for both fish (including bass, cod, dab and herring) and marine mammals.

Generally, the audiograms indicate that fish are sensitive to low frequency sound below 1 kHz, and that marine mammals are very sensitive to sound of frequencies above 1 kHz. Currently there are no accurate audiogram data available for the larger (mysticete) marine mammal species such as the blue whale, humpback whale and minke whale. Many of these species are known to use low frequency vocalisations for communication and hence are also likely to be sensitive to the low frequency components of underwater sound.

#### 9.4 BASELINE MONITORING

Background measurements at the North Hoyle site were taken in 2003 along two transects, one running parallel to the shore and of reasonably constant depth, the other perpendicular to the shore line and representing a line of approximately constant slope (i.e. steadily increasing depth). The reason for choosing this transect orientation is that the two cases of “constant depth” and “maximum rate of change of depth” were thought to be the two extreme cases in respect of propagation of noise. It is noted that the BHP Douglas oil and gas production platform was situated nearby.

The level of background noise at North Hoyle is towards the upper bound of typical deep water background noise levels. The overall sound pressure level varies significantly more during the daytime than at other times of day, due to the higher number of short local ship movements. The noise levels are higher at low wind speeds, contrary to the normal assumption that they will rise with increasing wind speed. At North Hoyle pre-existing man-made noise is probably a significant contributor to the background noise level. Significant variation in background noise was measured and can be categorised as follows:

- At frequencies of 2kHz to 100kHz there was little variation of noise level. It is thought that this noise is generated by wind and wave sources.
- At frequencies below 1 kHz or so, the results spread significantly. Interpretation of these results indicates that they are due to shipping movements. When there is local movement of shipping the levels increase significantly; however, even when there is no apparent local movement, distant ships can still contribute significantly to the noise.
- At low frequencies, below 200 Hz, the noise is dominated by shipping noise.

While measurements were being taken at North Hoyle it was noted that noise from the nearby Douglas oil and gas facility, situated to the north-east of the North Hoyle wind farm site, was present in some of the measurements and these levels could be heard during some of the measurements made at the wind farm site.

A transect, recorded at 5 m depth on the 30th May 2003, in close proximity to the platform, indicated a Source Level of 195 dB re 1 mPa @ 1 m, and 225.7 dB re 1 mPa @ 1 metre at 10 metres depth respectively (Nedwell et.al., 2004).

For the results at North Hoyle, the distribution of levels is centred around a mean at about 112 dB re 1  $\mu$ Pa. However, there is also a strong indication that there is a second process in operation, leading to a second peak in the noise distribution where the SPL is about 130 to 140 dB re 1  $\mu$ Pa. It is possible that this second peak is caused by man-made noise from other activity near the site (Nedwell et.al., 2004).

The species weighted background noise levels have been calculated for three fish (salmon (*Salmo salar*), dab (*Limanda limanda*) and cod (*Gadus morhua*) and for three marine mammals (bottlenose dolphin (*Tursiops truncatus*), harbour seal (*Phoca vitulina*), and harbour

porpoise (*Phocoena phocoena*). These common species were chosen from the relatively limited number of species for which audiograms of useable quality are known (Nedwell et.al., 2004).

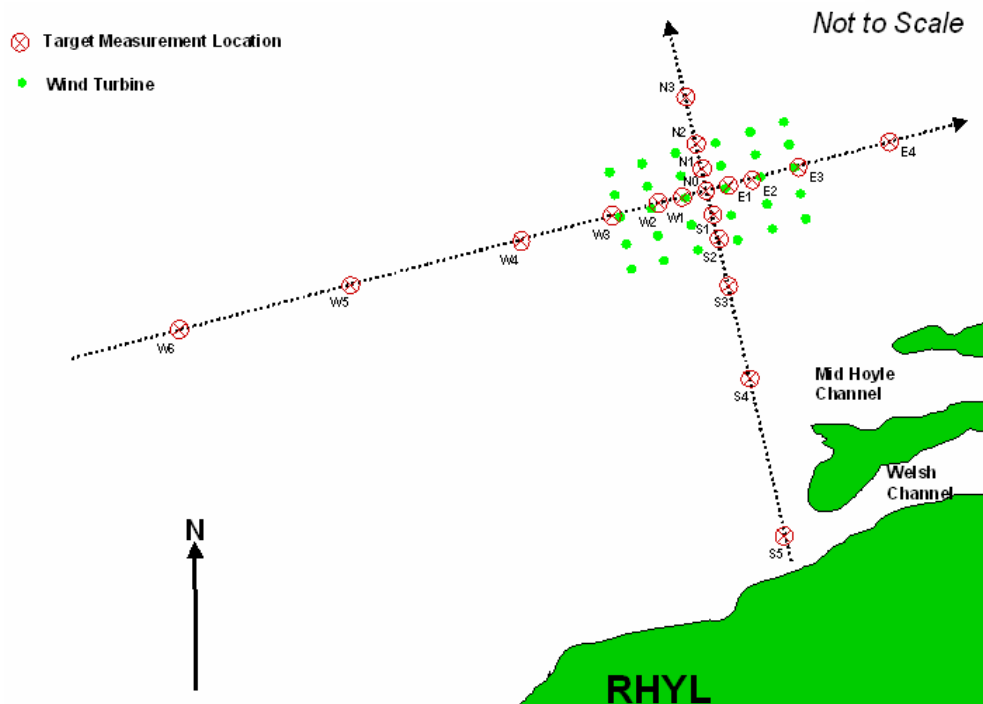
Marine mammals (dolphin, seal and porpoise) perceive a higher level of noise than the fish (salmon, cod and dab). Of the mammals, the porpoise perceives the highest level, at a mean of about 53 dBht (*Phocoena phocoena*). By comparison, the three species of fish perceive rather lower levels, the lowest being about 15 dBht (*Salmo salar*) for the salmon. This species is insensitive to sound, probably as a result of adaptation for noisy riverine environments (Nedwell et.al., 2004).

Fish detect primarily low frequencies, and hence the variability in the low frequency noise spectrum is reflected in the variability of the perceived levels for them. By comparison, marine mammals hear at high frequency.

In all cases, the species considered would perceive the background noise environment as being relatively quiet, and generally equivalent to the perception for humans of a typical rural night time background of 20 - 40 dB(A) (Nedwell et.al., 2004).

## 9.5 CONSTRUCTION NOISE MONITORING

The piling programme took place over five months and consisted of the driving of thirty steel piles into the seabed. The piles had an external diameter of 4 m, a wall thickness of 35 mm. They were driven using a Menck MHU500T piling hammer in seawater ranging from 10 to 15m depth. The average impact energy used to drive the piles was 450 kNm at an average of 35 blows per minute. The site is composed of predominantly gravelly sand with some small infrequent pockets of fine sand, gravel and clay. Figure 9.1 below illustrates the transects nominated for the during construction monitoring.



**Figure 9.1: Noise Hoyle noise monitoring transects. (Courtesy of COWRIE).**

Monitoring of construction piling noise took place on 30<sup>th</sup> and 31<sup>st</sup> May 2003.

**Results**

An estimation of the likely behavioural and physical effects on a number of species of fish and marine mammals was undertaken in 2004 using both conventional analysis and the dBht (species) scale. The measurements were previously interpreted to show:

- 1 that piling at North Hoyle, as presented in Nedwell et.al. (2004), with a Source Level of 260 dB re 1 µPa @ 1 metre for 5 m (metres) depth, and 262 dB re 1 µPa @ 1 m at 10 m depth.
- 2 that cable trenching at North Hoyle gave a Source Level of 178 dB re 1 µPa @ 1 m if a Transmission Loss of 22 log(R) is assumed;
- 3 that rock socket drilling produced a strong fundamental component at 125 Hz, and harmonics up to 1 kHz, but it was not possible to establish the Source Level and Transmission Loss. Tonal components of the drilling could, however, be identified at ranges of up to 7 km.

As a consequence of an improved model for propagation, the data for the NHOWF construction programme presented in the earlier report by Nedwell et.a.l (2004) has been re-analysed to incorporate absorption and found to have over-estimated predicted source noise levels for piling.

In the early stages of analysing the data on the noise from piling presented in Nedwell et.al (2004), a conventional straight line fit model (Geometric Loss, or GL, model) was used, which modelled sound losses due to spreading well but did not incorporate absorption losses which become important in shallow water due to interaction with seabed. The Transmission Loss of  $22 \log(R)$  used to calculate piling noise at distance has since been re-assessed in Nedwell et.al. (2007). The measured data from the North Hoyle impact piling operation subsequently indicated a sound transmission equation for a 4.0 m diameter pile of the form:

$$L_{\text{North Hoyle}} = 249 - 17 \log R - 0.0011 R.$$

thus giving a revised predicted source level noise of 249 dB re 1  $\mu\text{Pa}$  @ 1 m (see Table 9.2 below). At 500 metres distance the noise regressed to 203 dB re 1  $\mu\text{Pa}$  @ 500 m. The revised equation also illustrated that at distances of greater than 10km the previous predictions of noise level are greatly reduced.

Nedwell et.al. (2007) indicates that generally there is an increase in the Source Level of the piling with increasing pile diameter. It is clear from the data summarised below that the propagation terms N (geometric loss) and  $\alpha$  (absorption coefficient) are dominated by geological and bathymetric effects, although they indicate a significant degree of variation. Generally, high values of the loss term are associated with shallow water and low values with deep water, and vice-versa for the geometric spreading term N. This may be expected, since in shallow water the piling noise may be expected to interact more strongly with the seabed, leading to increased losses.

Data source	Pile diameter (m)	Source Level (dB re 1 Pa @ 1 m)	N	$\alpha$ dB/m)	Approximate depth at wind farm (m)
North Hoyle	4.0	249	17	0.0011	10 - 15
Scroby Sands	4.2	257	20	0.0030	3 - 30
Kentish Flats	4.3	243	20	0.0020	5 - 8
Barrow	4.7	252	18	0.0003	10 - 20
Burbo Bank	4.7	249	21	0.0047	15

**Table 9.2. Summary of the results of the analysis of unweighted peak-to-peak data for the piling operations at Round 1 wind farms. Source: COWRIE study Nedwell et.al. (2007)**

Nedwell et.al. (2007) indicates that the unweighted peak-to-peak Source Levels of the various piling operations vary between 243 dB re 1 Pa @ 1 metre, and 257 dB re 1 Pa @ 1 metre, having an average value of 250 dB re 1 Pa @ 1 metre. Therefore, it can be seen that the piling measured at North Hoyle represented close to the average.

### Species Interpretation

On the basis of all the measurements, a simple method can be used for estimating areas around a piling operation within which the two key auditory effects of noise will occur. This rule may be summarised as “Animals within the area bounded by the 90 dBht level contour will strongly avoid the noise. Animals within the area bounded by the 130 dBht level contour may suffer injury, including permanent damage to hearing”.

Nedwell et.al. (2007) presents updated species interpretation for the NHOWF in the re-analysis of the piling measurements section and are reproduced in Table 9.3 below. There are considerable differences in the perceived noise for the representative species considered. This highlights the importance of considering the effects of underwater noise on a species basis

About 75% of the measurements are in excess of 90dBht, which has been suggested as a threshold at which a “significant avoidance reaction” will occur, indicating that significant avoidance reaction by a range of species would be likely at the ranges at which measurements were made of up to 11 km (Nedwell et.al., 2004). The ranges at which significant avoidance reaction would be expected, based on a criterion of 90 dBht, have been reproduced below.

Species	Peak to peak Source noise level (dB <sub>ht</sub> @1m)	Behavioural impact range (based on 90 dB <sub>ht</sub> peak-to-peak level)
Cod ( <i>Gadus morhua</i> )	166	5500 m
Herring ( <i>Clupea harangus</i> )	177	11000 m
Salmon ( <i>Salmo salar</i> )	155	2000 m
Bottlenose Dolphin ( <i>Tursiops truncates</i> )	185	5700 m
Harbour Porpoise ( <i>Phocoena phocoena</i> )	191	9000 m
Common Seal ( <i>Phoca vitulina</i> )	154	3000 m

**Table 9.3. Calculated ranges for significant avoidance reaction as a function of species. Species Calculated range for significant avoidance reaction**

The range over which a strong avoidance response is likely to occur, for representative species of fish and marine mammal varies from 2000 metres for insensitive fish species up to 9000 metres and 11000 metres for the relatively sensitive for harbour porpoise and herring respectively.

**Noise Dose**

Although findings on noise dose are presented in Nedwell et.al.,(2007) for the Kentish Flats, Barrow and Burbo Bank sites, no equivalent findings are presented for the NHOWF. However, the following is noted in Nedwell et.al., (2004):

“The levels of sound recorded during piling were such that in the immediate vicinity of piling, say within 77 metres or so, the underwater noise could cause a high incidence of moderately severe blast-type injuries to marine mammals, including eardrum rupture.”

Based on more recent research from Nedwell et.al.,(2007), however, it can be postulated that by using the Kentish Flats interpretation (which is has a reasonably close propagation model for noise regression to that of North Hoyle) that the level of the pile driving falls below circa 90 dBht Leq at a range of about 250 metres for the harbour porpoise. A harbour porpoise could therefore be exposed to the noise during the entire pile driving operation without harm from accumulated Noise Dose, provided that during exposure it was at a range greater than 250 metres. This distance assumes that animals would remain static, however, if the animal was

fleeing it was determined that the critical distance (the distance over which an animal might receive a hazardous Noise Dose) for an animal fleeing piling noise was 10m. This is less than the distance at which traumatic hearing injury may occur as a result of a single noise exposure (i.e. when exposed to a level of 130 dBht or more), therefore, if an animal is protected from a single traumatic injury, it will be protected from accumulated injury from Noise Dose also (Nedwell et.al.,2007).

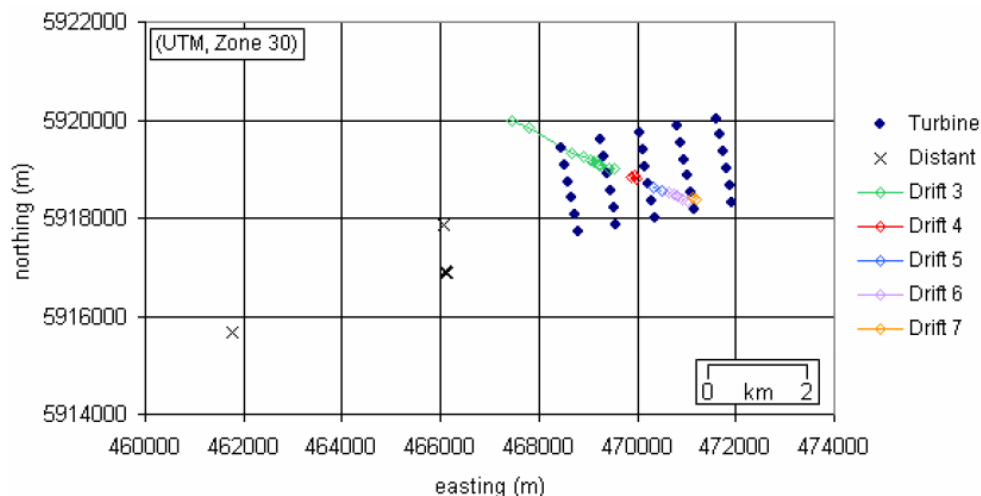
There is no reason to suspect that similar conclusions could not be reached from a similar analysis of noise data for NHOWF.

Nedwell et.al.,(2007) concludes that since the injury ranges indicated by the measurements [in the COWRIE study] do not exceed a few hundred metres, they indicate that observation by marine mammal observers and soft start procedures might be effective in reducing these effects of the noise.

### 9.6 OPERATIONAL NOISE MONITORING

Measurements of the noise created during the operation of several wind farms including North Hoyle, Scroby Sands, Kentish Flats and Barrow Offshore Wind Farms is presented in Nedwell et.al. (2007).

Measurements of noise of the operational North Hoyle wind farm were taken on 3 March 2005 between 0900 hours and 1600 hours as shown in Figure 9.2. On this day all the turbines, with the exception of WTG05, WTG06 and WTG10, were operating. The wind was from the north to north-west, at Force 4 at the start of taking measurements, but falling soon to Force 3 and then decreasing to Force 2 and Force 1 during the day.



**Figure 9.2. Sketch map showing the tracks of the measurement vessel when taking measurements of operational noise at the North Hoyle Offshore Wind Farm. (Courtesy of COWRIE)**

Measurements were taken at intervals every few hundred metres along the course of the drift. A total of nine spectra were plotted for Drift 3 during which the measurement boat drifted from

a position just over a kilometre to the north-west outside the wind farm, passing onwards a further kilometre within the wind farm; these illustrated the spectra of the sound at various positions on the drift. These are presented as the distance from the north-western-most turbine; it may be seen that the drift passed close to this turbine on entering the turbine array and continued onwards between the turbines in roughly the same direction.

Generally the spectral levels are similar, with no great increase as the measurements enter the active turbine array. The spectral measurements comprise three regions. Between 1 Hz and 20 Hz the level is roughly constant and is probably dominated by noise created by wave action. Between about 20 Hz and 80 Hz there is a small broad peak or “swathe” in the spectra. It is possible that this corresponds to noise from local shipping, although it is possible that there is a contribution from rotational noise from the wind farm. Higher frequencies, from 100 Hz upwards, may correspond to wind generated noise.

Figure 9.3 below has been presented as an isometric plot, with the spectral level presented as a function of both the frequency and range from the north-western turbine. No obvious contribution to the noise field from the turbines of the wind farm could be detected.

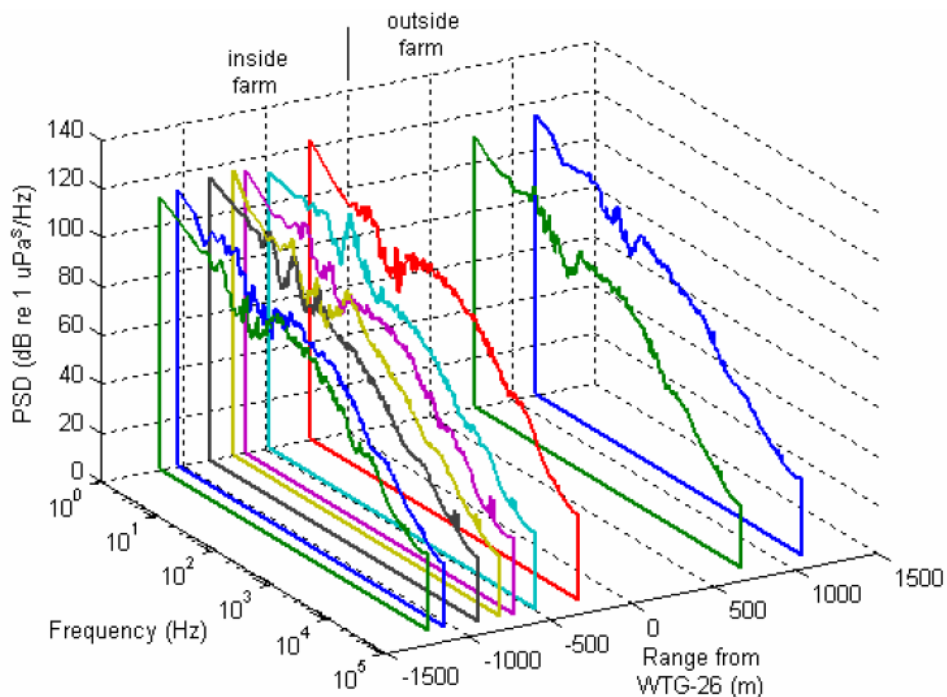


Figure 9.3. Spectra at various locations along Drift 3 at the North Hoyle Offshore Wind Farm. (Courtesy of COWRIE).

#### Species Perceived Sound Level in dBht units

The measurements indicate that the level of noise created by the NHOWF is low and insufficient to cause environmental effects (Nedwell et al., 2007). The noise was only above the ambient noise in the immediate vicinity of the turbines. Under these circumstances it was

found that the methods previously used to quantify the effects of piling noise (the distance within which a certain effect might be noted) were not appropriate, and therefore a statistical approach was used.

The noise levels were averaged over the measurements made within the wind farm, and an equivalent number made at distance from the wind farm (generally in excess of 1 km). Table 9.4 illustrates the level of noise in unweighted and dBht units within and outside the NHOWF. It may be seen from the top row that the unweighted level was 128 dB re 1 Pa within the wind farm, and 120 dB re 1 Pa outside the wind farm. On average, therefore, the vicinity of the wind farm was 8 dB noisier than was the case further away.

The same averaged levels are also presented for five species of fish and three marine mammals. There is a significant variation in the results; this may be expected as in some species indicating higher levels peaks in the noise from the wind farm may coincide with the most sensitive hearing range of that species. The increase is greater with fish than with marine mammals; possibly because fish are low frequency hearers and the spectrum of the wind farm's noise is predominantly low frequency.

The results have been averaged across the fish species and the marine mammal species in the final rows of the figure; the level is 9.4 dB higher on average for the fish species compared to 6.3 dB higher for the marine mammals. While it might be concluded that the effects of the noise would tend to be higher for fish than marine mammals, it should be noted that the difference in level is comparable with the variations that naturally occur as a result of sea conditions. Furthermore, the species perceived noise levels are not high enough to cause any behavioural reaction (mild behavioural reaction may be expected above 75 dBht). Therefore, it is thought very unlikely that the slightly higher levels within the wind farm have any significance.

Wind farm: North Hoyle	Inside Farm	Outside Farm	Difference
Unweighted (dB re. 1µPa)	128	120	8
Species	Species Perceived Level (dBht)		
Bass	15	9	6
Cod	38	27	11
Dab	22	9	13
Herring	41	35	6
Salmon	16	5	11
Bottlenose Dolphin	46	39	7
Harbour Porpoise	55	48	7
Common Seal	39	34	5
<b>Average difference – Marine Mammals Species</b>	6.3		
<b>Average difference - Fish Species</b>	9.4		
<b>Average difference - All Species</b>	8.25		

**Table 9.4. Average values of unweighted and of dBht levels for various species for operational noise at the North Hoyle Offshore Wind Farm.**

The measurements indicate that the level of noise created by the NHOWF is low and insufficient to cause environmental effects.

## 9.7 OTHER PUBLICATIONS

In July 2006, a report was published by Biola (Biologisch-landschaftsökologische Arbeitsgemeinschaft) titled the "Effects of offshore wind farm noise on marine mammals and fish", based on an earlier report as part of EIA work for wind farms in German waters. COWRIE has translated this report for inclusion on the COWRIE website. The report comprises an assessment of noise during construction / operation based on measurements from across Europe, the transmission of the noise and definition of zones of noise influence (audibility, response, masking, Temporary Threshold Shift (TTS)) on marine mammals and fish.

The Biola study suggested that noise impacts from operational turbines could cause effects on fish and benthic organisms.

In contrast to the findings of the Biola study, monitoring of working wind turbines by divers at North Hoyle undertaking a monopile colonisation survey in 2004 found Biolas claims to be unfounded with a range of fish and other species attached or in very close proximity to structures where noise from the turbines was audible by the divers.

## 9.8 SUMMARY OF FINDINGS

Previous reports have established that piling during wind farm construction creates high levels of underwater noise. Injury of marine species could be caused by the piling noise at distances of the order of 100 metres, and behavioural effects at ranges of the order of 10 kilometres or more. To further document the noise levels created during piling, further measurements are presented in Nedwell et.al. (2007), taken during piling on five wind farms, at North Hoyle, Scroby Sands, Kentish Flats, Barrow and Burbo Bank.

An improved analysis of previously reported piling data from North Hoyle has been undertaken, on piles of 4 metres diameter respectively, which includes the effects of absorption.

The Source Levels of these five piling operations varied between 243 and 257 dB re 1 Pa @ 1 metre, having an average value of 250 dB re 1 Pa @ 1 metre.

On the basis of the measurements, a method is proposed for estimating two key auditory effects for piling noise. This rule may be summarised as "Animals within the area bounded by the 90 dBht level contour will strongly avoid the noise. Animals within the area bounded by the 130 dBht level contour may suffer injury, including permanent damage to hearing" .

The 2004 COWRIE report previously predicted that for harbour porpoises and harbour seals, the zone of audibility for pile-driving extended to several tens of kilometres from the source. Behavioural responses are possible over several kilometres, perhaps up to ranges of 20 km. Nedwell et.al.(2007) updates the conclusions of the 2004 report based upon more recent research. The range over which a strong avoidance response was likely to occur in key species ranged from 2000 metres 11000 metres during piling at NHOWF.

Injury ranges indicated by the measurements in the COWRIE study do not exceed a few hundred metres, and suggest that observation by marine mammal observers and soft start procedures might be effective in reducing these effects of the noise.

In general, the level of noise created by operational offshore wind farms was found to be very low and no evidence was found of noise levels that might have the capacity to cause marine animals to avoid the area. The environment of a wind farm was found to be on average about 2 dB noisier for fish, and no noisier for marine mammals, than the surrounding area. This is no more than variations which might be encountered by these animals during their normal course of activity.

In order to assess the effect that this noise might have on marine animals, the levels have been calculated in dB<sub>ht</sub> units, which indicate the level of noise that the various species would perceive. In no case (i.e. for none of the wind farms, and for none of the species assessed), did the levels of noise within the wind farm exceed either the level of 90 dB<sub>ht</sub> at which a strong avoidance behaviour might be exhibited, or the level of 75 dB<sub>ht</sub> at which a mild avoidance behaviour would be expected. In general, the levels were found to be low and consistent with the levels of pre-existing background noise that the animals would normally live in.

In conclusion, no evidence was found of noise levels within operational wind farms that might have the capacity to cause marine animals to avoid the area.