European Offshore Wind Deployment Centre

Environmental Statement

Appendix 12.2: Marine Mammals EIA Technical Report

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GENESIS

European Offshore Wind Deployment Centre

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EIA Technical Report Marine Mammals

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1.1 INFORMATION FOR NON-TECHNICAL SUMMARY

This report follows the baseline marine mammal assessment report and provides an assessment of the potential impacts of the proposed European Offshore Wind Deployment Centre (EOWDC) upon marine mammals. In order to assess the potential effects of EOWDC relative to the baseline (existing) marine mammal environment a combination of qualitative assessments have been made that incorporate predictive modelling in order to estimate the potential magnitude and significance of any impacts. In the assessment the worst case development scenarios have been applied that are detailed in the Project Description. The impact assessment has considered the risks and impacts to marine mammals from the construction, operation and decommissioning of the EOWDC.

In the assessment of potential impacts a number of impact criteria were used for sound levels likely to cause physiological damage, audiological impact or behavioural disturbance to marine mammals. The use of multiple criteria and presentation of duplicate sets of results, such as potential ranges of impact was considered to be appropriate given the scientific uncertainty of acceptable criteria for impacts of sound upon marine mammals.

The significance of potentially killing a marine mammal during the piling of the EOWDC was assessed as being of major significance, however, with the successful adoption of the mitigation measures for piling, there are not anticipated to be any residual risks given that a marine mammal would have to be present in such close proximity to the pile driver (3 m) to be at risk.

Other forms of physical injury (non-auditory) are estimated to occur out to a greater range (60 m), and the risk of piling causing other forms of physical impacts cannot be ruled out, and has been assessed as being of major significance for all marine mammal species, the natural curiosity of seals may increase the risk of exposing both grey and common seals to sound levels capable of causing adverse physical effects.

The modelling results indicate that unless a cetacean is within the immediate vicinity of piling operations (<1.35 km) or a seal is situated within 3.6 km, the only possibility for an auditory injury to occur is during the initial piling period. It is expected that the perceived loudness of the piling activity will cause the marine mammal to exhibit an aversive behavioural reaction, with the animal moving from the area before the onset of any auditory injury can occur.

There is clearly a risk to individual marine mammals that are exposed to high sound levels in the immediate vicinity of the piling operation, given that marine mammals may be subject to sound levels that are capable of causing physical impacts, including both auditory and non-auditory impacts. Animals would have to be present within the immediate area of the pile driver to be at risk of physical effects and it is considered the risk of marine mammals receiving sound levels capable of causing their death appears to be remote.

The marine mammals which are most likely to be exposed are the more commonly sighted species within Aberdeen Bay, with the harbour porpoise, bottlenose dolphins and grey and common seals being the species most at risk from physical impacts. Given that the relatively small Moray Firth bottlenose dolphin population has been increasing its range expansion in a southerly direction, and that Aberdeen Bay frequently has bottlenose dolphins, especially during the winter and spring months, the potential impact both to the individual and population is considered to be of high magnitude and potentially of major significance. It should be considered the majority of bottlenose dolphins sightings have been observed frequenting the harbour mouth area and that the mitigation measures mentioned below they should be sufficient to ensure that no bottlenose dolphins are situated within 820 m prior to piling activities, if such measures are put in place the anticipated magnitude of the effects is expected to be negligible and thus be of minor significance to the bottlenose dolphin populations.

The range at which potential adverse behavioural responses is considerable being upto 22 km for harbour porpoise and 16 km for common and grey seals. For harbour porpoises the results of post-monitoring studies suggest that after piling stops the animals have been found to return to the area within a few hours. Therefore, behavioural disturbance, which would lead to displacement of marine mammals from the piling activities, is only expected to occur for the duration of piling activities.

The haul out locations of seals could be affected by the piling operations, which could cause the temporarily displacement of seals from such areas, the significance of this is considered to be moderate.

The potential exclusion of bottlenose dolphins through behavioural displacement for the duration of the piling activity and out to an extent of 16 km has been assessed as being of high magnitude, and therefore of potentially of major significance to the bottlenose dolphin. As bottlenose dolphins are present along the east coast of Scotland, it has been predicted that the temporary displacement of animals from the Aberdeen Bay area will be mitigated by animals moving into other areas within their natural range, this is a hypothetical assessment and is based on the available habitat range for bottlenose dolphins being extensive covering the coastal waters along the Scottish east coast.

For the other species of cetacean present in Aberdeen Bay they are not restricted to coastal areas and are present throughout a far wider area. Aberdeen Bay has not been recognised as being of particular importance for breeding or calving purposes for other cetacean species, the possible exception in that shallower coastal water of the east coast of Scotland have been speculated to have a role in breeding or calving for the white beaked dolphin during the summer period.

Any temporary exclusion of the cetacean species from Aberdeen Bay is considered to be of low to negligible magnitude, given that there is likely to be adequate areas for foraging relatively nearby. If piling occurs during summer months (July/August) the significance of this is likely to increase to moderate for the white beaked dolphins, but will still be a minor impact for all other cetacean species.

The vessels used in the construction of Aberdeen Bay may locally increase the ambient sound levels and as such may temporarily contribute to the displacement marine mammal from the vicinity of construction activities, the significance of this local displacement of marine mammals is negligible.

During the pile driving construction activities there is the potential for the sound to mask any seal vocalisations, potentially out to a distance of 80 km. Masking of biologically relevant sounds produced by high frequency cetaceans, such as the harbour porpoise, and possibly mid-frequency cetaceans, such as the bottlenose dolphin, is unlikely as the piling pulses have little high frequency energy. The pile driving pulse are of short duration, and are therefore may be below the time where full detection of signals is possible in cetaceans.

Other forms of construction sounds, such as those associated with vessel activity, are continuous type sounds, as opposed to the short duration impulsive piling sounds, and are therefore likely to be above the timeframe where full detection of the signals is possible by cetaceans, and are therefore likely to be audible. Although the vessel sounds are likely to be audible to marine mammals, they are not considered capable of masking the cetacean species that are most commonly present in Aberdeen Bay.

Marine mammals present in Aberdeen Bay are likely to be tolerant of the range of suspended sediment levels that can be present within background levels, the construction activities are not expected to generate high levels of suspended sediment other than locally elevated areas which will only exist for a short timeframe, such increases are not expected to have any form of impact upon marine mammals.

Marine mammals are highly mobile and are expected to follow their prey should they be displaced from the area during construction activities. Piling will be infrequent and temporary so that any disturbance to prey species will be intermittent and not consecutive so any foraging impacts are unlikely to be of sufficient magnitude or duration to adversely affect any life history traits of marine mammals. The marine mammals present in Aberdeen have been known to feed on varied prey species and should be adaptable should one of the more sensitive species to sound be temporarily displaced from the local area.

Increased shipping levels could be considered to increase the risk of collisions with marine mammals. Construction vessels will be transiting at slow speeds within Aberdeen Bay and are typically slow moving and generate low frequencies. It is considered that any marine mammals will be able to avoid approaching vessels. There have never been any reports of ship strikes from stranding records along the Grampian coast, which suggests the magnitude of the effect to marine mammals is negligible.

The noise from the operational wind farm is not considered to be capable of causing disturbance or displacement to marine mammals. There has been considerable variation in the reported underwater noise measurement from operational wind farms, yet all the sound levels reported thus far are relatively low.

These additional vessel arising from the maintenance of the EOWDC would not represent a significant increase on current vessel activity in this area. Aberdeen Bay is already very busy with a wide range of human activities and the small increase in vessel activity associated with the proposed wind farm is unlikely to cause any notable disturbance to marine mammals.

The worst case scenario in terms of seabed habitat lost would be through the use of gravity based structures for all eleven wind turbines; this would result in the loss of 0.03 km^2 of seabed habitat. The wind turbines are separated by a considerable distance from each other, this separation distance should not restrict the movement of marine mammals through the EOWDC. This loss of seabed habitat, in terms of similar available habitat within Aberdeen Bay is of negligible magnitude, with the significance of the impact being minor.

From the monitoring studies of constructed wind farms there is no evidence of any increases or decreases in marine mammal activity that would suggest attraction or avoidance related to magnetic fields. The information on the potential effects of EMF on marine mammals is largely unknown and further research is required to determine the potential risks this may pose to these species. The ecological significance of EMFs is an area of research which requires further study.

The Marine Mammal Protection Plan (MMPP) will be developed to address and mitigate any of the impacts identified as being of concern to marine mammals. The MMPP will outline the chosen mitigation procedures during any piling operations and construction activities to minimise the risk of impacts to marine mammals, the final MMPP will be developed in consultation with advice from statutory consultees. The programme of boat based and acoustic monitoring using C-Pods (moored hydrophones will continue throughout the development and construction of the EOWDC to enable any potential impacts upon marine mammals to be identified and recorded.

AOWFL will follow any advice provided by Marine Scotland on the European Protected Species licences to apply for, if these are required.

1.2 Introduction

Genesis Oil and Gas Consultants (GOGC) has been commissioned by AOWFL to undertake a marine mammal impact assessment of the EOWDC. The structure of the assessment can be summarised as follows:

- **Baseline Report** – this provides a summary of the existing information relating to the distribution and abundance of marine mammals in Scotland with a focus on Aberdeen Bay. This report draws on the findings of a desk based study and marine mammal research studies and also dedicated marine mammal surveys carried out for the purpose of supplementing the baseline for the EOWDC (GOGC, 2011).
- **EIA Technical Report** (this document) – an assessment of the impact of the project on marine mammals in the study area.

One of the primary issues identified at an early stage of the Impact Assessment was the potential impact of underwater sound from during both the construction, operation and decommissioning of the EOWDC. To aid the assessment Subacoustech Ltd were commissioned to provide underwater noise modelling for the installation of the foundations and determine potential impacts upon the marine mammal and other receptors within the developmental area. The impact assessment summaries the main findings of the Subacoustech report (Appendix 3.1 of the Environmental Statement for Subacoustech Ltd Report).

2. METHODOLOGY

Within the Environmental Impact Assessment Scoping Report (AOWFL, 2010) a number of marine mammal issues were raised and it is important to make due consideration of these in the impact assessment. The principal organisation which raised comments in respect of the marine mammal interests were Scottish Natural Heritage (SNH). The Joint Nature Conservation Committee (JNCC) had previously provided advice on the project, particularly the baseline survey design, as part of the originally proposed Aberdeen Offshore Wind Farm Scoping Report (AMEC, 2005).

2.1 Data Information and Sources

- DTI (2004). Guidance for the offshore windfarm consent process
- EMEC and Xodus (2010). Consenting, EIA and HRA Guidance for Marine Renewable Energy Developments in Scotland. Part one - marine renewables licensing process
- OSPAR (2008). Guidance on Environmental Considerations for Offshore Wind Farm Development. OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic
- SNH (2004). Marine renewable energy and the natural environment heritage: An overview and policy statement. Policy statement number 04/01
- Subacoustech (2011). Subsea noise modelling in support of the European Offshore Wind Deployment Centre Development
- Reports from previous studies occuring in the EOWDC development area that describe the marine mammal features of the study area have been summarised below:
    - IECS (2008). Boat based survey results for the AOWF 2007-2008
    - SMRU (2011). Boat based survey results for the EOWDC 2010-2011 (4 months of data)

2.2 Temporal Scales

There are four main phases in the development programme of the EOWDC that will be considered, these are:

- baseline (pre-construction)
- construction
- operation; and
- decommissioning

2.2.1 Baseline

The baseline or pre-construction phase considers the marine mammal abundance, distribution and seasonal occurrence within the EOWDC development area prior to any wind farm construction. The pre-construction environmental marine mammal baseline allows for a benchmark to which any changes to marine mammals can be compared. Any changes to marine mammal populations that could occur throughout the lifetime of the project that are the result of potential wide scale environmental changes such as climate change, or changes in prey availability, will also be compared to this phase. The pre-construction marine mammal baseline is discussed within the marine mammal baseline report (GOGC, 2011).

2.2.2 Construction

The construction phase considers the activities that are associated with installing the 11 foundations, wind turbines and subsea cables. A number of different foundation structures are being considered including: gravity based structure; monopiles; steel jackets; tripod on piles; and suction caisson. The final engineering for the subsea cables has yet to be completed but it is currently expected that there will be up to 4 main cables to the EOWDC and inter-array cables between the wind turbines. Potential impacts that have been assessed include:

- physical injury; including auditory and non-auditory injury;
- behavioural disturbance;
- interference with sound produced by marine mammals,
- indirect impacts of increasing suspended sediment levels; and
- displacement of prey species.

2.2.3 Operational

The operational phase will consider the impacts associated with the operational EOWDC. Potential impacts that will be assessed include: the loss of habitat as a result of the placement of the wind turbines, operational sound and Electromagnetic Fields (EMF) generated from the subsea cables.

2.2.4 Decommissioning

The decommissioning plan for the EOWDC has yet to be finalised and as such a detailed impact assessment on this section is not possible, the Description of the Proposed Project (Chapter 3 of the ES) provides an outline of the activities that are expected to be associated with the decommissioning of the EOWDC. The assumption taken in this assessment is that the wind farm and associated infrastructure, with the potential exception of the subsea cables, will be removed from the seabed as per the statutory requirements that will be in force at the time. The impacts upon marine mammals are expected to be similar to the construction activities as comparable vessels will be required. The main difference is that the removal of the foundations will not require pile driving and it is expected that impacts of underwater sound will be lower through the use of cutting techniques. The use of explosives has been ruled out. Certain foundations types will not requiring cutting and could be lifted from the seabed. The main impacts of decommissioning activities are expected to be physical and behavioural responses of marine mammals to the underwater sound levels generated.

2.3 Impact Methodology

Whilst the matrix approach has been applied as a way to categorise and assess the significance of any potential impacts to marine mammals, through discussions with SNH it has been communicated the importance of also applying rigorous professional judgement in determining significance of potential impacts. The assessment, where possible, has assessed potential impacts and the rationale behind arriving at such judgements with as much information on the reasons for arriving at a particular judgement for each of the environmental receptors involved.

For each impact, the assessment aims to describe the magnitude of effect (i.e. the change created by an activity in terms of its spatial extent, duration and scale) and the sensitivity of each receptor, that is, the resources that would be affected (based on the importance of the receptor and its recoverability). The combination of the effect and the sensitivity of the receptor are then used to derive the significance of the impact. The criteria used in the assessment are given below.

The spatial extent of effect:

- a national/international effect
- a regional effect
- a local effect (within 5 km of the site)
- a site-specific effect

The duration of effect:

- a long-term/permanent effect (more than ten years)
- a medium term effect (existing for five to ten years)
- a short-term effect (existing for one to five years)
- a temporary effect (existing for less than one year)

The scale of the effect:

- above accepted standards/guidelines
- within accepted standards/guidelines
- where no standards/guidelines available, impact relative to background conditions

The recoverability of the receptor:

- low or none
- medium
- high

The importance off the receptor (taking into account international, national and regional legislation and function within the ecosystem):

- high
- medium
- low

Impact significance is then given as Major, Moderate, Minor, or Negligible guided by the following matrix.

Table 1 Matrix used to assign level of significance of impact

Magnitude of Effect (spatial extent, duration of effect and scale)	**Sensitivity of Receptor (based on importance and recoverability)**			
	Very High	**High**	**Medium**	**Low**
Very High	Major	Major	Major	Moderate
High	Major	Major	Moderate	Minor
Medium	Major	Moderate	Moderate	Minor
Low	Moderate	Minor	Minor	Negligible
Negligible	Minor	Negligible	Negligible	Negligible

2.3.1 Implications of Significance

Where the significance is classified as moderate to major or major this is considered to be a potentially significant effect. It should be noted that significant effects need not be unacceptable or reversible.

2.3.2 Sensitivity of Marine Mammals and their Protected Status

For the purpose of this assessment, all cetacean species and seals that are likely to be found in Aberdeen Bay are of either national or international importance due to their conservation status. All cetacean species and seals are considered to be receptors of high importance due to the national and international protection measures afforded to them which are discussed in more detail below.

The Habitats Directive is implemented in Scotland through the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended in Scotland) termed the 'Habitat Regulations'. The Habitat Regulations provide the protection afforded to European Protected Species (EPS) animals listed on Annex IV of the Habitats Directive which includes all species of cetacean whose natural range occurs in Great Britain.

The European Protected Species Provisions create a number of offences that relate to causing injury or disturbance to EPS species as defined in regulation 39 of the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended). Before an EPS licence can be issued there are three tests which must be met by the appropriate licensing authority, which in the case of a renewable energy development would be issued by the Scottish Government. The EPS provisions do not apply to any of the seal species.

Test 1 – The licence application must demonstrably relate to one of the purposes specified in Regulation 44(2). In the case of this application any EPS licences would be issued are likely to be granted by Scottish Government on the basis of Regulation 44(2)(e) *for imperative reasons of overriding public interest including* *those of a social or economic nature and beneficial consequences of primary importance for the environment*.

Test 2 – A licence may not be granted unless Scottish Government is satisfied "*that there is no satisfactory alternative*".

Test 3- A licence cannot be issued unless Scottish Government is satisfied that the action proposed "*will not be detrimental to the maintenance of the population of the species concerned at favourable conservation status in the natural range*".

The harbour seal, common seal, the harbour porpoise and bottlenose dolphin are listed on Annex II of the Habitats Directive which require member countries to consider the designation of Special Areas of Conservation (SACs) for these animals. The cetacean species which require the designation of SACs are the bottlenose dolphin and the harbour porpoise (this is assessed separately in Chapter 29 Information to Inform the HRA).

The Marine (Scotland) Act 2010 introduces a number of measures for seal protection to update and replace the earlier Conservation of Seals Act 1970. It is now an offence to kill or take any seal at any time (with exceptions only under specific licence or for animal welfare) and it is also now an offence to harass seals at their haul-out sites.

2.4 Assessment of Cumulative Impacts

The cumulative assessment will address where predicted impacts of the EOWDC construction and operation could interact with impacts from other industry sectors within the same region and impact sensitive receptors. This may be through direct effects or spatially/temporally separated impacts on the same population of a receptor.

The main industries that will be considered for potential cumulative impacts are the renewable energy industry, aggregate industry, oil and gas and shipping.

A total of nine sites within Scottish Territorial Waters have been awarded for the construction of offshore wind farms. Since the announcement one of the sites, the Forth Array, has been withdrawn. Of the remaining 8 offshore wind farms the nearest three proposed wind farms are the Beatrice wind farm in the Moray Firth; approximately 150 km away and Neart na Gaiothe and Inch Cape are in the Firth of Forth, approximately 120 km to the south.

There are two Round 3 wind farms proposed off the east coast of Scotland outwith Scottish Teritorial Waters. The Moray Firth Offshore Wind Farm (eastern and western development) which is adjacent to the Beatrice offshore wind farm zone beyond the 12 nautical mile boundary, and the Firth of Forth Offshore Wind Farm which lies approximatley 70 km to the south of the proposed EOWDC.

According to the project timescales of the other foreseeable renewable energy projects, the construction of the EOWDC is planned for 2013, this is before any of the proposed renewable energy developments (Table 2). As such the assessment of cumulative impacts from construction will only assess the renewable energy developments that are already constructed, or are forecast to be constructed, within the same timeframe, not those that are planned to be developed in the future. Given the stage of development of the renewable projects yet to be constructed and the uncertainty as to the types of foundations and wind turbines that will be used, there is sparse information available to incorporate into any environmental impact assessment, which limits the effectiveness of cumulative assessments considering conceptual projects yet to be subject to a formal planning application.

This will limit the assessment of cumulative impacts from construction impacts to the Beatrice demonstrator, other operational and decommissioning impacts will make assessment, where possible, of the cumulative impacts from other yet un-consented renewable projects.

Table 2 Renewable Energy Developments that are Proposed within Scottish Territorial Waters and Beyond Territorial Waters

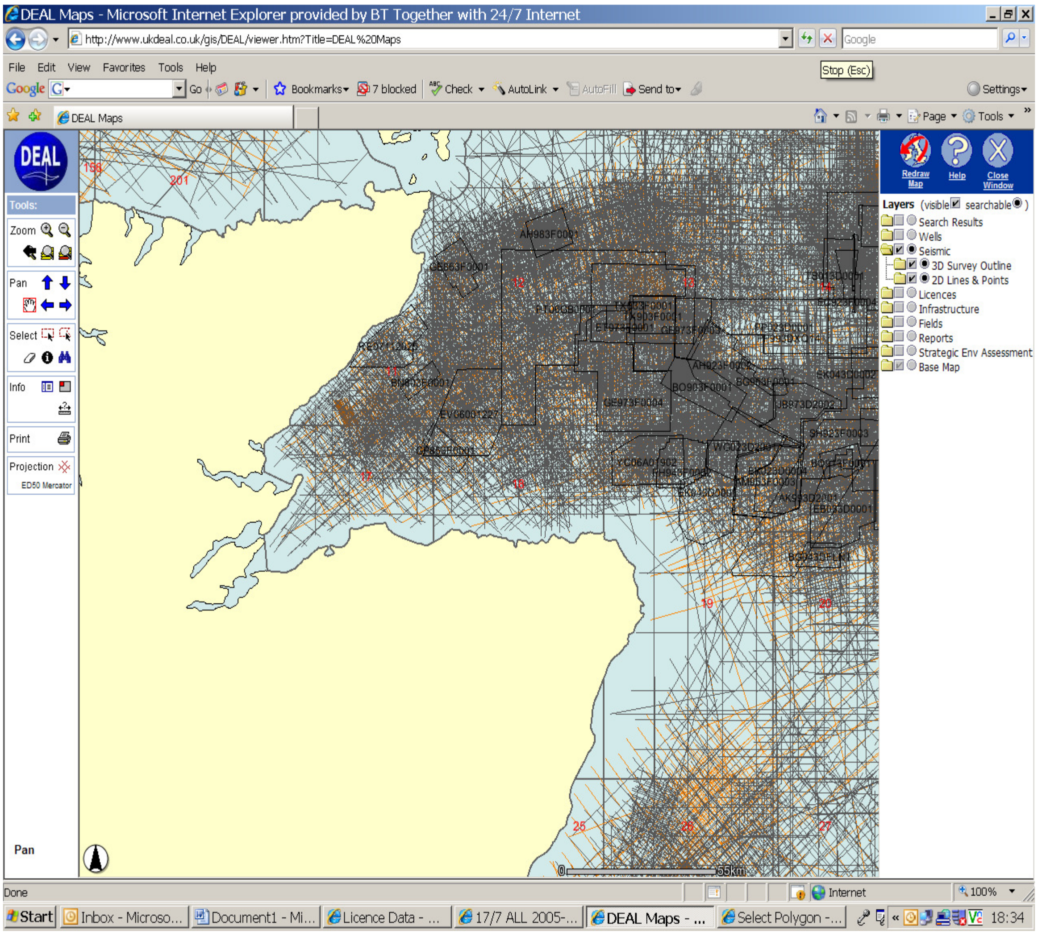
Name of development	Developer	MW	Wind turbines	Project timeframe construction
The Beatrice Demonstrator	Joint Venture Talisman and Scottish and Southern Energy	10	2	Installed operational
The Moray Firth Eastern Development	Moray Offshore Renewables Ltd	1300	67	Construction starts 2015
The Moray Firth Western Development			Not yet known	Unknown >2015 (EIA commences 2013)
Beatrice	Sea Energy Renewables Ltd & Scottish and Southern Energy	920	184	April 2014
Firth of Forth: Phase 1	Scottish and Southern Energy and Fluor	1075	215	2015
Firth of Forth: Phase 2		1435	287	Unknown >2015
Firth of Forth: Phase 3		955	191	Unknown >2015
Neart na Gaoithe	Mainstream Renewable Power	420	130	April 2014

The potential Ocean Laboratory will be considered in the assessment of cumulative impacts, although the design of the structure has yet to be completed it is possible that the foundation could be piled.

There are no known commercial aggregate dredging activities within the wider Aberdeen Bay area. Maintenance dredging does occur in the Aberdeen Harbour, with the next dredging scheduled to occur in 2012, there are no current dredging activities planned to occur during the construction phase.

The oil and gas industry has a considerable presence in the North Sea, the activities that are considered to be of most concern for marine mammals are the exploration activities including the seismic surveys and vessels used to support their activities. Seismic surveys in the North Sea are typically associated with areas of historic oil and gas activity (Figure 1).

Figure 1 Locations of previous seismic surveys in the North East of Scotland (DEAL 2011)



The locations of future seismic surveys are not yet known, as the industry is only required to submit details of the planned surveys a few months in advance of the planned operations. There are a number of seismic surveys that have been planned to in the Moray Firth but have yet to get final regulatory approval. PA Resources have proposed a 2-D seismic survey with a total duration of seven days using a 470 cubic inch array. Caithness Petroleum Ltd has submitted a proposal to undertake four exploration seismic surveys and one site survey, this is expected to last a total of 14 days, both surveys are planned to occur within the timeframe 1st August – 21st October 2011. Subject to these surveys occurring within the proposed timeframe they will both be completed in advance of any construction activities occurring in the EOWDC, as such they will not be considered as part of the in-combination assessment.

Aberdeen Harbour is an important base for the movement of vessels associated with supporting the oil and gas industry, transport of goods to the islands, and also to a lesser extent vessels used in the fishing industry. The disturbance and underwater sound produced by these vessels will be considered in the in-combination assessment.

2.5 Assessment of in-combination impacts

The term 'in-combination' will be used when considering the impacts of the proposals with other plans or projects on European sites. There is a degree of similarity and cross-over between cumulative and in-combination impacts as many of the activities that will be considered in the cumulative assessment are part of UK Government Plans or Project.

3. IMPACT ASSESSMENT

3.1 Construction Phase

3.1.1 Noise Generated during the Construction of the EOWDC May Cause Physiological Damage to Marine Mammals (Non-audiological Injury and Audiological Injury)

Worst Case Scenario: Piling of 8.5 m diameter pile at all eleven locations during one phase of installation (sequentially).

3.1.1.1 Potential Impacts

The construction activities will generate a number of sources of underwater sound, by far the loudest impulsive sound will be generated during the piling of the wind turbines. There have been several studies which have measured the underwater sound levels generated during piling of offshore wind turbines (Bailey, *et al*., 2010; Nedwell, *et al*., 2007). A general observation is that the source levels and underwater sound pressure levels have been found to increase with increasing diameter of the pile being driven, although other factors such as sediment type, energy of the pile driver have an influence on the overall sound levels generated. At the highest level, typically during underwater blast from explosives, sound has the ability to cause injury and, in extreme cases cause the death of exposed animals. Although, to date, there has never been any records of piling having caused any form of physical injury to a marine mammal.

Due to the current lack of information on potential lethal and physical injury effects from impact piling, this study has used the best available data from blast exposures to estimate impact zones. The wave forms from blast waves and piling are rather different; the transient pressure wave from an impact piling operation has roughly equal positive and negative pressure amplitude components and a relatively long duration of up to a few hundred milliseconds. By contrast, blast waves have a very high positive pressure peak followed by considerably lower amplitude, negative wave due to the momentum imparted to the water surrounding the explosive gas bubble. The pressure of a blast wave is normally quantified therefore in terms of the peak level, due to the dominance of the positive peak of the waveform. There is, therefore, a level of uncertainty as to whether a blast wave criterion can be directly applied to a transient waveform arising from an impact piling operation.

Lethal and direct physical injury from an underwater transient pressure wave are related to the peak pressure level, rise time and duration that the peak pressure acts on the body (usually measured by the impulse of the blast wave). The criteria that have been developed for assessing gross injury of this type are based on data from blast injury, at close range, to explosives. Injury has been related both to the incident peak positive pressure of the wave and to the impulse. A number of different techniques for assessing the duration of an impulsive waveform are described by Hamernik and Hsueh (1991) based on the studies by Coles, *et al*., (1968), Pfander, *et al*., (1980) and Smoorenburg (1982). The measure of impulse will, therefore, depend upon which technique is applied.

One of the challenges that AOWFL faced was determining appropriate source levels to model given that the wind turbines installed in Aberdeen Bay could potentially be the largest diameter wind turbines installed to date in offshore waters. In order to generate appropriate source levels to use, Subacoustech Ltd were commissioned to generate predictive underwater noise modelling for the pile to be installed and they used available piling measurements to derive suitable source level to model (Subacoustech, 2011 ref to Appendix 3.1).

The underwater sound modelling applied the Impulse Noise Sound Propagation and Impact Range Estimator (INSPIRE) model that has been specifically designed over five years to predict the likely level of underwater noise from impact piling operations. INSPIRE is a broadband model, that is, it does not calculate levels frequency by frequency, but in terms of the physics of the absorption of a pulse. INSPIRE uses a combination of loss caused by the spreading of the energy of the sound field (geometric loss) and loss caused by energy in the water column being absorbed in the underlying sea bed (absorption losses). This is used to estimate the likely transmission losses as the sound propagates away from the source; in this case impact piling. The model is therefore capable of estimating the effect of rapidly varying water depths that are commonly found in UK coastal waters.

The other main factor that affects the level of underwater noise is the local bathymetry, with sound attenuating at a faster rate over shallow water as opposed to deeper waters. The INSPIRE model uses digital bathymetric data provided by SeaZone Solutions Ltd, to input water depth data into the model.

3.1.1.2 Assessment of Noise Levels Capable of Causing Non-audiological Physical Impacts to Marine Mammals

A number of different impact criteria were used for the sound levels likely to cause physiological damage to marine mammals. Two of these criteria have been proposed by Parvin *et al*., (2007) and were developed to be applicable to all marine species, not just marine mammals. It should be stressed that within the scientific community there is yet no definitive accepted criteria for physical injury to marine mammals. For the assessment of physical injury to marine mammals this assessment applies a number of different impact criteria including those proposed by Parvin *et al*., (2007), and also the audiological impact criteria that have been developed by Southall *et al*., (2007). Although audiological hearing impacts are a form of physical injury they are considered in more detail in Section 3.1.1.3.

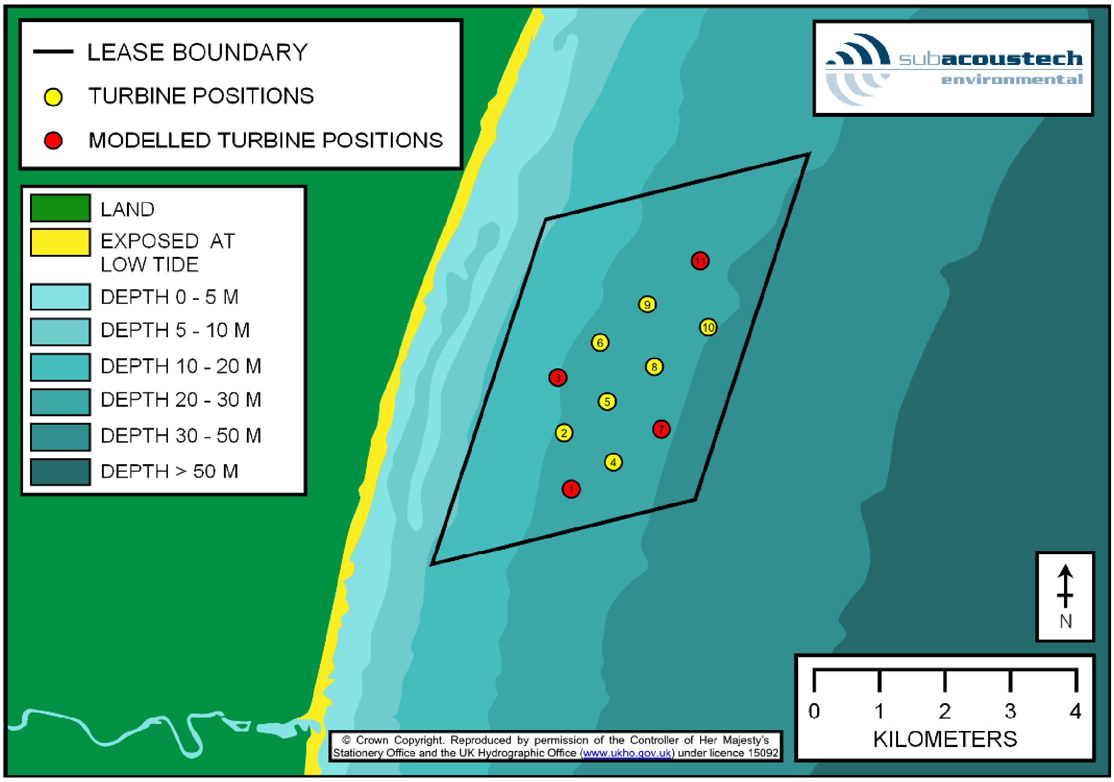
Given that the marine mammal scientific community are still actively debating appropriate impact criteria for marine mammals it was considered best practice to present a number of criteria and choose the most precautionary metric.

The sound levels that will be used in the assessment of physical impacts upon marine mammals are:

- lethal effect may occur in marine species where peak to peak levels exceed 240 dB re.1µPa
- physical injury may occur in marine species where peak to peak levels exceed 220 dB re.1µPa

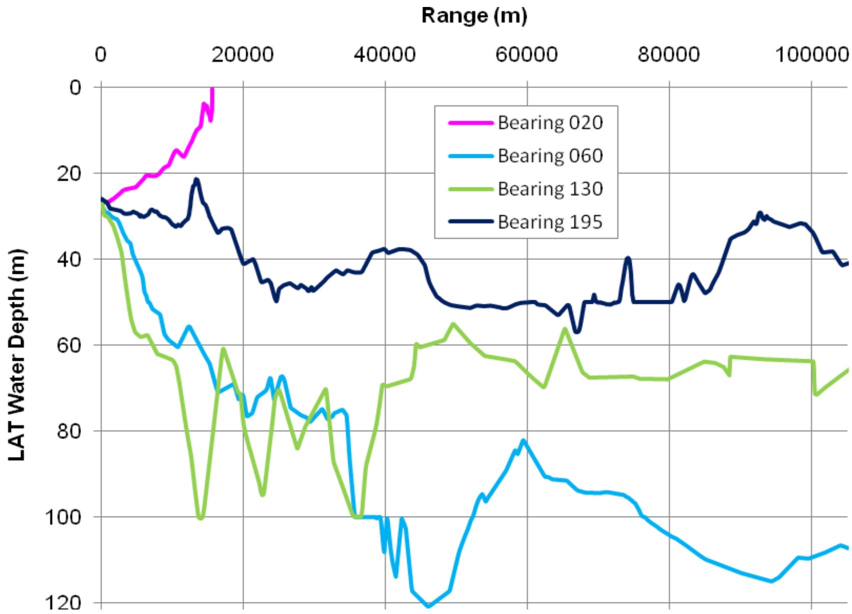
A plan of the proposed EOWDC that illustrates the four wind turbine positions that were used as the basis of the underwater noise modelling is shown in Figure 2. Wind turbine positions 1, 3, 7 and 11 were used and these locations are denoted by red circles. These four positions have been chosen to represent the greatest variation across the site in terms of location and to a lesser extent water depths, ranging from approximately 20 m Lowest Astronomical Tide (LAT) to the west to just under 30 m LAT to the east. The bathymetry is an important factor in underwater sound modelling as it influences the transmission loss that occurs to sound signals with greater losses typically occurring in shallow waters.

Figure 2 The EOWDC lease boundary area and wind turbine positions, wind turbines shown in red were used as representative modelling locations (Subacoustech, 2011)



Aberdeen Bay gradually deepens in easterly direction. In order to illustrate the varying bathymetry in the areas around the proposed EOWDC site, wind turbine number 11 has been used (Figure 3). As expected, the bearing with the shallowest water depth <20 m is bearing 20^0 (orientated towards the shoreline), whereas bearing 60^0 (heading out to the deep waters of the North Sea) encounters water depths in excess of 120 m.

Figure 3 Comparison of four representative depth profiles along transect from wind turbine position 11 indicating the varying bathymetry around the proposed EOWDC site used for the INSPIRE modelling (Subacoustech, 2011)



The underwater noise modelling was carried out at all four wind turbines locations. Shown in Figure 4 is the unweighted (unfiltered) noise generated from the piling of the 8.5 m wind turbine at wind turbine location number 11. The graph indicates that the lethal effect level (240 dB peak-peak) and the physical effect level (220 dB peak-peak) will be exceeded at 3 m and 60 m, respectively. As the environmental conditions are comparable for all the wind turbines; the modelling suggests that for physical impacts the anticipated ranges at which lethal effects and physical effects will be the same for all the wind turbine positions (Table 3).

Figure 4 Graph showing the unweighted peak to peak noise level with range for the four transects extending from wind turbine 11

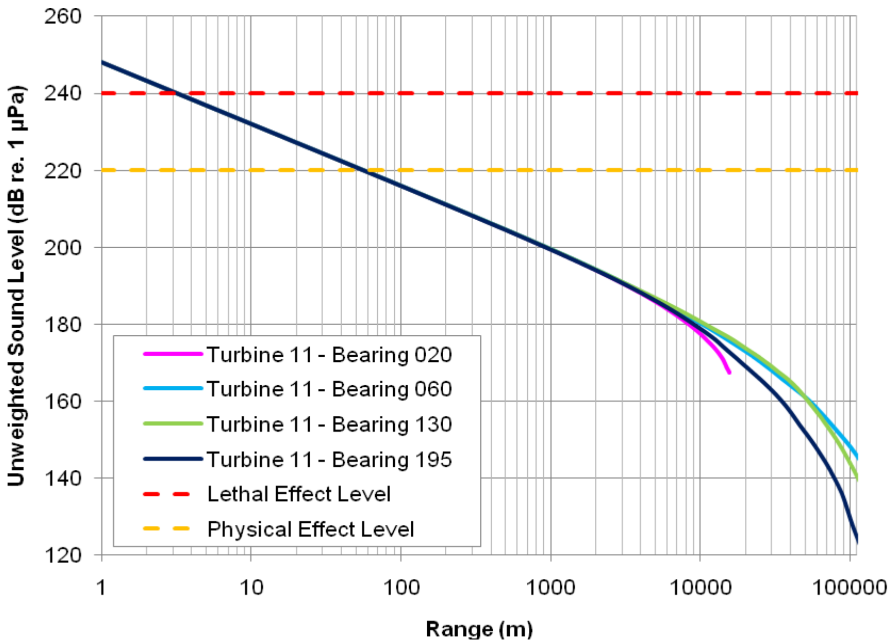


Table 3 Summary of ranges out to which lethal effect and physical injury is expected to occur in marine species using the criteria proposed in Parvin *et al.*, (2007)

Peak to Peak Levels	Wind Turbine 1	Wind Turbine 3	Wind Turbine 7	Wind Turbine 11
Lethal Effect Range to 240 dB re. 1 µPa	3 m	3 m	3 m	3 m
Physical Effect (non-auditory) Range to 220 dB re. 1 µPa	60 m	60 m	60 m	60 m

To date there has been no evidence of wind turbine installations causing any lethal, or physical injury effects upon marine mammals. It should be noted that these impact ranges are based on the extrapolation of data from measurements taken at considerably greater ranges since it is generally not possible to carry out measurements this close to impact piling operations, so the levels of underwater noise maybe lower than those estimated.

Although various species of marine mammals frequently occurring in Aberdeen Bay, some of which occur at high densities, it would still seem unlikely for any species to be present at such close proximity (3 m) to the piling location to suffer outright mortality. It is therefore thought that lethality is therefore unlikely to occur during piling.

In the context of exposure of marine mammal species to underwater sound it is very unlikely that marine mammals would experience injury unless constrained in a very high level continuous sound field for a prolonged period of time (Physical impacts from cumulative exposure are considered in Section 3.1.1.3). Other forms of physical injury (non-auditory) are estimated to occur out to a greater range (60 m), and the risk of piling causing physical impacts cannot be ruled out. However the natural curiosity of seals may increase the risk of exposing both grey and common seals to sound levels capable of causing adverse physical effects.

3.1.1.3 Assessment of Noise Levels Capable of Causing Audiological (Hearing Damage) to Marine Mammals

At a high enough level of sound, traumatic hearing injury may occur even where the time of exposure is short. Injury also occurs at lower levels of noise where the period of exposure is long. In this case, the degree of hearing damage depends on both the level of the noise and the time of exposure to it. To estimate the effect of impact piling taking place over a long period of time this concept of cumulative "Noise Dose" relationship has been used. For complex or time varying signals the degree of hearing damage has been related to the Noise Dose of the noise. The Noise Dose combines the continuous noise level containing the same sound energy as the time varying signal, and the duration of exposure.

This approach appears to translate to the underwater exposure of marine mammals, since for single exposure sounds Ward (1997) developed a level against exposure duration guide indicating that for sounds from 126 to 144 dB above hearing threshold (i.e. dB_{ht}), hearing injury can occur for exposure periods from 60 seconds to 1 second respectively. The data from Schlundt, *et al*., (2000) also indicates that this effect translates to marine mammal exposure to underwater sound. In the study, short duration sound exposures (one second continuous wave) at levels of approximately 130 dB above hearing threshold caused a small Temporary Threshold Shift (TTS) hearing injury in the bottlenose dolphin.

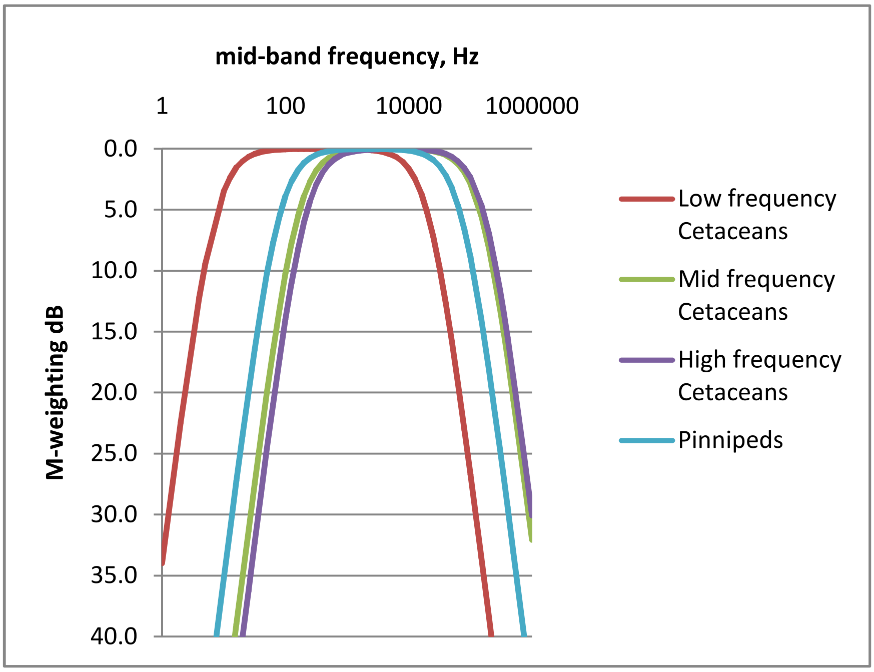
Hearing impairment in the form of a TTS in hearing may occur where an animal is exposed to a these levels, and Permanent Threshold Shift (PTS) will occur with repetitive exposure. The higher the Noise Dose above this limit, the more rapid will be the damage. It is likely that hearing impairment will occur where marine mammals are exposed to continuous or repeated high level underwater sound for relatively long periods of time; for impact piling the noise exposure can build up over many pile strikes. The Noise Dose that the animals will accumulate will depend on the received level of the underwater sound, which varies with range, and hence with the behaviour of the animal, and the time period and repetition rate of the pile strikes.

Nedwell *et al*., (2007) has suggested that the use of a 130 dB_{ht} (Decibels above hearing threshold) level, similar to that used for human exposure in air, provides a suitable criterion for predicting the onset of traumatic hearing damage (that is, where immediate traumatic and irreversible damage occurs), which recognises the varying hearing sensitivity of differing species.

The impact assessment also uses another set of exposure criteria that have been developed based on the evidence of auditory damage from numerous studies, termed the Southall criteria (Southall *et al.,* 2007). The Southall auditory injury criteria are based on both the unweighted peak pressure levels and M-weighted Sound Exposure Levels (dB re. 1 $\mu Pa^2 s$ (M)) for various groups of marine mammals. The use of a dual exposure metric is used, as it has been recognised that it is not only the exposure to peak levels of sound which is important but the total energy throughout the exposure. As a precaution for impact assessments it is recommended to apply the most conservative sound pressure level or sound exposure levels. These sound pressure level and sound exposure level recommended for marine mammals are presented in Table 4.

The sound exposure levels apply M-weighting this is essentially a simple way of applying a frequency dependant weighting to the hearing threshold of an animal, a more complex approach would be the use of the 'dBht'. There are numerous critics of the dBht approach in impact assessment, as it relies on the very few audiogram data that are available for marine mammals being correct and representative of all individuals within the population. Southall, *et al*., (2007) took account of the wide frequency dependence in the auditory response of marine species, and proposed M-Weighting frequency functions for low, mid and high frequency hearing cetaceans and pinnipeds (Figure 5). Otherwise extremely low and high frequency sounds that are detected poorly, if at all, might be subject to unrealistic criteria, for example a reduction of 10 decibels would be applied for a mid-frequency cetacean on exposure to a sound of 100 Hz.

Figure 5 M-Weighting criteria proposed for low, mid and high frequency cetaceans and pinnipeds (adapted from Southall et al., 2007)



The Southall study criteria can be used for both single pulse noise sources and multiple pulse sources (Table 4). The assessment estimated impact ranges for exposure to single pile strikes (Section 3.1.1) and also the cumulative exposure to multiple pulses over a typical installation period using the Sound Exposure Level (SEL) M-weighting metric (Section 3.1.1.3.2); threshold exposure values for single and multiple pulses using the Sound Pressure Level (SPL) and sound exposure levels are shown in Table 4.

Table 4 Proposed auditory exposure criteria for marine mammal frequency specific hearing groups: high, medium and low and seals as defined in Southall *et al.*, (2007)

Marine mammal group	Sound type	
	Single pulses	Multiple Pulses
Low Frequency Cetaceans		
Sound Pressure Level	230 dB re 1 µPa (peak)	230 dB re 1 µPa (peak)
Sound Exposure Level	198 dB re 1 $\mu Pa^2/s$ (M_{lf})	198 dB re 1 $\mu Pa^2/s$ (M_{lf})
Mid Frequency Cetaceans		
Sound Pressure Level	230 dB re 1 µPa (peak)	230 dB re 1 µPa (peak)
Sound Exposure Level	198 dB re 1 $\mu Pa^2/s$ (M_{mf})	198 dB re 1 $\mu Pa^2/s$ (M_{mf})
High Frequency Cetaceans		
Sound Pressure Level	230 dB re 1 µPa (peak)	230 dB re 1 µPa (peak)
Sound Exposure Level	198 dB re 1 $\mu Pa^2/s$ (M_{hf})	198 dB re 1 $\mu Pa^2/s$ (M_{hf})
Seals (in water)		
Sound Pressure Level	218 dB re 1 µPa (peak)	218 dB re 1 µPa (peak)
Sound Exposure Level	186 dB re 1 $\mu Pa^2/s$ (M_{pw})	186 dB re 1 $\mu Pa^2/s$ (M_{pw})

The species upon which the dB_{ht} analysis has been conducted in this study have been based upon regional significance and also crucially upon the availability of good peer-reviewed audiogram data shown in Figure 6.

The species of marine mammal considered in the impact assessment for which suitable audiogram data was available include:

- Bottlenose Dolphin: a marine mammal (toothed whale) with good high frequency hearing sensitivity. It is also used in this assessment as an indicative surrogate audiogram for Risso's Dolphin (Johnson, 1967). Although some audiogram data are available for the Risso's dolphin, it was considered that the quality of the audiogram data is not confirmed. Hence the bottlenose dolphin has been used to provide a conservative over-estimate of potential impacts;
- Harbour Porpoise: a marine mammal (toothed whale) that, based on current peer reviewed audiogram data is the most sensitive marine mammal to high frequency underwater sound (Kastelein *et al*., 2002);
- White-Beaked Dolphin: a marine mammal (toothed whale) with similar high frequency hearing to the bottlenose dolphin, but lower sensitivity to lower frequency noise (using the Striped Dolphin, *Stenella coeruleoalba*, audiogram(Kastelein, *et al*., 2003) as a surrogate as the White-Beaked Dolphin audiogram does not cover the entire audiometric range (Nachtigall, *et al*., 2007);
- Harbour (Common) Seal: a pinniped that based on current peer reviewed audiogram data is the most sensitive seal species to underwater sound (Møhl 1968; Kastak and Schusterman 1998). It is also used as a surrogate audiogram for Grey Seal.

As there is no single published dataset for seal species that covers the full audiometric range, the impact assessment is based on a weighting filter for the harbour seal that is the locus of the minimum threshold (most sensitive) data from several audiogram sources for the harbour seal. The data of Kastak and Schusterman (1998) is used for the frequency range from 100 Hz to 6.4 kHz, and the data from Mohl (1968) over the higher frequency range from 8 to 128 kHz (Figure 6).

It should also be noted that there is an absence of suitable audiogram data to use for baleen whales and there is no appropriate audiogram to use for the minke whale, the baleen whale most commonly sighted within Aberdeen Bay.

Figure 6 Audiograms applied in the marine mammal impact assessment

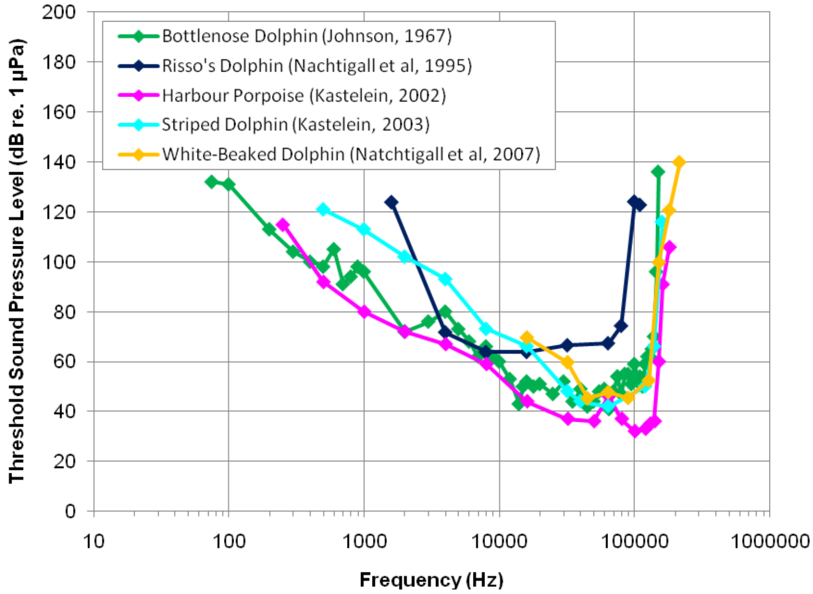


Table 5 shows the estimated impact ranges for traumatic hearing injury, using the dB_{ht} metric, for the marine species of interest, based on the 130 dB_{ht} criterion from Nedwell *et al.*, (2007). The results are given for each of the four locations modelled at the proposed EOWDC site. The 130 dB_{ht} perceived level is used to indicate traumatic hearing damage over a very short exposure time of only a few pile strikes at most.

The largest estimated impact ranges out to which hearing damage may occur are for harbour porpoise (570 m; at both wind turbine positions 7 and 11). The modelling indicates that the seal species are likely to suffer these effects out to the smallest ranges (120 m) (Table 5).

Table 5 Summary of ranges out to which hearing injury is predicted to occur in various marine species using the 130 dB_{ht} (Species) criteria while piling a 8.5 m diameter pile (Nedwell *et al., 2007)*

Species	130 dB_{ht} Ranges			
	Wind turbine 1	Wind turbine 3	Wind turbine 7	Wind turbine 11
Bottlenose Dolphin Risso's Dolphin	**290 m**	**290 m**	**290 m**	**290 m**
Harbour Porpoise	560 m	550 m	**570 m**	**570 m**
White-Beaked Dolphin	240 m	240 m	**250 m**	240 m
Harbour Seal /Grey Seal	**120 m**	**120 m**	**120 m**	**120 m**

Figures in bold were the maximum impact ranges for marine mammal species assessed

Table 6 presents the injury impact ranges using the single pulse peak level criteria for species of cetacean and pinniped proposed by Southall *et al*., (2007). The modelling indicates that the range for injury (PTS) to all hearing types of cetaceans when applying the Southall criteria is 5 m at all wind turbine locations modelled. The range for physical auditory injury for seals is a greater distance of 30 m from the wind turbines, as they are considered by Southall *et al*., (2007) to have an increased sensitivity to peak levels of underwater sound in comparison to cetaceans.

Table 6 Summary of the estimated mean ranges to various unweighted peak noise levels during installation of 8.5 m diameter piles, shown are the PTS criteria for all cetaceans and seals (Southall *et al*., 2007)

Peak Levels*	Wind turbine 1	Wind turbine 3	Wind turbine 7	Wind turbine 11
Range to 230 dB re.1µPa (Cetacean Injury criteria, Southall *et al*., 2007)	5 m	5 m	5 m	5 m
Range to 218 dBre.1µPa (Pinniped Injury criteria, Southall *et al*.,2007)	30 m	30 m	30 m	30 m

*Peak levels were calculated by reducing the peak-peak levels by 6 dB.

Table 7 summarises the estimated impact ranges out to which auditory injury may occur, based on the single pulse Sound Exposure Level (SEL) criteria which have taken consideration of the hearing capabilities of marine mammal function hearing groups (Southall *et al*., 2007). The largest estimated ranges are for the seals, the injury range was greater when modelling was carried out for the two deeper water turbines, with a mean range of auditory injury of between 120 and 130 m (130 m taken as the worst case). For the three cetacean groups the largest impact ranges are predicted for the low frequency cetaceans (20 m) followed by the mid frequency cetaceans (10 m) with the smallest ranges predicted for the high frequency cetaceans (7 m). This is due to piling noise containing mainly low frequency components. There was no observable variability between the wind turbine locations using the Southall criteria.

Table 7 Summary of the auditory injury range for marine mammals using the Southall *et al*., 2007 Sound Exposure Level M-weighting criteria for function hearing groups of marine mammals

	Auditory Injury Range* 198 dB re.1 µPa^2/s (M_{lf}/ M_{mf}/ M_{hf}/ M_{pf})
Low Frequency Cetaceans	20 m
Mid Frequency Cetaceans	10 m
High Frequency Cetaceans	7 m
Pinnipeds (in water)	130 m (worst case)

(M_{lf} = M weighted low frequency M_{mf}= M weighted medium frequency / M_{hf}= M weighted high frequency M_{pf})

Southall *et al*., (2007) recommend using the most conservative impact ranges in impact assessments. Therefore the impact ranges for that were based on the M-weighted sound exposure level will be the most precautionary to use for marine mammals for estimating injury from single pulses (Table 7), as opposed to using the peak sound pressure levels (Table 6). The impact ranges for single pulses are not the most appropriate metrics to apply for pile driving applications which consist of multiple pile strikes. For such installations it is important to make assessment of the cumulative nose dosage that could occur over an entire piling sequence, which is discussed further below.

It may be noted that the impact ranges (for single pulses; shown in Table 6 and Table 7) disagree with those predicted using the dB_{ht} model (Table 5). The modelling results indicate substantially lower ranges of effect for the species of cetacean when using the single pulse Southall *et al.,* (2007) criteria. The disparity in values can be attributed to fundamental differences between the sound levels that are considered to be capable of causing physical impact using the dB_{ht} method and Southall *et al*., (2007) approach. It should be noted however that the SEL of a noise source will vary with range in a different way to that which has been assumed for its SPL (as it depends upon the averaging period used to define the pulse); and this may account in part for the differing results, which is to be expected when applying different impact criteria. Irrespective of this, it can be considered that the dB_{ht} approach is more conservative than the Southall *et al*., (2007) exposure criteria in that it produces impact ranges that are far greater than those produced by the Southall criteria. However, it should be pointed out Southall *et al*., (2007), which has been widely supported by the scientific community consider their pressure and exposure values to be precautionary for the assessment of impacts to marine mammals.

3.1.1.3.1 Estimated Ranges at Which Auditory Hearing Damage May Occur for Multiple Pulses

The installation of each pile is anticipated to take a maximum of 24 hours, this value should be considered as the maximum possible duration, and although it is expected piling will be completed within a shorter timeframe (~ 8 hours). The steel pile will be driven into the seabed starting off with a gradual ramping up of power, increasing to a max rate of 32 strikes per minute.

In order to assess the range at which a marine mammal could experience physical injury the model applied different scenarios based on cumulative noise exposure of multiple pile strikes, and the receptor (marine mammal) being either a stationary, or fleeing animal; moving away from the sound source.

3.1.1.3.2 Assessment of Cumulative Exposure Applying the dBht Method

In the assessment of cumulative exposure, a 90 dBht level has been applied as the level at which impacts could occur for an exposure durations of 8 hours. The maximum expected duration of piling has been estimated to be 24 hours, although it is likely to be considerably shorted duration and would be dependent upon the diameter of piles and seabed conditions.

The 90 dBht level was selected on the results of the Masden *et al*., (2006) who demonstrated a near linear relationship between sound exposure level and duration of exposure. A doubling of the noise energy (eg 3 dB increase) results in a halving of the duration of exposure period required. The relationship between sound exposure level and duration of exposure is shown in Table 8.

Table 8 Comparison of noise exposure level and duration of exposure for a sound level of 90 dB_{ht}

Exposure Level dB(A) (dB_{ht})	Exposure Duration
90	8 hours
93	4 hours
99	1 hour
110	Approx. 5 minutes
120	Approx. 30 seconds
130	Approx. 3 seconds

An estimate of the minimum safe standoff distances from the piling operation has been based on the INSPIRE fleeing animal noise dose algorithm. Each standoff range indicates that if a particular species is closer than that range at the onset of piling, then they are unlikely to be able to flee the area before suffering hearing damage. This is based on a conservative swim speed of 1 metre per second (m/s) and takes into account the accumulated noise dose over a typical piling operation.

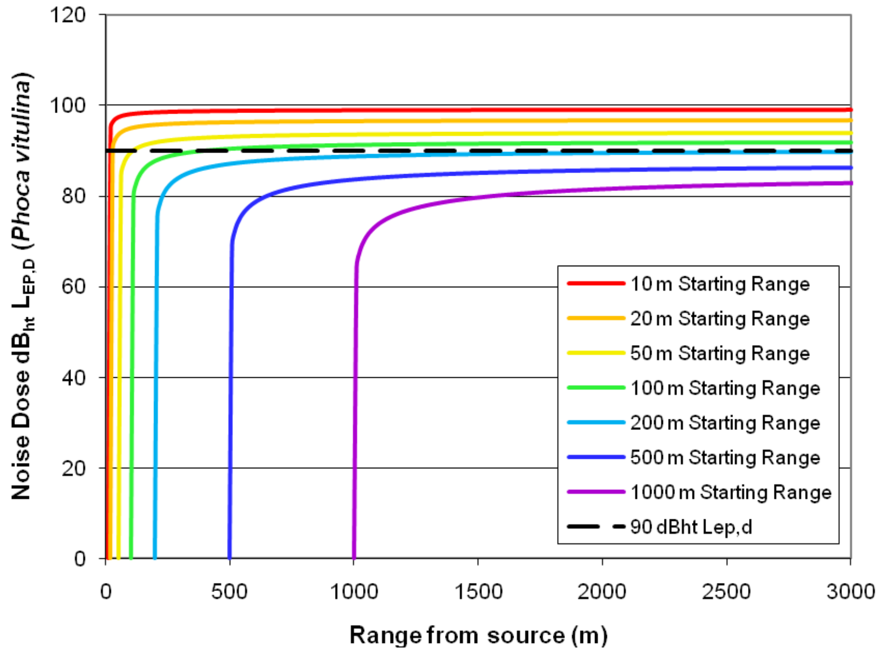
Figure 7 shows a detailed plot of the results of this modelling that has been carried out for each of the key species, in this case the figure is shown for species of seal. It can be seen that the 90 dB_{ht} $L_{EP, D}$ (Level of exposure and duration criteria; illustrated by the dashed line) is met between the 100 and 200 m starting range datasets (Table 9). The results of this indicate the ranges at which animals have to be before an injury is to occur, for example if a seal were to be closer to the piling operations than 190 m at the onset of piling it is unlikely to escape the area without receiving a damaging noise dose.

Table 9 presents the results of this modelling for the other species of marine mammal. It can be seen from these data that the harbour porpoise will need to be at the greatest distance (1,350 m) from the piling operation at its onset to avoid suffering hearing damage. If the fleeing animal is beyond the ranges presented in Table 9 they are likely to be able to reach a safe distance before receiving an unacceptable noise dose (when applying the 90 dB_{ht} criteria).

Table 9 Summary of the maximum starting ranges for various marine species using the fleeing animal noise dose model (when applying the 90 dB_{ht} criteria).

Marine Species	Maximum Starting Range for Fleeing Animal
Bottlenose Dolphin / Risso's Dolphin	120 m
Harbour Porpoise	1,350 m
White-Beaked Dolphin	460 m
Harbour Seal / Grey Seal	190 m

Figure 7 Estimated noise dose for a fleeing harbour / grey seal for impact piling of an 8.5 m diameter pile

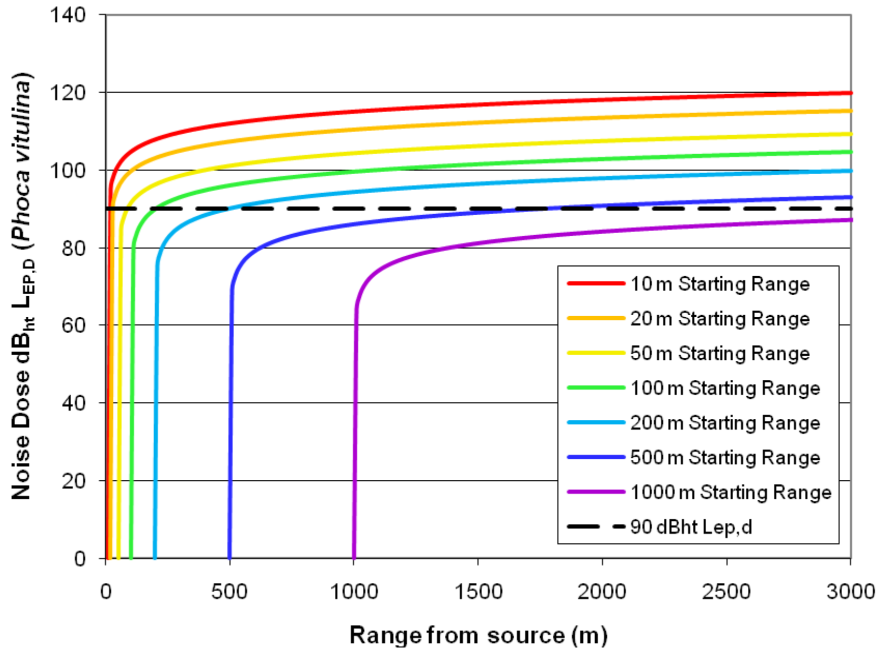


Noise dose modelling has also been carried out for a stationary animal during piling operations. It should be noted that this is considered an unlikely scenario as it implies that the animal makes no attempt to flee the high sound field area. This assessment has only been carried out for the harbour seal / grey seal and the results can be seen in Figure 8.

It can be seen that the results for the stationary animal modelling give much higher starting ranges than for the fleeing animal modelling, with the starting range for the harbour seal rising from 190 m (for a fleeing animal) up to almost 1 km for a stationary animal.

Further modelling to estimate similar impact ranges for other species has not been carried out for the stationary animal scenario as it is not felt to represent a realistic case. The data presented for the seal is provided to indicate the potential differences in the two scenarios.

Figure 8 Estimated noise dose for a stationary harbour / grey seal (used for illustrative purposes)



3.1.1.3.3 Assessment of Cumulative Exposure using Southall *et al*., (2007) Impact Criteria for Multiple Pulses

The accumulated exposure to sound for marine mammals has been assessed using the auditory injury criteria proposed by Southall *et al*., (2007). This has been done by calculating a standoff range for each marine mammal group, whereby it would safely be able to escape the affected area without receiving a damaging exposure to the sound. Table 10 shows a summary of these standoff ranges for fleeing animals, assuming a swim speed of 1 m/s. The largest standoff ranges are calculated for the seals, which, based on the M-weighting criteria are likely to need to be at a range of at least 3.6 km at the onset of piling to avoid a damaging exposure to the sound. Lower standoff ranges are predicted for the three cetacean groups with low frequency cetaceans being the most sensitive to the sound and high frequency cetaceans being the least.

Figure 9 shows the calculated multiple pulse M-weighted sound exposure levels for a fleeing high frequency cetacean at various starting ranges, from this it can be seen that if the animal was situated at a range of less than approximately 500 m from the piling operations at the onset of piling it is unlikely to escape the area without receiving a damaging exposure to noise according to the Southall *et al*., (2007) criteria. Figure 10 shows similar data for the high frequency cetacean group; however, this is for a stationary animal during the piling operations. It can be seen that the animal would have to be between 1 and 1.5 km at the onset of piling to avoid a damaging sound exposure level, assuming that it stayed in the same position throughout the entire piling operation. It should be noted that this scenario is considered highly unlikely as marine species are likely to attempt to escape areas where injury is likely to be caused.

Table 10 Summary of the maximum starting ranges for marine mammal groups before receiving an exposure that could cause auditory injury, using the multiple pulse criteria from Southall *et al.*, (2007)

Marine Mammal Group	Maximum Starting Range
Low Frequency Cetaceans	1,350 m
Mid Frequency Cetaceans	820 m
High Frequency Cetaceans	650 m
Seals (in water)	3,600 m

Figure 9 Estimated M-weighting Sound Exposure Levels from various starting ranges for high frequency cetaceans using the multiple pulse criteria from Southall *et al.*, (2007) for a fleeing animal

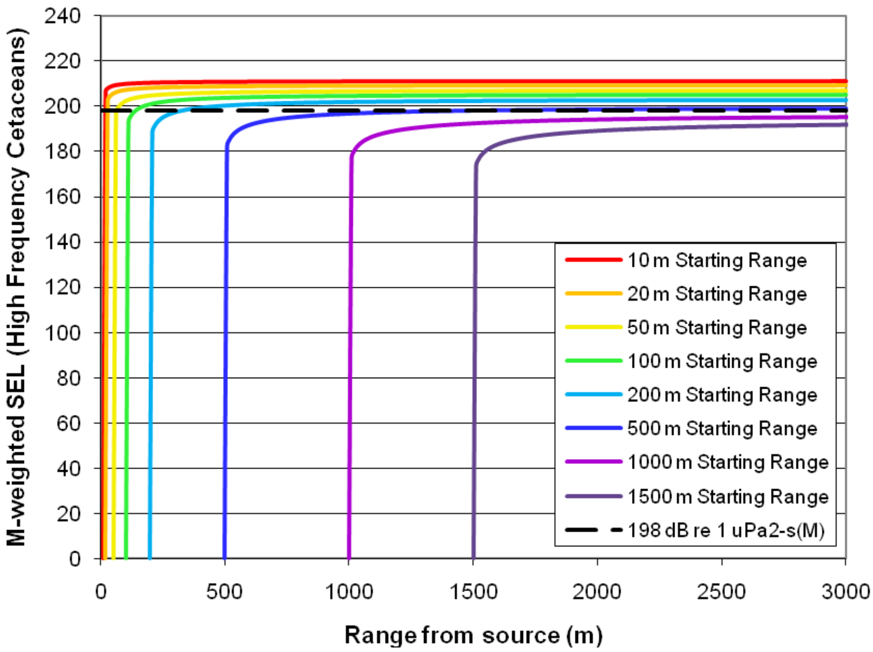
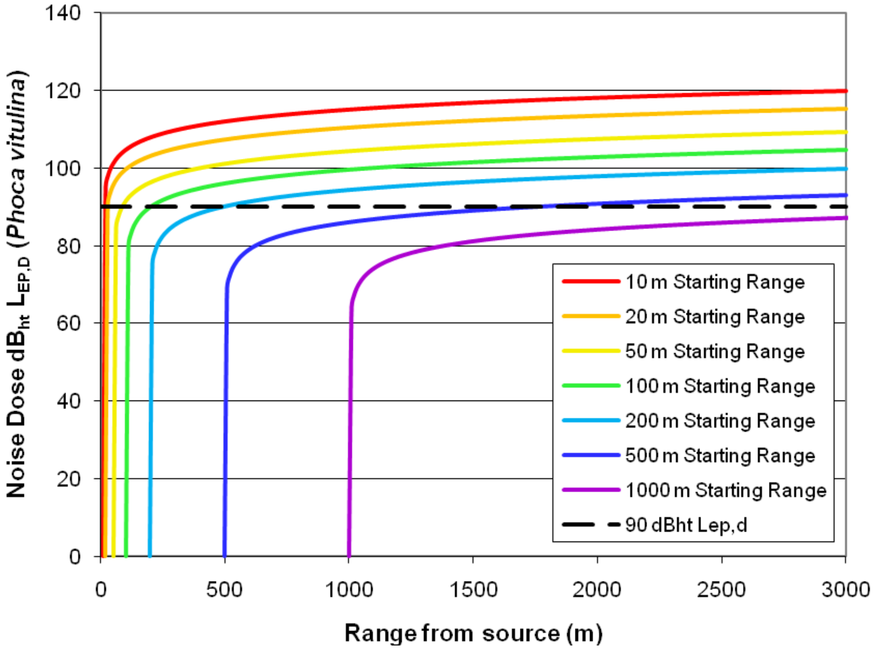


Figure 10 Estimated noise dose for a stationary harbour seal or grey seal for impact piling of an 8.5 m diameter pile



3.1.1.3.4 Summary of Cumulative Exposure Impacts Using the dB_{ht} and Southall *et al*., 2007 Exposure Criteria

Table 11 shows a comparison between multiple pulse auditory injury impact ranges for three marine mammals species calculated using the dB_{ht} criteria and the three equivalent M-weighted SEL marine mammal groups. The data indicate that, unlike the single pulse exposure modelling, in some cases the dB_{ht} metric provides the largest estimated range of impact and in some cases the M-weighted SEL metric provides the largest impact range. This discrepancy is a result of the different values used in the impact thresholds for the two metrics. Highlighted in bold are the precautionary values which have been chosen to apply in the cumulative impact assessment as the minimum distances that auditory impacts could occur in a fleeing animal scenario.

The ranges at which auditory injury could occur to marine mammals will be factored into the MMPP and the mitigation measures adopted during the construction activities. It should be noted that these results (fleeing animal scenario etc) do not take into account the mitigating effects of a soft start procedure; these results assume a high blow force at the onset of piling. As long as a soft start procedure is used the effect is likely to be considerably reduced.

Table 11 Summary of impact ranges comparing the multiple auditory injury ranges, using the fleeing animal model, predicted using the dBht criteria (Nedwell *et al*., 2007) and the M-weighted SEL (Southall *et al*., 2007) criteria

dB_{ht} (Nedwell *et al*, 2007)		M-weighted SELs (Southall *et al*, 2007)	
Species	**Multiple pulse auditory injury range (fleeing animal)**	**Equivalent M-weighting group**	**Multiple pulse auditory injury range (fleeing animal)**
Bottlenose Dolphin	120 m	Mid Frequency Cetacean	**820 m**
Harbour Porpoise	**1,350 m**	High Frequency Cetacean	650 m
Harbour Seal	190 m	Pinnipeds	**3,600 m**

Figures in bold represent the maximum auditory impact ranges

The modelling results indicate that unless a cetacean is within the immediate vicinity of piling operations (<1.35 km) or a seal is situated (3.6 km) in the local area, the only possibility for an auditory injury to occur is during the initial piling period. It is expected that the perceived loudness of the piling activity will cause the marine mammal to exhibit an aversive behavioural reaction, with the animal moving from the area before the onset of any auditory injury can occur.

There is clearly a risk to individual marine mammals that are exposed to high sound levels in the immediate vicinity of the piling operation, given that marine mammals may be subject to sound levels that are capable of causing physical impacts, including both auditory and non-auditory impacts. Animals would have to be present within the immediate area of the pile driver to be at risk of physical effects and it is considered the risk of marine mammals receiving sound levels capable of causing their death appears to be remote.

The marine mammals which are most likely to be exposed are the more commonly sighted species within Aberdeen Bay, with the harbour porpoise, bottlenose dolphins and grey and common seals being the species most at risk from physical impacts.

To individual marine mammals the potential impact is considered to be of high magnitude and potentially of major significance. In terms of risks to the population most of the marine mammal species; with the exception of the bottlenose dolphin, have wide ranging populations. Subsequently, the risk to the population level is anticipated to be of low magnitude and moderate significance. Given that the relatively small Moray Firth bottlenose dolphin population has been increasing its range expansion in a southerly direction, and that Aberdeen Bay frequently has bottlenose dolphins, especially during the winter and spring months, the potential impact both to the individual and population is considered to be of high magnitude and potentially of major significance. It should be considered the majority of bottlenose dolphins sightings have been observed frequenting the harbour mouth area and that the mitigation measures mentioned below they should be sufficient to ensure that no bottlenose dolphins are situated within 820 m prior to piling activities, if such measures are put in place the anticipated magnitude of the effects is expected to be negligible and thus be of minor significance to the bottlenose dolphin populations.

Other forms of construction associated sounds are expected to be dominated by vessel noise. In terms of direct physical injuries to hearing structures in marine mammals, it appears from the available research that loud and/or sustained exposures are required to cause even temporary changes in marine mammal hearing sensitivity (Southall *et al.*, 2007). Consequently, the likelihood that an isolated exposure to vessel noise would be sufficient to permanently damage the hearing of a marine mammal appears to be remote, and the significance of other forms of construction activities causing physical injury to marine mammals is considered to be of minor impact.

3.1.1.4 Mitigation

The mitigation measures that are planned to be used to minimise the risk of causing physical impacts to marine mammals are as follows:

- use of trained and experienced Marine Mammal Observers (having undertaken a JNCC recognised course);
- pre-piling search for marine mammals prior to piling monitoring a suitable sized exclusion zone;
- use of Passive Acoustic Monitoring (PAM) system monitored by experienced PAM operatives; and
- soft-start (gradual ramp up) of pile driver.

The modelling of cumulative exposure to piling noise indicates that in a fleeing animal situation the marine mammal that is most sensitive to pile driving sound are the seals, and that to avoid auditory injury they will have to be 3.6 km away from the piling location. A typical mitigation zone for marine mammal observers to monitor has been recommended as a default 1 km (JNCC, 2010), the results of the modelling indicate that this zone should be increased for seals (but will also be applied to all marine mammal species).

Given that there is a risk to marine mammals in the immediate vicinity of the piling operations, and the risk is apparently greater for seal species, it may be worth considering the use of Acoustic Mitigation Devices (AMD's) which, providing they are used appropriately, could temporarily displace marine mammals from the area prior to piling operations. The use of devices whose purpose is to deter marine mammals could be seen as advantageous given the potential risk to marine mammals from noise impacts from pile driving, by removing animals or certain species from the area of operations this action may minimise the risk of causing injury.

AOWFL recognise that the use of AMD's as part of the mitigation measures for piling is currently an area of active scientific research (Kastelein, *et al.*, 2010). From a review of commercially available Acoustic Mitigation Devices there are a number which have been designed as seal deterrents, including the Lofitech, Ace Aquatech (Nedwell, *et al.*, 2010), and their use could prove advantageous as part of the overall mitigation strategy during construction. Any use of AMD's will be subject to strict timing constraints so that the underwater noise generated will be minimised. If these are used it is envisaged that they will be subject to timing and deployment constraints, for example being deployed 1 hour prior to the commencement of the soft-start and switched off immediately after the piling has ceased (Kastelein, *et al.*, 2010). It is also recognised that the use of any such devices may require European Protected Species licences to deploy as they will constitute deliberate disturbance of marine mammals.

AOWFL are open to incorporating the latest advice on the mitigation procedures used as part of the development of the EOWDC. The final MMPP will be agreed following advice and consultation with SNH and Marine Scotland.

3.1.1.5 Residual Impacts

In order to determine the residual impacts, it has been assumed that the mitigation measures described in Section 3.1.1.4 will be successfully implemented then it is expected that physical impacts to marine mammals are unlikely to occur. Impacts on marine mammals would be of negligible magnitude and, therefore, of minor significance.

3.1.1.6 Cumulative Impacts

There are not anticipated to be any cumulative impacts from other renewable energy projects, as all construction activities of other nearby proposed wind farm developments are expected to commence after the EOWDC has been completed. Should the proposed project timescale for the construction of the EOWDC change and coincide with the commencement of construction activities of other renewable energy projects, then further assessment of cumulative impacts from concurrent piling shall be carried out at a later date.

The development and installation of the proposed Ocean Laboratory could occur within the same construction period as the piling of the foundation structures. The installation of the Ocean Laboratory would be comparable to the installation of another monopole. As a worst case the piling of the Ocean Laboratory will take 24 hours and is unlikely to result in any significant cumulative impacts, providing that the mitigation measures that were used for the wind turbines are applied.

The other industrial activity that could cause physical impacts to marine mammals are seismic surveys. There are currently no planned surveys times to occur during the construction period of the EOWDC. There is unlikely to be any seismic surveys occurring simultaneously with the pile driving, as the sound underwater sound interferes with recording of the sound signals received from the seabed. As such any seismic surveys that are planned to occur in the waters of the North Sea, will be timed to avoid known periods of pile driving activity. The waters immediately offshore the north east of Scotland has a low prospectively for hydrocarbons and as such are of little interest to the oil and gas industry. The closest hydrocarbon field to the EOWDC is the Buzzard field which is situated 100 km away.

3.1.1.7 In-Combination Impacts

No in-combination impacts are anticipated.

3.1.1.7.1 Monitoring

The piling operation will follow the MMPP. The presence of marine mammals will be monitored during the construction period through the continuation of the boat based surveys and through the use of static C-pods deployed throughout Aberdeen Bay. The presence of observers and acoustic recording instrument (C-pods) deployed throughout the development stage will enable an assessment of marine mammals presence during construction. Post construction analysis of the acoustic monitoring data collected by the C-pods with other visual observation effort will allow an assessment and validation of construction impacts.

3.1.2 Noise Generated during the Construction of the EOWDC May Cause Behavioural Disturbance and Displacement to Marine Mammals

Worst Case Scenario: Piling of 8.5 m diameter pile at all eleven locations during one phase of installation (sequentially).

3.1.2.1 Potential Impacts

Behavioural disturbance to marine mammals can be caused by elevated sound levels. Upon receiving a sound level capable of causing disturbance the animal may exhibit a number of behaviours, one of the most apparent would be opting to swim away from the source (considered to be an aversive response to the sound signal). This section will assess the potential for piling sound to displace marine mammals from the area by assessing the potential for sound levels to induce a behavioural response. There are a number of sound sources that will be associated with construction activities, the principal sources being associated with construction vessels including: piling barge, support vessels, and other vessels involved with installing seabed cables and infrastructure.

Underwater sound generated by vessels has been recognised as capable of causing a number of different types of behavioural responses in marine mammals, including changing their distribution and abundances. Also it has been suggested that prolonged exposure to increased ambient noise may lead to physiological and behavioural stress (McDonald, *et al*., 2006; Parks and Clark 2005). Thus chronic exposure to noise can permanently impair important biological functions and may lead to consequences that are as severe as those induced by acute exposure from impulsive type sounds.

The construction vessels will only be present within the Aberdeen Bay for the duration of construction activities, which is a relatively short period of time. Moreover, Aberdeen Bay has a number of well established shipping lanes and the vessel noise associated with construction activities is not expected to cause a significant change to ambient sound levels.

Other types of construction activities that are expected to generate underwater noise other than the foundation installation are the cable trenching activities. Measurements of cable trenching activities at North Hoyle Offshore Wind Farm estimated that the sound levels were dominated by the noise from the vessel, and the predicted source levels (178 dB re.1µPa@1m) were considered to be below the level which would cause any behavioural reaction in marine mammals (npower renewables 2002). The cable laying activities as part of the construction of the EOWDC are likely to utilise a similar type of vessel, therefore the sound levels generated are thought to be comparable and are not of any particular concern for causing behavioural impacts to marine mammals.

In terms of the sound levels generated by construction by far the greatest contributor to underwater sound in terms of its peak sound pressure level will be the piling sound, therefore the assessment of behavioural impacts will focus principally on this noise source. The assessment of behavioural impacts will use and compare the results of two impact approaches, the dB_{ht} criteria; proposed by Nedwell *et al*., (2007) and the behavioural response criteria, Southall *et al*., (2007).

3.1.2.2 Assessment of Behavioural Impacts Using the dB_{ht} mectric

Measurements of underwater noise are frequently presented in terms of the overall linear level of that sound, such as its spectral level or peak pressure. This, however, does not provide an indication of the impact that the sound will have upon a particular fish or marine mammal species. This is of fundamental importance when considering the behavioural response of species to activities generating underwater noise, as avoidance is associated with the perceived level of loudness and vibration of the sound by the species. Therefore, the same underwater noise may have a different impact on different species with different hearing sensitivities.

The dB_{ht}(*Species*) metric (Nedwell *et al*, 2007) has been developed as a means for quantifying the potential for a behavioural impact on a species in the underwater environment. As any given sound will be perceived differently by different species (since they have differing hearing abilities) the species name must be appended when specifying a level. For instance, the same construction event for salmon (*Salmo salar*) might have a level of 70 dB_{ht} (*Salmo salar*) and for bottlenose dolphin a level of 110 dB_{ht}(*Tursiops truncatus*). Table

12 below summarises the assessment criteria for the dB_{ht} metric, the higher dB_{ht} levels are correspond to a greater behavioural effect, or at very high levels hearing damage (Nedwell, *et al*. 2007).

Table 12 Assessment criteria proposed by Nedwell *et al*., (2007) used in the impact assessment for behavioural impacts of underwater noise on marine mammals

Level in dB_{ht}(Species)	Effect
75	Significant avoidance
90 and above	Strong avoidance reaction by virtually all individuals.
Above 110	Tolerance limit of sound; unbearably loud.
Above 130	Possibility of traumatic hearing damage from single event.

In addition, a lower level of 75 dB_{ht} has been used for analysis as a level of "significant avoidance." At this level, about 85% of individuals will react to the noise, although the effect will probably be limited by habituation (Subacoustech 2011).

Figure 11 and Figure 12 shows the results for modelling 8.5 m diameter piles in terms of peak to peak dB_{ht} (*Species*) perceived sound levels for the marine species of interest for a deep water transect and a shallower water transect respectively. The depth profiles for these transects are shown in Figure 3.

Figure 11 Estimated peak to peak dB_{ht} level with range plot of various marine mammals and fish species along a deep water transect (wind wind turbine 11, bearing 60^{o}) during the installation of a 8.5 m pile

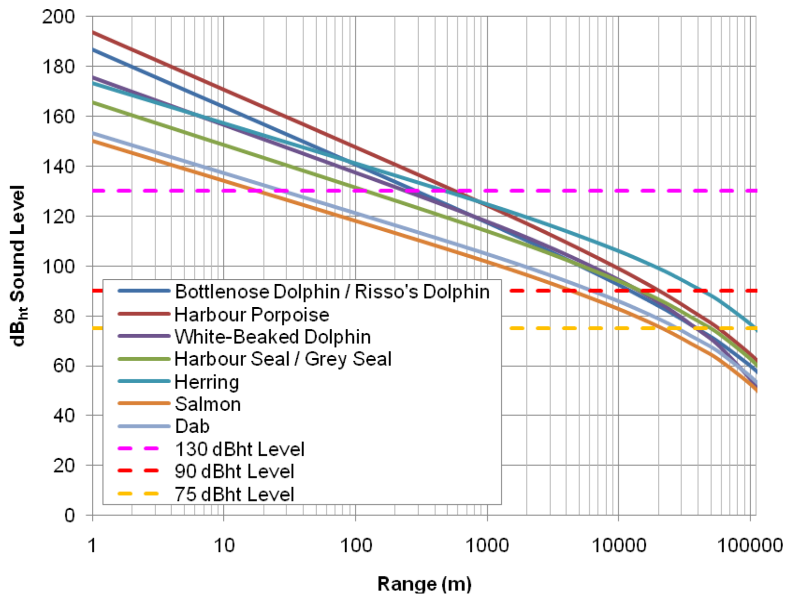


Figure 12 Estimated peak to peak dB_{ht} level with range plot of various marine mammals and fish species along a shallow water transect (wind wind turbine 11, bearing 195^{o}) during the installation of a 8.5 m pile

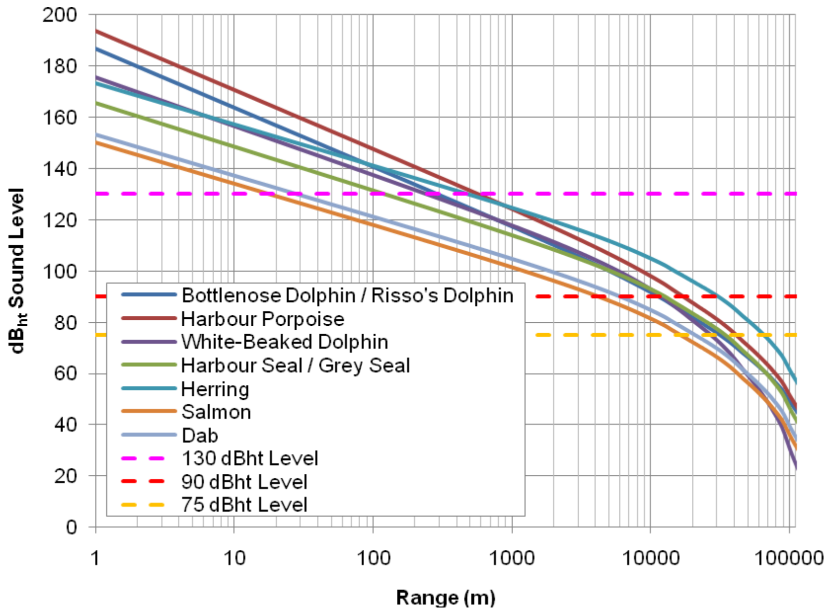


Table 13 - Table 16 present a comparison of estimated 90 dB_{ht} impact ranges for behavioural response for the species of interest. Mean ranges along with the overall range of values are presented for all four wind turbine positions.

The largest range for a behavioural response is predicted for the harbour porpoise, which is likely to receive an underwater noise level of 90 dB_{ht} out to maximum of 22 km from piling operations. The smallest 90 dB_{ht} impact ranges predicted for species of marine mammal is for bottlenose dolphin and Risso's dolphin, with behavioural response ranges of between 12 and 13 km.

The INSPIRE model calculates impact ranges along transect paths from a selected point, in this case the wind turbine positions, along 180 equally spaced transects (one every 2^{o}). The maximum, minimum and mean ranges from all of these transects are collected in the tables below. It should be noted that the minimum ranges are for transects heading into shallow water, and in most cases, are reaching the coastline before the sound has attenuated to below 90 dB_{ht}. Hence why, for example, all the minimum ranges from Wind turbine 1 are calculated to be 3 km, as this is the minimum distance between the wind turbine position and the coastline. All the predicted received noise for all the key species is still above 90 dB_{ht} at this particular piece of coastline.

The mean values quoted in the tables take into account all of the transects, these apparently shorter impact ranges are also used in the averaging.

Table 13 Summary of the estimated behavioural impact ranges for piling an 8.5 m diameter pile at wind turbine position 1 using the dB_{ht} impact criteria

Species	90 dB_{ht} Range	
	Mean	Range of values
Bottlenose Dolphin / Risso's Dolphin	8.5 km	3.0 – 13 km
Harbour Porpoise	12 km	3.0 – 21 km
White-Beaked Dolphin	9.3 km	3.0 – 15 km
Harbour Seal /Grey Seal	9.6 km	3.0 – 16 km

Table 14 Summary of the estimated behavioural impact ranges for piling an 8.5m diameter pile at wind wind turbine position 3 using the dB_{ht} impact criteria

Species	90 dB_{ht} Range	
	Mean	Range of values
Bottlenose Dolphin / Risso's Dolphin	7.9 km	2.3 – 12 km
Harbour Porpoise	11 km	2.3 – 20km
White-Beaked Dolphin	8.4 km	2.3 – 14km
Harbour Seal /Grey Seal	8.7 km	2.3 – 15 km

Table 15 Summary of the estimated behavioural impact ranges for piling an 8.5m diameter pile at wind wind turbine position 7 using the dB_{ht} impact criteria

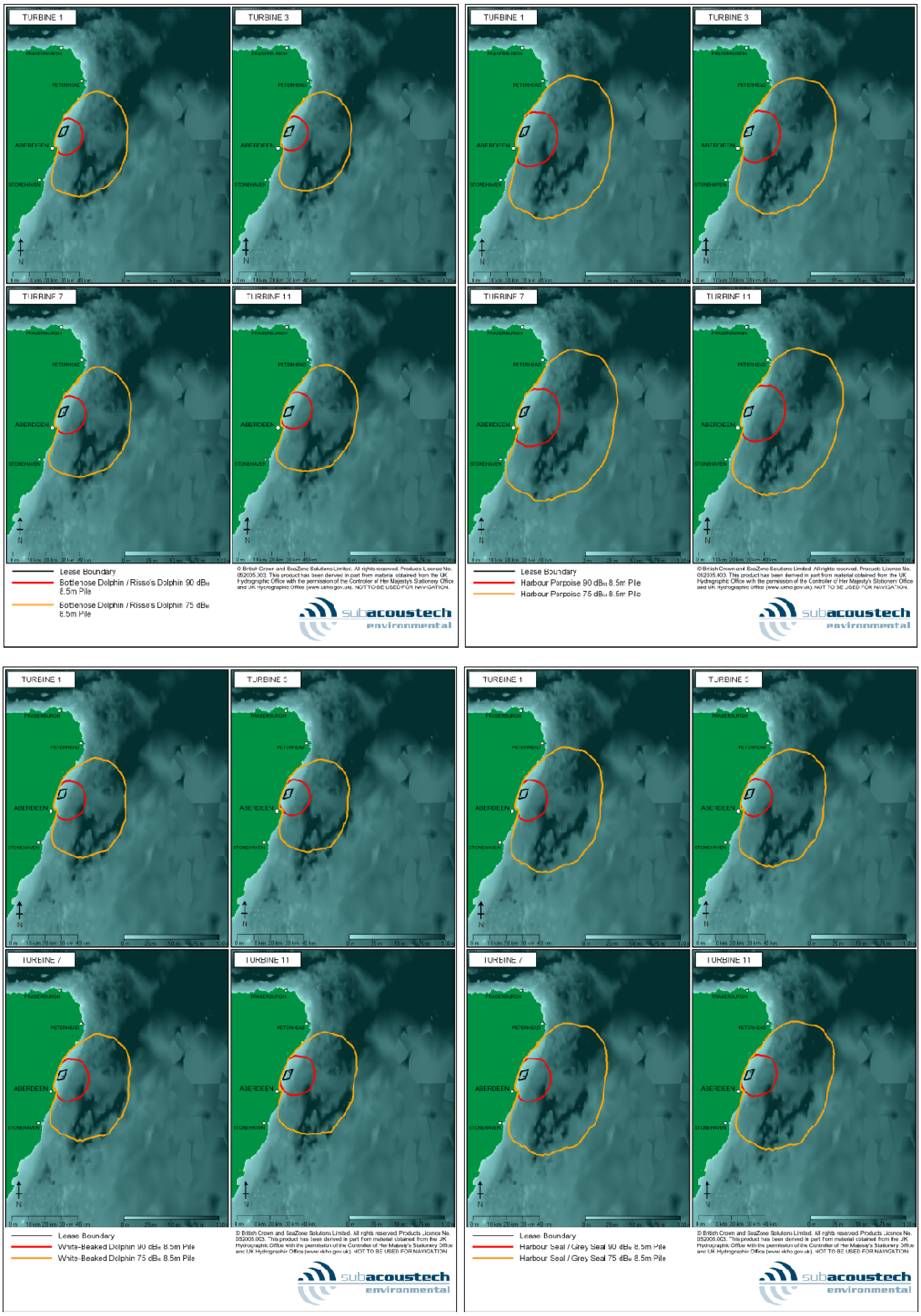
Species	90 dB_{ht} Range	
	Mean	Range of values
Bottlenose Dolphin / Risso's Dolphin	9.5 km	4.1 – 13 km
Harbour Porpoise	13 km	4.1 – 22 km
White-Beaked Dolphin	10 km	4.1 – 16 km
Harbour Seal /Grey Seal	11 km	4.1 – 16 km

Table 16 Summary of the estimated behavioural impact ranges for piling an 8.5m diameter pile at wind wind turbine position 11 using the dB_{ht} impact criteria

Species	90 dB_{ht} Range	
	Mean	Range of values
Bottlenose Dolphin / Risso's Dolphin	9.2 km	3.8 – 13 km
Harbour Porpoise	13 km	3.8 – 21 km
White-Beaked Dolphin	10 km	3.8 – 16 km
Harbour Seal /Grey Seal	10 km	3.8 – 16 km

These results are also presented graphically as contour plots in Figure 13, with each group of images showing the 90 and 75 dB_{ht} impact ranges for each marine species of interest. The 75 dB_{ht} level is a lower behavioural avoidance level, although the effect will probably be limited in duration by habituation. In general, the 90 dB_{ht} criteria level is thought to represent the most useful measure of behavioural disturbance in this case. It can be seen from these figures that the maximum impact ranges stretch out to the east and north east of the proposed EOWDC into the deeper water of the North Sea, where, in some places, water depths are in excess of 100 m LAT. The data indicate that, in nearly all cases, the minimum 90 dB_{ht} contours are the same for each pile; this is due to sound levels being above 90 dB_{ht} for these species at the Scottish coastline. The difference between the impact ranges at the four wind turbine sites is similar. The largest impact ranges are estimated for wind turbines 7 and 11; this is due to being situated on the east boundary of the proposed EOWDC, which is closer to the deep water of the North Sea.

Figure 13 Contour plots showing the estimate 90 and 75 dB_{ht} peak impact ranges for bottlenose / risso's dolphins, harbour porpoise, white beaked dolphin and harbour / grey seals during the installation of an 8.5 m diameter pile (Subacoustech, 2011)



3.1.2.3 Assessment of Behavioural Impacts Using Southall et al., 2007

The assessment of behavioural disturbance also applied the Southall *et al*., (2007) criteria, where the onset of a behavioural response has been proposed as the sound exposure level capable of causing a Temporary Threshold Shift (TTS) in the hearing ability of marine mammals. The criteria associated to be capable of causing a TTS are shown in Table 17 (Southall *et al*., 2007).

Table 17 Proposed behavioural response criteria in terms of single pulses for various marine mammal hearing groups (including low, mid and high frequency cetaceans and seals in water)

Marine mammal group	Sound type
	Single pulses & Multiple pulses
Low Frequency Cetaceans	
Sound Exposure Level	183 dB re 1 µPa^2/s (M_{lf*})
Mid Frequency Cetaceans	
Sound Exposure Level	183 dB re 1 µPa^2/s (M_{mf*})
High Frequency Cetaceans	
Sound Exposure Level	183 dB re 1 µPa^2/s (M_{hf*})
Seals (in water)	
Sound Exposure Level	171 dB re 1 µPa^2/s (M_{pw*})

(M_{lf} = M weighted low frequency M_{mf}= M weighted medium frequency / M_{hf}= M weighted high frequency M_{pf})

The Southall *et al*., (2007) criteria specify that behavioural avoidance is anticipated to occur at a frequency weighted (M- weighted) sound exposure level of 183 dB re.1 µ Pa^2/s (referenced to 1 micro Pascal squared seconds). The sound pressure levels modelled during the piling operation were weighted accordingly and the anticipated maximum impact ranges were determined. Table 18 – Table 21 show summaries of the single pulse behavioural impact ranges predicted. It can be seen that the largest impact ranges are predicted for the seals with behavioural avoidance predicted out to a range of 1.6 km. The three cetacean groups predict lower single pulse behavioural impact ranges, ranging from 280 m, for low frequency cetaceans, to 100 m, for high frequency cetaceans.

Due to these SEL levels predicting relatively low impact ranges, no maximum and minimum ranges have been included as, at these close ranges, changes in bathymetry do not affect the attenuation of sound significantly, resulting in relatively uniform results.

Table 18 Summary of ranges out to which a behavioural avoidance reaction in cetaceans in the low frequency hearing group may occur using the Southall *et al*., (2007) criteria

Low Frequency Cetaceans	Behavioural Avoidance Range 183 dB re. 1 µPa^2/s (M_{lf})
Wind turbine 1	270 m
Wind turbine 3	260 m
Wind turbine 7	280 m
Wind turbine 11	280 m

Table 19 Summary of ranges out to which a behavioural avoidance reaction in cetaceans in the mid frequency hearing group may occur using the Southall *et al.*, (2007) criteria

Mid Frequency Cetaceans	Behavioural Avoidance Range 183 dB re. 1 µPa^2/s (M_{mf})
Wind turbine 1	120 m
Wind turbine 3	110 m
Wind turbine 7	120 m
Wind turbine 11	120 m

Table 20 Summary of ranges out to which a behavioural avoidance reaction in cetaceans in the high frequency hearing group may occur using the Southall *et al.*, (2007) criteria

High Frequency Cetaceans	Behavioural Avoidance Range 183 dB re. 1 µPa^2/s (M_{hf})
Wind turbine 1	100 m
Wind turbine 3	100 m
Wind turbine 7	100 m
Wind turbine 11	100 m

Table 21 Summary of ranges out to which a behavioural avoidance reaction in seals (in water) may occur using the Southall *et al.*, (2007) criteria

Seals in water	Behavioural Avoidance Range 183 dB re. 1 µPa^2/s (M_{pw})
Wind turbine 1	1.6 km
Wind turbine 3	1.5 km
Wind turbine 7	1.6 km
Wind turbine 11	1.6 km

3.1.2.4 Summary of Behavioural Impacts and Comparison between dBht and Southall et al., (2007) approach

Table 22 presents a comparison between the mean predicted dB_{ht} behavioural avoidance impact ranges and the mean M-weighted SEL behavioural avoidance impact ranges for the equivalent marine mammal groups for modelling undertaken for wind turbine position 1.

Again it can be seen that the impact ranges for dB_{ht} differ substantially from those predicted using the M-weighted SEL criteria. The ranges using the M-weighted SEL criteria are thought to be highly optimistic, and are in conflict with the limited amount of published information currently available. For instance, harbour porpoise have been found to avoid an area around similar pile driving operations out to a distance of 15 km (Tougaard, *et al.*, 2006). The most conservative (precautionary) estimates of the extent of potential disturbance have been highlighted in bold (Table 22).

Table 22 Summary of impact ranges comparing the single pulse behavioural avoidance ranges predicted using the dB_{ht} criteria (Nedwell *et al.*, 2007) and the M-weighted SEL approach (Southall *et al.*, 2007) (using wind turbine position 1 for illustration)

dB_{ht} (Nedwell *et al*, 2007)		M-weighted SELs (Southall *et al*, 2007)	
Species	**Mean behavioural avoidance range (90 dB_{ht})**	**Equivalent M-weighting group**	**Mean behavioural avoidance range**
Bottlenose Dolphin	**8.5 km**	Mid Frequency Cetacean	120 m
Harbour Porpoise	**12 km**	High Frequency Cetacean	100 m
Harbour Seal	**9.6 km**	Pinnipeds (in water)	1.6 km

The behavioural effects are only expected to occur during the piling activities and as such as limited to a maximum time period of 24 hours per pile, although it is expected to take considerably less time than this. The piling of jacket structures is expected to require piles with smaller diameters and will take less time to install, although there will be a greater number of piles per platform. Any behavioural effects that occur to the marine mammals are expected to be reversible, in that their behaviour will no longer be changed when the piling activity has ceased.

The range at which potential adverse behavioural responses is considerable being upto 22 km for harbour porpoise and 16 km for common and grey seals. For harbour porpoises the results of post-monitoring studies suggest that after piling stops the animals have been found to return to the area within a few hours. Therefore, behavioural disturbance, which could lead to displacement of marine mammals from the piling activities, is only expected to occur for the duration of piling activities.

The closest seal haul out location identified from SMRU aerial surveys was 7.9 km away (SMRU, 2007), however, harbour seals are also known to occasionally haul out on the sand banks at the Bridge of Don. Both locations are within the radius of potential behavioural displacement. If piling occurs when seals are hauled out no impacts would be expected. Sound impacts would only occur once the animal returns to the water if piling is ongoing. In shallow waters however, the levels of sound an animal receives decreases rapidly due to the greater transmission loss associated with shallower waters. The haul out locations of seals could be affected by the piling operations, which could cause the temporarily displacement of seals from such areas, the significance of this is considered to be moderate.

Aberdeen Bay is recognised as being important for bottlenose dolphins, although there remains some uncertainty as to how the area is used throughout the year by the Moray Firth population of dolphins. The potential exclusion of bottlenose dolphins through behavioural displacement for the duration of the piling activity and out to an extent of 16 km has been assessed as being of high magnitude, and therefore of potentially of major significance to the bottlenose dolphin. As bottlenose dolphins are present along the east coast of Scotland, it has been predicted that the temporary displacement of animals from the Aberdeen Bay area will be mitigated by animals moving into other areas within their natural range, this is a hypothetical assessment and is based on the available habitat range for bottlenose dolphins being extensive covering the coastal waters along the Scottish east coast.

For the other species of cetacean present in Aberdeen Bay they are not restricted to coastal areas and are present throughout a far wider area. Aberdeen Bay has not been recognised as being of particular importance for breeding or calving purposes for other cetacean species, the possible exception in that shallower coastal water of the east coast of Scotland have been speculated to have a role in breeding or calving for the white beaked dolphin during the summer period.

If piling occurs during summer months (July/August) the significance of the behavioural disturbance is likely to be major for the white beaked dolphins, but will still be of moderate impact for all other cetacean species with the exception of the bottlenose dolphin (major). Any temporary exclusion of the cetacean species from Aberdeen Bay is considered to be of minor significance, given that there is likely to be adequate areas for foraging relatively nearby.

The vessels used in the construction of Aberdeen Bay may locally increase the ambient sound levels and as such may temporarily contribute to the displacement marine mammal from the vicinity of construction activities, the significance of this local displacement of marine mammals is negligible.

3.1.2.5 Mitigation

No further mitigation measures above and beyond the MMPP are going to be put in place.

3.1.2.6 Residual Impacts

Upon cessation of piling marine mammals that have been exposed to sound levels capable of inducing behavioural effects (such as swimming away from the area of elevated underwater sound) are expected to return to the abundance and densities levels that are consistent with their redistribution not being significantly changed from levels prior to construction activities. Aberdeen Bay has had a number of notable construction activities in the past including beach protection works and harbour modifications all of which have not appeared to have any lasting impact upon the use of the area by marine mammals. Assuming that marine mammals return to the area after the construction activities have finished there are not anticipated to be any residual impacts.

3.1.2.7 Cumulative Impacts

The cumulative impacts for behavioural disturbance and displacement of marine mammals are not anticipated to be significant during the construction of the EOWDC as this is expected to be the only renewable energy project in Scottish territorial waters where construction is planned to commence during 2013.

3.1.2.8 In-Combination Impacts

There are no other activities that are planned to occur in the wider area that are expected to cause additional behavioural disturbance and displacement of marine mammals.

3.1.2.9 Monitoring

No further monitoring over and above the MMPP is proposed.

3.1.3 Noise Generated during the Construction of the EOWDC May Cause Interference with use of Sound by Marine Mammals

Worst Case Scenario: Piling of 8.5 m diameter pile at all eleven locations during one phase of installation (sequentially).

3.1.3.1 Potential Impacts

Marine mammals use sound for a variety of purposes including in communication, orientation, predator avoidance and foraging. The range of sounds used by marine mammals is broad, and ranges from the low frequency calls of baleen whales to the ultrasonic clicks of 145 kHz in harbour porpoise (Villadsgaard, *et al*., 2007). Harbour seals communicate using low frequency calls and have a well developed under water hearing system (Kastak and Schusterman 1998). Harbour seal males produce underwater vocalisations during the mating season to attract females or to compete with other males and are known to establish territories in the waters offshore of haul-out sites (Hayes, 2004). The results of the acoustic surveys have demonstrate the use of Aberdeen Bay for foraging activities by the harbour porpoise (echolocation clicks) and vocalisations of other dolphin species.

During the pile driving construction activities there is the potential for the sound to mask any seal vocalisations, potentially out to a distance of 80 km (Thomsen, *et al*., 2006). The spatial scale of the potential masking will be dependent upon prevailing ambient sound levels and 80 km is a theoretical maximum. The actual significance of this potential impact is expected to be low given that there are no notable haul out locations in close proximity to Aberdeen Bay and that any potential masking will be temporary.

Masking of biologically relevant sounds produced by high frequency cetaceans, such as the harbour porpoise, and possibly mid-frequency cetaceans, such as the bottlenose dolphin, is unlikely as the piling pulses have little high frequency energy (Thomsen *et al*., 2006). Pile driving pulses are of short duration, and are therefore may be below the time where full detection of signals is possible in cetaceans (Thomsen *et al*., 2006).

Other forms of construction sounds, such as those associated with vessel activity, are continuous type sounds, as opposed to the short duration impulsive piling sounds, and are therefore likely to be above the timeframe where full detection of the signals is possible by cetaceans, and are therefore expected to be audible. Although the vessel sounds are likely to be audible to marine mammals, they are not considered to be capable of masking the cetacean species that are most commonly present in Aberdeen Bay.

3.1.3.2 Mitigation

No mitigation is required.

3.1.3.3 Residual Impacts

The magnitude of the impact on marine mammal vocalisations is considered to be low for seal and negligible for other cetacean species. The overall significance is considered to be moderate for seals and minor for cetaceans. After completion of the construction works there are not anticipated to be any residual impacts.

3.1.3.4 Cumulative Impacts

The Ocean Laboratory will add cumulatively to the construction sound generated, although this is only expected to represent a minor additional cumulative impact that is expected to occur over a short installation timeframe (that would be equivalent of the installation an additional wind turbine), therefore there are no significant impacts expected upon the use of sound by marine mammals.

3.1.3.5 In-Combination Impacts

Cumulatively, vessel noises are a concern for increasing the ambient underwater sound levels, and have been found to influence the vocalisation behaviours of the cetaceans that generate low frequency calls, such as certain species of baleen whales. The development will increase shipping levels and as such will cumulatively contribute to increased underwater sound levels for the duration of the construction activities. Considering Aberdeen Bay is within a relatively busy shipping area, and as large baleen whales are relatively rare in this area of the North Sea, the local elevation of underwater sound is considered to be of minor to negligible significance.

3.1.3.6 Monitoring

No specific monitoring is required.

3.1.4 Installation of Wind Turbines and Cable will Cause Elevated Suspended Sediment Levels within Aberdeen Bay, Which May Impact upon Marine Mammals

Worst Case Scenario: Piling of 8.5 m diameter pile at all eleven locations during one phase of installation (sequentially) and installation the cable within the proposed corridor.

3.1.4.1 Potential Impacts

The impacts of the construction activities of the EOWDC and cable corridor have been considered within the assessment of coastal processes (see the Coastal Process Assessment, Chapter 8 of the ES). This assessment considered the suspended sediment concentrations that would result from the installation of 11 monopiles and the trenching of the cable within the predicted corridor.

The installation of the monopole wind turbines has been shown to result in the release of silts and fine sands which become suspended following mobilisation by the construction works (ABPmer, 2011). The displaced sediment will not act in the same manner of the surficial sediments which are not as easily suspended. The sediment plume has a wider concentration of 8 mg/l, with maximum concentrations reaching 100 mg/l in local areas. The main area of SSC changes lies between the area of Aberdeen Harbour, and 5 km south of the Ythan estuary.

The modelling indicates that the installation of the cable will result in the release of silts and fine sands which become suspended, this material does undergo deposition on the bed when the tidal flow is insufficient to maintain suspension, it does not remain on the seabed long-term such that it becomes resuspended. The cable lay activities are expected to as a worst case generated locally elevated concentrations of 90 mg/l occurring.

Naturally high suspended sediment concentrations are can be found in Aberdeen Bay (43 mg/l), although the installation of the wind turbines is expected to produce levels in excess of these levels, the source of suspended sediment is temporal and will cease once the construction activities are completed. Also it is highly unlikely that all the foundations will be gravity bases, therefore the magnitude of impacts from suspended sediments is expected to be considerably reduced.

Cetaceans generally have poor vision, the exception being the dolphin species which have well developed eyes for seeing above and below the water. In foraging pinnipeds vision has been suggested to be the predominant source of sensory information (Levenson and Schusterman 1999), but the presence of blind but well nourished seals in the wild have challenged this view, although more recently water turbidity has been proposed to be an important factor in the sensory ecology of pinnipeds ((Newby, *et al*., 1970; Weiffen, *et al*., 1996).

Marine mammals present in Aberdeen Bay are likely to be tolerant of the range of suspended sediment levels that can be present within background levels and would be also expected to be resilient to temporary elevation of suspended sediments that would occur during storms and when the Rivers Dee and Don are in flood. The construction activities will not generate excessively high levels of suspended sediment, and any locally high levels will only be present for a temporary duration, the direct impact on marine mammals is anticipated to be negligible.

3.1.4.2 Mitigation

No mitigation is proposed.

3.1.4.3 Residual Impacts

This impact has been assessed as being of negligible significance and no residual impacts are anticipated.

3.1.4.4 Cumulative Impacts

None anticipated.

3.1.4.5 In-Combination Impacts

None anticipated.

3.1.4.6 Monitoring

No specific monitoring is required

3.1.5 Construction of the EOWDC May Cause Displacement of Prey Species of Marine Mammals

Worst Case Scenario: Piling of 8.5 m diameter pile at all eleven locations during one phase of installation (sequentially).

3.1.5.1 Potential Impacts

Changes to prey species as a result of construction activities could potentially have an indirect impact upon marine mammals present in Aberdeen Bay. The impact assessments of the Marine Ecology (Chapter 8 of the ES), Commercial Fisheries (Chapter 21 of the ES) and Salmon and Sea Trout (Chapter 22 of the ES) have been used to assess potential indirect impacts to marine mammals from changes to prey species.

The principal impact identified was from construction associated noise during the installation of the monopiles, this has been assessed as capable of causing displacement of fish species. The magnitude of the displacement is dependent upon the hearing sensitivity of the fish species, with the most sensitive fish species, such as the herring, potentially being displaced as far as 47 km from the piling location

(Subacoustech, 2011). The range of noise induced behavioural displacement for other species of fish which have reduced hearing sensitivity is considerably reduced.

Marine mammals are highly mobile and are expected to follow their prey should they be displaced from the area during construction activities. Piling will be infrequent and temporary so that any disturbance to prey species will be intermittent and not consecutive so any foraging impacts are unlikely to be of sufficient magnitude or duration to adversely affect any life history traits of marine mammals. The marine mammals present in Aberdeen have been known to feed on varied prey species and should be adaptable should one of the more sensitive species to sound be temporarily displaced from the local area.

3.1.5.2 Mitigation

Although the mitigation measures were principally designed for marine mammals, measures such as the soft-start may minimise the risk of causing any physical injury to prey species, as they may move away from the area before any physical impacts are caused.

3.1.5.3 Residual Impacts

This magnitude of the impact upon marine mammals is considered to be negligible, the significance of the impact is considered to be minor.

3.1.5.4 Cumulative Impacts

The construction of the Ocean Laboratory is another aspect that could cumulatively add to the disturbance of marine life and prey species of marine mammals. The associated disturbances that would result from the installation of one additional structure are not considered to result in any significant adverse impacts upon marine mammals.

3.1.5.5 In-Combination Impacts

None anticipated.

3.1.5.6 Monitoring

No specific monitoring is required

3.1.6 Increased Vessel Activity at the Proposed EOWDC May Disturb Marine Mammals

Worst Case Scenario: Installation of 10 MW wind turbines with gravity based foundations.

3.1.6.1 Potential Impacts

The exact vessels requirements have yet to be finalised for each of the development scenarios. It is expected that the required vessels for the wind turbines are a jack-up installation vessel and a feeder barge to transport the wind turbine components to the jack-up vessel. The gravity based structure is considered the worst case foundation structure, as this may require a marginally greater number of vessels (tugs) to float the structure to the location and 2-4 transfer vessels to be used daily in the construction period. Other vessels that will be used in the construction period will include a cable lay vessel and potentially a dive support vessel for rock placement.

During the construction period it is expected that some construction vessels will be undergoing daily movements to and from Aberdeen Harbour, however, at this stage in the project the locations where construction materials will be stored has not yet been finalised as such it is not possible to specify precise details regarding movements of all construction vessels.

Seals have inquisitive behaviour which makes them susceptible to approaching vessels, especially those that are associated with a potential food such as fishing vessels. Certain cetaceans, such as bottlenose dolphins, can be temporarily attracted to moving vessels and bow-ride, whereas other species such as the harbour porpoise appear to exhibit avoidance behaviour and swim away from vessels.

Bottlenose dolphins are often sighted in the middle of the harbour mouth, in the centre of the shipping channel leaving Aberdeen harbour. This species appears to tolerate high levels of daily shipping activity including the movement of large shipping vessels to and from the harbour.

Increased shipping levels could be considered to increase the risk of collisions with marine mammals. Construction vessels will be transiting at slow speeds within Aberdeen Bay and are typically slow moving and generate low frequencies. It is considered that any marine mammals will be able to avoid approaching vessels. There have never been any reports of ship strikes from stranding records along the Grampian coast, which suggests the magnitude of the effect to marine mammals is negligible.

3.1.6.2 Mitigation

All vessels that access the EOWDC site will be instructed to keep within the existing shipping lanes as far as is reasonably practicable and within the zone designated as the wider working area.

3.1.6.3 Residual Impacts

The magnitude of the impact on marine mammals is assessed as being negligible, the significance of this impact is assessed as being minor.

3.1.6.4 Cumulative Impacts

The are not anticipated be any novel types of vessels required to install the Ocean Laboratory that are not already considered to be required as part of the installation of the foundations and turbines (eg heavy lift vessels, barges etc). It is only the duration that vessels are present within Aberdeen Bay that will change during the construction period. The expected installation duration of the Ocean Laboratory has not been finalised, although foundations could be installed in 24 hours, with any topsides potentially taking a similar timeframe. As the Ocean Laboratory will only result in a minor increase in vessel activity, over a short time frame, there are not anticipated to be any adverse cumulative impacts that could disturb marine mammals.

The increase in shipping as part of the construction activities will temporarily, albeit to a small degree, increase the shipping traffic and number of vessels within Aberdeen Bay. The principal effect will be the increase in sound levels and vessel associated disturbance to marine mammals, the overall significance of this is expected to be minor given the volume of shipping traffic that frequents Aberdeen harbour, or transits through the Bay.

3.1.6.5 In-Combination Impacts

None anticipated.

3.1.6.6 Monitoring

No specific monitoring is necessary.

3.2 Operational Phase

3.2.1 The Underwater Sound Generated from the Operational Noise at the EOWDC May Disturb Marine Mammals

Worst Case Scenario: Installation of 10 MW wind turbines with monopile foundations.

3.2.1.1 Potential Impacts

Measurements from operational offshore wind farms suggest that noise generated is generally at low levels and dominated by low frequencies (Nedwell, *et al*., 2007). There have been no measurements from operational wind farms to suggest that source levels ever exceed 145 dB (root mean squared) re.1µPa@1m and such levels are the absolute highest back-calculated source levels recorded (Wahlberg and Westerberg 2005). All measurements of operational wind farm noise have suggested that the received levels (what the animal receives) drop to <120 dB (rms) re.1µPa@1m at 100 m, and that levels propagating in the water column beyond this distance will be low.

Comparing the audiogram data of the harbour porpoise and the bottlenose dolphin with the frequency level of the sound produced from the operational wind farm it becomes highly unlikely that this sound will be audible beyond a distance of 100 m (Madsen, *et al*., 2006). For the low frequency hearing specialists that could be present in Aberdeen such as the harbour seals and baleen whale species, such as the minke whale, Masden *et al*., (2006) estimates that the zone of audibility has a theoretical maximum of >10 km, but the ambient sound levels and propagation losses will reduce this zone considerably. Post monitoring studies at the Barrow Offshore Wind Farm found that the operational noise within the wind farm was detectable out to a distance of 600 m at which it became indistinguishable from ambient noise (BOwind 2008). The known sound levels produced by operating wind farms are low by comparison to modern cargo ships, which have source levels around 175 dB (rms) re.1µPa@1m (NRC 2005).

Marine mammals have been recorded in close proximity to other fixed and noisy features such as drilling rigs and oil production platforms, often using such features for foraging. Therefore, it is not expected that these species will suffer adverse effects from the limited noise and vibration produced by wind turbines. There has been considerable variation in the reported values from operational wind farms, yet all the sound levels reported thus far are relatively low. It is appreciated that no studies have yet attempted to measure marine mammal reactions to operational wind farms and this is a potential area of future research.

Maintenance vessels are only expected to consist of one or two smaller transfer vessels working on at most a daily basis and occasionally larger vessels used for any major repairs. These additional vessel movements would not represent a significant increase on current vessel activity in this area. Aberdeen Bay is already very busy with a wide range of human activities and the small increase in vessel activity associated with the proposed wind farm is unlikely to cause any notable disturbance to marine mammals.

3.2.1.2 Mitigation

No specific mitigation is required.

3.2.1.3 Residual Impacts

The current information suggests that the magnitude of effects upon marine mammals are likely to be negligible, and therefore of minor significance. No residual impacts are expected.

3.2.1.4 Cumulative Impacts

Marine mammals do not appear to be affected by turbine noise generated by wind farms. Therefore the cumulative effects of the EOWDC with the Beatrice demonstrator project is expected to be negligible. Given the potential scale of proposed offshore wind farm developments in Scottish waters with large areas that could be exposed to low levels of operational generated sound the potential for significant cumulative impacts upon marine mammal populations cannot be ruled out, with the significance of such impacts being unknown.

At a local level within Aberdeen Bay the operation of the wind turbines will contribute to increasing the ambient sound levels, the degree of influence will be dependent upon the operational state of the wind turbines (eg wind speed), local weather conditions (eg sea state) and other sources of underwater sound. The operational sound levels are only likely to be detectable from other sound sources within close proximity to the wind turbines and as such are not considered likely to result in any significant in-combination impacts.

3.2.1.5 In-Combination Impacts

None anticipated.

3.2.1.6 Monitoring

No specific monitoring is planned for operational noise.

3.2.2 Loss of Habitat for Marine Mammals within Aberdeen Bay

Worst Case Scenario: Installation of 10 MW wind turbines with gravity based foundations, resulting in a net habitat loss of 0.03 km^2

3.2.2.1 Potential Impacts

Once operational the presence of the wind turbines in the water column removes previously available habitat to marine and could create a barrier to the passage of marine mammals through Aberdeen Bay. The worst case scenario in terms of seabed habitat lost would be through the use of gravity based structures for all eleven wind turbines, this would result in the loss of 0.03 km^2 of seabed habitat (the loss of habitat is a worst case as it takes into potential impacts of scouring). The wind turbines are separated by a considerable distance from each other, this separation distance should not restrict the movement of marine mammals through the EOWDC.

Once operational the wind turbines could act as attractants to colonising benthic fauna, which in turn could attract fish and marine mammal predators. Studies have identified the presence of previously unrecorded species of fish and invertebrates after the development of a wind farm, and it is possible that these in turn could be prey items of marine mammals. The benefit of wind farms to marine mammals is currently uncertain, any positive effects such as providing a limited increase in prey are likely to be only restricted to the immediate vicinity of the EOWDC are as such are expected to have a negligible overall benefit. Further research is needed to justify any claims of positive benefit of renewable energy developments upon marine mammals.

This loss of seabed habitat, in terms of similar available habitat within Aberdeen Bay is of negligible magnitude, with the significance of the impact being minor.

3.2.2.2 Mitigation

No specific mitigation is required.

3.2.2.3 Residual Impacts

The current information suggests that any effects upon marine mammals are likely to be minor, there may be some beneficial effects upon certain marine mammals species, although the overall benefit of this is likely to be negligible.

3.2.2.4 Cumulative Impacts

The Ocean Laboratory will result in the incremental loss of habitat in Aberdeen Bay, the exact dimensions of the structure have yet to be determined so quantification of the loss is not possible, although it is expected to be comparable as a ‘worst case’ to an offshore oil and gas platform.

The only other offshore wind farm that will have been constructed at the proposed development time for the EOWDC will have been the Beatrice demonstrator, which consisted of two steel jackets in the Moray Firth, the cumulative impacts of the loss of habitat associated with the EOWDC, Beatrice demonstrator and Ocean Laboratory are negligible.

The cumulative impacts associated with the loss of habitat from proposed offshore wind farm developments (including territorial waters and Round 3) is not yet known, although it could result in significant impacts to certain populations of marine mammals, the significance of the impact will depend upon the types of foundations used and the overall footprint of the renewable energy developments in relation to available habitat.

The oil and gas industry has historically been the main offshore industry in the North Sea which places infrastructure, in the forms of platforms, wells and pipeline on the seabed thus removing available habitat for marine mammals. Other industries that contribute to the modification of seabed habitat by laying subsea cables are the telecommunications. The density of oil and gas structures and other subsea cables in relation to total seabed is minimal and therefore no in-combination impacts are expected when the cumulative loss and modification of seabed habitat are considered together.

3.2.2.5 In-Combination Impacts

None anticipated.

3.2.2.6 Monitoring

No specific monitoring is planned for the loss of seabed habitat.

3.2.3 The Cables will Generate Electromagnetic Fields (EMF) Which may Disturb Marine Mammals

Worst Case Scenario: 4 shore cables (total distance 26 km) and inter-array cables (total distance 13 km)

3.2.3.1 Potential Impacts

Electromagnetic fields (EMF) are associated with the operational phase once the cables are conducting electricity. Potential impacts to animals include attraction or repulsion from the fields, behavioural interference (navigation) and physiological effects (Chapter 13 Electromagnetic Fields).

Animals that are attracted to EMFs as a result of confusion with the signal with those of prey species may waste energy, whilst repulsion of animals will result in the reduction of available habitat or disrupt the movement or migration of animals throughout Aberdeen Bay. Disruption to the navigation or orientation may arise for those species using the Earth's geomagnetic field to orientate or time behavioural movements in response to daily events such as tidal cycles. Depending on the magnitude and persistence of the magnetic field, the impact could be a relatively minor temporary change in swimming direction or a more serious impact on migration. The potential physiological effects on marine organisms may include impacts on cell development. There is a lack of targeted research into the potential effects of EMFs generated from offshore wind farms so impacts remain hypothetical.

The current design is planned to use a maximum of 4 shore cables (26 km) and inter-array cables (13 km) that will use an Alternating Current (AC). At this stage in the design process it is not yet known what the power requirements of the cables will be.

There are three components associated with power cables that are elements of EMF. Firstly, there is an electric field, secondly there is a magnetic field outside of the cable and thirdly there is an induced electric field (iE-field). The electric field is of little relevance as the design of the AC cables is shielded by a metallic screen within an industry standard cable this ensures the electric field does is not present beyond the cable.

Magnetic fields from AC power cables rapidly decrease with increasing distance from the cable and within a few metres they are largely undetectable. The magnetic field is proportional to the current, meaning that an increase of the current by five times would lead to an increase of the magnetic field strength by the same.

Cartilaginous fish, which include the elasmobranchs, are the major group of organisms that are known to be electroreceptive. There are no cetacean species which are known to be electroreceptive. Only one semi-aquatic Monotreme (egg laying mammal that is only found in Australia and New Guinea) has been found to use electroreception, which it uses to localise benthic invertebrates (Bullock 1999).

Cetaceans are believed to use weak anomalies in the geomagnetic field as cues for orientation and navigation, this hypothesis was tested by analysing the magnetic fields data of the United States Continental Shelf with cetacean stranding data. The results demonstrate a relationship between cetaceans stranding positions and the geomagnetic field along the U.S Atlantic continental margin (Kirschvink *et al*., 1986).

Marine mammals in Aberdeen Bay in the vicinity of the proposed EOWDC are thought to be able to detect magnetic fields and are also likely to use the Earth's magnetic field for the purposes of orientation and navigation. The magnetic field produced by the EOWDC could possibly result in the disruption of orientation and navigational behaviours. It is not known if the EMF would result in attraction or navigation to marine mammals, or cause other forms of behavioural responses.

The available information on potential impacts from submarine AC cables on magnetoreceptive or electroreceptive species is relatively sparse, with the focus of the studies having been conducted on effects of EMF on migrating eels and elasmobranchs which exhibited behavioural responses to the stimuli. From the monitoring studies of constructed wind farms there is no evidence of any increases or decreases in marine mammal activity that would suggest attraction or avoidance related to magnetic fields. The information on the potential effects of EMF on marine mammals is largely unknown and further research is required to determine the potential risks this may pose to these species. The ecological significance of EMFs is an area of research which requires further study.

3.2.3.2 Mitigation

The electric field will be shielded by an industry standard cable which will stop any electric field being generated beyond the cable. Cable burial increases the distance between any receivers of EMF and the source, but burying the cable only has a minor impact upon the magnetic field as burial of cables to a depth of 5m has essentially the same effect as a cable buried to 1 m.

3.2.3.3 Residual Impacts

Even assuming that marine mammals exhibit some small scale effects, the small areas affected together with the lack of evidence for any significant effects on marine mammals implies that this potential effect is considered to be of minor significance for marine mammals. Further research is needed to fully understand how EMFs are interpreted and used by marine mammals in order to more accurately determine impacts.

3.2.3.4 Cumulative Impacts

The Ocean Laboratory will need to be powered although the electricity generation system has not been selected yet as it will depend upon the requirements of the Ocean Laboratory. A power cable running from the shoreline may be used, and it is initial thought that this will be an AC 11 kV single power line. The magnitude of the EMF effects are likely to be lower than the wind turbine cables, as the strength of EMF fields decreases in lower powered cables, there are not anticipated to be any significant EMF impacts as the result of EMF fields from a power cable to the Ocean Laboratory.

Given the current knowledge of the effects of EMF upon marine mammals it is not expected that there will be any significant cumulative impacts from other constructed renewable energy developments, although it is accepted that further research is required.

The issue of cumulative impacts from power cables may become more of a concern, and the impact of greater significance, with the construction of the proposed wind farms and other forms of renewable energy in UK waters.

There are no known active subsea cables within the Aberdeen Bay area, therefore no cumulative EMF impacts are expected.

3.2.3.5 In-Combination Impacts

None anticipated.

3.2.3.6 Monitoring

No specific monitoring is planned for EMF.

3.3 Decommissioning Phase

3.3.1 Noise Associated with the Decommissioning of the EOWDC May Cause Disturbance to Marine Mammals

Worst Case Scenario: Removal of eleven 10 MW wind turbines, foundations and associated cables and inter-array cables

3.3.1.1 Potential Impacts

The decommissioning plan for the EOWDC has yet to be finalised and as such a detailed impact assessment on this section is not possible, the Description of the Proposed Project provides an outline of the activities that are expected to be associated with the removal of the EOWDC.

The main potential impact to marine mammals is expected to be from the underwater sound and associated disturbance that could arise from decommissioning activities. The activities associated with decommissioning are expected to require similar types of vessel to construction activities including a heavy lift and support vessels. The decommissioning vessels will produce relatively low levels of predominantly low frequency sound throughout during active periods. The impacts from vessels is expected to be temporary and of minor significance.

At the end of the design life the wind turbine foundations will have to be removed from the seabed and if monopiles or steel jackets have been used they will have to be cut. Current non-explosive pile cutting techniques include mechanical and abrasive cutting. Mechanical cutters use either, hydraulically actuated carbide tipped tungsten blades or diamond wire to mill through the inside of piles. Abrasive cutters have mechanisms to direct a water jet containing cutting materials to abrasively wear away steel. In both these techniques sound will be generated by the action of the cutter on the pile and by the machinery which drives the cutter. This sound may radiate into the water directly through the pile via a waterborne path or via the substrate by a ground borne path.

It would be highly unlikely that explosives will be considered for use on the basis of a risk of their perceived environmental impact, with mechanical cutting being the preferred choice to cut structures below the seabed.

AOWFL are not aware of any measurements of the underwater sound levels produced mechanical or abrasive cutters. The lack of published results makes it difficult to assess the environmental impact of cutting steel foundation structures, it is expected that the peak sound levels will be considerably below those generated from impact pile driving. The duration of cutting steel structures will be over a period of hours, per structure, so any impacts will be temporary.

The magnitude of any impacts upon marine mammals will be dependent upon the type of activities that are planned as part of the decommissioning programme; the selection of the removal technique for the foundation is likely to generate the highest sound levels from all decommissioning activities.

Given the current uncertainties in the type of activities that the decommissioning programme will entail, and the lack of any published studies on measurements of cutting of steel structures the magnitude of effect has been assessed as low/medium, with the overall significance being a moderate to major impact on marine mammals. The final decommissioning plan once submitted will allow for a revaluation of the potential impacts upon marine mammals.

3.3.1.2 Mitigation

The Impact Assessment associated with the decommissioning plan will identify any potential impacts and mitigation according to potential environmental risks. It is expected that any risks to marine mammals from decommissioning activities will be mitigated through the use of appropriate measures, such as the use of marine mammal observers and mitigation zones.

3.3.1.3 Residual Impacts

Providing that the mitigation measures are implemented successfully no residual impacts are envisaged from decommissioning activities.

3.3.1.4 Cumulative Impacts

The sound levels generated by decommissioning activities involving mechanical cutting are unlikely to radiate to other areas proposed for renewable energy development. Cumulative decommissioning impacts are only expected to occur if other renewable projects are decommissioning simultaneously to the EOWDC. Consideration will be given to any other renewable energy developments which may be embarking on decommissioning activities within a similar timeframe to the EOWDC, although at this stage there are no significant cumulative decommissioning impacts envisaged.

3.3.1.5 In-Combination Impacts

No in-combination impacts are anticipated from decommissioning activities.

3.3.1.6 Monitoring

Mitigation measures are planned to help ensure that the decommissioning programme will not have a significant impact on the environment. The exact detail of the mitigation and monitoring will be decided during the impact assessment associated with the formulation of the decommissioning plan. During the decommissioning works monitoring of activities will be in place to minimise any impacts that have been identified.

3.4 Summary of Mitigation and Monitoring

The MMPP will specify the procedures to be put in place to minimise the risk of causing adverse impacts to marine mammals. One of the key aspects of the MMPP will be outlining the mitigation measures that are planned to be used in the event of piling, these are:

- Use of trained and experienced Marine Mammal Observers (having undertaken a JNCC recognised course);
- Pre-piling search for marine mammals prior to piling monitoring a suitable sized exclusion zone;
- Use of Passive Acoustic Monitoring (PAM) system monitored by experienced PAM operatives; and
- Soft-start (gradual ramp up) of pile driver.
- Consideration of the use of Acoustic Mitigation Devices; if used they will be subject to stringent operating procedures.
- AOWFL are open to incorporating the latest advice on the mitigation procedures used as part of the development of the EOWDC. The final Marine Mammal Protection Plan (MMPP) will be agreed following advice and consultation with SNH and Marine Scotland.

The disturbance of marine mammals by construction vessels will be controlled and monitored by stipulating working areas.

Throughout the construction of the EOWDC there will be a programme of boat surveys that will be simultaneously collecting data on the distribution and abundance of marine mammals using a combination of visual and towed acoustic techniques. In addition, there will be a series of eleven C-Pods (acoustic hydrophones) that will be permanently moored within Aberdeen Bay. The analysis of these data sources will enable an assessment of the actual impacts of construction activities in relation to the project impacts identified during the impact assessment.

During the decommissioning works monitoring of activities will be in place to minimise any impacts that have been identified, with the exact detail of monitoring programmes having yet to be determined.

Table 23 Summary of Impact Assessment

Impact	Environ-mental effect	Probability of effect occurring	Magnitude	Duration	Spatial extent	Significance level*	Mitigation	Residual impacts	Monitoring
Construction									
Sound	Physiological damage (death) marine mammals	Negligible	High	Temporary	Site specific 3 m from piling	Major	Marine Mammal Protection Plan (MMPP) Including piling mitigation measures; soft –start Marine Mammal Observers, Passive Acoustic Monitoring (PAM).	None	MMPP
	Physiological damage (non-auditory) injury	Very Low			Local (injury possible to 60 m and cumulative dosage impacts upto 3.6 km)				
	Physiological damage (auditory damage) to marine mammals	Very Low	High	Temporary	Local (species specific ranges)	Major	MMPP	None	MMPP
	Behavioural disturbance and displacement	High*(seasonally variable for white beaked dolphins)	High (bottlenose dolphins, White beaked dolphins	Temporary	Regional	Major (piling sound)	MMPP	None	MMPP

			Low (other species marine mammals)			Minor (piling and construction sound)			
Sound (piling)	Interference of sound produced by seals	Low	Low / Negligible	Temporary	Local	Moderate / Minor	MMPP	None	None
	Interference of sound produced by cetaceans	Very low	Negligible	Temporary	Local	Minor	MMPP	None	None
Sound (all other construction sounds)	Interference sound marine produced by mammals	Very low	Negligible	Temporary	Local	Minor	MMPP	None	None
Suspended sediment levels	Impact to marine mammals (foraging etc)	Negligible	Negligible	Temporary	Local	Minor	None	None	None
Disturbance to prey species	In-direct impact upon marine mammals	Low	Low	Temporary	Regional	Moderate	None	None	None
Construction vessels and infrastructure	Disturbance to marine mammals	Negligible	Negligible	Temporary	Local	Minor	MMPP	None	MMPP

Operation									
Operational noise wind turbines	Disturbance to cetaceans	Low	Negligible	Long term	Site specific	Minor	None	None	None
	Disturbance to seals and baleen whales	Medium	Low	Long term	Local	Moderate	None	None	None
Maintenance vessels	Disturbance marine mammals	Negligible	Negligible	Long term	Local	Minor	None	None	None
Wind turbine foundations	Habitat loss	High	Low	Long term	Local	Moderate	None	None	None
Electromagnetic Fields	Disturbance to marine mammals	Negligible	Negligible	Long term	Local	Minor	None	None	None
Decommissioning									
Cutting of foundations	Disturbance to marine mammals	Low / Medium	Moderate	Temporary	Local	Moderate / Major	Decommissioning Plan recommended mitigation	None	None

*All marine mammal species are protected species as such their sensitivity within the impact assessment, is considered to be 'Very high', therefore even when the magnitude of effect has been assessed as being of negligible significance this still results in a 'minor' significant impact.

3.5 SUMMARY

The impact assessment has considered the risks and impacts to marine mammals from the construction, operation and decommissioning of the EOWDC.

The significance of potentially killing a marine mammal during the piling of the EOWDC was assessed as being of major significance, however, with the successful adoption of the mitigation measures for piling, there are not anticipated to be any residual risks given that a marine mammal would have to be present in such close proximity to the pile driver (3 m) to be at any risk. It is considered the risk of marine mammals receiving sound levels capable of causing their death appears to be remote.

Other forms of physical injury (non-auditory) are estimated to occur out to a greater range (60 m), and the risk of piling causing other forms of physical impacts cannot be ruled out, and has been assessed as being of major significance for all marine mammal species. The natural curiosity of seals may increase the risk of exposing both grey and common seals to sound levels capable of causing adverse physical effects.

The cumulative noise dose modelling indicate that unless a cetacean is within the immediate vicinity of piling operations (<1.35 km) or a seal is situated within 3.6 km, the only possibility for an auditory injury to occur is during the initial piling period. It is expected that the perceived loudness of the piling activity will cause the marine mammal to exhibit an aversive behavioural reaction, with the animal moving from the area before the onset of any auditory injury can occur.

The marine mammals which are most likely to be exposed are the more commonly sighted species within Aberdeen Bay, with the harbour porpoise, bottlenose dolphins and grey and common seals being the species most at risk from physical impacts. Given that the relatively small Moray Firth bottlenose dolphin population has been increasing its range expansion in a southerly direction, and that Aberdeen Bay frequently has bottlenose dolphins, especially during the winter and spring months, the potential impact both to the individual and population is considered to be of high magnitude and potentially of major significance. It should be considered the majority of bottlenose dolphins sightings have been observed frequenting the harbour mouth area and that the mitigation measures mentioned below they should be sufficient to ensure that no bottlenose dolphins are situated within 820 m prior to piling activities, if such measures are put in place the anticipated magnitude of the effects is expected to be negligible and thus be of minor significance to the bottlenose dolphin populations.

The range at which potential adverse behavioural responses is considerable being upto 22 km for harbour porpoise and 16 km for common and grey seals. For harbour porpoises the results of post-monitoring studies suggest that after piling stops the animals have been found to return to the area within a few hours. The haul out locations of seals could be affected by the piling operations, which could cause the temporarily displacement of seals from such areas. Therefore, behavioural disturbance, which would lead to displacement of marine mammals from the piling activities, is only expected to occur for the duration of piling activities.

The potential exclusion of bottlenose dolphins through behavioural displacement for the duration of the piling activity and out to an extent of 16 km has been assessed as being of high magnitude, and therefore of potentially of major significance to the bottlenose dolphin. As bottlenose dolphins are present along the east coast of Scotland, it has been predicted that the temporary displacement of animals from the Aberdeen Bay area will be mitigated by animals moving into other areas within their natural range, this is a hypothetical assessment and is based on the available habitat range for bottlenose dolphins being extensive covering the coastal waters along the Scottish east coast.

For the other species of cetacean present in Aberdeen Bay they are not restricted to coastal areas and are present throughout a far wider area. Aberdeen Bay has not been recognised as being of particular importance for breeding or calving purposes for other cetacean species, the possible exception in that shallower coastal water of the east coast of Scotland have been speculated to have a role in breeding or calving for the white beaked dolphin during the summer period.

If piling occurs during summer months (July/August) the significance of the behavioural disturbance could be major for the white beaked dolphins, but of minor significance impact for all other cetacean species with the exception of the bottlenose dolphin (major). Any temporary exclusion of the cetacean species (except bottlenose from Aberdeen Bay is considered to be of moderate significance, given that there is likely to be adequate areas for foraging relatively nearby.

The vessels used in the construction of Aberdeen Bay may locally increase the ambient sound levels and cause disturbance and may temporarily contribute to the displacement marine mammal from the vicinity of construction activities, the significance of this local displacement of marine mammals is minor.

During the pile driving construction activities there is the potential for the sound to mask any seal vocalisations, potentially out to a distance of 80 km (Thomsen, *et al*., 2006). The spatial scale of the potential masking will be dependent upon prevailing ambient sound levels and 80 km is a theoretical maximum. The actual significance of this potential impact is expected to be low given that there are no notable haul out locations in close proximity to Aberdeen Bay and that any potential masking will be temporary.

Masking of biologically relevant sounds produced by high frequency cetaceans, such as the harbour porpoise, and possibly mid-frequency cetaceans, such as the bottlenose dolphin, is unlikely as the piling pulses have little high frequency energy (Thomsen *et al*., 2006). Pile driving pulses are of short duration, and are therefore may be below the time where full detection of signals is possible in cetaceans (Thomsen *et al*., 2006). The magnitude of the impact on marine mammal vocalisations is considered to be low for seal and negligible for other cetacean species. The overall significance is considered to be moderate for seals and minor for cetaceans. After completion of the construction works there are not anticipated to be any residual impacts.

Vessel sounds are likely to be audible to marine mammals, they are not considered to be capable of permanently masking the sounds produced by cetacean species that are most commonly present in Aberdeen Bay.

No impacts to marine mammals are anticipated from an increase in suspended sediments levels as the increases are still within the ranges they are expected to be tolerant of.

Marine mammals are highly mobile and are expected to follow their prey should they be displaced from the area during construction activities. Piling will be infrequent and temporary so that any disturbance to prey species will be intermittent and not consecutive so any foraging impacts are unlikely to be of sufficient magnitude or duration to adversely affect any life history traits of marine mammals. The marine mammals present in Aberdeen have been known to feed on varied prey species and should be adaptable if one of the more sensitive species to sound is temporarily displaced from the local area.

Increased shipping levels could be considered to increase the risk of collisions with marine mammals. Construction vessels will be transiting at slow speeds within Aberdeen Bay and are typically slow moving and generate low frequencies. It is considered that any marine mammals will be able to avoid approaching vessels. There have never been any reports of ship strikes from stranding records along the Grampian coast, which suggests the magnitude of the effect to marine mammals is negligible.

The noise from the operational wind farm is not considered to be capable of causing disturbance or displacement to marine mammals. There has been considerable variation in the reported underwater noise measurement from operational wind farms, yet all the sound levels reported thus far are relatively low.

Aberdeen Bay is already very busy with a wide range of human activities and the small increase in vessel activity associated with the maintenance of the proposed EOWDC is unlikely to cause any notable increase disturbance to marine mammals.

The worst case scenario in terms of seabed habitat lost would be through the use of gravity based structures for all eleven wind turbines; this would result in the loss of 0.03 km^2 of seabed habitat. The wind turbines are separated by a considerable distance from each other, this separation distance should not restrict the movement of marine mammals through the EOWDC. This loss of seabed habitat, in terms of similar available habitat within Aberdeen Bay is of negligible magnitude, with the significance of the impact being minor.

Given the current uncertainties in the type of activities that the decommissioning programme will entail, and the lack of any published studies on measurements of cutting of steel structures the magnitude of effect has been assessed as low/medium, with the overall significance being a moderate to major impact on marine mammals. The final decommissioning plan once submitted will allow for a revaluation of the potential impacts upon marine mammals.

From the monitoring studies of constructed wind farms there is no evidence of any increases or decreases in marine mammal activity that would suggest attraction or avoidance related to magnetic fields. The information on the potential effects of EMF on marine mammals is largely unknown and further research is required to determine the potential risks this may pose to these species. The ecological significance of EMFs is an area of research which requires further study.

The MMPP will be developed to address and mitigate any of the impacts identified as being of concern to marine mammals. The MMPP will outline the chosen mitigation procedures during any piling operations and construction activities to minimise the risk of impacts to marine mammals, the final MMPP will be developed in consultation with advice from statutory consultees. The programme of boat based and acoustic monitoring using C-Pods will continue throughout the development and construction of the EOWDC to enable any potential impacts upon marine mammals to be identified and recorded.

AOWFL will follow any advice provided by Marine Scotland on the European Protected Species licences to apply for, if these are required.

3.6 Glossary

AOWFL Aberdeen Offshore Wind Farm Limited

AMD Acoustic Mitigation Device

DECC Department Energy and Climate Change

DTI Department of Trade and Industry

EOWDC European Offshore Wind Deployment Centre

EIA Environmental Impact Assessment

EMEC European Marine Energy Centre

EMF Electromagnetic Fields

GOGC Genesis Oil and Gas Consultants

IECS Institute of Estuarine and Coastal Studies

JNCC Joint Nature Conservation Committee

OSPAR The Convention for the Protection of the Marine Environment of the North-East Atlantic

PTS Permanent Threshold Shift

SMRU Sea Mammal Research Unit

SNH Scottish Natural Heritage

TTS Temporary Threshold Shift

3.7 Units

dB decibel

dB_{ht} decibel above hearing threshold

Hz hertz

kilo thousand

m metre

µ micro

Pa Pascal

s second

4. BIBLIOGRAPHY

ABPmer. *European Offshore Wind Deployment Centre: Coastal Process Assessment Report.* ABPmer Ltd, 2011.

AMEC. *Scoping Environmental Impact Assessment Aberdeen Windfarm.* AMEC and AREG, 2005.

AOWFL. *Environmental Impact Assessment Scoping Report European Offshore Windfarm Deployment Centre (EOWDC).* Aberdeen Offshore Windfarm Limited, 2010.

Bailey, H, B Senior, D Simmons, J Rusin, G Picken, and P Thompson. "Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals." *Marine Pollution Bulletin*, 2010: 60: 888-897.

BOwind. *Barrow Offshore Windfarm: Post construction monitoring report, first annual report.* Barrow Offshore Windfarm (BOwind), 2008.

Bullock, T.H. "The future of research on electroreception and electro communication." *The Journal of Experimental Biology*, 1999: 202: 1455-1458.

Coles, R.R.A, G.R Garinther, C.G Rice, and D.C. Hodge. "Hazardous exposure to impulse noise." *Journal of the Acoustical Society of America*, 1968: 43: 336-343.

DEAL. *Digital Energy Atlas and Library.* 6 May 2011. https://www.ukdeal.co.uk/ (accessed May 6, 2011).

DECC. *Decommissioning of offshore renewable energy installations under the Energy Act: Guidance notes for industry. .* Department of Energy and Climate Change (DECC), 2011.

DTI. *Guidance for the offshore windfarm consent process .* Department for Trade and Industry (DTI) and Marine and Consents and Environment Unit (MCEU), 2004.

EMEC and Xodus Aurora. *Consenting, EIA and HRA Guidance for Marine Renewable Energy Developments in Scotland. Part one - marine renewables licensing process.* EMEC and Xodus Aurora, 2010.

GOGC. *Marine Mammal Environmental Baseline for the European Offshore Windfarm Deployment Centre.* Genesis Oil and Gas Consultants, 2011.

Hamernik, R.P, and K.D. Hsueh. "Impulse noise: Some definition, physical acoustics and other considerations." *Journal of the Acoustical Society of America*, 1991: 90(1): 189-196.

Hayes, S.A., Costa, D.P., Harvey, J.T. and Le Boeuf, B.J. 2004. Aquatic mating strategies of the male Pacific harbour seal (*Phoca vitualina richardsi*): Are males defending the hotspot? Marine Mammal Science 20(3): 639-656.

JNCC. *Protection of marine European Protected Species from the offences of injury and disturbance.* Joint Nature Conservation Committee, 2010 draft.

Johnson, C.S. *Sound detection thresholds in marine mammals.* Pages 247-260 in W.N. Tavolga,ed. Marine Bio-acoustics, Vol. 2. Pergamon Press, Oxford, UK, 1967.

Kastak, D, and R.J. Schusterman. "Low-frequency amphibious hearing in pinnipeds: methods, measurements, noise and ecology." *Journal of the Acoustical Society of America*, 1998: 103: 2216-2228.

Kastelein, R.A, L Hoek, N Jennings, C.A.F de Jong, J.M Terhune, and M, Dieleman. *Acoustic Mitigation Devices (AMD's) to deter marine mammals from pile driving areas at sea: audibility and be.* COWRIE Ref: SEAMAMD-09, Technical Report 31st July 2010. , 2010.

Kastelein, R.A, M Hagedoorn, and W.W.L Au. "Audiogram of a harbour porpoise (Phocoena phocoena) measured with narrow-band frequency modulaterd signals." *Journal of the Acoustical Society of America*, 2002: 334-344.

Kastelein, R.A, M Hagedoorn, W.W.L Au, and D. de Haan. "Audiogram of a striped dolphin (Stenella coeruleoalba)." *Journal of the Acoustical Society of America*, 2003: 113, 1130–1137.

Kastelein, R.A, N Jennings, C Verboom, C de Haan, and N. M. Schoonem. "Differences in the response of a striped dolphin (Stenella coeruleoalba) and a harbour porpoise (Phocoena phocoena) to an acoustic alarm." *Marine Environmental Research 61.*, 2006: 363–378.

Kirschvink, J.L, A.E Dizon, and J.A. Westphal. "Evidence from strandings for geomagnetic sensitivity." *Journal of Experimental Biology*, 1986: 120: 1-24.

Levenson, D.H, and R.J. Schusterman. "Dark adaption and visual sensitivitiy in shallow and deep diving pinnipeds." *Marine Mammal Science* (Marine Mammal Science), 1999: 15(4): 1303-1313.

Madsen, P.T, M Wahlberg, Tougaard J, K Lucke, and P Tyac. "Wind wind turbine underwater noise and marine mammals: implications of current knowledge and data needs." *Marine Ecology Progress Series.*, 2006: 309: 279-295.

McDonald, M.A, Hildebrand J.M, and Wiggins S.M. "Increases in deep ocean ambient noise in the Northeast Pacific west of San Nicolas Island, California." *Journal of the Acoustical Society of America*, 2006: 711-718.

Møhl, B. "Auditory sensitivity of the common seal in air and water." *J. Aud. Res.*, 1968: 8; 27-38.

Nachtigall, P.E, T.A Mooney, K.A Taylor, and M.M.L. Yuen. "Hearing and Auditory Evoked Potential Methods Applied to Odontocete Cetaceans ." *Aquatic Mammals, Volume 33, Number 1,* , 2007: 6-13(8).

Nedwell, J.R, A.G Brooker, S.A.H Bryant, and R.J. Barham. *Measurements of Underwater Noise Generated by Acoustic Mitigation Devices.* Subacoustech Report No. E238R0122 to COWRIE. ISBN 978-0-9565843-2-8, 2010.

Nedwell, J.R, S.J Parvin, B Edwards, r Workman, A.G Brooker, and Kynoch J.E. *Measurement and interpretation of underwater noise during construction and operation of offshore windfarms in UK waters.* Report for COWRIE, Subacoustech , 2007.

Newby, T.C, F.M Hart, and R.A. Arnold. "Weight and blindness and of harbour seals." *Journal of Mammology*, 1970: 51(1): p152.

npower renewables. *The North Hoyle Environmental Statement.* npower, 2002.

NRC. *Marine mammal populations and ocean noise, determining when noise causes biologically significant effects.* Washington, DC.: The National Academy Press, 2005.

OSPAR. *Guidance on Environmental Considerations for Offshore Wind Farm Development.* OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic, 2008.

Parks, S.L, and C.W Clark. "Variation in acoustic activity of North Atlantic right whales in three critical habitat areas in 2004." *Journal of the Acoustical Society of America, 117*, 2005: 2469.

Parvin, S.J, J.R Nedwell, and E. Harland. *Lethal and physical injury of marine mammals and requirements for Passive Acoustic Monitoring.* Subacoustech Report, 2007.

Pfander, F, H Bongartz, H Brinkmann, and H. Kietz. "(1980). Danger of auditory impairment from impulse noise: A comparative study of the CHABA damage-risk criteria and those of the Federal Republic of Germany. ." *Journal of the Acoustical Society of America* , 1980: 69: 628-633.

Schlundt, C.E, J.J Finneran, D.A Carder, and S.H. Ridgway. "Temporary shift in masked hearing thresholds of bottlenose dolphins (Tursiops truncates) and white whale (Delphinapterus leucas) after exposure to intense tones." *Journal of the Acoustical Society of America*, 2000: 107(6): 3496-3508.

Smoorenburg, G.F. " Damage risk criteria for impulse noise. ." *In New Perspectives on Noise-induced Hearing Loss, Edited by Hamernik R P, Henderson D and Salvi R (Raven, New York),* , 1982: pp471-490.

SMRU Ltd (2007) Harbour and grey seal haul out survey data for the period 1997 and 2005. Sea Mammal Research Ltd.

SNH. *Marine renewable energy and the natural environment heritage: An overview and policy statement.* Scottish Natural Heritage. Policy statement number 04/01, 2004.

Subacoustech. *Subsea noise modelling in support of the European Offshore Wind Deployment Centre Development. Subacoustech Environmental Report.* Southampton: Subacoustech Environmental Ltd, Claylands Road Bishop's Waltham, 2011.

Technip. *Rochdale Envelope EOWDC.* Technip and Vattenfall, 2011.

Technip. *Rochdale Envelope Requirements for the European Offshore Wind Development Centre .* Technip and Vattenfall, 2011.

Thomsen, F, K Lüdemann, R Kafemann, and W. Piper. *Effects of offshore wind farm noise on marine mammals and fish,.* Newbury, UK: Biola, Hamburg, Germany on behalf of COWRIE Ltd, , 2006.

Tougaard, J, et al. "Harbour porpoise on Horns Reef Effects of the Horns Reef Wind Farm." Final Report to Vattenfall , 2006.

Villadsgaard, A, Wahlberg, M, and J. Tougard. "Echolocation signals of wild harbour porpoise." *Journal of Experimental Biology*, 2007: 210: 56-64.

Wahlberg, M, and H. Westerberg. "Hearing in fish and their reaction to sounds from offshore wind farms." *Marine Ecology Progress Series*, 2005: 288: 295–309.

Weiffen, M, B Möller, B Mauch, and G. Denhârdt. "Effect of water turbidity on the visual acuity of harbour seals (Phoca vitulina)." *Vision research*, 1996: 46: 1777-1788