

Inch Cape Offshore Wind Farm

New Energy for Scotland

Offshore Environmental Statement:
VOLUME 2E
**Appendix 14B: Marine Mammals
Piling Impact Assessment**



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List of Abbreviations and Acronyms

dB	Decibel
dB_{nt} (Species)	Likely loudness of a sound perceived by that species e.g. 90 dB _{nt} (<i>Phoca vitulina</i>)
ES	Environmental Statement
F1A FoF	Noise modelling location 1 (at Firth of Forth Alpha)
F2 FoF	Noise modelling location 2 (at Firth of Forth Bravo)
F3 IC	Noise modelling location 3 (at Inch Cape)
F4 IC	Noise modelling location 4 (at Inch Cape)
F5 NnG	Noise modelling location 5 (at NnG)
F6 NnG	Noise modelling location 6 (at NnG)
FTOWDG	Forth and Tay Offshore Wind Developers Group
FoF	Firth of Forth Phase 1 Offshore Wind Farm
IC	Inch Cape
ICOL	Inch Cape Offshore Limited
IEEM	Institute of Ecology and Environmental Management
INSPIRE	Impulse Noise Sound Propagation and Impact Range Estimator (model developed by Subacoustech Environmental Ltd)
JNCC	Join Nature Conservation Committee
MORL	Moray Offshore Renewables Limited
ML	Most Likely (piling scenario)
MS	Marine Scotland
MSS	Marine Scotland Science
NnG	Near na Gaoithe Offshore Wind Farm (Mainstream Renewable Power site)
OWF	Offshore Wind Farm
PBR	Potential Biological Removal
PTS	Permanent Threshold Shift
SAC	Special Area of Conservation

SAFESIMM	Statistical Algorithms For Estimating the Sonar Influence on Marine Megafauna
SCOS	Special Committee on Seals
SEL	Sound Exposure Level
SMRU	Sea Mammal Research Unit
SNH	Scottish Natural Heritage
WC	Worst Case (piling scenario)

14B Marine Mammals Piling Impact Assessment

14B.1 Introduction

It is generally accepted that the construction activity that generates the highest level of underwater noise is pile driving associated with driven foundations. This process involves driving piles into the sea bed using an impulse pile driving technique for several hours at a time. The level of noise produced is related to the blow energies required to pile the foundation, with the required blow energy dependent upon various factors including: pile design and diameter; seabed characteristics; and water depth (Diederichs *et al.*, 2008). The propagation of noise produced through the water column is also dependent on a number of factors including the depth of the water. The piling process as currently proposed in the Inch Cape Offshore Wind Farm (OWF) Design Envelope is highly likely to produce noise levels which have the potential to cause harm to marine mammals within the vicinity of the pile location (Richardson *et al.*, 1995) if no mitigation is put in place prior to initiation of piling activity.

Marine mammals have very good underwater hearing and as a consequence are sensitive to increased underwater noise (Koschinski *et al.*, 2003, Thomsen *et al.*, 2006, Madsen *et al.*, 2006). Cetaceans rely heavily on sound to feed, navigate and to interact socially. Sound travels much further underwater than in air, resulting in anthropogenic noise potentially affecting marine mammals at relatively large distances from the source.

Marine mammal responses to increased anthropogenic noise have been outlined in Chapter 14 and have not been reiterated here.

Some of these responses can be subtle and difficult to detect, and there are many documented cases of apparent tolerance of anthropogenic noise (for example: Richardson *et al.*, 1995; 1999; Madsen *et al.*, 2002; Croll *et al.*, 2001). Marine mammal responses to piling include behavioural disturbance, auditory injury and potentially physical injury or death at very close ranges. Although the consequences of the more direct impacts (such as physical injury and mortality) are relatively clear, it is more difficult to assess the biological consequences of behavioural responses and auditory injury. Nevertheless, these have the capacity to lead to higher energetic demands on the individual, higher predation risk, or decreased reproduction; potentially impacting both the individual and the population as a whole.

Sounds emitted during piling generally are of a low frequency and although some components from driving impulses can be up to 100 kHz, most energy emitted is below 1000 Hz (Evans, 2008). Research on harbour porpoise and harbour seals carried out in Germany (Thomsen *et al.*, 2006) suggested they may respond to piling noise up to 20 km away, with the potential for masking of communication signals occurring well beyond 80 km. Similar predictions have been reported by a number of other studies in the North and Baltic seas (Tougaard *et al.*, 2003; Tougaard *et al.*, 2005; Madsen *et al.*, 2006; Tougaard *et al.*, 2009). Animals (including fish) close to the source of a high level of noise may also be physically injured (Thomsen *et al.*, 2006; Madsen *et al.*, 2006).

14B.2 Noise Propagation Modelling

Table 14B.1 below summarises the ways in which impacts of underwater noise can be assessed for marine mammal species.

Table 14B.1: Simple Definition of Metrics Used in Noise Propagation Modelling (reproduced from Subacoustech Environmental Ltd (Subacoustech))

Metric	Definition
dB re 1 μ Pa	Un-weighted, peak-to-peak levels of sound energy. This metric has been used to predict radii of potential effects of physical injury and death.
dB _{ht} (<i>Species</i>)	Developed as a means for quantifying the likelihood of behavioural impacts of a sound on a particular species i.e. takes into account species differences in hearing sensitivity at different frequencies (Nedwell <i>et al.</i> , 2007b).
M-weighted Sound Exposure Level (SEL)	Developed as a means of assessing potential for auditory injury. Sound is frequency weighted for four functional groups of marine mammals by effectively removing frequencies outside the hearing ranges of each group i.e. high frequency cetaceans (porpoises), mid frequency cetaceans (dolphins) and low frequency cetaceans (whales) cetaceans and pinnipeds (seals) (based on Southall <i>et al.</i> , 2007).

Southall *et al.* (2007) has proposed five groupings of marine mammal, based on their hearing ability and sensitivity. The marine mammal species that are observed within the Firth of Forth and Tay are set out in Table 14B.2 below, with the exception of pinnipeds listening in air – which we have omitted because potential noise impacts will be restricted to underwater noise (airborne noise is not expected to reach appreciable levels at seal haul out sites).

Table 14B.2: Marine Mammal Hearing Ability and Sensitivity based on Southall *et al.* (2007)

Hearing group	Estimated auditory bandwidth	Species relevant to the Inch Cape Offshore Wind Farm
Pinnipeds listening in water	75 Hz to 75 kHz	Harbour seal Grey seal
High frequency cetaceans	200 Hz to 180 kHz	Harbour porpoise
Mid frequency cetaceans	150 Hz to 160 kHz	Bottlenose dolphin White-beaked dolphin
Low frequency cetaceans	7 Hz to 22 kHz	Minke whale

The likely loudness of a sound perceived by a species (dB_{ht} (*Species*)) metric has been developed as a means of quantifying the potential for a behavioural and physical impact on a species in the underwater environment. For the purposes of this assessment, the dB_{ht} (*Species*) criteria have been used to model the perceived noise level and influence radii for

individual species from piling related noise. 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.

The following criteria which have been provided by Subacoustech (Table 14B.3) have been applied in this assessment for levels of noise likely to cause physical and behavioural effects.

Table 14B.3: Criteria for Assessing Effects on Marine Mammal Receptors (after Nedwell *et al.*, 2007)

Level in dB or dB _{ht} (<i>Species</i>)	Predicted Effect
240 dB re 1 µPa and above	Lethal effects may occur
220 dB re 1 µPa and above	Physical injury may occur
130 dB re 1 µPa and above	Possibility of traumatic hearing damage from a single event
110 dB _{ht} and above	Tolerance limit of species – unbearable loud
90 dB _{ht} and above	Strong avoidance reaction by virtually all individuals
75 dB _{ht} and above	Mild avoidance reaction ¹

The dB re 1 µPa metric relates to the energy of the sound wave while, as described above, the dB_{ht} (*Species*) metric relates to the degree of audibility to each species. For the purposes of this assessment, potential displacement effects have been assessed out to 50 dB_{ht} (species) i.e. out to the equivalent of background noise levels. The assumption is that no animals will be displaced beyond 50 dB_{ht} (species)(Figure 14B.6).

Auditory injury criteria have been proposed by Southall *et al.* (2007) based on M-weighted SELs – see Table 14B.4 below. These have been applied in this assessment.

Table 14B.4: Auditory Injury Criteria based on Southall *et al.* (2007)

Species	SEL level likely to cause PTS onset
Pinnipeds	186 dB
All cetaceans (high, mid and low frequency)	198 dB

For the purposes of this report, noise modelling was carried out by Subacoustech to predict the exposure of marine mammals to piling noise (see Chapter 11: Underwater Noise). dB_{ht} (which have been used to quantify potential behavioural impacts) and SEL (which have been used to quantify potential auditory injury) noise range contours have been modelled. The predicted SELs were modelled assuming a level of noise exposure produced within a 24 hour period, and represent the SEL which has the potential to cause the onset of Permanent Threshold Shift (PTS) in the species group considered.

14B.2.1 Audiograms

An important concept in marine mammal hearing is that of the audiogram, which describes the relationship between frequency and hearing sensitivity. Audiograms generally exhibit a U-shaped pattern with highest sensitivity at the bottom of the curve e.g. Figure 14B.1,

¹ Care should be taken when interpreting the term ‘mild’ in relation to displacement at the 75 dB_{ht} level – Figure 14B.6 shows that approximately 40% of animals are displaced at 75 dB_{ht}.

Figure 14B.2. In general, the region of highest sensitivity tends to reflect the frequencies that each species vocalises at. Baleen whales (which include minke and humpback whales) produce low frequency sounds with few signals extending above 10 kHz, while dolphins and porpoises produce mid and high frequency signal sounds across a very wide frequency, including specialised clicks used for echolocation (Richardson *et al.*, 1995; Southall *et al.*, 2007). Seals communicate below and above water, and are believed to hear best at frequencies of 1-30 kHz (Richardson *et al.*, 1995; Southall *et al.*, 2007). Examples of the hearing range for different marine mammal species can be found in Table 14B.2.

Subacoustech reviewed and reproduced audiograms (Nedwell *et al.*, 2007) for a wide range of mid, high and low frequency cetacean species and seals, and these have been used to predict audibility ranges from construction-related activities.

There are currently no audiograms available for minke whales. In the absence of an empirical audiogram, Moray Offshore Renewables Limited (MORL) commissioned a literature review to obtain a modelled audiogram for a member of the same family (baleen whales) based on inner ear anatomy and vocal range. The humpback audiogram range was identified (Erbe, 2002), and compared to audiograms which Subacoustech hold on file. The range was found to be of a similar shape to the seal composite audiogram (see Figure 14B.1 and Figure 14B.2 below) but of a different sensitivity.

Subacoustech therefore increased the sensitivity of the seal audiogram by 12 decibel (dB) to fall within the two humpback ranges provided by Erbe (2002). This approach has been widely consulted upon and has received a degree of acceptance due to the lack of other data. Therefore, in the absence of better data, this approach has been adopted for minke whale for the purpose of this assessment. Similarly, the bottlenose dolphin audiogram was used as a surrogate for white-beaked dolphin and the harbour seal audiogram was used as a surrogate for grey seal (see Chapter 11: Underwater Noise and associated Appendix 11A for details).

Figure 14B.1: Humpback Whale Audiogram Range and Seal Composite Audiogram Comparison

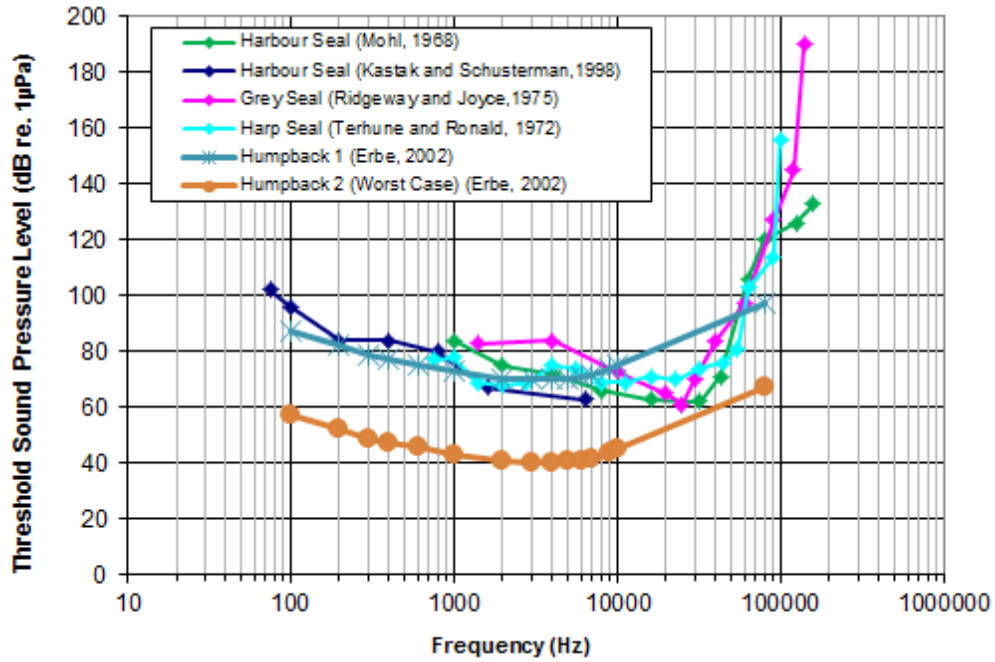
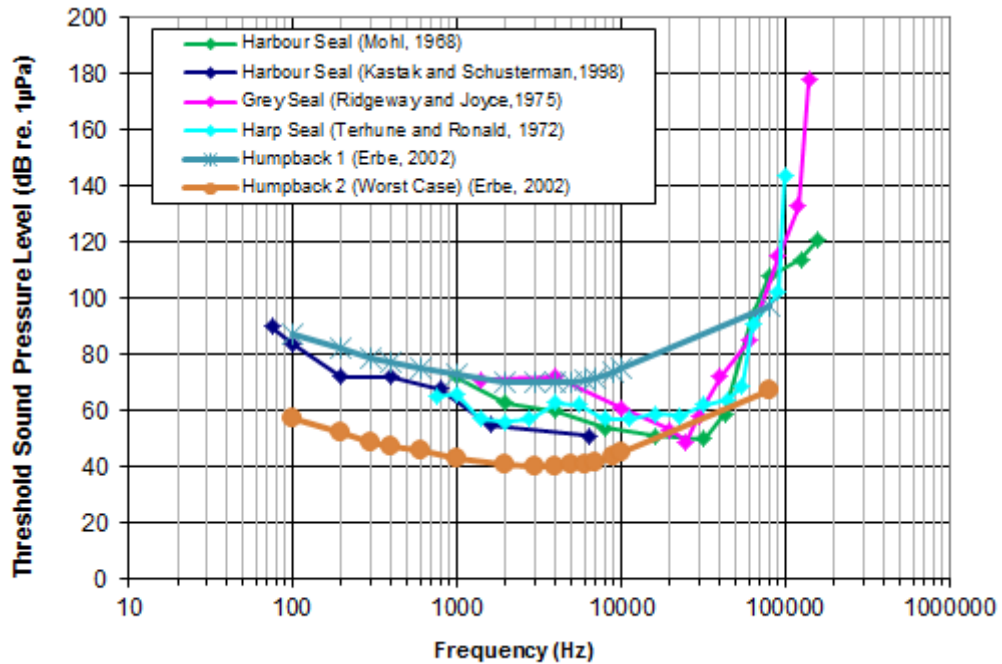


Figure 14B.2: Humpback Whale Audiogram Range and Seal Composite Audiogram Shifted by 12 dB for Comparison



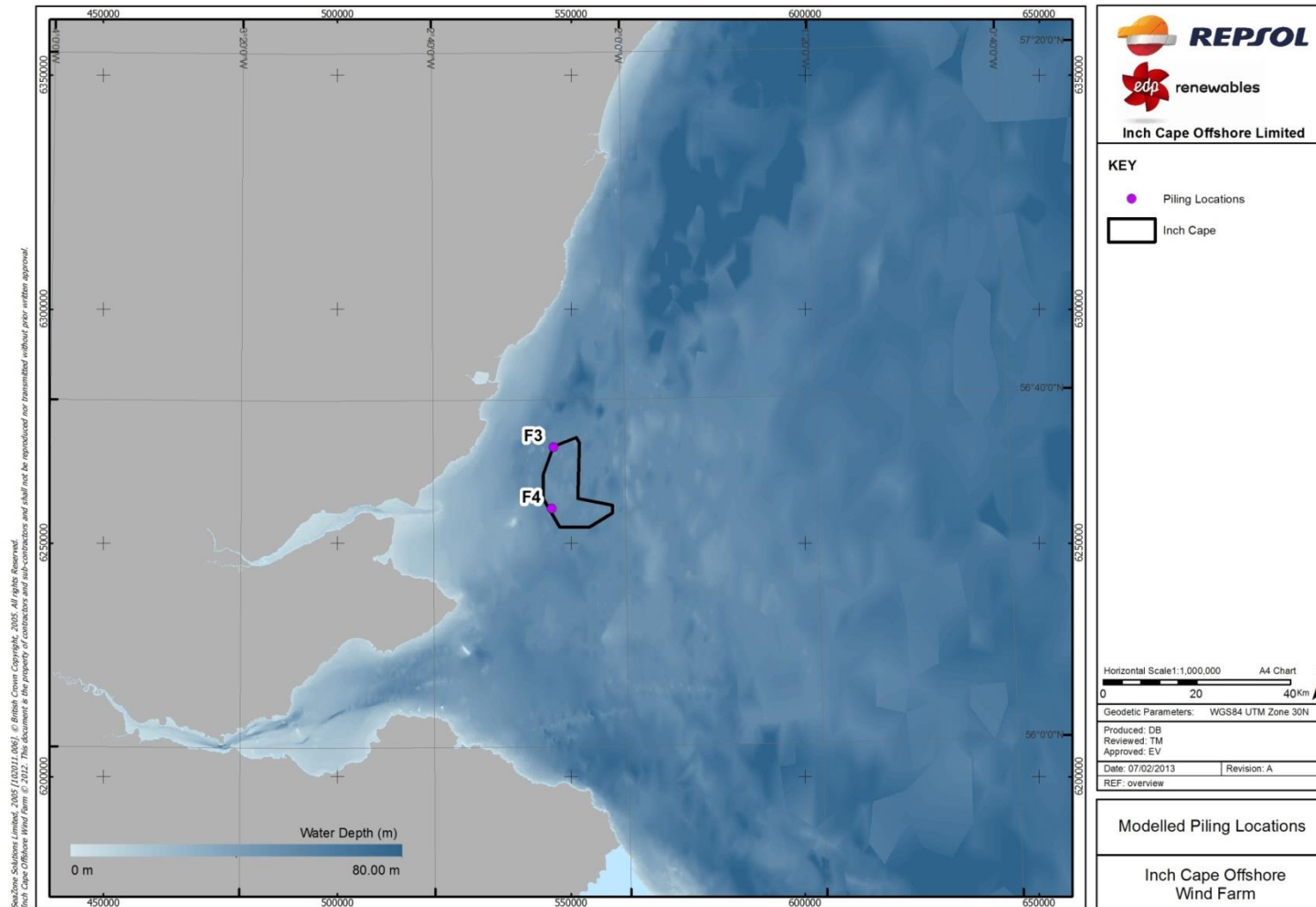
14B.2.2 Noise modelling

Noise modelling (using the Impulse Noise Sound Propagation and Impact Range Estimator (INSPIRE) model run by Subacoustech) was carried out at two different locations within the Inch Cape Development Area – see Figure 14B.3 and Table 14B.5 below. The ‘most sensitive’ location (that closest to areas of greatest animal density) was used for each species. This was location F3 for harbour porpoise, bottlenose dolphin and minke whale and location F4 for white-beaked dolphin, harbour seal and grey seal (Table 14B.5).

Table 14B.5: The ‘Most Sensitive’ Inch Cape Noise Modelling Location for Each Species (Assigned based on Information about their Density Distribution)

Location F3	Location F4
Harbour porpoise	White-beaked dolphin
Bottlenose dolphin	Harbour seal
Minke whale	Grey seal

Figure 14B.3: Noise Modelling Locations at the Inch Cape Development Area



As described in Chapter 11: Underwater Noise (Section 11.3, Design Envelope and Embedded Mitigation), pile drivability assessments which utilised data from site geotechnical and bore hole surveys were undertaken for representative sites within the Inch Cape Development Area. These assessments provided the modelled number and blow energies of drives likely to be required to pile drive 2.438 m diameter pins to the required depth during the installation of turbine foundations at the site. Due to the different ground conditions across the site, two pile drivability assessments were undertaken. The first, representing the most likely (ML) ground conditions to be encountered, estimated that pin piles could be installed in approximately 2.1 hours with a 1200 kJ hammer. The second, representing the worst case (WC) in which harder substrate could be encountered, estimated piling could take up to 4.2 hours using the same sized hammer. The blow energies and duration of the piling activity for these two scenarios are provided below in Table 14B.6.

Table 14B.6: Results of Pile Drivability Assessments for the Most Likely and Worst Case

Scenario	Most Likely		Worst Case	
Pile Diameter (mm)	2438		2438	
Hammer Capacity (kJ)	1200		1200	
Max blow energy (kJ)	1080		1080	
Total Piling Duration (hours per pile)	2.1		4.2	
Ramp-up Details	Time (minutes at % efficiency)	Efficiency (% of max blow energy)	Time (minutes at % efficiency)	Efficiency (% of max blow energy)
	20	15	20	15
	20	40	20	40
	10	60	10	60
	75	90	201	90
Average strike rate during soft start (per s)	0.3		0.3	
Average strike rate (per s)	2		2	
Total number of piles	944		944	

The most likely ground conditions are estimated to represent 70 per cent of the site, with worst case constituting an estimated 30 per cent. The above blow energy profiles have been utilised by Subacoustech Ltd to model predicted underwater noise arising from the pile driving activities associated with up to 213 turbines, three met masts and five offshore substations. Although the piles required for the offshore substations may be larger than those required for the WTGs and met masts (up to 3 m rather than 2.438 m), it is likely that an equivalent size of hammer will be used to install them on site. Because they will be installed during same period as the WTGs and similar blow energies will be required, it is considered that their installation is included within the Design Envelope assessed.

As described above (Table 14B.1), modelling has been undertaken for the following three criteria which have been used to illustrate different biological effects:

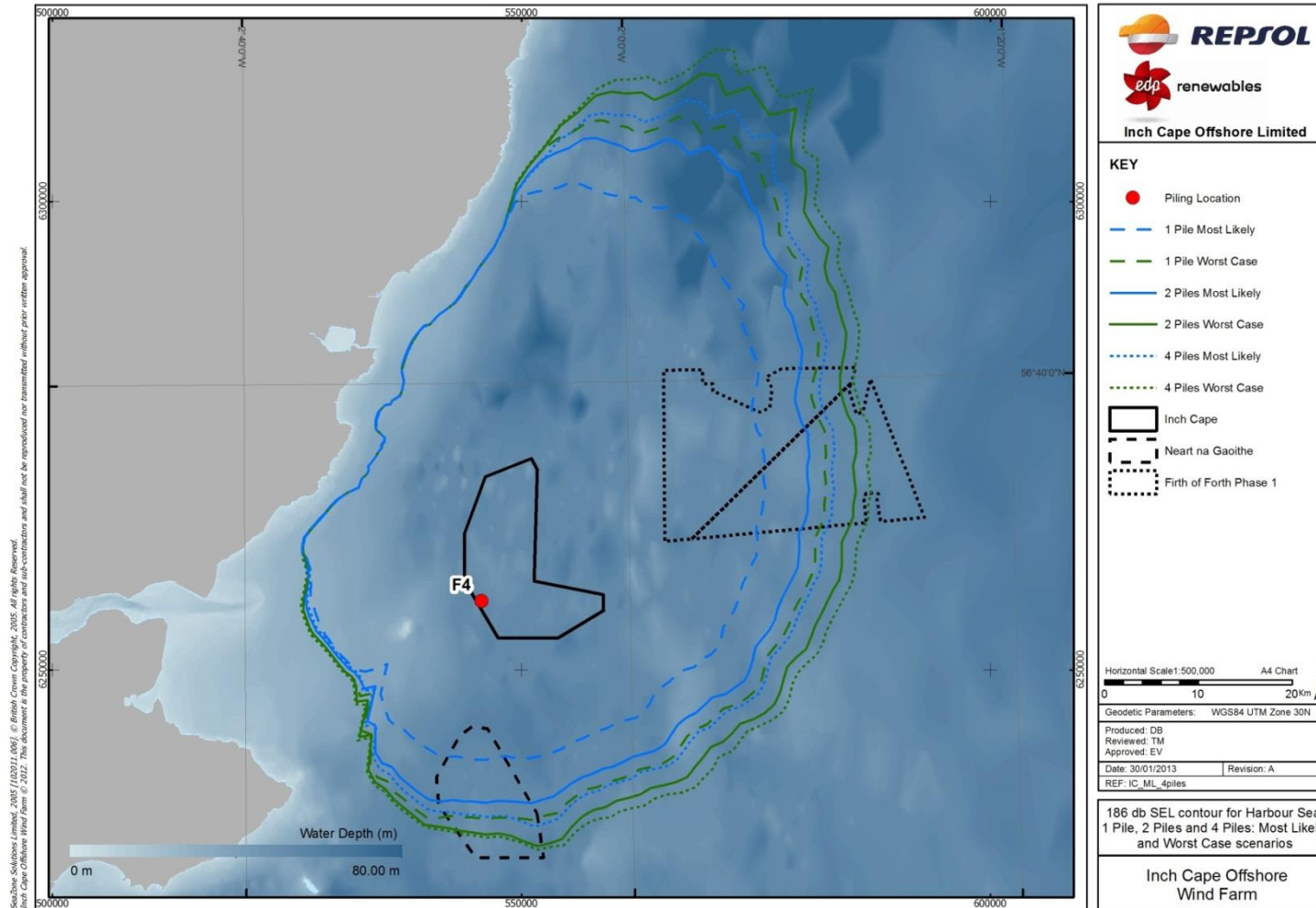
- dB re 1 μ Pa has been used to predict radii of potential effects of physical injury and lethal effects
- dB SEL have been used to quantify potential auditory injury (including PTS onset)
- dB_{ht} (*Species*) have been used to quantify potential behavioural impacts (displacement)

Underwater noise modelling has indicated that during piling operations, physical injury and lethal effects impacts to marine mammals are in the order of 40 and 6 metres respectively from the pile. It is very unlikely that marine mammals will be exposed to noise levels which have the potential to cause lethal effects/physical injury because a mitigation protocol has been developed by the Statutory Nature Conservation Agencies in order to reduce this risk to negligible levels (JNCC, 2010).

While the dB_{ht} (*Species*) criteria represents noise levels that are audible to each marine mammal species and thus reflect an instantaneous noise level, the dB SEL criteria is sensitive to the duration of noise production because it reflects the total sound exposure of the animal as it swims away from the noise source throughout the duration of a pile driving event. The SEL will therefore be sensitive to the increased duration of noise associated with the worst case pile drivability scenario compared to the most likely scenario described in Table 14B.6, and the number of piles installed within a 24 hour period.

Modelling using INSPIRE to predict SELs from pile driving multiple, consecutive pin piles into representative substrate types of the Development Area in one 24 hour period showed that, due to the logarithmic nature of the SEL equation, the majority of the noise exposure for animals that led to modelled onset of PTS occurred during the first piling event. Figure 14B.4 shows the INSPIRE-modelled 186 dB SEL contours for fleeing harbour seals from one, two and four pin piles driven into location F4 at Inch Cape, for both most likely and worst case piling durations.

Figure 14B.4: INSPIRE-Modelled 186 dB SEL Contours for Fleeing Harbour Seals from One, Two and Four Pin Piles Driven into Location F4 at Inch Cape Development Area (for both Most Likely and Worst Case Piling Durations)



Installation of two pin piles per 24 hour period is considered to be most representative of likely construction activity on the Inch Cape Development Area. The majority of currently available construction vessels would drive two pin piles from one location and then be required to mobilise and reposition in order to pile the remaining two pin piles of the foundation. Thus for the most likely scenario, dB SEL modelling to represent potential PTS onset of all marine mammal species has been carried out using the example of two pin piles being installed consecutively per 24 hour period. While it is highly unlikely that four pin piles (requiring 4.2 hours per pin to drive) could be installed from one vessel within a single 24 hour period using current technology, this eventuality was included within the worst case of one of the modelled scenarios in order to address the potential for installation of up to four pin piles (requiring 2.1 hours of piling) within 24 hours. The difference between the 186 dB SEL for harbour seals for two and four pin piles within one 24 hour period, as illustrated in Figure 14B.4, is not considered to be significant.

In addition to the noise arising from piling utilising a single construction vessel deployed on Inch Cape, modelling using INSPIRE has also been undertaken to represent two piling vessels in operation simultaneously on Inch Cape. This modelling has used both most likely and worst case piling scenarios. A piling duration of two years within the four year construction window for Inch Cape has been incorporated into the impact assessment. While the use of two construction vessels is likely to reduce the total number of months in which piling impacts are experienced, the piling activity may be concentrated within summer months in order to reduce the weather downtime that is likely to be experienced during winter months. Therefore, a two year piling scenario has been incorporated within the assessment for both one and two construction vessels on Inch Cape.

Cumulative modelling with other Forth and Tay Offshore Wind Developers Group (FTOWDG) projects (Firth of Forth Phase 1 and Neart na Gaoithe) has used only most likely piling scenarios for each project (see Section 14B.5 for details of the cumulative noise modelling locations and scenarios). Cumulative worst case is not considered likely as piling vessels are unlikely to encounter the hardest substrate modelled at all locations simultaneously.

Four scenarios were modelled (Table 14B.7). Because this Table is referred to throughout this section of the document it is recommended that it be printed out separately for ease of reference.

Table 14B.7: Details of the Scenarios Used for Predicting the Impacts of Piling Noise on Marine Mammals at the Inch Cape Development Area. ML = (2.1 hours per pile), WC = (4.2 hours per pile)

Scenario	Location	Species Modelled	ML or WC	Number of Piles per 24 h
1a	F3	Minke whale Bottlenose dolphin Harbour porpoise	ML (2.1 hours per pile)	2 piles
1b	F4	White-beaked dolphin Harbour seal Grey seal		
2a	F3	Minke whale Bottlenose dolphin Harbour porpoise	WC (4.2 hours per pile)	4 piles
2b	F4	White-beaked dolphin Harbour seal Grey seal		
3	F3 + F4	All	ML (2.1 hours per pile)	4 piles
4			WC (4.2 hours per pile)	8 piles

14B.3 Assessment Methodology

This section outlines the assessment methodology used in order to assess the potential impacts of pile driving noise on marine mammal species.

The approach taken here follows the framework developed by the University of Aberdeen, Sea Mammal Research Unit (SMRU) Ltd, Natural Power Consultants and Subacoustech Ltd for assessing the impacts of pile driving noise on the Moray Firth harbour seal population (Thompson *et al.*, Submitted). During development of the Moray Firth seal assessment framework, consultations were carried out with Scottish Natural Heritage (SNH), Joint Nature Conservation Committee (JNCC) and Marine Scotland (MS) and the methodology described below has since been consulted upon with the same organisations as part of the Inch Cape Offshore Wind Farm environmental impact assessment process.

This assessment concentrates on the key species highlighted in Appendix 14A: Marine Mammals Baseline and summarised in Chapter 14: Marine Mammals:

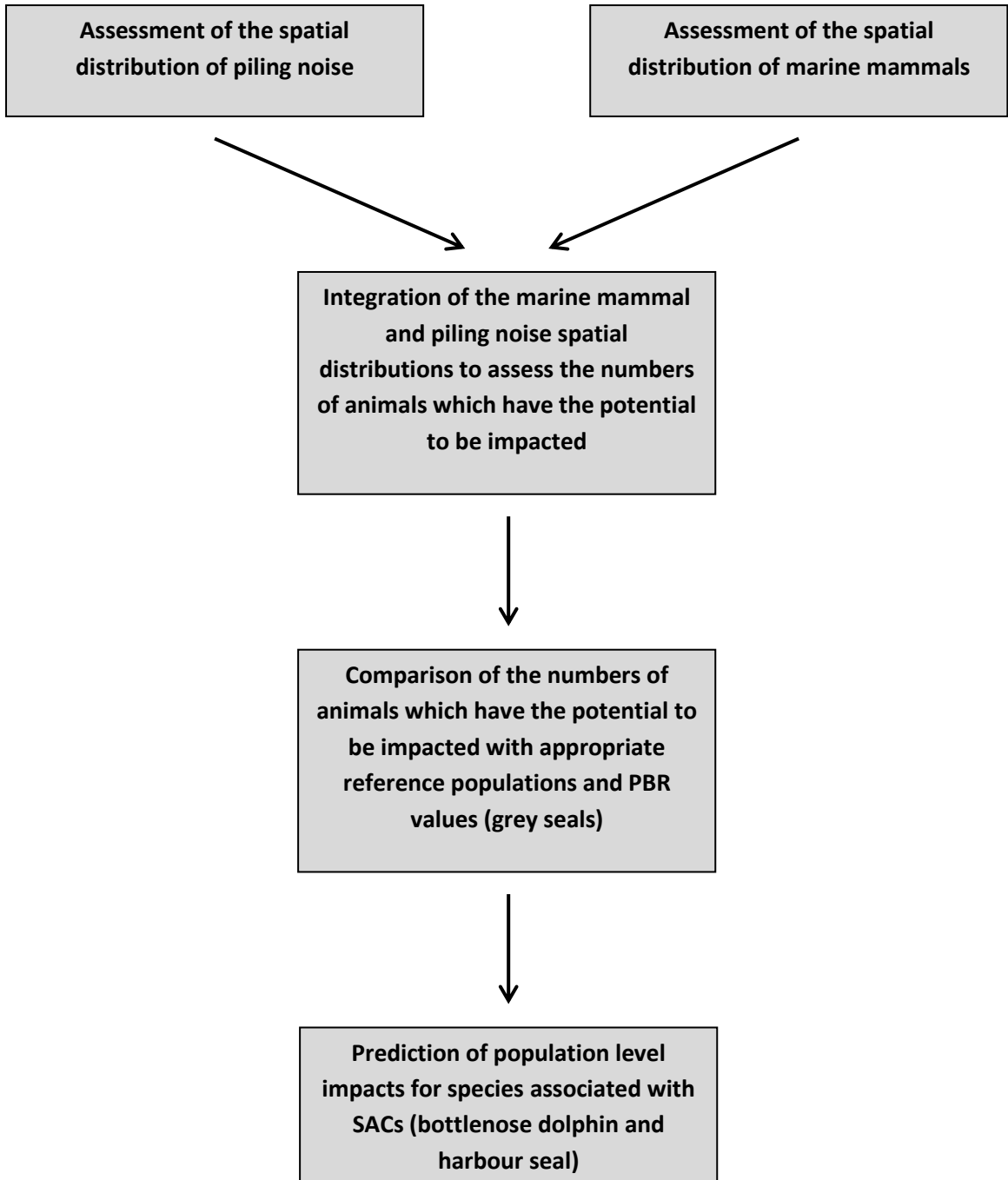
- Harbour seal, (*Phoca vitulina*);
- Grey seal (*Halichoerus grypus*);
- Harbour porpoise, (*Phocoena phocoena*);
- Bottlenose dolphin, (*Tursiops truncatus*);
- White-beaked dolphin, (*Lagenorhynchus albirostris*);
- Minke whale, (*Balaenoptera acutorostrata*);

There are five stages to the assessment methodology, as follows:

- Assessment of the spatial distribution of marine mammals;
- Assessment of the spatial distribution of piling noise;
- Integration of the marine mammal and piling noise spatial distributions to assess the numbers of animals which have the potential to be impacted;
- Comparison of the numbers of animals which have the potential to be impacted with appropriate reference populations and potential biological removal (PBR) values (grey seal); and
- Prediction of population level impacts for species associated with Special Areas of Conservation (SACs) (bottlenose dolphin, harbour seal).

The order these stages were carried out, and which information we need to have in order to generate subsequent information, is shown in Figure 14B.5 below.

Figure 14B.5: Schematic of the Assessment Methodology Used in Order to Assess the Potential Impacts of Pile Driving Noise on Marine Mammal Species



14B.3.1 Methodology for Assessing the Spatial Distribution of Marine Mammals

The data used to describe the distribution of each species comes from a variety of sources including boat surveys across the Development Area, aerial surveys across the three Firth of Forth and Tay Offshore Wind Farm (FTOWDG) sites, and SMRU telemetry and haul out count data (see Appendix 14A: Marine Mammals Baseline for details of baseline for each species).

The data were analysed in order to provide species-specific density surfaces (i.e. density estimates spread across a five by five kilometre grid) as follows:

Harbour and Grey Seal

Density surfaces for harbour and grey seals were produced for the FTOWDG and surrounding area using SMRU telemetry and haul out count data (Jones and Matthiopoulos, 2011). Telemetry data, which have been collected by SMRU since 1988, give information on where the sample of tagged animals went and what areas of land and sea they used. The sample of tagged animals, assumed to be representative of the population as a whole, was combined with estimates of total population size (using counts from 1988 to 2009 for grey seals and counts from 2006 to 2009 for harbour seals) to provide estimates of total population usage of, or estimated density in, the FTOWDG and surrounding area (Section 14A.2.3 in Appendix 14A: Marine Mammals Baseline). Recent count data for harbour seals were used because earlier counts do not reflect their current status on the east coast. Usage of earlier counts would have led to an over-estimate of the number of harbour seals currently using the FTOWDG area because the east coast population is experiencing a severe decline.

Harbour Porpoise, White-beaked Dolphin and Minke Whale

Density surfaces for harbour porpoise, white-beaked dolphin and minke whale were produced as part of the FTOWDG Integrated Cetacean Analysis (Mackenzie *et al.*, 2012) which used data collected during visual boat-based surveys carried out at each of the three Firth of Forth OWF sites commissioned by the individual developers and The Crown Estate-funded aerial survey data which was collected across the whole Forth and Tay region (Section 14A.2.2 in Appendix 14A: Marine Mammals Baseline).

Production of density estimates involved data preparation, correcting counts for variations in detectability and availability, and fitting density surface models to the corrected counts to estimate abundance and distribution over the surveyed area. For the density surfaces used, models were fit to the average of the data across the survey period (2009-2011). The spatial extent of the survey area was much reduced in 2011 compared with 2009 and 2010 because there was no aerial survey effort in 2011.

For harbour porpoise and minke whale, the depth relationship (signalling fewer animals in shallower waters) was statistically significant i.e. the spatial structure of porpoise and minke whale densities was explicable by bathymetry alone.

For white-beaked dolphin the spatial surface was statistically significant while the depth relationship (which signalled fewer animals in shallower waters) was not. This is likely due to the high levels of uncertainty where the data are sparse.

The harbour porpoise, white-beaked dolphin and minke whale density surfaces were extended to cover the full extent of the spatial distribution of piling noise for those species (i.e. to include all grid cells which contained dB_{ht} (*Species*) values greater than or equal to 50). This was done by calculating the average density across each surface and applying that value to any five by five kilometre grid squares which were not surveyed.

Bottlenose Dolphin

Because there is a lack of fine-scale data on the distribution of bottlenose dolphins off the east coast of Scotland, the 20 m depth contour was used to differentiate between the 'coastal strip' (where bottlenose dolphins tend to be encountered) and the 'non-coastal strip' (where bottlenose dolphins tend not to be encountered). The choice of the 20 m depth contour as this differentiation was informed by data from the south side of the Moray Firth where > 95 per cent of sightings made were within the 20 m depth contour (Culloch and Robinson, 2008, Robinson *et al.*, 2007). It is possible that distance from shore may also be a good predictor (as per Bailey and Thompson, 2009) but this relationship was not explored.

The east coast bottlenose dolphin population (195 individuals, 95 per cent highest posterior density intervals²: 162-253; Cheney *et al.*, 2012) was assumed to be split 50:50 between the east coast (from Rattray Head south) and the Moray Firth (Cape Wrath to Rattray Head; as it was for the MORL Moray Firth R3 Zone 1 (Eastern Development Area) Environmental Statement (ES) (MORL ES). The 98 individuals assumed to be present on the east coast were spread evenly across the area inside the 20 m depth contour. Zero density was used out with the 20 m depth contour (the SCANS II Block V density estimate, which could have been applied to the non-coastal strip, is made up of just one bottlenose dolphin sighting which was inside the 20 m depth contour in the Firth of Forth; SCANS II, 2006).

This method assumes that animals are distributed equally within the coastal strip, which is not the case (dolphins tend to occur in clusters or be absent). This is deemed to be a conservative assumption.

14B.3.2 Methodology for Assessing the Spatial Distribution of Piling Noise

Predicted noise propagation from piling was modelled using the INSPIRE model by Subacoustech (Chapter 11: Underwater Noise).

To make predictions of auditory injury (Permanent Threshold Shift, PTS), M-Weighted Sound Exposure Levels (SELs) (Southall *et al.*, 2007) were modelled. SELs were generated for 198 dB for cetacean species and 186 dB for pinnipeds, based on the Southall *et al.*, (2007) criteria

² Highest posterior density intervals are cited when Bayesian methods have been used to generate estimates and are analogous to confidence intervals. Here we can say, with 95 per cent certainty, that the true abundance is no lower than 162 and no greater than 253 individuals.

(Table 14B.4). SELs are modelled assuming a level of noise produced within a 24 hour period. As such, installation of one, two or up to four pin piles in a 24 hour period will impact the SEL and therefore the PTS predictions. It is likely that the Inch Cape Offshore Limited (ICOL) construction programme will involve between two ('most likely' scenario) and four ('worst case' scenario) pile installations in each 24 hour period of either 2.1 hours or 4.2 hours duration.

For behavioural response predictions, INSPIRE was used to predict received noise levels (dB_{ht} (*Species*) by the receptor). The dB_{ht} (*Species*) contours were generated at 5 dB_{ht} increments out to 50 dB_{ht} (from 0 to 50 dB_{ht} a mild reaction, probably not sustained³, may be observed in a minority of individuals; Nedwell *et al.*, 2007). Recent noise monitoring at locations within the Moray Firth SAC suggests that 50 dB_{ht} represents noise levels that approximate to background within coastal regions (Prof. Paul Thompson, Aberdeen University, personal communication). Representations of these outputs can be found in Appendix 14C: Piling Noise Assessment Figures.

The SEL and dB_{ht} contours were then used to estimate the maximum perceived level of noise in each five by five kilometre grid square (see Appendix 14C: Piling Noise Assessment Figures).

14B.3.3 Methodology for Integrating the Marine Mammal and Piling Noise Spatial Distributions to Assess the Numbers of Animals which have the Potential to be Impacted

Using SAFESIMM for Received Levels that May Lead to PTS Onset

The numbers of animals receiving sound levels sufficient for PTS onset was predicted using the programme Statistical Algorithms For Estimating the Sonar Influence on Marine Megafauna (SAFESIMM), which currently provides a robust and defensible representation of animal movements in response to noise (see King *et al.*, 2012 for details). In summary, SAFESIMM utilises outputs from INSPIRE to provide estimates of the number of individuals of each species that may experience PTS onset from a particular sound field (in this case piling) by simulating the three dimensional movements of thousands of simulated animals through this sound field, based on known characteristics of the diving and swimming behaviour of each species, and records the cumulative SEL of each simulated individual. SAFESIMM uses a series of dose-response relationships derived from Finneran *et al.* (2005) to determine the likely effect of sound exposure on the different marine mammal groups. The resulting model outputs are scaled by the at sea animal density data to provide predicted numbers of individuals of each species that could be exposed to SELs sufficient to induce the onset of PTS.

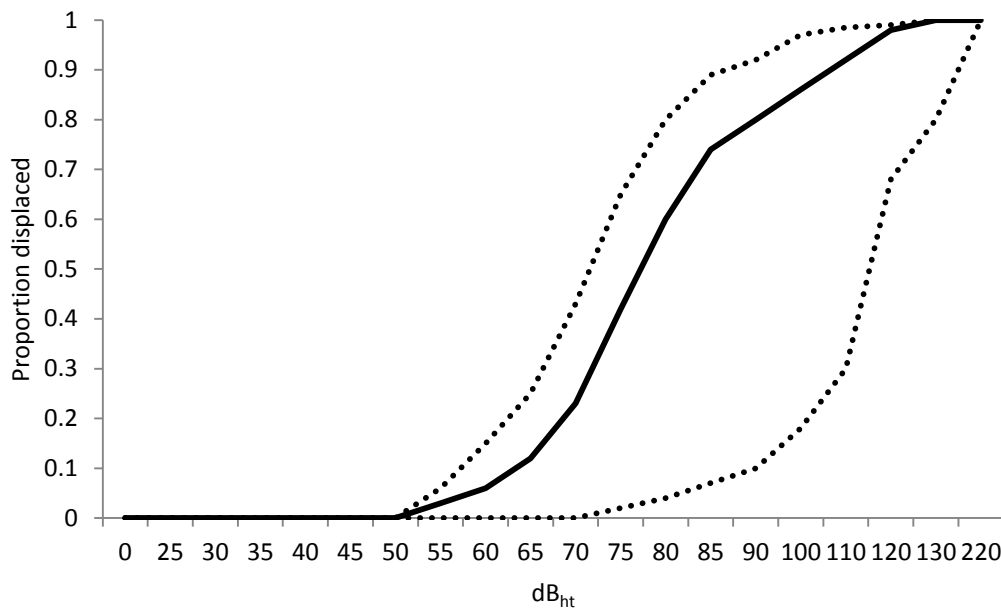
³ Term taken from Nedwell *et al.*, 2007 and is taken to imply some degree of habituation is expected.

Using a Dose-response Relationship for Received Levels that may Lead to Displacement

The numbers of animals receiving sound levels sufficient for displacement were calculated as follows:

- a) Animal density data included one of two different uncertainty measures: confidence intervals (CIs) and coefficients of variation (CVs). Where CIs were provided these values were used for calculation of upper and lower uncertainty intervals. Where CVs were provided, these were used to calculate standard deviation and this was added and subtracted from the mean values to give values for the upper and lower uncertainty respectively. If lower uncertainty estimates fell below zero they were set to zero.
- b) No measure of uncertainty was provided with noise predictions.
- c) For each species and pile location, the noise surface data and species density surface data were imported into Geographic Information Systems (GIS).
- d) The spatial join tool in GIS was used to link the noise surfaces with the species density surfaces.
- e) Linked spreadsheets were exported into Microsoft Excel (EXCEL) (raw data).
- f) Data for grid squares in which animal densities were predicted were extracted into another sheet (since the exported spreadsheet still included all of the noise grid squares whether they were linked to corresponding densities or not) (linked data).
- g) The coordinates of each dataset were used to check that the data had been linked correctly.
- h) The noise data for which no density data were available were extracted (excess data).
- i) If the predicted noise for the excess data was greater than zero, GIS was used to visualise where the extra noise was predicted to occur. Where the majority of a five by five kilometre square was on land, this square was discounted.
- j) Where density surfaces did not cover the entire region of the sea for which noise was predicted (minke whale, harbour porpoise and white-beaked dolphin) grid squares for which no density estimates were available were assigned the average value across the predicted density surface and the mean of the associated uncertainty intervals.
- k) The vlookup function in EXCEL was used to calculate the proportional response to the noise level predicted for each grid square (Figure 14B.6). Since response predictions were provided with upper and lower uncertainty estimates, the mean response was then multiplied by the mean animal density, the lower response by the lower animal density and the upper response by the upper animal density for each grid square. Estimates therefore incorporate uncertainty relating to both density surfaces and predicted response.

Figure 14B.6: The Dose-Response Relationship (using the best estimate (-) and the Upper and Lower Estimates (---)) which was Used to Predict Displacement (Produced Using Data from Appendix 7.3B of the MORL ES)



- l) For each scenario, predicted numbers of animals responding per grid square for each relevant pile were summed. If the sum for any given grid square was greater than the predicted number of animals in that grid square, the number of animals responding was set to the predicted number of animals in that square. These values were then summed to give predictions (or 'best estimates') of numbers of animals responding across the Development Area e.g. for harbour seals at location F4 the best estimate was 322 (see Table 14B.15).
- m) For grey seal and harbour seal, the 'total population estimates' calculated by summing the estimates of the density surface grid cells did not match the reference population estimates due to the different data and time periods used to generate them. For example, the density surface for harbour seal was generated using count data collected over a number of years (2006-2009) while the size of the reference population was estimated using the most recent count of the ECMA (2007). In order to address this, i.e. so that the 'numbers of animals displaced' calculations were scaled appropriately, the distributions of animals provided in the density surfaces were assumed to be correct but the numbers were scaled to reflect the appropriate reference population estimates (Table 14B.8). Uncertainty intervals were calculated by dividing the lower uncertainty for the predicted response by the upper predicted density and vice versa (e.g. for harbour seals at location F4 the lower uncertainty level was 32 and the higher uncertainty level was 416; Table 14B.15). The area used was the East Coast Management Area.
- n) For the Inch Cape only scenarios (1 to 4; see Table 14B.7), all of the (5 dB_{ht}) noise contours were included in the calculations of the numbers of animals responding (results referred to as "50 dB_{ht} displacement"). For the cumulative scenarios (5 and 6;

see Table 14B.29), calculations of the numbers of animals responding were done twice using different levels of information for Inch Cape as only 130, 90 and 75 dB_{ht} (*Species*) contours were available for the Firth of Forth and Neart na Gaoithe sites):

- In the first method (results referred to as “75 dB_{ht}” and “90 dB_{ht}”), Inch Cape noise contours below 75 dB_{ht} (*Species*) were excluded because contours below 75 dB_{ht} (*Species*) were not available for the Firth of Forth Phase 1 and Neart na Gaoithe sites) but the intermediate (5 dB_{ht}) noise contours which were available for Inch Cape were used.
- In the second method, only the 75, 90 and 130 dB_{ht} contours from all three sites were used to calculate the numbers of animals predicted to be displaced down to perceived noise levels of 75 dB_{ht} (results referred to as “75 dB_{ht} (standardised)”) and only the 90 and 130 dB_{ht} contours were used to calculate the numbers of animals predicted to be displaced down to perceived noise levels of 90 dB_{ht} (results referred to as “90 dB_{ht} (standardised)”). This was done in order to achieve consistency among the three sites, because these are the contours available for the Firth of Forth Phase 1, Neart na Gaoithe and Inch Cape sites. The intermediate (5 dB_{ht}) noise contours which were available for Inch Cape were not used for this second method (because they were not available for the Firth of Forth and Neart na Gaoithe sites) and, for this reason, we would expect fewer animals to be predicted to be displaced (because 75 dB_{ht} and 90 dB_{ht} lie at either end of the steepest part of the dose response curve (Figure 14B.6) and the proportion displaced at 75 dB_{ht} has been applied to dB_{ht} values up to 90 dB_{ht}).

14B.3.4 Methodology for Assessing the Numbers of Animals Which Have the Potential to be Impacted Against Appropriate Reference Populations and PBR Values (Grey Seal)

This phase compares the number of individuals predicted to experience a noise related effect to an agreed⁴ regional or reference population size in order to assess the magnitude of impacts.

Reference Populations

Table 14B.8 below provides details of the reference populations against which numbers of animals impacted have been compared, and the justification for selecting these reference populations.

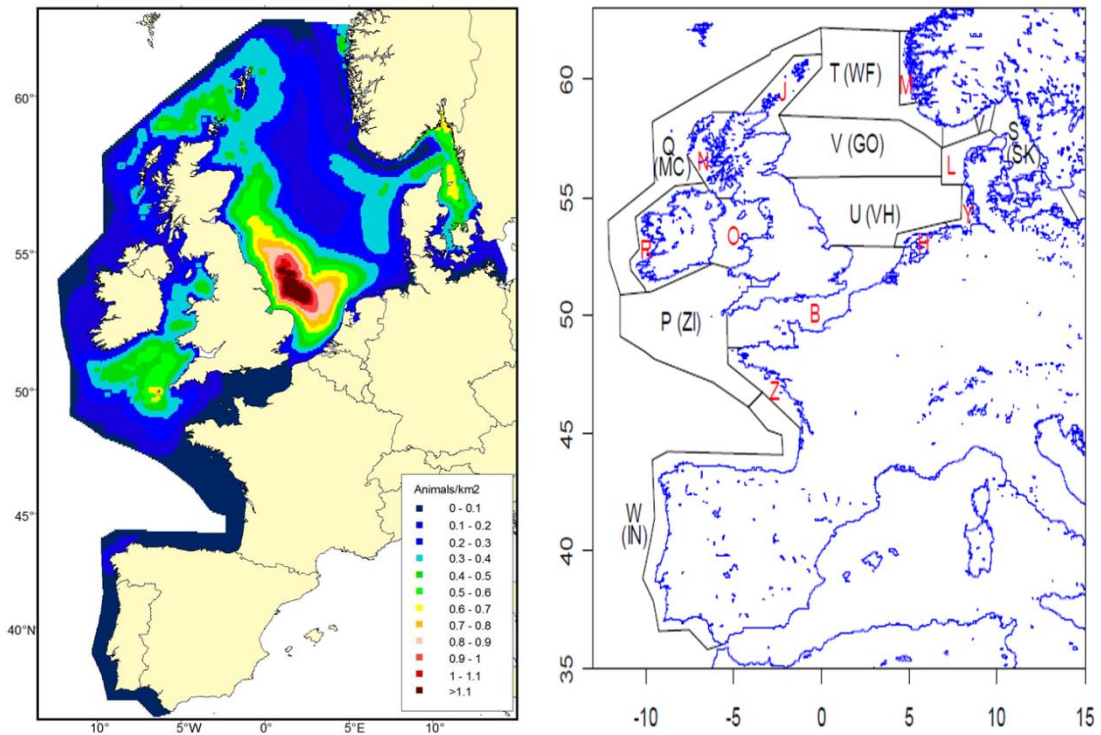
⁴ Agreed with SNH and Marine Scotland through FTOWDG, and Inch Cape only, discussions and consultations.

Table 14B.8: Reference Populations for the Six Different Species Assessed

Species	Reference population	Justification	Year(s) to which estimate applies	Abundance estimate	Source
Harbour seal	East Coast Management Area count corrected for animals at sea	This is the population against which SNH/ MS Science (MSS) advised that potential impacts are referenced	2007	638	SMRU survey data
Grey seal	East Coast Management Area count corrected for animals at sea	This is the population against which SNH/MSS advised that potential impacts are referenced	2007	7,112	SMRU survey data
Harbour porpoise	SCANS II North Sea Blocks (T, V and U)	SNH/MS recommended that the 'national population' was used. In the absence of any further information or advice, the SCANS II modelled distribution (Figure 14B.7) has been used to inform the extent of the national population	2005	159,040	SCANS II (2006)
Bottlenose dolphin	East coast population	It was assumed that the east coast bottlenose dolphin population (195 individuals, 95 % highest posterior density intervals: 162-253; Cheney <i>et al.</i> , 2012) was split 50:50 between the east coast and the Moray Firth	2006	98	Cheney <i>et al.</i> (2012)
White-beaked dolphin	European Atlantic continental shelf waters	White-beaked dolphins in the eastern North Atlantic are morphologically different to those in the west. The most appropriate reference population to use is that in the northeast Atlantic (although the abundance estimate used is likely to be a subset of the eastern North Atlantic 'stock')	2005	22,664 (CV = 0.42; 95 % CI = 10,341 - 49,670)	SCANS II (2006)

Species	Reference population	Justification	Year(s) to which estimate applies	Abundance estimate	Source
Minke whale	North Atlantic	<p>The International Whaling Commission (IWC) recognises four stocks of minke whales in the North Atlantic: Northeast Atlantic, Central North Atlantic, West Greenland and Canadian East Coast (which includes the US east coast). Population estimates were last reviewed by the IWC Scientific Committee in 2003 (although a new estimate for West Greenland was accepted in 2006). Using information on the stock structure of minke whales in the North Atlantic (Anderwald <i>et al.</i>, 2011), it was concluded that the most appropriate reference population to use was all four IWC-defined stocks in the North Atlantic</p>	~2000	181,922 (CV = 0.09)	International Whaling Commission/ IUCN Red List

Figure 14B.7: SCANS II Modelled Distribution of Harbour Porpoises (Redrawn from SCANS II, 2006)



PBR (Values for Grey Seals)

PBR is the number of individuals that can be removed from a population without causing a decline in that population.

Although PBR is widely used, it is recognised that it may not be the best method for managing seal populations. However, the information required for assessing carrying capacity or determining appropriate alternative management targets is not yet available and in the short term the Special Committee on Seals (SCOS) has advised that a conservative version of the PBR should continue to be used for managing anthropogenic impacts on Scottish seal populations (SCOS, 2011).

PBRs are calculated annually for each of the Seal Management Areas by the SMRU using the latest counts.

The PBR for grey seals for the East Coast Seal Management Area for 2012 is 277 (The Scottish Government, 2013).

14B.3.5 Methodology for Predicting Population Level Impacts for Species with SACs (Harbour Seal and Bottlenose Dolphin)

Information on the number of individuals displaced or having the potential to experience PTS onset was used in population models to assess the long-term impacts on harbour seal and bottlenose dolphin populations. The numbers of individuals of each species group which had the potential to be impacted by noise related disturbance or onset of PTS were calculated using the methodology described in Section 14B.3.3 above.

Assumptions were made about how exposure to noise might influence demographic parameters, and the effects of displacement and potential PTS onset were modelled as a direct impact on survival and reproduction. Models were run for a period of 25 years (which is considered appropriate due to the potential for one to two generations of marine mammal species to be affected during the impact period, therefore long term impacts with respect to population change (if any) will be evident during this time. This time scale also concurs with conservation assessments, including those used by the International Union for Conservation of Nature (IUCN), where a 25 year time scale is applied when considering conservation status). Population level effects of the different construction scenarios were explored and compared to baseline scenarios with no construction.

Harbour Seals

ICOL applied MORL's 'Framework for assessing the impacts of pile-driving noise from offshore wind farm construction on the Moray Firth harbour seal population' to the Firth of Forth and Tay harbour seal population. The main difference between these areas is that the harbour seal population in the Moray Firth is increasing while that in the Firth of Forth and Tay area is declining (Duck *et al.*, 2011). The approach used for the Inch Cape assessment is detailed in Appendix 14D: Harbour Seal Assessment.

Previous to the work described here, stakeholders and ICOL are not aware of any efforts to interpret outputs of population level modelling upon such a severely declining SAC population in relation to conservation objectives. Through consultation with stakeholders and Marine Scotland, ICOL have adapted a methodology previously used for a harbour seal population in favourable conservation status (Moray Firth). This methodology and results are presented in Appendix 14D: Harbour Seal Assessment.

Bottlenose Dolphins

The approach used was as for the MORL ES, using VORTEX to model viability of the East coast bottlenose dolphin population using the Population Viability Analysis model previously published in Thompson *et al.* (2000).

This model was based upon best available demographic and life history values, adjusted to produce, on average, a population that was stable or very slightly increasing. Although detailed demographic and life-history data are not available for this population, the latest Site Condition Monitoring report for the Moray Firth SAC does highlight that there is a >99 per cent chance that the population is either stable or increasing (Cheney *et al.*, 2012).

The baseline scenario (i.e. no piling) was run 1000 times to provide a distribution of final population sizes after 25 years (Figure 14B.8). The starting year (Year 0) was 2012. Different construction scenarios were then compared with this baseline by running each scenario 100 times and presenting both the population trajectories and a histogram of final population sizes. Piling was assumed to occur over two years (2016 and 2017) for the Inch Cape only scenarios and over five years (2014-2018) for the cumulative construction scenarios (see Section 14B.5 below for details of cumulative assessment undertaken).

Potential impacts of displacement and potential PTS onset were implemented by harvesting either calves or adults from the population to simulate effects of behavioural displacement and PTS onset respectively. The relationship between the number of individuals displaced and modelled to experience PTS onset is as described within the MORL ES; namely that displacement was modelled to represent failure to successfully reproduce (calf harvesting) and that PTS onset was modelled as age related mortality (harvesting of adult animals). The number of animals that were harvested in each scenario was based on the percentage of the population that the numbers of animals displaced or affected by PTS represented (Table 14B.9).

Ten different scenarios were run, including the baseline (Table 14B.10).

a) Displacement

The consequence of potential displacement of bottlenose dolphins from feeding grounds within the Firth of Tay is unknown at this time. In order to model impacts upon population dynamics, it was considered that a reduction in condition of breeding females, and so failure of breeding attempts during the years of construction (piling), represents a conservative outcome that can be modelled. Thus displacement was modelled to result in a reduction in reproduction, proportional to the proportion of the population that was displaced in each construction (piling) year. The magnitude of this impact was always worst case, rounding up numbers of calves and always taking more females if there were an odd number of calves (Table 14B.10).

Calculations were based on there being an average of four female and four male calves produced in each year from a stable population of 196 bottlenose dolphins (University of Aberdeen, unpublished data). Therefore, if 100 per cent of the population were displaced (i.e. displacement from both the Firth of Forth and the Moray Firth at one time), all eight calves were harvested the next year. If ten per cent were displaced, one (female) calf was harvested the next year (ten per cent of the eight calves rounded up).

b) PTS

PTS was modelled in a similar way, by harvesting 25 per cent of the animals modelled to be exposed to sufficient SELs to induce PTS onset in each year (as was the case in the MORL ES where it was assumed that the mortality risk of PTS is likely to be of a similar magnitude to the impact of old age). Again, the magnitude of this impact was worst case, rounding up the

numbers of individuals, biasing towards females and assuming all these animals were adults (and so breeding) rather than younger age classes (Table 14B.10).

Table 14B.9: Inputs into the Population Model: Numbers of Bottlenose Dolphins Modelled to Experience PTS Onset and which have the Potential to be Displaced with the Percentage of the Population that this Represents

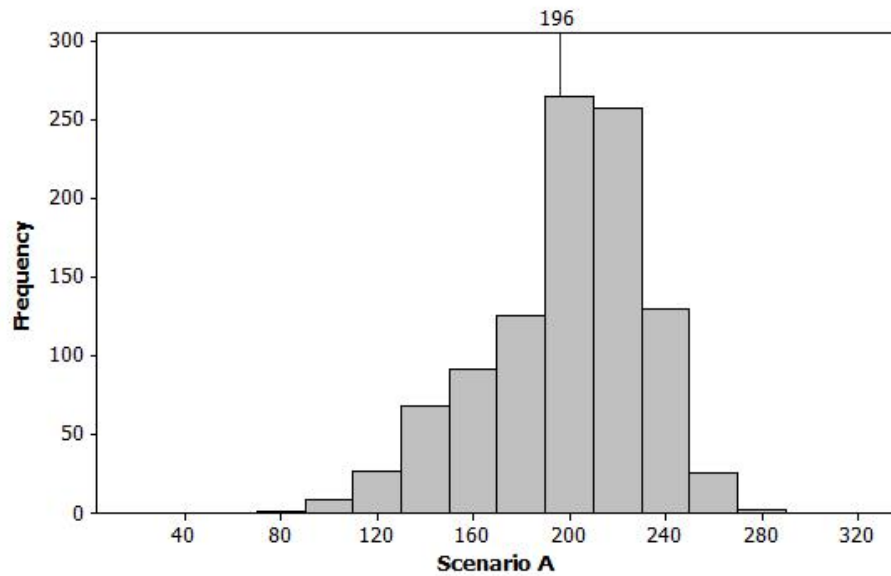
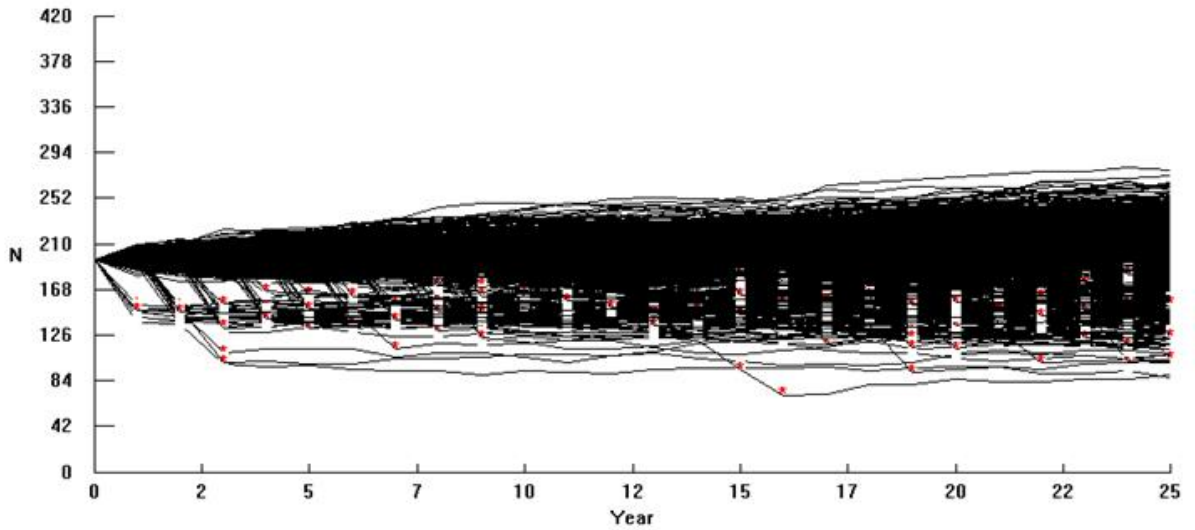
Construction Scenario	Number of bottlenose dolphins modelled to experience PTS				Number of bottlenose dolphins modelled to be displaced					
	WC		ML		Low		Best		High	
	#	%	#	%	#	%	#	%	#	%
F3 IC	1.7	0.87	1.2	0.61	1	0.51	15	7.65	22	11.22
F3 IC & F4 IC	2.9	1.48	1.9	0.97	1	0.51	19	9.69	27	13.78
F3 IC + F1A FoF + F5 NnG ⁵	n/a	n/a	4.3	2.19	1	0.51	17	8.67	23	11.73
F3 IC + F4 IC + F1A FoF + F2 FoF + F5 NnG + F6 NnG ⁵	n/a	n/a	4.8	2.45	2	1.02	21	10.71	28	14.29

⁵ Details of the cumulative assessment scenarios undertaken are provided below within Table 14B.29 in Section 14B.5, Prediction of Impacts – Cumulative Scenarios. The inputs into the population model are provided within Tables 14B.9 and 14B.10 as they are relevant to the methodology section.

Table 14B.10: Details of the Different Modelling Scenarios Showing Which Combinations of Values Were Used for PTS onset and Displacement in the Population Model. The Numbers of Calves and Adults Harvested in Each Scenario is Also Shown

Label	Construction scenario	PTS onset	Displacement	Calves harvested		Adults Harvested	
				Male	Female	Male	Female
A	Baseline	None	None	0	0	0	0
B	F3 IC	Worst Case	Best Estimate	0	1	0	1
C	F3 IC	Most Likely	Best Estimate	0	1	0	1
D	F3 IC and F4 IC	Worst Case	Best Estimate	0	1	0	1
E	F3 IC and F4 IC	Most Likely	Best Estimate	0	1	0	1
F ⁵	F3 IC and F5 NnG and F1A FoF	Most Likely	Best Estimate	0	1	1	1
G ⁵	F3 IC and F5 NnG and F1A FoF	Most Likely	Highest Estimate	0	1	1	1
H ⁵	F3 IC and F4 IC and F5 NnG and F6 NnG and F2 FoF and F1A FoF	Most Likely	Best Estimate	0	1	1	1
I ⁵	F3 IC and F4 IC and F5 NnG and F6 NnG and F2 SFoF and F1A FoF	Most Likely	Highest Estimate	1	1	1	1
J ⁵	Extreme to include 100% breeding failure for 5 years	Scenario H and I	100 %	4	4	1	1

Figure 14B.8: Bottlenose Dolphin Population Modelling Scenario A: Baseline (PTS none, Displacement none)



14B.3.6 Certainty in Predictions

The conservative nature of many of the assumptions made during development of the assessment methodology is likely to have resulted in a substantial cumulative over-prediction of impacts. Table 14B.11 below provides details on the assumptions that have

been made during this impact assessment and why they represent the most conservative approach possible in each case.

Table 14B.11: Assumptions Made During the Marine Mammal Impact Assessment and their Degree of Conservatism

Assumption		Degree of Conservatism
1	INSPIRE noise propagation modelling is conservative over the 20-50 km range	Comparison of INSPIRE model predictions with published measured recordings (Bailey <i>et al.</i> , 2010) indicate that the INSPIRE model predictions for unweighted peak levels provide a relatively good fit of the measured data. Modelled and measured noise levels correlate well at distances up to 20 km from the piling event, but provide a conservative prediction of sound levels across the wider area (20-50 km). The modelling of transmitted against measured sound levels and the evidence of the conservative nature of the prediction has been provided within the MORL ES.
2	Noise modelling locations to represent indicative piling activity have always been chosen to be closest to sensitive receptors or produce the largest spatial extent of effect	This approach introduces an inherent conservatism over the duration of the construction phase. For example, for Scenario 1a (described in Table 14.7) a single location closest to the sensitive receptors (minke whale, bottlenose dolphin and harbour porpoise) has been chosen and effects modelled to occur for two years. This is an overestimation of effect as the majority of piling will be more distant than this most sensitive location, and the piling will not be constant throughout the two year period.
3	Allocation of perceived noise level to each 5x5 km grid square used for marine mammal displacement modelling always used the highest level predicted for each square	Section 14B.3.2 illustrates how the modelled perceived noise levels for each species under individual construction scenarios were allocated. A perceived noise level that equated to the highest dB _{ht} (<i>Species</i>) radii that touched the 5x5 km grid square was assigned to each square, rather than allocating a dB _{ht} (<i>Species</i>) level that corresponded to the greatest proportion of the square.
4	Harbour porpoise behaviour was used as a proxy for bottlenose dolphin in the modelled disturbance from piling noise	Analysis of available data (that was presented within the MORL ES) indicates higher level responses by harbour porpoises than bottlenose dolphins to similar noise levels. Thus, using harbour porpoise as a proxy for bottlenose dolphin is likely to produce an overestimation of associated effect upon the bottlenose dolphin population.
5	Modelled avoidance of areas predicted to experience high piling related noise for the full duration of the construction period (i.e. animals modelled to not return in between periods of piling)	No data are currently available on the period of time that will elapse between the cessation of piling activity and the return of animals displaced. Animals have therefore been modelled to remain excluded for the full duration of the construction period (i.e. a number of years). It is considered likely that animals will return between some piling events, especially during breaks in construction activity (e.g. due to bad weather). Assuming displacement for the entire period of piling therefore represents a highly conservative assumption.

Assumption		Degree of Conservatism
6	Effect of displacement on reproduction rates of harbour seal and bottlenose dolphins	Population modelling has been undertaken to assess the population consequences of effects experienced by individual harbour seals and bottlenose dolphins. Animals modelled as being displaced for the full period of piling have been assumed to either fail to produce young or for the young produced to not survive. This is considered to be a conservative assumption, at least in part due to the considerations described in 5 (that the animals are displaced for the entire duration of the piling phase, and do not return to favoured feeding grounds in periods of no construction activity such as that induced by bad weather).
7	The 186 dB SEL criteria was used for modelling the number of individual seals exposed to noise of sufficient volume and duration to induce PTS onset	The available literature for the rationale supporting the 186 dB SEL criteria for seals was reviewed as part of the MORL ES. The scientific advisers working with MORL concluded that the evidence did not support the differential sensitivity of seals over cetaceans, and proposed a common criterion (198 dB SEL) for all species assessed. Peer and stakeholder consultation on this approach concluded that while there was general agreement that the 186 dB SEL criteria was likely to be overly conservative, there was little evidence to support reducing the criteria to 198 dB SEL. It was generally agreed that the likely criteria for the noise exposure and duration to induce PTS onset would be somewhere between the 198 and 186 dB SEL level. As a result of this consultation the 186 dB SEL has also been used here as a conservative modelling scenario (recognising that there is likely to be an over estimation of numbers of seals modelled to have the potential to experience the onset of PTS).
8	SAFESIMM was used to model the number of individual animals which have the potential to experience noise levels sufficient to induce PTS onset	SAFESIMM estimates for the number of individuals which have the potential to experience the onset of PTS due to piling noise are potentially high because animals in SAFESIMM make 'randomised walk' movements away from the noise source and therefore take longer to leave the area affected by noise of sufficient volume to induce PTS onset than those in the INSPIRE model, where animals flee at a speed of 1.5 m/s away from the noise source. Furthermore, seals in SAFESIMM continue to receive a noise dose regardless of whether they were diving or at the surface when, in reality, seals at the surface will have their heads above the water and therefore not receive this dose. The use of SAFESIMM to estimate the number of individuals exposed to sufficient noise to induce PTS onset therefore represents a conservative element of the impact assessment methodology.
9	Consequence of PTS is a 25 % risk of mortality	The PTS onset criteria proposed by Southall <i>et al.</i> , (2007) represents an estimate of the noise levels at which a reduction in hearing acuity may start to occur. There are no empirical data on actual levels of PTS in marine mammals, or on whether such hearing impairment may affect their survival. The 25 % mortality risk used in these models is considered highly conservative, but has been used due to the degree of uncertainty surrounding the consequences of these criteria.

Assumption		Degree of Conservatism
10	Animals are modelled not to recover between noise doses associated with piling activity	The scientific community anticipate that there will be some degree of recovery between individual hammer strikes associated to the piling (termed effective quiet), and thus modelling no such recovery is a conservative assumption in the light of the unknown quantity of this recovery.
11	Cumulative piling related impacts have been modelled as piling associated to all three Projects being carried out together over a five year period of 2014 - 2018.	<p>It is recognised that piling activity in all five years is unlikely. Although construction of NnG is scheduled to begin in 2014, details within the NnG indicate that piling is not scheduled to begin until 2015. Details provided with the FoF Phase 1 ES indicate that piling at FoF Phase 1 is scheduled to be undertaken from 2016-2017. Piling within 2018 has been included in this assessment to allow for programme slippage of any of the three sites included.</p> <p>In the years when piling is being undertaken, it is extremely unlikely that piling will be carried out at all three sites for the full period. However, displacement has the potential to occur over relatively large areas for individual sites and thus the impact radii from piling at locations within two or three projects will overlap. It is considered that the complexity of attempting to model distinct piling phases of individual projects is not warranted when considered against the uncertainties detailed above.</p>

14B.4 Prediction of Impact – Inch Cape Only

14B.4.1 Lethal Effects and Physical Injury - All Marine Mammals

Table 14B.3 above provides the assessment criteria for noise impacts upon marine mammal species. The results provided below in Table 14B.12 give details of predicted ranges for lethal effects (240 dB) and physical injury (220 dB) for all marine mammals, assuming an animal fleeing speed of 1.5 m/s.

This modelling has indicated that during piling operations, physical injury and lethal impacts to marine mammals are in the order of 40 and 6 metres respectively from the pile (See Section 11A.6.1, Appendix 11A: Underwater Noise).

Table 14B.12: The Ranges over which Physical Injury (220 dB) and Lethal Effects (240 dB) are Predicted for all Marine Mammals

Unweighted (all marine mammals)	240 dB	220 dB
Min range (m)	4	38
Max range (m)	6	40
Mean range (m)	5	39

It is very unlikely that marine mammals will be exposed to noise levels which have the potential to cause death/physical injury because a mitigation protocol has been developed by the Statutory Nature Conservation Agencies in order to reduce this risk to negligible levels (JNCC, 2010). Therefore death/physical injury is not discussed further within this Appendix.

14B.4.2 Auditory Injury and Displacement - Pinnipeds

Auditory Injury (PTS)

Table 14B.13 below details the ranges from a piling event over which seals (grey and harbour) have the potential to experience the onset of PTS.

For a single installation vessel, seals are predicted to have the potential to experience the onset of PTS (modelled at location F4, the most sensitive location for seals based on their spatial distribution) up to a maximum of 37.7 km from piling events under the most likely scenario (2.1 hours per pile and two piles in a 24 hour period i.e. Scenario 1b) and up to a maximum of 48.1 km under the worst case construction scenario (4.2 hours per pile and four piles in a 24 hour period i.e. Scenario 2b).

The maximum ranges are larger for Scenarios 3 and 4 utilising two piling vessels on site at the same time, one at location F3 and the other at location F4. Scenario 3 represents what is considered to be the most likely piling scenario for two vessels (2.1 hours per pile and up to four piles in a 24 hour period) and Scenario 4 the worst case scenario for two vessels (4.2 hours per pile and up to eight piles in a 24 hour period).

Table 14B.13: SEL (186 dB) Ranges for Potential PTS Onset in Pinnipeds

Scenario	Min range (km)	Max range (km)	Mean range (km)	Figure in Appendix 14C
1b	16.1	37.7	29	Figure 14C.8
2b	16.1	48.1	32.1	Figure 14C.9
3	14.5	55.3	35.3	Figure 14C.10
4	14.5	66.3	38.9	Figure 14C.11

Displacement

Table 14B.14 below provides details of the ranges from a piling event at which harbour seals are predicted to have the potential to experience noise levels which could elicit displacement behaviour. These ranges are also applicable to grey seals. The 90 and 75 dB_{ht} (harbour seal) contour rows have been highlighted in bold because these are the thresholds at which strong and mild behavioural avoidance are predicted to occur (Nedwell *et al.*, 2007; Table 14B.3) respectively.

Seals are predicted to have the potential to be displaced up to 151.1 km from piling (Table 14B.14) with a smaller proportion of animals being displaced at increasing distances from piling (Figure 14B.6). At 50 dB_{ht} the proportion of animals actually expected to be displaced is very low (see Figure 14B.6). The maximum ranges at 90 dB_{ht} (strong behavioural avoidance) and 75 dB_{ht} (mild behavioural avoidance) are 15.7 km and 45.2 km respectively.

Table 14B.14: The Maximum Ranges at which a Behavioural Response is Predicted to Occur in Harbour Seals in Response to Piling at Location F4 (see also Figure 14C.12 in Appendix 14C: Piling Noise Assessment Figures)

Harbour seal dB _{ht}	Max range (km)	Harbour seal dB _{ht}	Max range (km)
170	0.0	105	3.4
165	0.1	100	5.9
160	0.1	95	9.8
155	0.1	90	15.7
150	0.2	85	23.4
145	0.2	80	33.8
140	0.2	75	45.2
135	0.2	70	62.8
130	0.3	65	81.0
125	0.3	60	100.1
120	0.6	55	124.5
115	1.0	50	151.1
110	1.9		

14B.4.3 Assessment of Significance

Harbour Seal

The number of harbour seals predicted to be affected by PTS onset (at 186 dB) falls within a range of 47 to 78 individuals depending upon the Scenario assessed; 47, which is equivalent to 7.4 per cent of the reference population for the most likely scenario for one construction vessel (2.1 hours per pile and two piles in a 24 hours window, i.e. Scenario 1b), and 78 individuals (12.2 per cent of the population) for the worst case for two construction vessels (4.2 hours per pile and four piles in a 24 hours window i.e. Scenario 4; Table 14B.15).

Using the 5dB_{ht} contours out to 50dB_{ht} described above in Section 14B.3.3, the number of harbour seals predicted to exhibit some form of behavioural response is 322 individuals during the use of one construction vessel (Scenario 1b), and 340 individuals if two vessels are used at any one time (Scenario 4). These values of displaced individuals have been used for the assessment of potential impacts of piling at Inch Cape.

When standardised for 75 and 90 dB_{ht} to facilitate the cumulative assessment process (as explained in Section 14B.3.3 above), the number of animals predicted to exhibit a strong avoidance reaction (90 dB_{ht}) is 125 for most likely (one construction vessel, 2.1 hours per pile and two piles per 24 hours; Scenario 1b) which is equivalent to 19.6 per cent of the reference population and 156 for worst case (two construction vessels, 4.2 hours per pile and four piles per 24 hours; Scenario 4) which is equivalent to 24.5 per cent of the reference population. The number predicted to exhibit a mild avoidance reaction (out to 75 dB_{ht}) is 239 (most likely for one construction vessel, Scenario 1b) which is equivalent to 37.5 per cent of the reference population and 257 (worst case for two construction vessels, Scenario 4) which is equivalent to 40.3 per cent of the reference population.

Current advice from regulators is that the East Coast Management Area should be used as the reference population for harbour seals. The most recent count of the East Coast Management Area (of 459 harbour seals) was made in 2007 (SMRU unpublished data). When multiplied by a correction factor in order to take into account the number of seals which were at sea when the count was made (the proportion hauled out was estimated at 0.72; Lonergan *et al.*, 2011a), the reference population for the East Coast Management Area numbers 638 harbour seals. The percentage of the reference population predicted to be affected ranges from 7.4 to 12.2 per cent for PTS (low magnitude of impact) to up to 53.3 per cent for behavioural displacement (high magnitude of impact; Table 14B.15).

The conservation status of UK harbour seals is considered to be Unfavourable - Inadequate (JNCC, 2007). The period to which this assessment relates is January 2001 to December 2006. The next assessment, which will cover the period 2007-2012, is due in 2013.

Table 14B.15: Number of Harbour Seals (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise at Inch Cape. The Reference Population Abundance is 638 (see Table 14B.8)

Scenario	PTS (186 dB)		Displacement									
			50 dB _{ht}		75 dB _{ht}		75 dB _{ht} (standardised) ⁶		90 dB _{ht}		90 dB _{ht} (standardised)	
	n	%	n	%	n	%	n	%	n	%	n	%
1b	47	7.4	322	50.5	278	43.6	239	37.5	127	19.9	125 (17 - 1598)	19.6
2b	59	9.2	(32 - 416)		(32 - 329)		(22 - 299)		(20 - 134)			
3	65	10.2	340	53.3	298	46.7	257	40.3	160	25.1	156 (29 - 162)	24.5
4	78	12.2	(49 - 435)		(49 - 344)		(34 - 316)		(39 - 166)			

Assessment of Population Level Effects

The potential impact of auditory injury on harbour seals is assessed as low (<10 per cent of the population) for a single vessel to medium (10 to 20 per cent of the population) for two vessels operating at the same time, and of medium duration. The predicted impact is therefore minor (single vessel) to moderate (two vessels).

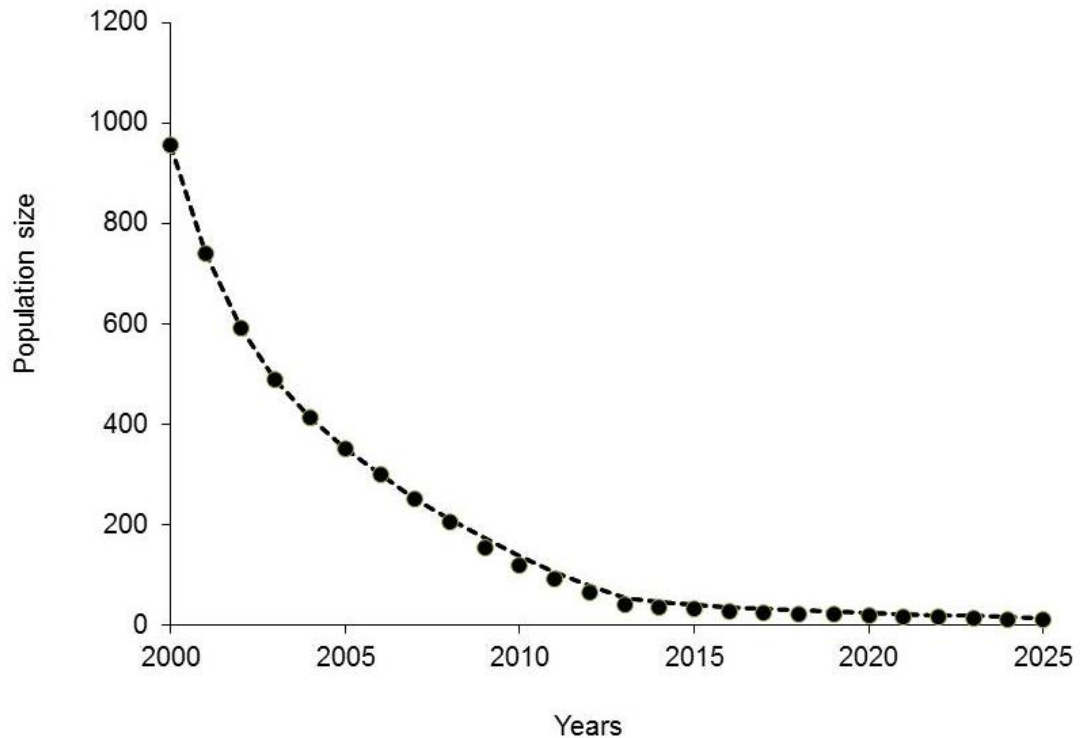
The potential impact of behavioural displacement on harbour seals is assessed as high magnitude (>20 per cent) and of medium duration (construction years), and therefore major.

⁶ See Section 14B.3.3 for an explanation of the difference between 75/90 dB_{ht} and 75/90 dB_{ht} (standardised). In summary, only the 75, 90 and 130 dB_{ht} contours were used to calculate the numbers of animals predicted to be displaced at 75 dB_{ht} (standardised) in order to achieve consistency among the three sites for cumulative studies. The intermediate (5 dB_{ht}) Inch Cape noise contours were not used in these standardised models. This means that fewer animals are predicted to be displaced for 75 dB_{ht} (standardised) compared to 75 dB_{ht} (because 75 and 90 dB_{ht} lie at either end of the steepest part of the dose response curve and the proportion displaced at 75 dB_{ht} has been applied to dB_{ht} values up to 90 dB_{ht}).

However, piling is likely to occur for between only 11-23 per cent of the two year piling phase, depending upon the number of vessels used and hardness of the substrate encountered (see Table 14.2, Chapter 14: Marine Mammals). Therefore, by assuming that modelled displacement continues for the full two years of piling duration, actual potential for impacts due to behavioural displacement are likely to be less than stated.

As described above, previous to the work described here, stakeholders and ICOL are not aware of any efforts to interpret outputs of population level modelling upon such a severely SAC declining population in relation to conservation objectives. By 2016, when piling at the Inch Cape Development Area is due to commence, the harbour seal population is likely to be of negligible size. Details can be found in Appendix 14D: Harbour Seal Assessment but, in summary, a baseline scenario in which the corkscrew seal death issue has been solved (i.e. current levels of adult mortality are reduced) was run (Figure 14B.9); this assumption of reduced adult mortality, although unlikely, was made so that there were more than zero animals in the baseline scenario than if the current mortality trends continue i.e. so that there was a baseline against which the outputs of the construction scenario could be compared. In the construction scenario, the two year piling period was shifted from 2016-2017 to 2008-2009 because, from the modelling outputs, the harbour seal population will already be of negligible size at the start of the actual piling period. There is little difference between the baseline and construction scenarios (Figure 14B.9) therefore it is concluded that impacts from piling on harbour seals at the population level are likely to be minor.

Figure 14B.9: Harbour Seal Population Modelling - Comparison of Baseline (---) and Construction (●●●) Scenarios in a Modelled Scenario where the Corkscrew Seal Death Issue has been Solved and Piling Occurs in 2008-2009



Grey Seal

Grey seals, the primary reason for selection of both the Isle of May and the Berwickshire and North Northumberland Coast SACs, are predicted to have the potential to experience PTS onset up to a maximum of 66.3 km from the piling events in the worst case scenario for two construction vessels (4.2 hours per pile and 4 piles per a 24 hours window; Scenario 4) and up to 37.7 km from the piling event in the most likely scenario for one construction vessel (1.2 hours per pile and 2.1 hours per a 24 hours window; Scenario 1b) using the M-weighted SEL criteria (Table 14B.13).

Grey seals are predicted to have the potential to exhibit a behavioural response out to a maximum range of 151.1 km from the source of piling noise (50 dB_{ht}; Table 14.14). 50 dB_{ht} is almost equivalent to background/ambient noise levels. The maximum ranges from each piling location for 90 dB_{ht} (strong behavioural avoidance) and 75 dB_{ht} (mild behavioural avoidance) are 15.7 km and 45.2 km respectively.

The number of grey seals predicted to be affected by PTS onset range between 478 individuals for the most likely scenario (one construction vessel, 2.1 hours per pile and two piles per a 24 hours window; Scenario 1b) and 822 individuals for the worst case scenario (two construction vessels, 4.2 hours per pile and four hours per a 24 hours window; Scenario 4) (Table 14B.16).

Using the 5dB_{ht} contours out to 50 dB_{ht} described above in Section 14B.3.3, the number of grey seals predicted to exhibit some form of behavioural response is 3058 individuals during the use of one construction vessel, and 3212 individuals if two vessels are used at any one time.

Current advice from regulators is that the East Coast Management Area should be used as the reference population for grey seals. The most recent count of the East Coast Management Area (of 2347 grey seals) was made in 2007 (SMRU unpublished data). When multiplied by a correction factor in order to take into account the number of seals which were at sea when the count was made (the proportion hauled out was estimated to be 0.33; Lonergan *et al.*, 2011b), the reference population for the East Coast Management Area numbers 7112 grey seals. The percentage of the reference population predicted to be affected ranges from 6.7 to 11.6 per cent for PTS onset (low magnitude of impact) to up to 45.2 per cent for a behavioural response (high magnitude of impact; Table 14B.16).

When standardised for 75 and 90 dB_{ht} (as explained in Section 14B.3.3 above), the number of grey seals predicted to exhibit a strong avoidance reaction (90 dB_{ht}) is 519 (most likely for one construction vessel, Scenario 1b) which is equivalent to 7.3 per cent of the reference population and 669 (worst case for two construction vessels, Scenario 4) which is equivalent to 9.8 per cent of the reference population; the number predicted to exhibit a mild avoidance reaction (75 dB_{ht}) is 1914 (most likely for one construction vessel, Scenario 1b) which is equivalent to 26.9 per cent of the reference population and 2050 (worst case for two construction vessels, Scenario 4) which is equivalent to 28.8 per cent of the reference population.

The conservation status of UK grey seals is considered to be Favourable (JNCC, 2007).

Table 14B.16: Number of Grey Seals (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise at Inch Cape. The Reference Population Abundance is 7112 (see Table 14B.8)

Scenario	PTS (186 dB)		Displacement									
			50 dB _{ht}		75 dB _{ht}		75 dB _{ht} (standardised)		90 dB _{ht}		90 dB _{ht} (standardised)	
	n	%	n	%	n	%	n	%	n	%	n	%
1b	478	6.7	3058	43	2380	33.5	1914	26.9	526	7.4	519	7.3
2b	613	8.6	(211 – 4469)		(211 - 3086)		(138 - 2723)		(81 - 598)		(71 - 592)	
3	647	9.1	3212	45.2	2507	35.3	2050	28.8	684	9.6	669	9.8
4	822	11.6	(244 – 4682)		(244 - 3237)		(158 - 2882)		(119 - 778)		(92 - 768)	

Assessment of Population Level Effects

The potential impact of auditory injury on grey seals is assessed as between low (one vessel; <10 per cent of reference population) to medium (two vessels; <12 per cent of the reference population) magnitude, of medium duration and is therefore minor (single vessel) to moderate (worst case and two vessels).

The 2012 PBR (i.e. the number of animals that can be removed from the population within any one year, without causing a decline) for grey seals in the East Coast Management Area is 277⁷. If it is assumed that 25 per cent of the animals predicted to develop PTS are lost from the population or 'harvested', as has been assumed when predicting population level effects for bottlenose dolphins, this would equate to removal of 120 individuals (most likely for one construction vessel, Scenario 1b). This is equivalent to 44 per cent of the current PBR. For a worst case for piling at two locations at Inch Cape, this would equate to removal of 206 individuals (Scenario 4) which is equivalent to 74 per cent of the current PBR. Therefore, for all of the ranges of potential piling scenarios, the potential impact of PTS at the population level is within the allowed 'take' (PBR) and no population modelling was undertaken.

The potential impact of behavioural displacement on grey seals is assessed as high magnitude (>20 per cent) for the total displacement calculated out to 50 dB_{ht} of medium term (2 years), and therefore major in the medium term. Due to the conservative approach taken to modelling potential impacts, these numbers are considered to be highly conservative and are likely to represent an over-estimation of the number of animals affected. The grey seals which have the potential to be displaced due to piling at Inch Cape may not breed in the Firth of Forth. In addition, grey seals travel extensively and use a wide range of habitats including multiple foraging areas and haul out sites. Displacement is therefore not expected to have the same effect on grey seals as it might have on a species which does not travel so extensively. Given that the grey seal population in the East Coast Management Area is thought to be increasing (Appendix 14A: Marine Mammals Baseline), there is likely to be suitable alternative habitat for feeding and hauling out and it is likely that animals will become habituated to the lower levels of piling noise, it is considered unlikely that behavioural displacement will have a long-term impact at the population level and will therefore be minor in the long term.

14B.4.4 Auditory Injury and Displacement - Cetaceans**Auditory Injury (PTS)**

Table 14B.17, Table 14B.18 and Table 14B.19 below detail the ranges at which high, mid and low frequency cetaceans are predicted to have the potential to experience the onset of PTS using the M-weighted SEL criteria of 198 dB, for both most likely and worst case construction scenarios.

⁷ Available online from: <http://www.scotland.gov.uk/Topics/marine/Licensing/SealLicensing>

High frequency cetaceans, e.g. harbour porpoises, are predicted to have the potential to experience the onset of PTS from piling noise at location F3 (the most sensitive location based on the spatial distribution of harbour porpoises) up to a maximum of 2.7 km away under the most likely construction scenario for a single construction vessel (Scenario 1a, two piles which take 2.1 hours each in a 24 hour period) and up to a maximum of 11.8 km under the worst case construction scenario (Scenario 4, four piles which take 4.2 hours each in a 24 hour period).

PTS contours for mid frequency cetaceans were modelled from both F3 and F4. Location F3 was judged to be the most sensitive location for bottlenose dolphins based on their spatial distribution. From this location mid frequency cetaceans are predicted to have the potential to experience PTS onset up to a maximum of 2.4 km away under the most likely construction scenario for one construction vessel (Scenario 1a, two piles which take 2.1 hours each in a 24 hour period), and up to 11.4 km away for worst case construction (Scenario 4, four piles which take 4.2 hours each in a 24 hour period). Location F4 was judged the most sensitive location for white-beaked dolphins based on their spatial distribution. From this location, mid frequency cetaceans are predicted to have the potential to experience the onset of PTS up to a maximum of 2.2 km away under the most likely construction scenario (Scenario 1b) and 11.4 km under the worst case construction scenario (Scenario 4,).

Low frequency cetaceans, e.g. minke whales, are predicted to have the potential to experience the onset of PTS due to piling at location F3 (the most sensitive location based on the spatial distribution of minke whales) up to a maximum of 6.9 km away under the most likely construction scenario for one construction vessel (Scenario 1a) and up to a maximum of 18.8 km under the worst case construction scenario (Scenario 4, four piles which take 4.2 hours each in a 24 hour period).

Table 14B.17: SEL ranges for Potential PTS Onset in High Frequency Cetaceans (e.g. Porpoises)

High Frequency Cetacean – SEL (198 dB)				
Scenario	Min range (km)	Max range (km)	Mean range (km)	Figure in Appendix 14C
1a	1.7	2.7	2.2	Figure 14C.26
2a	2	4.1	3	Figure 14C.30
3	3	10.1	6.6	Figure 14C.34
4	3.7	11.8	8	Figure 14C.37

Table 14B.18: SEL Ranges for Potential PTS Onset in Mid Frequency Cetaceans (e.g. Dolphins)

Mid Frequency Cetacean – SEL (198 dB)				
Scenario	Min range (km)	Max range (km)	Mean range (km)	Figure in Appendix 14C
1a	1.5	2.4	2	Figure 14C.27
1b	1.5	2.2	2	Figure 14C.28
2a	1.8	3.7	2.7	Figure 14C.31
2b	1.8	3.2	2.7	Figure 14C.32
3	2.7	9.7	6.3	Figure 14C.35
4	3.5	11.4	7.7	Figure 14C.38

Table 14B.19: SEL Ranges for Potential PTS Onset in Low Frequency Cetaceans (e.g. Minke Whales)

Low Frequency Cetacean – SEL (198 dB)				
Scenario	Min range (km)	Max range (km)	Mean range (km)	Figure in Appendix 14C
1a	4.4	6.9	5.7	Figure 14C.29
2a	4.4	9.8	7.2	Figure 14C.33
3	7.2	15.2	11.4	Figure 14C.36
4	7.3	18.8	13.5	Figure 14C.39

Displacement

Table 14B.20 to Table 14B.23 below provide details of the ranges at which animals have the potential to be displaced during the predicted piling activity at Inch Cape.

At the time the Subacoustech modelling was carried out, no audiograms for minke whales or white-beaked dolphins were available. Humpback whale (another low frequency cetacean) and bottlenose dolphin (another mid frequency cetacean) audiograms, respectively, were used as proxies (see Section 14B.2.1 for details). The values for bottlenose and white-beaked dolphins in the following tables are different because different modelling locations were used – as explained above, the most sensitive location for white-beaked dolphins is F4 while the most sensitive location for bottlenose dolphins is F3.

The maximum ranges for 90 and 75 dB_{ht} have been highlighted in bold because these are the thresholds at which strong and mild behavioural avoidance (that have been used in the other FTOWDG proposal impact assessments) are predicted to occur, respectively (Nedwell *et al.*, 2007; Table 14B.3).

Harbour porpoises are predicted to have the potential to exhibit a behavioural response up to 176.6 km from each piling activity (50 dB_{ht}; Table 14B.20). Bottlenose dolphins are predicted to have the potential to exhibit a behavioural response up to 127.7 km from piling (50 dB_{ht}; Table 14B.21). White-beaked dolphins are predicted to have the potential to exhibit a behavioural response up to 119.2 km from piling (50 dB_{ht}; Table 14B.22). Minke whales are predicted to have the potential to exhibit a behavioural response up to 235.4 km from piling (50 dB_{ht}; Table 14B.23).

Table 14B.20: The Maximum Ranges at which a Behavioural Response is Predicted to Occur in Harbour Porpoises in Response to Piling at Location F3 (see also Figure 14C.40 in Appendix 14C: Piling Noise Assessment Figures)

Harbour porpoise dB _{ht}	Max range (km)	Harbour porpoise dB _{ht}	Max range (km)
170	0.1	105	5.6
165	0.1	100	8.7
160	0.1	95	13.3
155	0.2	90	19.8
150	0.2	85	28.2
145	0.2	80	38.9
140	0.3	75	53.9
135	0.4	70	72.6
130	0.6	65	93.3
125	0.9	60	117.5
120	1.4	55	146.2
115	2.3	50	176.6
110	3.6		

Table 14B.21: The Maximum Ranges at which a Behavioural Response is Predicted to Occur in Bottlenose Dolphins in Response to Piling at Location F3 (see also Figure 14C.41 in Appendix 14C: Piling Noise Assessment Figures)

Bottlenose dolphin dB _{ht}	Max range (km)	Bottlenose dolphin dB _{ht}	Max range (km)
170	0.1	105	3.4
165	0.1	100	5.4
160	0.1	95	8.5
155	0.2	90	12.9
150	0.2	85	19.3
145	0.2	80	27.1
140	0.2	75	36.5
135	0.3	70	50.2
130	0.3	65	66.4
125	0.5	60	85.2
120	0.8	55	103.6
115	1.4	50	127.7
110	2.2		

Table 14B.22: The Maximum Ranges at which a Behavioural Response is Predicted to Occur in White-beaked Dolphins in Response to Piling at Location F4 (see also Figure 14C.42 in Appendix 14C: Piling Noise Assessment Figures)

White-beaked dolphin dB _{ht}	Max range (km)	White-beaked dolphin dB _{ht}	Max range (km)
170	0.1	105	3.4
165	0.1	100	5.4
160	0.1	95	8.3
155	0.2	90	12.5
150	0.2	85	18.2
145	0.2	80	25.7
140	0.2	75	35.3
135	0.3	70	45.9
130	0.3	65	62.0
125	0.5	60	78.9
120	0.8	55	97.1
115	1.4	50	119.2
110	2.2		

Table 14B.23: The Maximum Ranges at which a Behavioural Response is Predicted to Occur in Minke Whales in Response to Piling at Location F3 (see also Figure 14C.43 in Appendix 14C: Piling Noise Assessment Figures)

Minke whale dB _{ht}	Maximum range (km)	Minke whale dB _{ht}	Maximum range (km)
170	0.1	105	12.7
165	0.1	100	20.3
160	0.1	95	29.3
155	0.2	90	41.4
150	0.2	85	57.2
145	0.2	80	77.0
140	0.2	75	96.2
135	0.4	70	119.2
130	0.8	65	145.1
125	1.4	60	171.5
120	2.4	55	200.9
115	4.4	50	235.4
110	7.5		

14B.4.5 Assessment of Significance

Harbour Porpoise

The number of harbour porpoises predicted to be affected by PTS onset is low for both the most likely scenario for a single vessel (Scenario 1a, 2 piles which take 2.1 h each per 24 h period; 16 individuals) and the worst case for two piling vessels (Scenario 4, each piling four piles which take 4.2 h each per 24 h period; 30 individuals) (Table 14B.24). In comparison, a much larger number (486 individuals) are predicted to have the potential to be displaced during piling activities using a single construction vessel. Under the worst case construction scenario (using two vessels) 556 individuals are predicted to have the potential to be displaced.

Current advice from regulators is that the ‘national population’ should be used as the reference population for harbour porpoises. In the absence of a definition of a ‘national population’, we have used the sum of the abundance estimates for the SCANS II North Sea Blocks (Blocks T, U and V; Table 14B.8). The percentage of the national/reference population predicted to be affected ranges from < 0.1 per cent for PTS (low magnitude of impact) to 0.3 per cent for behavioural displacement (low magnitude of impact; Table 14B.24).

When standardised for 75 and 90 dB_{ht} (as explained in Section 14B.3.3 above), the number of harbour porpoises predicted to experience strong behavioural avoidance (90 dB_{ht}) is 108 (most likely for one construction vessel, Scenario 1a) which is equivalent to 0.1 per cent of the reference population and 137 (worst case for two construction vessels, Scenario 4) which is equivalent to 0.1 per cent of the reference population; the number predicted to exhibit a mild avoidance reaction (75 dB_{ht}) is 266 (most likely for one construction vessel, Scenario 1a) which is equivalent to 0.17 per cent of the reference population and 326 (worst case for two construction vessels, Scenario 4) which is equivalent to 0.21 per cent of the reference population.

The conservation status of UK harbour porpoises is considered to be Favourable (JNCC, 2007).

Table 14B.24: Number of Harbour Porpoises (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise at Inch Cape. The Reference Population Abundance is 159,040 (see Table 14B.8)

Scenario	PTS		Displacement									
			50 dB _{ht}		75 dB _{ht}		75 dB _{ht} (standardised)		90 dB _{ht}		90 dB _{ht} (standardised)	
	n	%	n	%	n	%	n	%	n	%	n	%
1a	16	< 0.1	486 (22 - 1728)	0.3	313 (22 - 893)	0.2	266 (14 - 807)	0.17	112 (16 - 268)	0.1	108 (11 - 263)	0.1
2a	20	< 0.1										
3	24	< 0.1	556 (29 - 1934)	0.3	382 (29 - 1089)	0.2	326 (18 - 998)	0.21	144 (21 - 355)	0.1	137 (13 - 348)	0.1
4	30	< 0.1										

The number of harbour porpoises predicted to experience the onset of PTS is small and the number with the potential to exhibit behavioural responses is large. However, the percentage of the reference population predicted to be affected by both PTS onset and behavioural responses is low (<10 per cent) and the duration of the effect is medium term (effects predicted to occur over the two years of piling activity). Therefore the impact at the population level is deemed to be minor.

Bottlenose Dolphin

Bottlenose dolphins are predicted to have the potential to experience PTS onset up to a maximum of 2.4 km from the piling event in the most likely scenario for one construction vessel (Scenario 1a) and up to 11.4 km from the piling event in the worst case scenario for two construction vessels (Scenario 4) using the M-weighted SEL criteria (Table 14B.18).

Bottlenose dolphins are predicted to have the potential to be displaced up to a maximum range of 127.7 km (50 dB_{ht}; Table 14B.21) from the source of piling noise. The maximum ranges for 90 dB_{ht} (strong behavioural avoidance) and 75 dB_{ht} (mild behavioural avoidance) are 12.9 km and 36.5 km respectively. The area from which bottlenose dolphins are predicted to have the potential to be displaced extends from Holy Island in the south to Aberdeen in the north (using the 50 dB_{ht} criteria; Figure 14C.41 in Appendix 14C: Piling Noise Assessment Figures). There is the potential for piling at the Inch Cape Development Area to create a barrier to movement between the Moray Firth and the Firth of Tay although this is unlikely because piling activity will not be continuous (it is likely to occur for between 11 to 23 per cent of the time depending upon the number of vessels and stiffness of ground encountered). It is unknown at the present time how long it will take for bottlenose dolphins to return to an area they have been displaced from once piling has stopped.

The range in number of bottlenose dolphins predicted to be affected by PTS onset is low for both the most likely scenario for one vessel (Scenario 1a, 1.2 individuals) to the worst case for two vessels (Scenario 4, 2.9 individuals) (Table 14B.25). A larger number (15 individuals) are predicted to have the potential to exhibit behavioural displacement out to 50 dB_{ht} from a single piling noise source (19 individuals from two piling noise sources).

These numbers were derived using an inferred density surface which was created using the best available information (Section 14B.3.1). However, it should be noted that bottlenose dolphins differ from some of the other species in the area because they are generally either absent from a particular location, or are present there as part of a group, i.e. assuming that half the east coast population is spread *evenly* along the coast from Peterhead to the Farne Islands is not very realistic. This means that the number of bottlenose dolphins predicted to experience PTS onset and/ or be displaced is likely to be an overestimate if they are actually absent at a given point in time, or an underestimate if they are present at that point in time but are there as part of a group.

The 'reference population' for bottlenose dolphin used in this assessment is the East Coast population (assumption derived after discussion with experts) which numbers 195 individuals (95 per cent highest posterior density intervals 162-253; Cheney *et al.*, 2012). For

the purposes of this assessment it has been assumed that the population is split 50:50 between the Moray Firth and the east coast at any point in time. Therefore, for the purposes of this impact assessment, the reference population against which numbers of animals affected by the Inch Cape Offshore Wind Farm piling noise alone have been compared is 98 individuals (Table 14B.8). Calculated against this reference population, the percentage of the reference population predicted to be affected ranges from 1.2 (most likely for one construction vessel, Scenario 1a) to 3.0 per cent (worst case for two construction vessels, Scenario 4) for PTS onset (low magnitude of impact) to 15.3 per cent for behavioural displacement out to 50 dB_{ht} from the piling activity of a single construction vessel (Scenario 1a) and 19.4 per cent for two construction vessels (Scenario 4; medium magnitude of impact; Table 14B.25).

When standardised for 75 and 90 dB_{ht} (as explained in Section 14B.3.3 above), the number of bottlenose dolphins predicted to experience strong behavioural avoidance (90 dB_{ht}) is 3 (most likely for a single construction vessel, Scenario 1a and worst case for two construction vessels, Scenario 4) which is equivalent to 3.1 per cent of the reference population; the number predicted to exhibit a mild avoidance reaction (75 dB_{ht}) is 10 (most likely for a single construction vessel, Scenario 1a) which is equivalent to 10.2 per cent of the reference population and 13 (worst case for two construction vessels, Scenario 4) which is equivalent to 13.3 per cent of the reference population.

The conservation status of UK bottlenose dolphins is considered to be Favourable (JNCC, 2007).

Table 14B.25: Number of Bottlenose Dolphins (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise at Inch Cape. The Reference Population Abundance is 98 (see Table 14B.8)

Scenario	PTS		Displacement									
			50 dB _{ht}		75 dB _{ht}		75 dB _{ht} (standardised)		90 dB _{ht}		90 dB _{ht} (standardised)	
	n	%	n	%	n	%	n	%	n	%	n	%
1a	1.2	1.2	15	15.3	12	12.2	10 (1 - 14)	10.2	3 (0 - 3)	3.1	3 (0 - 3)	3.1
2a	1.7	1.7	(1-22)		(1-16)							
3	1.9	1.9	19	19.4	16	16.3	13 (1 - 18)	13.3	3 (0 - 3)	3.1	3 (0 - 3)	3.1
4	2.9	3	(1-27)		(1-21)							

The potential for PTS onset in bottlenose dolphins is possible. The number of animals predicted to be affected is small (percentage of the population is 3 or less) and the duration of the effect is medium term (two years of piling activity) therefore the impact is minor.

The potential for behavioural displacement in bottlenose dolphins is considered to be likely. The number of animals predicted to be affected is medium (between 15 and 20 per cent) for 50 dB_{ht} and of medium duration. Therefore, the impact is considered to be moderate for the duration of the piling activities.

Assessment of Population Level Effects

Four different Inch Cape only scenarios (B to E) were modelled, two of which used the most likely values (C and E) and two of which used the worst case values for PTS (B and D; see Table 14B.9 and Table 14B.10 in Section 14B.3.5). Table 14B.26 below shows how the modelled scenarios (B to E) relate to the scenarios used for predicting the impacts of piling noise on marine mammals at the Inch Cape Offshore Wind Farm (Scenarios 1 to 4; Table 14B.7). The best estimate of the number of dolphins predicted to be displaced (15 for piling activity for a single vessel (C and E) or 19 for piling from two vessels (B and D)) was used. These numbers were implemented in the modelling by harvesting one female calf and one adult female from the population in each scenario (to simulate the effects of behavioural displacement and PTS; see Section 14B.3.5 above).

Table 14B.26: Modelled and Piling Noise Scenario Labels

Modelled scenario label	Scenario description	Piling noise scenario label
B	F3 IC	2a
C	F3 IC	1a
D	F3 IC and F4 IC	4
E	F3 IC and F4 IC	3

The modelling (Figure 14B.10 to Figure 14B.13) indicates that it is likely that there will be no population level effects of piling activity on the size of the east coast bottlenose dolphin population over a period of 25 years. Scenarios B to E all had final population sizes in the 200 individuals bin after 25 years, which is the same as the baseline scenario (A; Figure 14B.8).

Figure 14B.10: Bottlenose Dolphin Population Modelling Scenario B: F3 IC (PTS WC, Displacement Best Estimate)

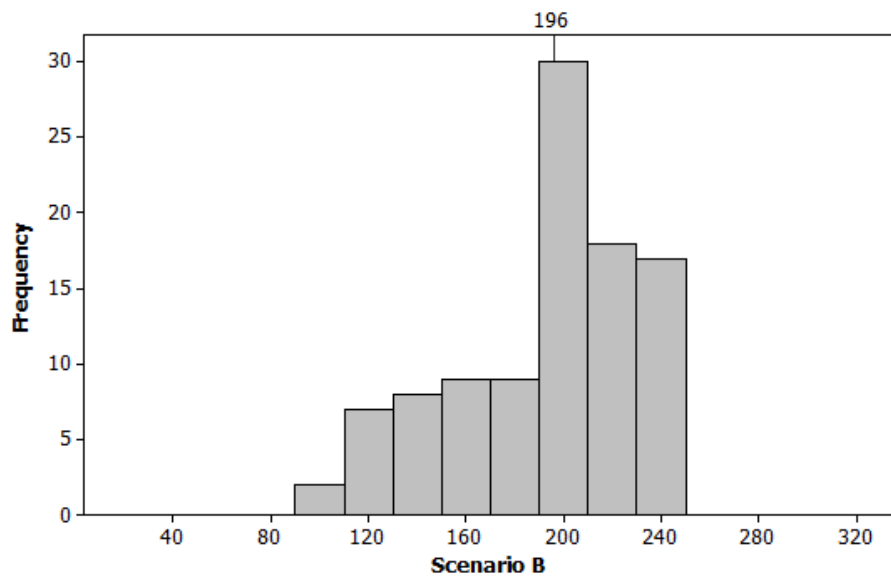
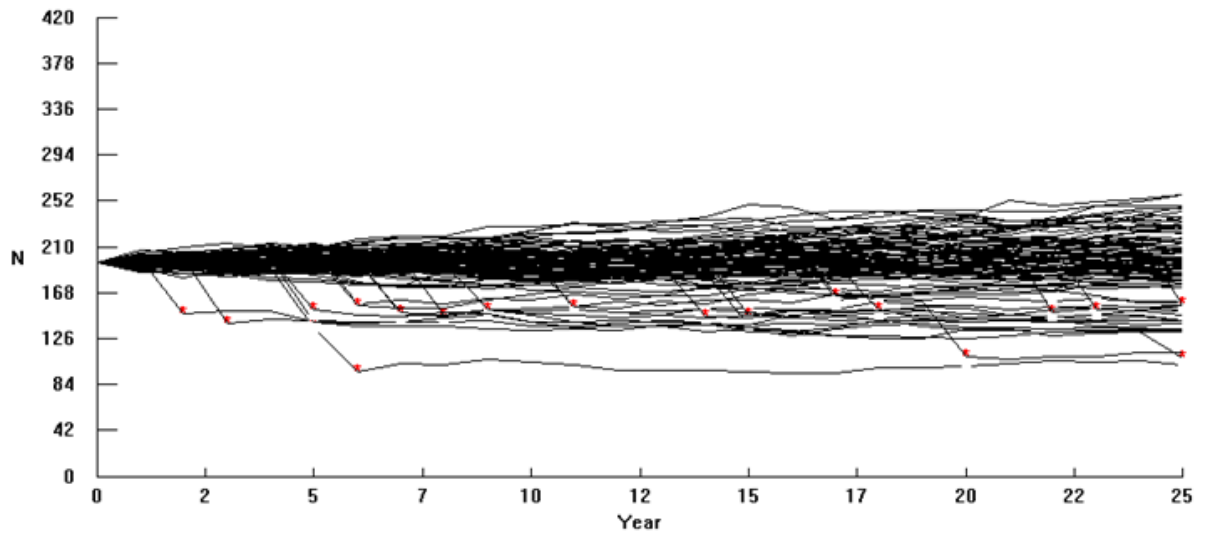


Figure 14B.11: Bottlenose Dolphin Population Modelling Scenario C: F3 IC (PTS ML, Displacement Best Estimate)

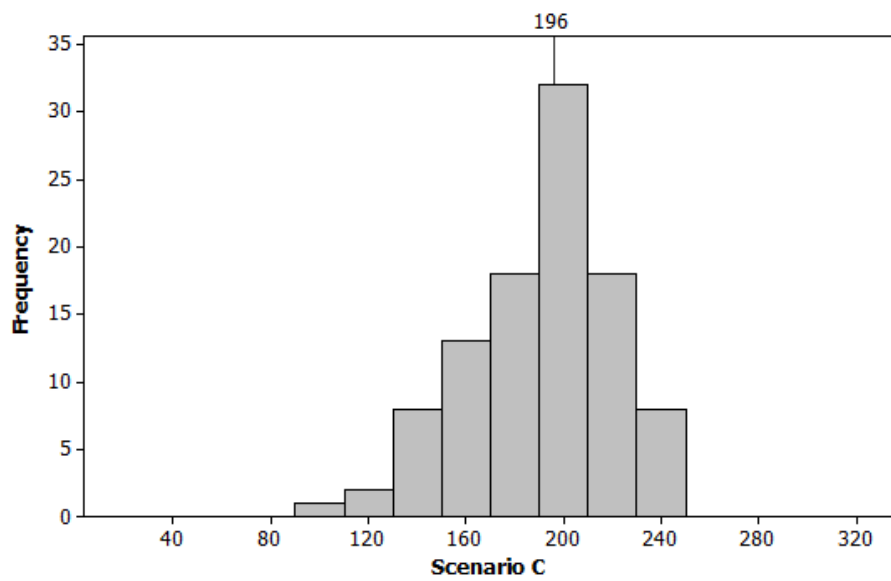
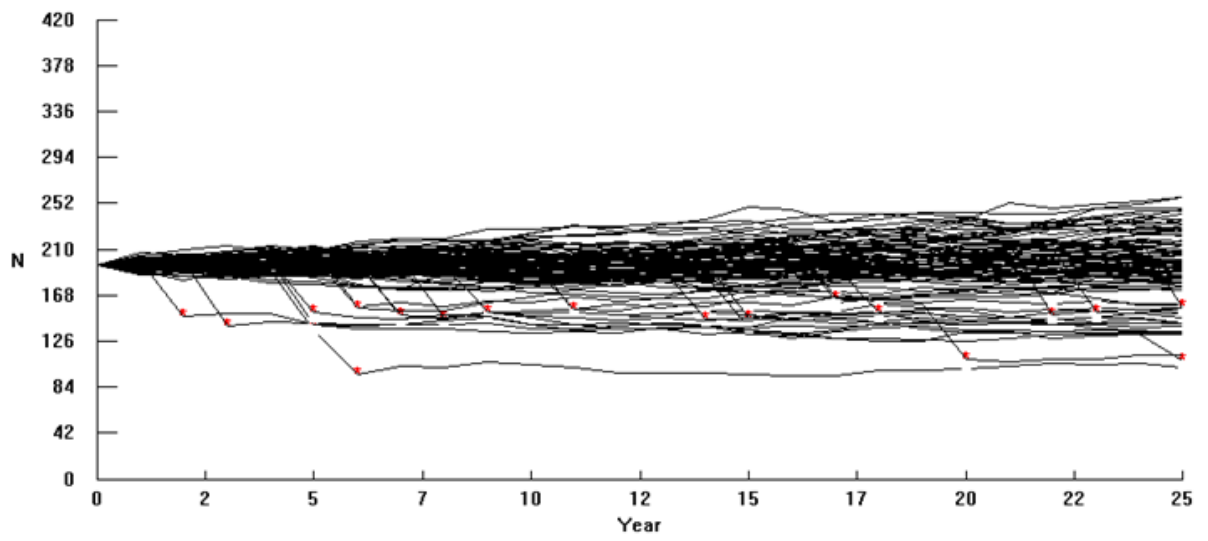


Figure 14B.12: Bottlenose Dolphin Population Modelling Scenario D: F3 IC and F4 IC (PTS WC, Displacement Best Estimate)

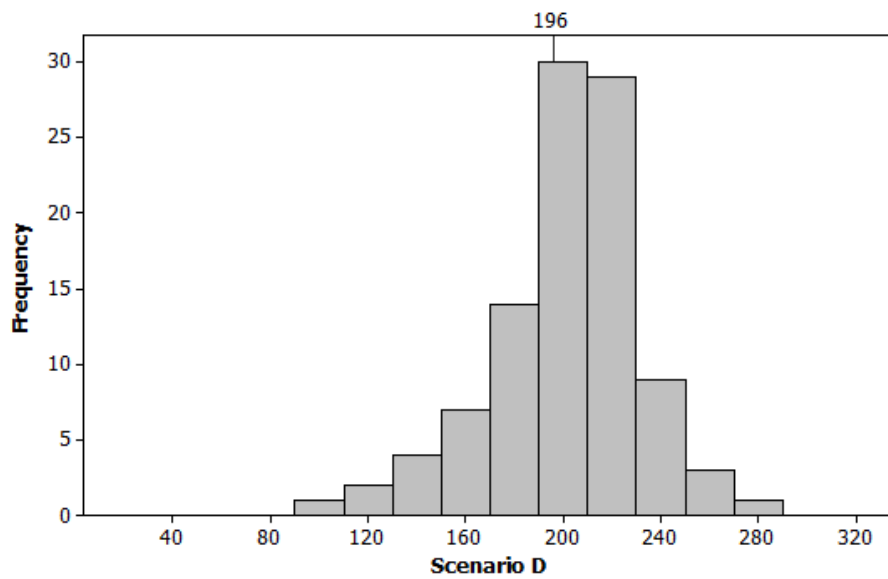
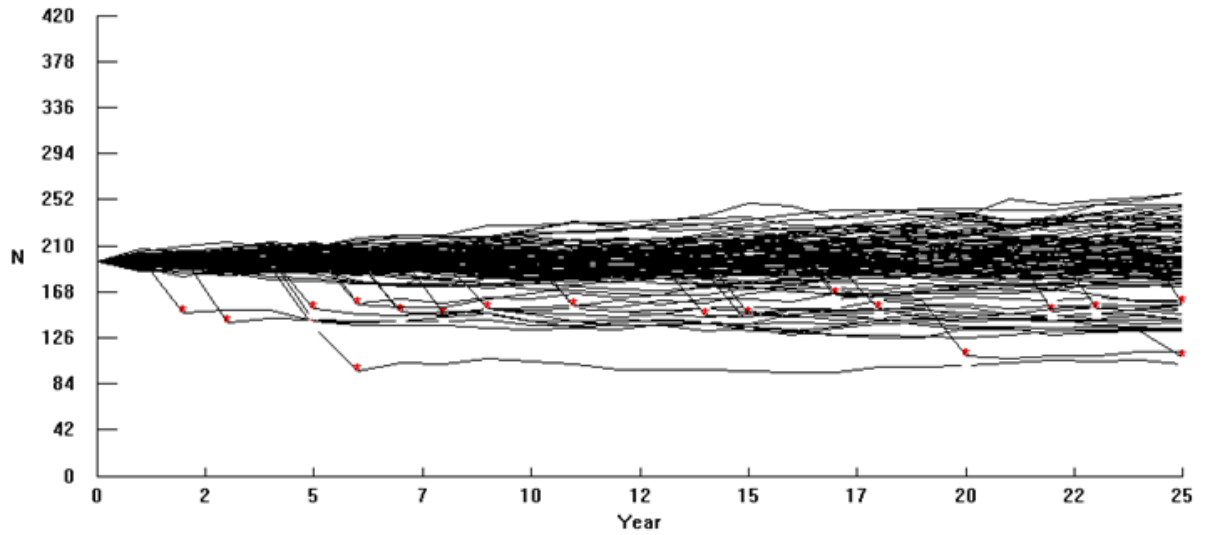
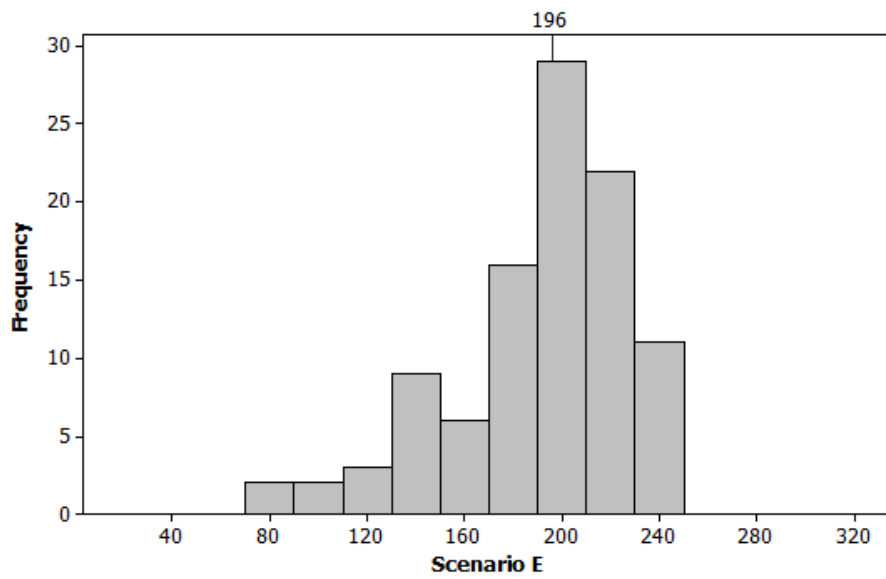
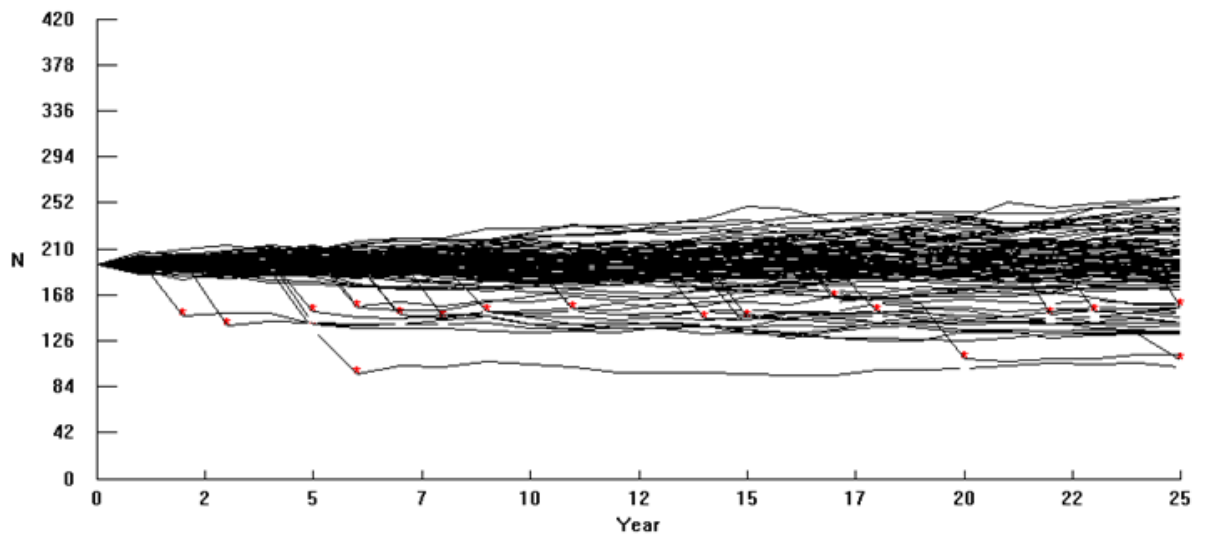


Figure 14B.13: Bottlenose Dolphin Population Modelling Scenario E: F3 IC and F4 IC (PTS ML, Displacement Best Estimate)



Population level modelling indicates that impacts of PTS onset and behavioural displacement are unlikely to cause a decline at the population level in the long term. Therefore, significance of the impact at the population level is deemed to be minor in the long term. .

White-Beaked Dolphin

White-beaked dolphins, mid frequency cetaceans, are predicted to have the potential to experience PTS onset up to a maximum of 2.2 km from the piling event in the most likely scenario (one construction vessel, Scenario 1b) and 11.4 km from the piling events in the worst case scenario (two construction vessels; Scenario 4) using the M-weighted SEL criteria (Table 14B.18).

White-beaked dolphins are predicted to have the potential to exhibit behavioural responses out to a maximum range of 119.2 km (50 dB_{ht}; Table 14B.22) from the source of piling noise. The maximum ranges for 90 dB_{ht} (strong behavioural avoidance) and 75 dB_{ht} (mild behavioural avoidance) are 12.5 km and 35.3 km respectively.

The number of white-beaked dolphins predicted to be affected by PTS onset is low for both the most likely scenario using one construction vessel (Scenario 1b, 7 individuals) and the worst case scenario from two construction vessels (Scenario 4, 13 individuals; Table 14B.27). A larger number of individuals (43 for one construction vessel, 51 for two construction vessels) are predicted to exhibit some degree of behavioural displacement out to 50 dB_{ht}.

When standardised for 75 and 90 dB_{ht} (as explained in Section 14B.3.3 above), the number of white-beaked dolphins predicted to experience strong behavioural avoidance (90 dB_{ht}) is 4 (most likely scenario using one construction vessel, Scenario 1b) which is equivalent to <0.1 per cent of the reference population and 11 (worst case scenario using two construction vessels, Scenario 4) which is equivalent to <0.1 per cent of the reference population; the number predicted to exhibit a mild avoidance reaction (75 dB_{ht}) is 20 (most likely using one construction vessel, Scenario 1b) which is equivalent to 0.1 per cent of the reference population and 27 (worst case using two construction vessels, Scenario 4) which is equivalent to 0.1 per cent of the reference population.

Because white-beaked dolphin is a wide-ranging species, the reference population against which numbers of animals affected have been compared is that in European Atlantic continental shelf waters. The percentage of the reference population predicted to be affected ranges from < 0.1 per cent for PTS (low magnitude of impact) to 0.2 per cent for behavioural displacement (low magnitude of impact; Table 14B.26).

The conservation status of UK white-beaked dolphins is considered to be Favourable (JNCC, 2007).

Table 14B.27: Number of White-beaked Dolphins (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise at Inch Cape. The Reference Population Abundance is 22,664 (see Table 14B.8)

Scenario	PTS		Displacement									
			50 dB _{ht}		75 dB _{ht}		75 dB _{ht} (standardised)		90 dB _{ht}		90 dB _{ht} (standardised)	
	n	%	n	%	n	%	n	%	n	%	n	%
1b	7	<0.1	43	0.2	24	0.1	20	0.1	4	<0.1	4	<0.1
2b	8	<0.1	(1 - 284)		(1 - 136)		(1 - 121)		(0 - 22)		(0 - 22)	
3	11	<0.1	51	0.2	31	0.1	27	0.1	12	0.1	11	<0.1
4	13	<0.1	(2 - 330)		(2 - 169)		(1 - 153)		(1 - 59)		(1 - 58)	

The percentage of the reference population of white-beaked dolphins predicted to be affected is low (<10 per cent) for both PTS and behavioural displacement and the duration is medium (two years of piling activity), therefore the impact at the population level is deemed to be minor.

Minke Whale

Minke whales, low frequency cetaceans, are predicted to have the potential to experience PTS onset up to a maximum of 6.9 km from the piling event in the most likely scenario for one construction vessel and 18.8 km from the piling event in the worst case scenario for two vessels using the M-weighted SEL criteria (Table 14B.19).

Minke whales are predicted to exhibit some behavioural response out to a maximum range of 235.4 km (50 dB_{ht}; Table 14B.23) from the source of piling noise. The maximum ranges for 90 dB_{ht} (strong behavioural avoidance) and 75 dB_{ht} (mild behavioural avoidance) are 41.4 km and 96.2 km respectively.

The number of minke whales predicted to have the potential to develop PTS onset is low for both the most likely scenario using one construction vessel (Scenario 1a; 13 individuals) scenario and the worst case scenario using two construction vessels (Scenario 4; 24 individuals; Table 14B.28). A much larger number (500 individuals) are predicted to exhibit some degree of behavioural displacement from a single piling event (Scenario 1a), with this number increasing to 543 if two construction vessels encounter the worst case piling scenario (Scenario 4).

Because minke whale is a wide-ranging species, the reference population against which numbers of animals affected have been compared is the Northeast Atlantic stock. The percentage of the reference population predicted to be affected ranges from < 0.1 per cent for PTS (low magnitude of impact) to 0.3 per cent for behavioural displacement (low magnitude of impact; Table 14B.28).

When standardised for 75 and 90 dB_{ht} (as explained in Section 14B.3.3 above), the number of minke whales predicted to experience strong behavioural avoidance (90 dB_{ht}) is 159 (most likely scenario using one construction vessel, Scenario 1a) which is equivalent to 0.1 per cent of the reference population and 191 (worst case scenario using two construction vessels, Scenario 4) which is also equivalent to 0.1 per cent of the reference population; the number predicted to exhibit a mild avoidance reaction (75 dB_{ht}) is 327 (most likely scenario using one construction vessel, Scenario 1a) which is equivalent to 0.2 per cent of the reference population and 361 (worst case using two construction vessels, Scenario 4) which is equivalent to 0.2 per cent of the reference population.

The conservation status of UK minke whales is considered to be Favourable (JNCC, 2007).

Table 14B.28: Number of Minke Whales (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise at Inch Cape. The Reference Population Abundance is 181,922 (see Table 14B.8)

Scenario	PTS		Displacement									
			50 dB _{ht}		75 dB _{ht}		75 dB _{ht} (standardised)		90 dB _{ht}		90 dB _{ht} (standardised)	
	n	%	n	%	n	%	n	%	n	%	n	%
1a	1	<0.1	500	0.3	386	0.2	327	0.2	165	0.1	159 (7 - 849)	0.1
2a	1	<0.1	4514		3026		2723		865			
3	1	<0.1	543	0.3	425	0.2	361	0.2	197	0.1	191 (8 - 1024)	0.1
4	2	<0.1	4846		3294		2949		1043			

The percentage of the reference population of minke whales predicted to be affected by PTS and behavioural displacement is low (<1 per cent) and the duration is medium (up to two years of piling activity), therefore the impact at the population level is deemed to be minor.

14B.4.6 Summary

Table 14B.29 below presents a summary of the potential impacts from piling at the Inch Cape Offshore Wind Farm. Potential effects on all marine mammal species are predicted to be of medium term duration (i.e. the two years of piling duration the construction phase of up to four years).

Effects on the non-SAC species (harbour porpoise, white-beaked dolphin and minke whale) are predicted to be of low magnitude (less than 10 per cent of the population will be affected) and therefore minor.

Effects at the population level were examined for the SAC species (bottlenose dolphins, grey seals and harbour seals). For all three species population level effects are unlikely. For harbour seals, the integrity of the Firth of Tay and Eden Estuary SAC is already not being

maintained (without impacts relating to the construction of any offshore wind farms; see Appendix 14D: Harbour Seal Assessment).

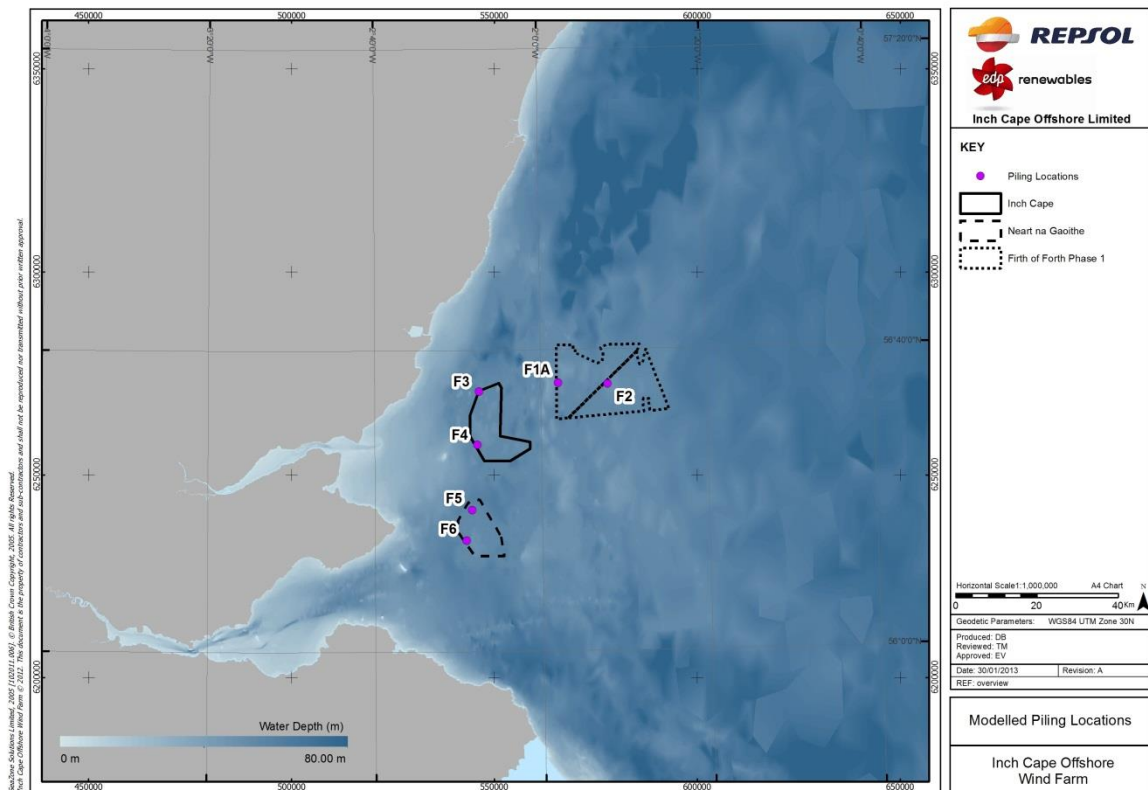
Table 14B.29: Summary of Potential Impacts from Construction Piling Noise on Relevant Marine Mammal Receptors

Receptor	Potential Impact: Piling at Inch Cape
Harbour seal	Minor to Moderate (PTS onset) and Major (behavioural avoidance) (medium term) but likely minor impact in the long term (illustrative modelling has been carried out because current population projections predict that the harbour seal population will be of negligible size at the start of the actual piling period of 2016).
Grey seal	Minor to Moderate (PTS onset) and Major (behavioural avoidance) (medium term) but comparisons to current PBR predict Minor impact in the long term.
Harbour porpoise	Minor for both PTS onset and behavioural impacts.
Bottlenose dolphin	Minor (PTS onset) and Minor to Moderate (behavioural avoidance) (medium term) but population modelling predicts Minor impact at the population level in the long term.
White-beaked dolphin	Minor for both PTS onset and behavioural impacts
Minke whale	Minor for both PTS onset and behavioural impacts

14B.5 Prediction of Impact – Cumulative Scenarios

The INSPIRE noise propagation modelling described in Section 14B.2 was extended to include potential additional foundation piling activity taking place at two other OWF sites close to the Inch Cape Offshore Wind Farm; Seagreen’s Firth of Forth Phase 1 site (FoF) and Mainstream’s Neart na Gaoithe site (NnG; noise modelling locations shown in Figure 14B.14 below). As FoF and NnG impact assessments for marine mammals were centred on the 130, 90 and 75 dB_{ht} (*Species*) contours for displacement, the cumulative assessment has been conducted using these predicted contours for all species. The methodology for this ‘standardisation’ of impact prediction is described above in Section 14B.3.3.

Figure 14B.14: Noise Modelling Locations at the Inch Cape, Firth of Forth Phase 1 and Neart na Gaoithe OWF Sites



Two cumulative scenarios were modelled (Table 14B.32):

- Two piles at one location at IC, one pile at FoF and one pile at NnG within one 24 hour period (Scenario 5); and
- Four piles at IC (two at each of two locations) and one pile at each FoF and NnG location within one 24 hour period (Scenario 6).

The ‘most sensitive’ Inch Cape Development Area piling modelling locations were the same as those used in the Inch Cape only scenarios (Section 14B.2). The most sensitive locations for receptor species at Seagreen’s Firth of Forth site were F1A (Alpha) for minke whale, bottlenose dolphin and seals and F2 (Bravo) for white-beaked dolphin and harbour porpoise, again based on the species’ spatial distribution (see Figure 14C.2 to Figure 14C.7 in Appendix 14C: Piling Noise Assessment Figures). Location F5 at Mainstream’s Neart na Gaoithe site was used as the most sensitive for all receptor species (Figure 14B.14). For assessments including possible simultaneous piling at two locations per site (six vessels in total), locations F1A and F2 were both use for FoF, and F5 and F6 for NnG.

Table 14B.30 and 14B.31 present the blow energy profiles that have been used by Subacoustech Ltd to undertake the noise propagation modelling.

Table 14B.30: Most Likely Predicted Blow Energy Profile Required to Drive a 2500 mm Diameter Pin Pile at the Neart na Gaoithe Site

Impact Energy (kJ)	Number of strikes	Duration (s)
240	600	1200
996	5400	10800

Table 14.31: Most likely Predicted Blow Energy Profile Required to Drive a 2000 mm Diameter Pin Pile at the Firth of Forth Site (Phase 1)

Impact Energy (kJ)	Number of strikes	Duration (s)
180	223	298
420	527	702
660	478	637
900	217	289

Table 14B.32: Details of the Scenarios Used for Predicting the Cumulative Impacts of Piling Noise on Marine Mammals (all Using the Most Likely Blow Energies Piling Scenarios). F1A to F6 are the Piling Locations (see Figure 14B.14)

Scenario	Location	Number of piles per 24h	Species modelled
5a	F3 IC + F5 NnG + F1A FoF	2 piles at IC, 1 pile at NnG, 1 pile at FoF	Bottlenose dolphin Minke whale
5b	F4 IC + F5 NnG + F1A FoF		Harbour seal Grey seal
5c	F3 IC + F5 NnG + F2 FoF		Harbour porpoise
5d	F4 IC + F5 NnG + F2 FoF		White-beaked dolphin
6	F3 IC + F4 IC + F5 NnG + F6 NnG + F1A FoF + F2 FoF	2 piles at F3, 2 piles at F4, 2 piles at NnG (1 at F5, 1 at F6), 2 piles at FoF (1 at F1A, 1 at F2)location	All

According to the proposed construction timelines of the three FTOWDG offshore wind farms (Inch Cape, Firth of Forth Phase 1 and Neart na Gaoithe) (summarised in Table 14B.33 below), piling has the potential to be carried out at two of the three projects in 2015 (Neart na Gaoithe and Firth of Forth Phase 1) and at the three projects in 2016. To ensure that this cumulative impact assessment is inclusive of a potential slip in project timelines of any or all of the three projects, the impact assessment has been undertaken assuming piling activity on all three projects for five years from 2014 to 2018. It is recognised that piling activity on all three projects in all five years is extremely unlikely, and thus this assessment is very likely to over-estimate cumulative impacts. However, displacement has the potential to occur over relatively large areas for each project and thus the impact radii from piling at locations within two or three projects will overlap. It is considered that the complexity of attempting

to model distinct piling phases of individual projects is not warranted when considered against the uncertainties detailed in Table 14B.11.

Table 14B.33: Construction Timelines of the FTOWDG Projects. Years during which Piling is Scheduled to Take Place are Shaded Grey

Offshore Wind Farm	Year				
	2014	2015	2016	2017	2018
Neart na Gaoithe					
Firth of Forth Phase 1					
Inch Cape					
Potential for programme slippage					

14B.5.1 Lethal Effects and Physical Injury - All Marine Mammals

Table 14B.34 (below) provides details of the predicted ranges for lethal effects (240 dB) and physical injury (220 dB) for all marine mammals from each of the piling locations for the two cumulative piling scenarios (which are detailed in Table 14B.32 above).

This modelling has indicated that during piling operations, physical injury and lethal impacts to marine mammals are in the order of 40 and 6 metres respectively from the pile (See Section 11A.6.1, Appendix 11A: Underwater Noise). These ranges apply to each of the up to six piling locations for which noise modelling has been undertaken.

Table 14B.34: The Ranges Over which Physical Injury (220 dB) and Lethal Effects (240 dB) are Predicted for all Marine Mammals

Unweighted (all marine mammals)	240 dB	220 dB
Min range (m)	4	38
Max range (m)	6	40
Mean range (m)	5	39

It is very unlikely that marine mammals will be exposed to noise levels which have the potential to cause death/physical injury because a mitigation protocol has been developed by the Statutory Nature Conservation Agencies in order to reduce this risk to negligible levels (JNCC, 2010). Therefore death/physical injury is not discussed further within this appendix.

14B.5.2 Auditory Injury and Displacement - Pinnipeds

Auditory Injury (PTS)

Table 14B.35 details the ranges over which seals (harbour and grey) have the potential to experience the onset of PTS, using the M-weighted SEL criteria of 186 dB, for the two different cumulative construction scenarios.

Table 14B.35: SEL (186 dB) Ranges for the Potential for PTS Onset in Pinnipeds, for the Cumulative Construction Scenarios (Most Likely Blow Energies Piling Scenarios)

Construction scenario	Min range (km)	Max range (km)	Mean range (km)	Figure in Appendix 14C
5b	21.6	38.8	31	Figure 14C.71
6	24.3	57.5	38.4	Figure 14C.72

Displacement

Figures 14C.73 and 14C.74 (Appendix 14C: Piling Noise Assessment Figures) show the areas and ranges over which harbour (and grey) seals are predicted to have the potential to experience noise levels which could elicit strong (using the 90 dB_{ht} criteria) and mild (using the 75 dB_{ht} criteria) behavioural responses. The approximate ranges are shown in Table 14B.36 below.

Table 14B.36: Approximate Ranges of the 90 and 75 dBht Contours from the Piling Locations for Pinnipeds for the Cumulative Construction Scenarios

Scenario	Approximate maximum range of the dB _{ht} contour from the piling locations (km)		Figure in Appendix 14C
	90 dB _{ht}	75 dB _{ht}	
5b	15	49	Figure 14C.73
6	18	53	Figure 14C.74

14B.5.3 Assessment of Significance**Harbour Seal**

The number of harbour seals predicted to have the potential to be exposed to SELs sufficient to induce the onset of PTS and to have the potential to be displaced is provided in Table 14B.37 below.

Depending on the scenario (one or two vessels operating on each site simultaneously), the percentage of the reference population predicted to be affected ranges from 11.3 to 14.1 per cent for PTS onset, 45.0 to 46.7 per cent out to mild avoidance behaviour and 32.3 to 35.2 per cent for strong avoidance behaviour (Table 14B.37).

Table 14B.37: Number of Harbour Seals (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise in the Cumulative Construction Scenarios. The Reference Population Abundance is 638 (see Table 14B.8).

Scenario	PTS (186 dB)		Displacement			
			75 dB _{ht} (standardised)		90 dB _{ht} (standardised)	
	n	%	n	%	n	%
5b	72	11.3	287 (32 - 348)	45.0	206 (29 - 218)	32.3
6	90	14.1	298 (47 - 363)	46.7	226 (42 - 239)	35.4

The potential impact of PTS onset in harbour seals is predicted to be of medium magnitude (>10 per cent) and medium term duration, therefore moderate in the medium term.

The potential impact of behavioural displacement on harbour seals is predicted to be of high magnitude (>20 per cent) and medium duration and therefore be major in the medium term. However, piling is likely to occur for a relatively small percentage of the total construction time (11-23 per cent of the two year piling phase) and therefore the actual potential for behavioural displacement is likely to be less than stated for the full two year duration.

Assessment of Population Level Effects

Illustrative modelling work (detailed in Appendix 14D: Harbour Seal Assessment and summarised in Section 14B.3.5 and Section 14B.4.2 of this Appendix for Inch Cape only) which has been carried out indicates that there is little difference between the baseline and construction scenarios for The Project alone (Figure 14B.9). Therefore it was concluded that impacts from piling on harbour seals at the population level are likely to be minor in the long term. It should be noted that it may not be possible to measure any added loss that activities at the FTOWDG OWF developments might have on the population in the long-term because by the time piling is due to commence the harbour seal population is likely to be of negligible size.

Grey Seal

The number of grey seals predicted to have the potential to be exposed to SELs sufficient to induce the onset of PTS and to have the potential to be displaced is given in Table 14B.38 below.

Depending on the scenario (one or two vessels operating on each site simultaneously), the percentage of the reference population predicted to be affected ranges from 10.4 to 13.6 per cent for PTS onset, 35.8 to 40.3 per cent for mild avoidance behaviour and 16.7 to 22.3 per cent for strong avoidance behaviour (Table 14B.38).

Table 14B.38: Number of Grey Seals (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise in the Cumulative Construction Scenarios. The Reference Population Abundance is 7112 (see Table 14B.8)

Scenario	PTS (186 dB)		Displacement			
			75 dB _{ht} (standardised)		90 dB _{ht} (standardised)	
	n	%	n	%	n	%
5b	737	10.4	2546 (249 - 3454)	35.8	1191 (184 - 1353)	16.7
6	969	13.6	2867 (369 - 3787)	40.3	1585 (307 - 1793)	22.3

The percentage of the reference population predicted to be affected by PTS onset (magnitude) is medium and the duration of the effect is medium term, therefore the impact is moderate in the medium term.

The percentage of the reference population predicted to be affected by behavioural displacement is high for a single vessel on each site and also for two vessels on each site (>20 per cent) and the duration is medium term, therefore major impact in the medium term (for the piling duration).

Assessment of Population Level Effects

The 2012 PBR (i.e. the number of animals that can be removed from the population in that year without causing a decline) for grey seals in the East Coast Management Area is 277⁸. If we assume that 25 per cent of the animals predicted have the potential to be exposed to SELs sufficient to induce the onset of PTS are lost from the population, or ‘harvested’, this would equate to removal of 184-242 individuals from the population depending on the scenario (one or two vessels operating on each site simultaneously). This is equivalent to 67-87 per cent of the current PBR. Therefore, the potential impact of PTS onset at the population level is within the allowed ‘take’ (PBR) for both cumulative construction scenarios and therefore is not predicted to cause a decline in the East Coast Management Area population.

Therefore the overall assessment of significance of potential impact of PTS at the population level is considered to be of minor in the long term.

Modelling undertaken has predicted 35.8 – 40.3 per cent of the grey seal reference population may exhibit mild behavioural responses to piling noise; it is predicted that 16.7 to 22.3 per cent may exhibit strong behavioural responses. This equates to an impact of major significance at 75 dB_{ht} and moderate to major significance at 90 dB_{ht}. The grey seals which have the potential to be displaced due to cumulative piling at all three FTOWDG OWF developments (Firth of Forth, Neart na Gaoithe and Inch Cape) may not breed in the Firth of Forth. In addition, grey seals travel extensively and use a wide range of habitats including multiple foraging areas and haul out sites. Displacement is, therefore, not expected to have the same effect on grey seals as it might have on a species which does not travel so

⁸ <http://www.scotland.gov.uk/Topics/marine/Licensing/SealLicensing>

extensively. Given that the grey seal population in the East Coast Management Area is thought to be increasing (Appendix 14A: Marine Mammals Baseline), there is likely to be suitable alternative habitat for feeding and hauling out and it is likely that animals will become habituated to the lower levels of piling noise, it is considered unlikely that behavioural displacement will have a long-term impact at the population level.

Therefore the overall assessment of impact on grey seals in the long term is likely to be minor.

14B.5.4 Auditory Injury and Displacement - Cetaceans

Auditory Injury (PTS)

Table 14B.39, Table 14B.40 and Table 14B.41 below detail the ranges over which high, mid and low frequency cetaceans are predicted to experience the potential onset of PTS using the M-weighted SEL criteria of 198 dB for the two different cumulative construction scenarios (one or two vessels operating simultaneously on each of the three sites) total of three or six vessels at any one time.

Table 14B.39: SEL Ranges for PTS Onset in High Frequency Cetaceans (e.g. Harbour Porpoises) for the Cumulative Construction Scenarios (Most Likely Blow Energy Piling Scenario)

High Frequency Cetaceans – SEL (198 dB)	Min range (km)	Max range (km)	Mean range (km)	Figure in Appendix 14C
Scenario 5c	0.1	12.9	2.7	Figure 14C.83
Scenario 6	0.1	24.7	6.7	Figure 14C.87

Table 14B.40: SEL Ranges for PTS Onset in Mid Frequency Cetaceans (Bottlenose and White-beaked dolphins) for the Cumulative Construction Scenarios (Most Likely Blow Energy Piling Scenario)

Mid Frequency Cetaceans – SEL (198 dB)	Min range (km)	Max range (km)	Mean range (km)	Figure in Appendix 14C
Scenario 5a (bottlenose dolphin)	0.1	12.7	2.6	Figure 14C.84
Scenario 5d (white-beaked dolphin)	0.1	17.6	2.7	Figure 14C.85
Scenario 6 (bottlenose dolphin and white-beaked dolphin)	0.1	24.8	6.5	Figure 14C.88

Table 14B.41: SEL Ranges for PTS Onset in Low Frequency Cetaceans (e.g. Minke Whales) for the Cumulative Construction Scenarios (Most Likely Blow Energy Piling Scenario)

Low Frequency Cetaceans – SEL (198 dB)	Min range (km)	Max range (km)	Mean range (km)	Figure in Appendix 14C
Scenario 5a	0.1	16	5	Figure 14C.86
Scenario 6	2	26.3	11.9	Figure 14C.89

Displacement

Figures 14C.90 to 14C.96 (Appendix 14C: Piling Noise Assessment Figures) show the areas and ranges over which harbour porpoises, bottlenose dolphins, white-beaked dolphins and minke whales are predicted to have the potential to experience noise levels which could elicit strong (using the 90 dB_{ht} criteria) and mild (using the 75 dB_{ht} criteria) behavioural responses. The approximate ranges are shown in Table 14B.42 (Scenario 5) and Table 14B.43 (Scenario 6) below. The general increase in maximum range of dB_{ht} contours associated with Scenario 6 are a consequence of the increased spread of the piling locations. For example the inclusion of NnG F6 and FoF F2 for all species.

Table 14B.42: Approximate Ranges of the 90 and 75 dBht Contours from the Piling Locations for Cetaceans for Scenario 5 (One Vessel Operating on Each Site)

Species	Approximate maximum range of the dB _{ht} contour from the piling locations (km)		Figure in Appendix 14C
	90 dB _{ht}	75 dB _{ht}	
Harbour porpoise	18	58	Figure 14C.90
Bottlenose dolphin	11	40	Figure 14C.91
White-beaked dolphin	11	35	Figure 14C.92
Minke whale	42	89	Figure 14C.93

Table 14B.43: Approximate Ranges of the 90 and 75 dBht Contours from the Piling Locations for Cetaceans for Scenario 6 (Two Vessels Operating on Each Site Simultaneously)

Species	Approximate maximum range of the dB _{ht} contour from the piling locations (km)		Figure in Appendix 14C
	90 dB _{ht}	75 dB _{ht}	
Harbour porpoise	22	58	Figure 14C.94
Bottlenose dolphin	11	42	Figure 14C.95
White-beaked dolphin	11	42	Figure 14C.95
Minke whale	45	91	Figure 14C.96

14B.5.5 Assessment of Significance

Harbour Porpoise

The numbers of harbour porpoises predicted to have the potential to be exposed to SELs sufficient to induce the onset of PTS and to have the potential to exhibit a behavioural response are provided in Table 14B.44 below.

For both cumulative construction scenarios (one or two vessels operating simultaneously on each of the three sites), the percentage of the reference population predicted to be affected is less than 0.1 per cent for PTS onset, 0.3 to 0.4 per cent for mild avoidance behaviour and 0.2 per cent for strong behavioural avoidance (Table 14B.44).

Table 14B.44: Number of Harbour Porpoises (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise in the Cumulative Construction Scenarios. The Reference Population Abundance is 159,040 (see Table 14B.8)

Scenario	PTS		Displacement			
			75 dB _{ht} (standardised)		90 dB _{ht} (standardised)	
	n	%	n	%	n	%
5c	22	< 0.1	555 (30 - 1712)	0.3	268 (23 - 663)	0.2
6	32	< 0.1	577 (33 - 1771)	0.4	292 (26 - 735)	0.2

The number of harbour porpoises predicted to be affected by PTS onset and/or behavioural effects is large. However the percentage of the reference population predicted to be affected is low (<10 per cent) and the duration of the effect is medium term. The impact at the population level is deemed therefore to be minor.

Bottlenose Dolphin

The number of bottlenose dolphins that have the potential to be exposed to SELs sufficient to induce the onset of PTS is less than five for both cumulative scenarios (Table 14B.45). The number predicted to have the potential to be displaced is less than 20.

Depending on the scenario, the percentage of the reference population predicted to be affected ranges from 4.4 to 4.9 per cent for PTS onset, 15.3 to 17.3 per cent for mild avoidance behaviour and 3.1 per cent for strong behavioural avoidance (Table 14B.45).

Table 14B.45: Number of Bottlenose Dolphins (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise in the Cumulative Construction Scenarios. The Reference Population Abundance is 98 (see Table 14B.8)

Scenario	PTS		Displacement			
			75 dB _{ht} (standardised)		90 dB _{ht} (standardised)	
	n	%	n	%	n	%
5a	4.3	4.4	15 (1 - 21)	15.3	3 (0 - 3)	3.1
6	4.8	4.9	17 (1 - 26)	17.3	3 (0 - 3)	3.1

Assessment of Population Level Effects

Four different cumulative scenarios were modelled (F to I – see Table 14B.46; Figure 14B.15 to Figure 14B.18 below). The impacts from each scenario were modelled to be exerted upon the population for five years (2014 to 2018 inclusive). The outputs indicate that it is likely that there will be no population level effects of cumulative piling activity on the size of the east coast bottlenose dolphin population over a period of 25 years from piling from the FTOWDG projects (the majority of the model runs had final population sizes after 25 years of 200 individuals, i.e. the same as the baseline scenario, Figure 14B.8).

Table 14B.46: Cumulative Modelled and Piling Noise Scenario Labels

Modelled scenario label	Scenario description	Piling noise scenario label
F	F3 IC and F5 NnG and F1A FoF	5a
G	F3 IC and F5 NnG and F1A FoF	5a
H	F3 IC and F4 IC and F5 NnG and F6 NnG and F2 FoF and F1A FoF	6
I	F3 IC and F4 IC and F5 NnG and F6 NnG and F2 SFoF and F1A FoF	6
J	Extreme to include 100% breeding failure for 5 years	Cumulative FTOWDG, MORL and Beatrice

Figure 14B.15: Bottlenose Dolphin Population Modelling Scenario F: F3 IC and F5 NnG and F1A FoF (PTS ML, Displacement Best Estimate) for Five Years of Piling (from 2014 to 2018)

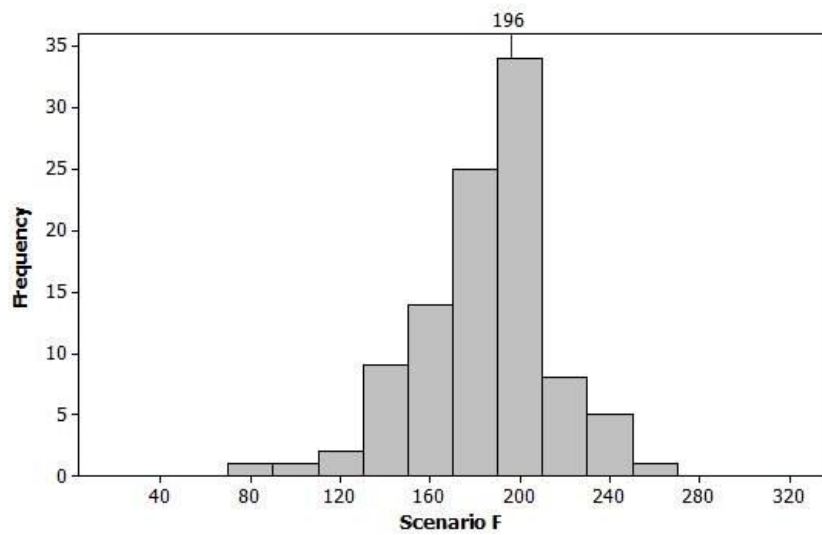
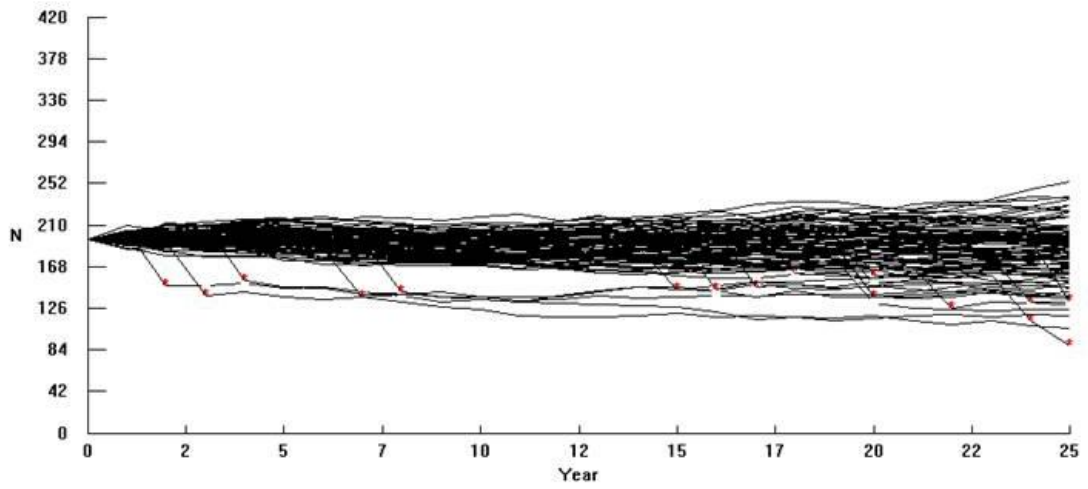


Figure 14B.16: Bottlenose Dolphin Population Modelling Scenario G: F3 IC and F5 NnG and F1A FoF (PTS ML, Displacement Highest Estimate) for Five Years of Piling (from 2014 to 2018)

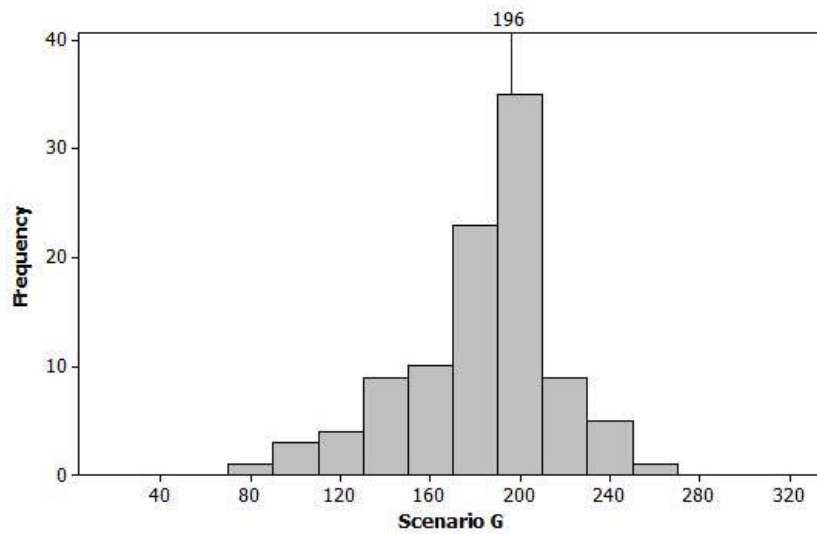
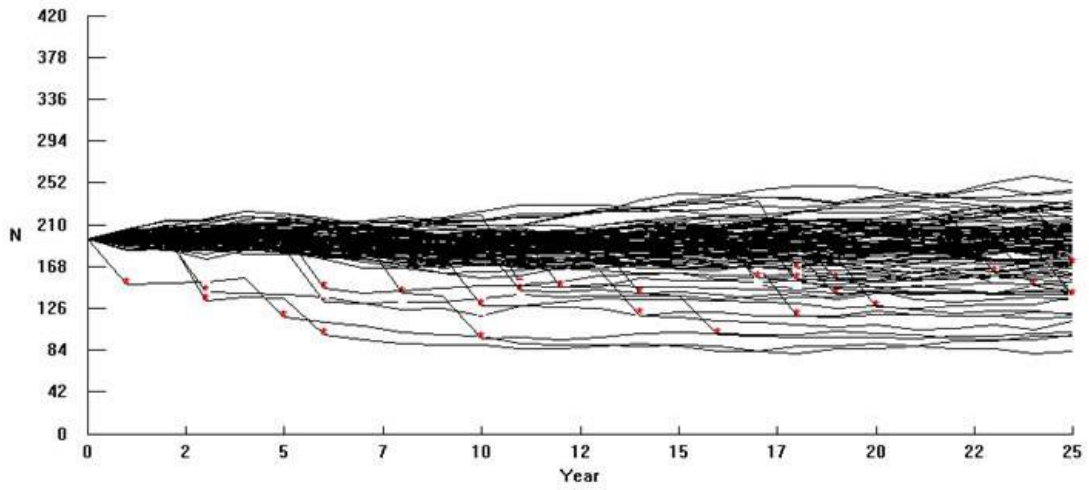


Figure 14B.17: Bottlenose Dolphin Population Modelling Scenario H: F3 IC and F4 IC and F5 NnG and F6 NnG and F2 FoF and F1A FoF (PTS ML, Displacement Best Estimate) for Five Years of Piling (from 2014 to 2018)

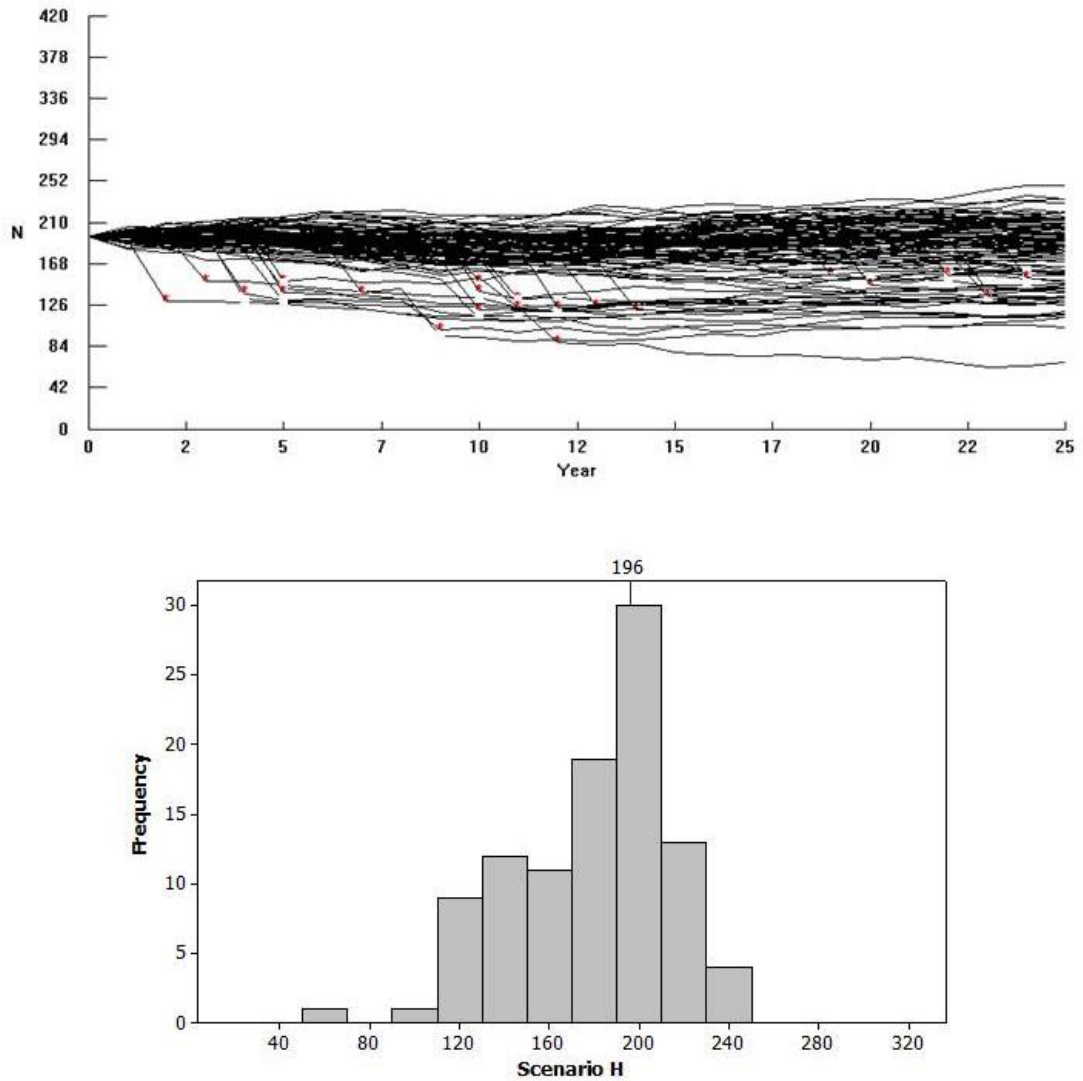
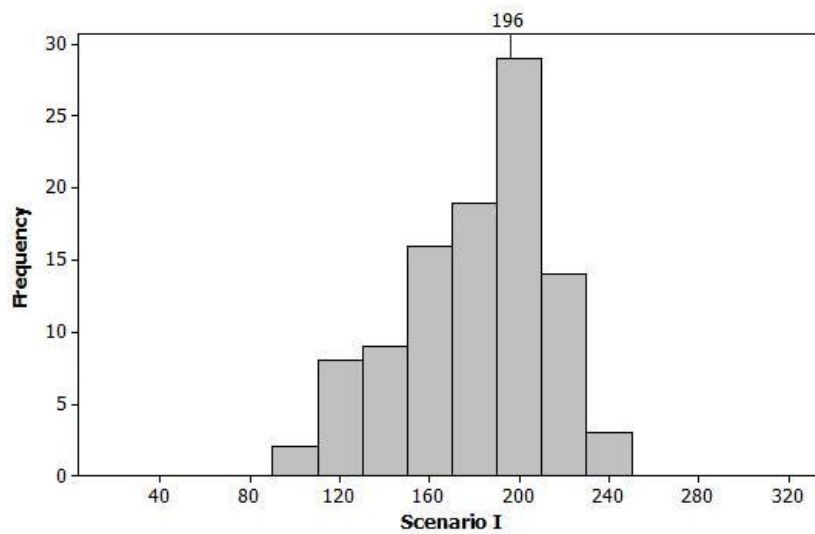
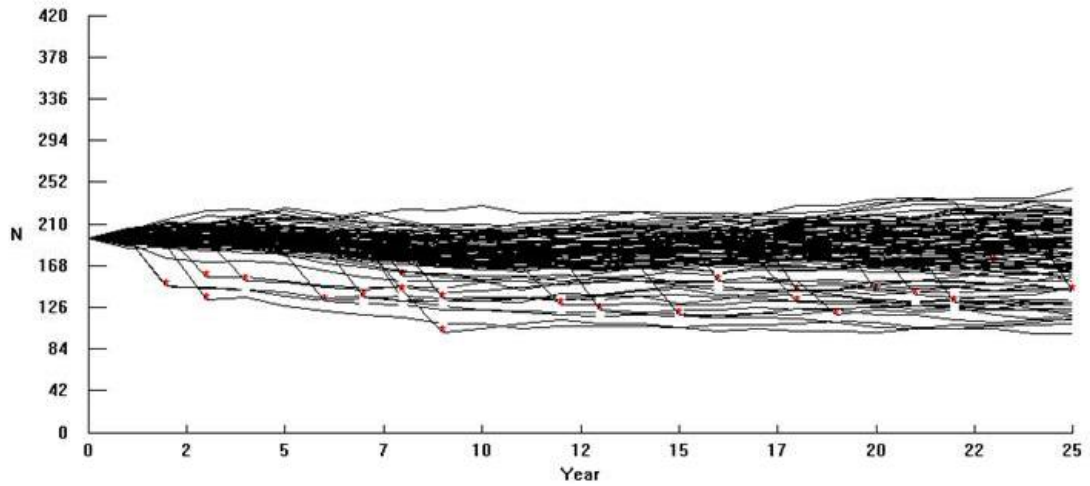


Figure 14B.18: Bottlenose Dolphin Population Modelling Scenario I: F3 IC and F4 IC and F5 NnG and F6 NnG and F2 FoF and F1A FoF (PTS ML, Displacement Highest Estimate) for Five Years of Piling (from 2014 to 2018)



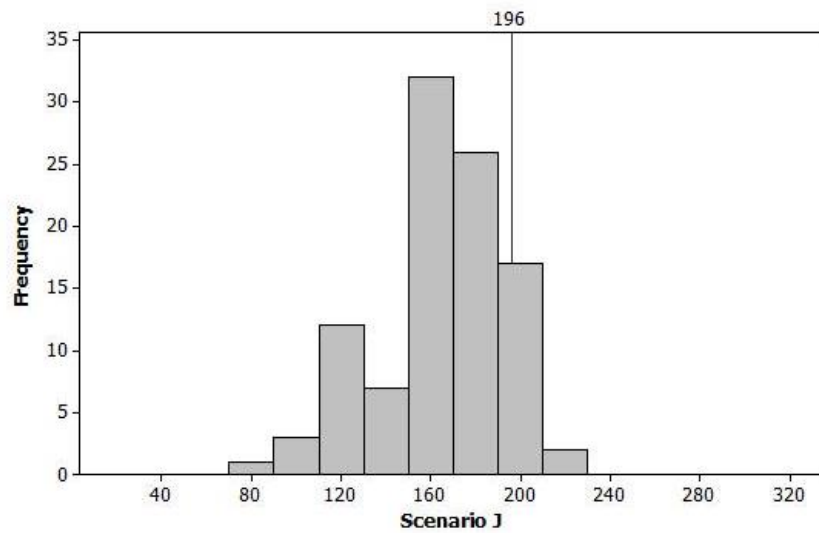
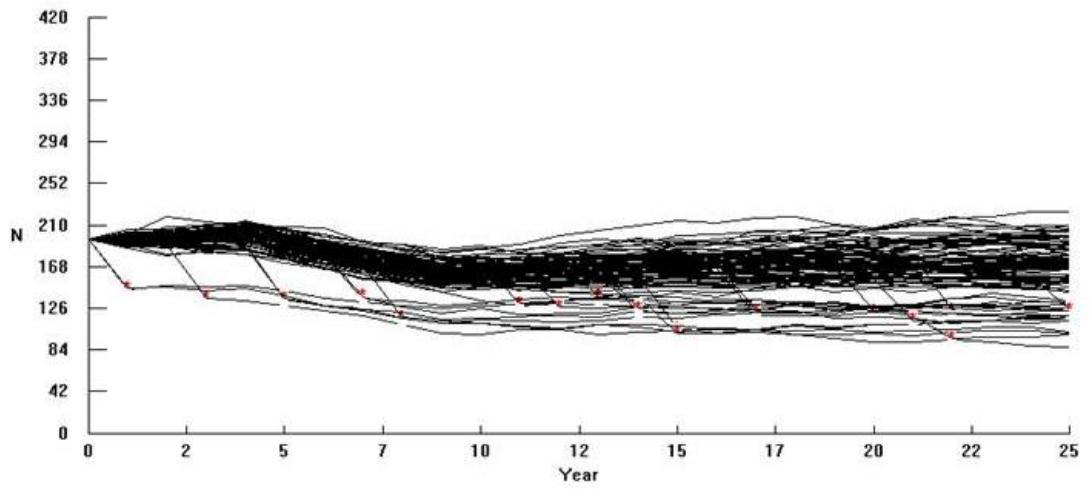
The potential impact for PTS onset in bottlenose dolphins is predicted to be of low magnitude. The duration of the effect is medium term therefore impacts are predicted to be of minor.

The percentage of the reference population predicted to be affected by behavioural displacement is medium (>10 per cent) and the duration of the effect is medium term (up to five years). Therefore impacts are predicted to be moderate in the medium term.

Modelling has shown that impacts of PTS onset and behavioural displacement are unlikely to cause a decline at the population level. Therefore the impact at the population level is deemed to be minor in the long term.

An additional 'extreme' cumulative scenario in which all calves were harvested following each year of construction was also modelled to attempt to illustrate the potential impact of concurrent piling at both the FTOWDG and Moray Firth (Beatrice and MORL, with proposed piling activity which overlaps that of construction within the Firth of Forth and Tay) offshore wind farm developments. The construction years used were 2014 to 2018. All five cumulative projects lie within range of the East Coast of Scotland bottlenose dolphin population (Scenario J; Table 14B.46). The outputs (Figure 14B.19 below) indicate that it is possible that the cumulative piling activity described may result in a small effect at the population level (the majority of the model runs had final population sizes after 25 years of 160 individuals). Whether this would be detectable given the likely confidence interval associated with any population estimate (e.g. the 95 per cent highest posterior density intervals associated with the current population estimate of 195 individuals are 162-253; Cheney *et al.*, 2012) is unclear.

Figure 14B.19: Bottlenose Dolphin Population Modelling Scenario J: Extreme to Include 100% Breeding Failure for 5 Years (2014-2018)



White-Beaked Dolphin

The number of white-beaked dolphins that have the potential to be exposed to SELs sufficient to induce the onset of PTS, and predicted to have the potential to be displaced, is provided in Table 14B.47 below.

For both cumulative construction scenarios, the percentage of the reference population predicted to be affected is less than or equal to 0.1 per cent for PTS onset, 0.3 per cent for mild avoidance behaviour and 0.1 to 0.2 per cent for strong behavioural avoidance (Table 14B.47).

Table 14B.47: Number of White-Beaked Dolphins (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise in the Cumulative Construction Scenarios. The Reference Population Abundance is 22,664 (see Table 14B.8)

Scenario	PTS		Displacement			
			75 dB _{ht} (standardised)		90 dB _{ht} (standardised)	
	n	%	n	%	n	%
5d	11	< 0.1	59 (2 - 316)	0.3	25 (1 - 108)	0.1
6	16	0.1	67 (3 - 351)	0.3	35 (2 - 168)	0.2

The number of white-beaked dolphins predicted to be affected by PTS onset and/or behavioural displacement is small and the duration of the effect is medium term. The percentage of the reference population predicted to be affected is low (<10 per cent) therefore the impact of any population level effects occurring as a result of PTS onset in and/or displacement of white-beaked dolphins is deemed to be minor.

Minke Whale

The number of minke whales that have the potential to be exposed to SELs sufficient to induce the onset of PTS and predicted to have the potential to be displaced is provided in Table 14B.48 below.

For both cumulative construction scenarios, the percentage of the reference population predicted to be affected is less than 0.1 per cent for PTS onset, 0.3 per cent for mild avoidance behaviour and 0.1 to 0.2 per cent for strong behavioural avoidance (Table 14B.48).

Table 14B.48: Number of Minke Whales (n) and Proportion of Reference Population (%) Predicted to Develop PTS or Exhibit Behavioural Displacement as a Result of Piling Noise in the Cumulative Construction Scenarios. The Reference Population Abundance is 181,922 (see Table 14B.8)

Scenario	PTS		Displacement			
			75 dB _{ht} (standardised)		90 dB _{ht} (standardised)	
	n	%	n	%	n	%
5a	17	< 0.1	467 (16 - 3820)	0.3	267 (13 - 1640)	0.1
6	24	< 0.1	545 (19 - 4462)	0.3	314 (15 - 1989)	0.2

The number of minke whales predicted to be affected by PTS onset and / behavioural displacement is small. The percentage of the reference population predicted to be affected is low (<10 per cent) the duration of the effect is medium. Therefore the impact of any population level effects occurring as a result of PTS onset in and/or displacement of minke whale is deemed to be minor.

14B.5.6 Summary

Table 14B.49 below shows a summary of the level of significance of any population level effects occurring as a result of piling at the Project with other projects. Potential effects on all marine mammal species are predicted to be of medium term duration (months to a few years i.e. the piling phase).

Effects on the non-SAC species (harbour porpoise, white-beaked dolphin and minke whale) are predicted to be of low magnitude (less than 10 per cent of the population will be affected) and therefore of minor impact.

Effects at the population level were examined for the SAC species (bottlenose dolphins, grey seals and harbour seals). For all three species, population level effects are unlikely. For harbour seals, the integrity of the Firth of Tay and Eden Estuary SAC is already not being maintained (without impacts relating to the construction of any offshore wind farms; see Appendix 14D: Harbour Seal Assessment).

Table 14B.49: Summary of Potential Impacts from Cumulative Construction Scenario Piling Noise on Relevant Marine Mammal Receptors

Receptor	Potential Impact: Piling at the Project, FoF Phase 1 and NnG
Harbour seal	Moderate (PTS onset) and Major impact (behavioural avoidance) in the medium term but likely Minor impact in the long term (illustrative modelling has been carried out because current population projections predict that the harbour seal population will be of negligible size at the start of the actual piling period).
Grey seal	Moderate (PTS onset) and Major impact (behavioural avoidance) in the medium term. Comparisons to current PBR predict Minor impact in the long term.
Harbour porpoise	Minor impact for both PTS onset and behavioural avoidance.
Bottlenose dolphin	Minor (PTS onset) and Moderate impact (behavioural avoidance) in the medium term but population modelling predicts Minor impact at the population level in the long term. A potentially un-measurable reduction in population size may occur if piling schedules of the FTOWDG and Moray Firth projects coincide and the combined impacts result in complete failure of the entire population to raise young for five years. Given the highly precautionary nature of the population modelling (detailed in Table 14B.11), it is considered highly unlikely that this degree of breeding failure would occur.
White-beaked dolphin	Minor impact for both PTS onset and behavioural avoidance.
Minke whale	Minor impact for both PTS onset and behavioural avoidance.

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