SSE Renewables
E1 EAST PROPOSED EXPORT CABLE CORRIDOR GEOPHYSICAL SURVEY

European Protected Species Licence Supporting Information

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Export Cable Corridor
Geophysical Survey
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Contents

Tables

Figures

Appendices

List of Abbreviations, Definitions and Units

Term	Definition/ Description
CESMU	Coastal East Scotland Management Unit
CGNSMU	Celtic and Greater North Seas Management Unit.
E1E	E1 East Option Agreement Area.
ECOMMAS	East Coast Marine Mammal Acoustic Study.
EPS	European Protected Species. Animals listed in Annex IV(a) of the Habitats Directive, whose natural range includes any area in Great Britain. Animals also listed in Schedule 2 of the Habitats Regulations and Schedule 1 of the Offshore Marine Regulations.
FCS	Favourable Conservation Status. Determined by Article 1(i) of the Habitats Directive.
GNSMU	Greater North Sea Management Unit.
HESS	High Energy Seismic Survey.
HF	High Frequency.
Hz	Hertz. Unit of measure commonly used to measure wave frequencies, including sound waves.
JNCC	Joint Nature Conservation Committee.
LF	Low Frequency.
MMRU	Marine Mammal Research Unit.
MBES	Multibeam Echosounder.
MU	Management Unit.
NMFS	National Marine Fisheries Service.
NSMU	North Sea Management Unit.
PTS	Permanent Threshold Shift.
SAC	Special Area of Conservation.
SBP	Sub Bottom Profiler.
Scottish Territorial Waters	Part of the sea adjacent to the coast of Scotland that is considered to be part of the territory of that state and subject to its sovereignty (extends to 12 nautical miles from coastline).
SEL	Sound Exposure Level.
SPL	Sound Pressure Level.
SSS	Side Scan Sonar.
TTS	Temporary Threshold Shift.
USBL	Ultra Short Base Line.
VHF	Very High Frequency.

1 INTRODUCTION

1.1 Background

1.1.1 SSE Renewables (hereafter referred to as 'SSER') and their partners Copenhagen Infrastructure Partners (CIP) and Marubeni were awarded an option agreement to develop E1 East (E1E) in January 2022 as part of the ScotWind seabed leasing programme (Figure 1.1). The SSER E1 East Array Area is located approximately 80.6 km southeast of Aberdeen.

1.1.2 SSER is currently undertaking a geophysical survey across the Array Area, in line with relevant mitigation and management measures agreed with MS-LOT for those surveys. SSER are now planning to undertake geophysical survey of the Proposed Export Cable Corridors, leading from the Array Area to Fettereso and Cousland respectively (Figure 1.1).

1.1.3 Noise from the geophysical survey is readily transmitted underwater and there is potential for sound emissions from the survey to affect marine mammals. As there is potential for EPS to be disturbed by the proposed geophysical survey across the E1 East Proposed Export Cable Corridor Area, this EPS assessment and licence is required.

1.2 Purpose of this document

1.2.1 This Supporting Information Document provides a summary of the legislative context with respect to EPS and provides (Section 1.3), an overview of the licensable operations that will be undertaken as part of the SSER E1 Proposed Export Cable Corridor Area geophysical survey (Section 1.4), and the relevant EPS that have been identified within the operational area (Section 3).

1.2.2 This document provides evidence to inform considerations relevant to the three EPS Licence tests: "Overriding Public Interest" (see Section 4.1) and "No Satisfactory Alternatives" tests (see Section 4.2). This document also informs consideration of the "Favourable Conservation Status" test (see Section 4.3). These are defined and discussed in Section 1.3 below.

1.3 Legislative Context

1.3.1 The European Commission (EC) Habitats Directive (92/43/EEC) lists all cetaceans in Annex IV, i.e. species for which a system of strict protection needs to be established. There is a requirement to consider EPS through the Habitats Directive which is transposed into UK law in Scotland by the Conservation (Natural Habitats) Regulations 1994 (as amended) (out to 12 nautical miles (nm)) (the "Habitats Regulations"). Beyond 12 nm, for all UK administrations, the Conservation of Offshore Marine Habitats and Species Regulations 2017 consolidate and update the Offshore Marine Conservation (Natural Habitats &c) Regulations 2007 (the "Offshore Marine Regulations").

1.3.2 An EPS Licence can only be granted for specific purposes set out in the Conservation (Natural Habitats) Regulations 1994 (as amended). For the Licence to be granted, the relevant regulations provide that the regulating authority will need to be satisfied the following criteria are met:

- Test 1 (Overriding Public Interest Test) – If the competent authority is satisfied that, there being no alternative solutions, the plan or project must be carried out for imperative reasons of overriding public interest, which may be of a social or economic nature (Regulation 44(2));

- Test 2 (No Satisfactory Alternatives Test) - There are no satisfactory alternative locations for the Development or alternative methods to the Licensable Operations (Regulation 44(3)(a)); and

- Test 3 (Favourable Conservation Status Test) - The Licensable Operations will not be detrimental to the maintenance of the population of the species concerned at a favourable conservation status (FCS) in their natural range (Regulation 44(3)(b)).

1.3.3 This EPS Licence Application is for dolphins, porpoises and whales as cetacean EPS. Five cetacean species have the potential to occur in the vicinity of the E1 East Proposed Export Cable Corridor

Area and have been considered in the risk assessment. These include: Atlantic white-sided dolphin (*Lagenorhynchus acutus*), bottlenose dolphin (*Tursiops truncatus*), harbour porpoise (*Phocoena phocoena*), minke whale (*Balaenoptera acutorostrata*), and white-beaked dolphin (*Lagenorhynchus albirostris*)

1.3.4 The Habitats Regulations and the Offshore Marine Regulations make it an offence to deliberately kill, injure, or capture an EPS, as listed under Annex IV of the Habitats Directive. In addition, the Habitats Regulations 1994 (as amended in Scotland) make it an offence to deliberately disturb wild animals of EPS.

1.3.5 Regulation 39(2) provides additional protection to cetaceans to ensure protection at all times, regardless of the circumstances of the mammal at the time of the disturbance. Therefore, this is a catch-all regulation that goes beyond the specific circumstances set out in Regulation 39(1).

1.3.6 If there is a risk of injury or disturbance to EPS that cannot be removed or sufficiently reduced by using alternative methods to those associated with the activity and/or mitigation measures, then the activity may still be able to go ahead under licence provided that the three tests described above are satisfied.

1.3.7 Article 1(i) of the Habitats Directive defines Favourable Conservation Status (FCS) of a species. The status of each EPS considered in this Licence has been presented in the species-specific assessments in Section 3.

1.4 Licensable Operations

1.4.1 In the context of this EPS Licence Application, the Licensable Operations are those aspects of the geophysical survey methodology which have the potential to cause direct or indirect effects (including injury or disturbance) on marine mammals.

1.4.2 The surveys will involve the use of the following geophysical equipment:

- Multibeam Echosounder (MBES);
- Side Scan Sonar (SSS);
- Sub Bottom Profiler (Chirp / Pinger / Boomer) (SBP);
- Ultra Short Base Line (USBL);
- Sleeve Gun (10 cubic inches (cu.in.). air gun); and
- Sparker.

1.4.3 It is noted that with regard to the two impulsive noise sources (i.e. Sparker and Sleeve gun) that the Sparker is the primary option for use for this survey with the Sleeve gun included as a contingency option.

1.4.4 In consideration of the activities (described above) involved in the geophysical survey of the E1 East Proposed Export Cable Corridor Area it is considered that the use of these equipment may result in sound sources that could constitute a disturbance offence under the Habitats Regulation and is therefore a Licensable Operation.

1.4.5 It is anticipated that the earliest planned start date for the geophysical surveys is September 2022, and the latest end date is March 2023, to account for potential weather disruption and/or operational delays.

1.4.6 The E1 East Proposed Export Cable Corridor Area geophysical survey is expected to last 60 days, including possible weather delays (Table 1.1). The Licensable Operations will be carried out within the survey area which will cover up to 1,126.1 km^2 (Table 1.1). Manoeuvring of the vessel, as well as to enable soft-start and line run-out will also occur within this area. The operation could be vessel-based or unmanned, with this still to be determined.

1.4.7 Approximately up to 502.7 km^2 of the survey area overlaps with the 12nm zone (Table 1.1).

Table 1.1: Survey characteristics for the E1 East Proposed Export Cable Corridor Area survey

Project Detail	E1 East
Number of working days	60
Proposed Export Cable Corridor Area (Survey Area) (km^2)	1,126.1
Proposed Export Cable Corridor Area within 12 nm zone (km^2)	502.7

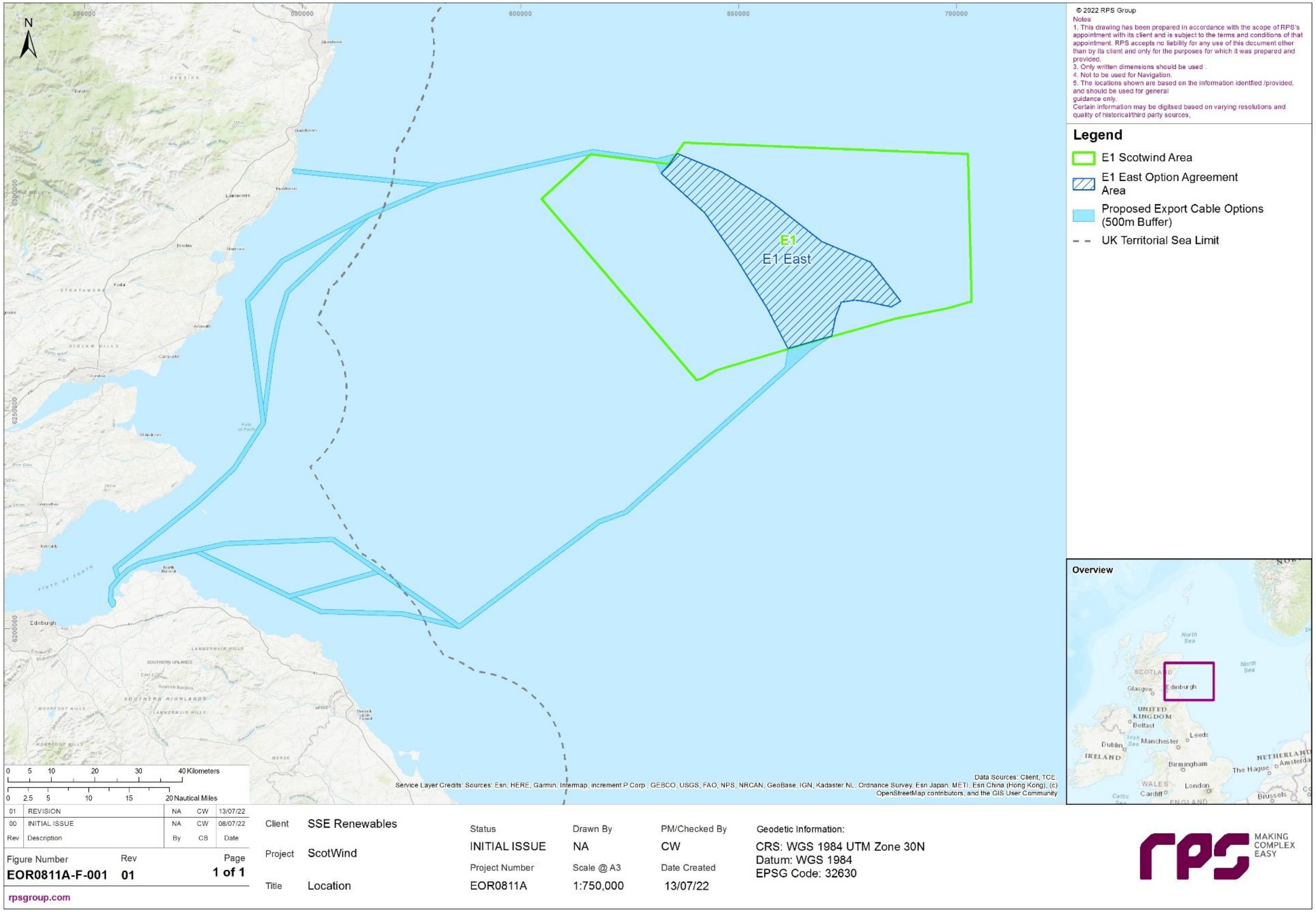

Figure 1.1: E1 East Proposed Export Cable Corridor Survey Area.

2 SUBSEA NOISE ASSESSMENT

2.1 Introduction

2.1.1 Underwater noise has the potential to affect marine life in different ways depending on its noise level and characteristics. Richardson *et al.* (1995) defined four zones of noise influence which vary with distance from the source and level. These are:

- **The zone of audibility:** this is the area within which the animal can detect the sound. Audibility itself does not implicitly mean that the sound will affect the marine mammal.
- **The zone of masking:** this is defined as the area within which noise can interfere with the detection of other sounds such as communication or echolocation clicks. This zone is very hard to estimate due to a paucity of data relating to how marine mammals detect sound in relation to masking levels (for example, humans can hear tones well below the numeric value of the overall noise level).
- **The zone of responsiveness:** this is defined as the area within which the animal responds either behaviourally or physiologically. The zone of responsiveness is usually smaller than the zone of audibility because, as stated previously, audibility does not necessarily evoke a reaction.
- **The zone of injury / hearing loss:** this is the area where the sound level is high enough to cause tissue damage in the ear. This can be classified as either temporary threshold shift (TTS) or permanent threshold shift (PTS). At even closer ranges, and for very high intensity sound sources (e.g., underwater explosions), physical trauma or even death are possible.

2.1.2 For this study, it is the zones of injury and disturbance (i.e., responsiveness) that are of concern (there is insufficient scientific evidence to properly evaluate masking). To determine the potential spatial range of injury and disturbance, a review has been undertaken of available evidence, including international guidance and scientific literature. The following sections summarise the relevant thresholds for onset of effects and describe the evidence base used to derive them.

2.1.3 To inform the cetacean risk assessment, a subsea noise assessment was undertaken for cetacean EPS in order to determine the spatial extent of potential effects from the proposed activities, on key species. The assessment considered the potential for injury effects (physiological damage) and behavioural disturbance to occur as a result of the geophysical survey.

2.1.4 The subsea noise assessment used sound source data for the types of equipment likely to be used, provided by the appropriate manufacturers. The sonar (non-impulsive) and impulsive survey equipment likely to be used in the assessment are detailed in Table 2.1 and Table 2.2 respectively.

Table 2.1: Sonar (Non-impulsive) Survey Equipment Parameters Used in Assessment (Seiche, 2021).

Survey Type	Equipment	Frequency, kHz	Source Level, dB re 1 µPa re 1 m (rms)	Pulse rate, s^{-1}	Pulse Width, ms	Beam Width (Degrees)
Multibeam Echo Sounder	Norbit iWBMS	400 kHz	225	60	0.5	0.9° x 1.9°
Side Scan Sonar	Edgetech 6205s	230 kHz (LF) 550 kHz (HF)	210	15	15	0.54° (LF) 0.36° (HF)
Parametric Sub Bottom Profiler	Innomar SES Medium	100 kHz (primary) 4,5,6,8,10,12 kHz selectable secondary frequencies	248	50	0.07-1.5	2.0°

Survey Type	Equipment	Frequency, kHz	Source Level, dB re 1 µPa re 1 m (rms)	Pulse rate, s^{-1}	Pulse Width, ms	Beam Width (Degrees)
Ultra Short Base Line	Sonardyne 8300 /	19–34 kHz	202	1	5	Omni

Table 2.2: Impulsive Survey Equipment Parameters Used in Assessment (Seiche, 2021).

Source	Equipment	Source Level, dB re 1 µPa re 1 m (peak)	Source SEL, dB re 1 µPa^{2}s re 1 m	Source level, dB re 1 µPa re 1 m (rms)	T90, ms
TI Sleeve Gun	TI Sleeve Gun 10CU	224	195	214	13.5
Sparker	Geosource 200-400	219	182	214	0.7

2.1.5 The metrics used to describe sound in the assessment include:

- Peak Sound Pressure Level (SPL) – the difference between the lowest pressure variation (rarefaction) and the highest pressure variation (compression);
- Root Mean Square (rms) – SPL as a description of the average amplitude of the variations in pressure over a specific time window; and
- Sound Exposure Level (SEL) – measure of the total sound energy of an event or a number of events (e.g. over the course of the survey period) and normalised to one second.

2.2 Assessment Criteria

2.2.1 Injury (Permanent Threshold Shift)

2.2.1 Auditory injury in marine mammals can occur as PTS, where there is no hearing recovery in the animal.

2.2.2 Injury criteria were proposed for two different types of sound as follows (Southall *et al.,* 2019):

- Impulsive sounds – typically transient, brief (less than 1 second), broadband, consisting of high peak sound pressure with rapid rise time and decay (ANSI 1986; NIOSH 1998; ANSI 2005). The impulsive sounds category includes sound sources such as seismic surveys, impact piling and underwater explosions; and
- Non-impulsive sounds – can be broadband, narrowband or tonal, can be brief or prolonged, continuous or intermittent, and typically without high peak sound pressure with rapid rise time and decay (impulsive sounds) (ANSI 1995; NIOSH 1998). The non-impulsive sounds category includes sound sources such as continuously running machinery, sonar and vessels.

2.2.3 The injury criteria proposed by Southall *et al*. (2019) are based on linear (i.e. un-weighted) peak pressure levels and mammal hearing-weighted (M-weighted) SELs. The peak pressure is the maximum level the animal may experience, and this is relevant because it assesses the potential for injury to occur instantaneously. SEL allows the assessment to consider whether the total energy that the animal receives as it flees the area will cumulatively lead to injury over the period of time assessed.

2.2.4 The relevant criteria proposed by Southall *et al*. (2019) are summarised in Table 2.3.

Table 2.3: Summary of Permanent Threshold Shift (PTS) Onset Acoustic Thresholds (Southall *et al*., 2019).

Hearing Group	Parameter	Impulsive	Non-impulsive
Low-frequency (LF) Cetaceans (e.g. Minke Whale)	SPL (dB re 1 µPa (Peak)), Unweighted	219	-
	SEL (dB re 1 µPa²s), LF Weighted	183	199
High-frequency (HF) Cetaceans (e.g. Bottlenose Dolphin, White-beaked Dolphin, Atlantic White-Sided Dolphin)	SPL (dB re 1 µPa (Peak), Unweighted	230	-
	SEL (dB re 1 µPa²s), HF Weighted	185	198
Very High-frequency (VHF) Cetaceans (e.g. Harbour Porpoise)	SPL (dB re 1 µPa (Peak), Unweighted	202	-
	SEL (dB re 1 µPa²s), VHF Weighted	155	173

2.2.2 Behaviour

2.2.1 There is also the potential for impacts on behaviour from underwater sound sources. Significant (i.e., non-trivial) disturbance may occur when there is a risk of animals experiencing sustained or chronic disruption of behaviour or when animals are displaced from an area, with subsequent redistribution being significantly different from that occurring due to natural variation.

2.2.2 This assessment adopts a conservative approach and uses the US National Marine Fisheries Service (NMFS 2005a) Level B harassment thresholds for impulsive and non-impulsive sounds. Level B Harassment is defined as having the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering, but which does not have the potential to injure a marine mammal or marine mammal stock in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild. This description of non-trivial disturbance and has therefore been used as the basis for onset of behavioural change in this assessment.

2.2.3 Appropriate guidance sets the marine mammal level B harassment threshold for continuous noise at 120 dB re 1 µPa (rms) (NMFS, 2005). This value sits mid-way between the range of values identified in Southall *et al*. (2007) for continuous sound, but is lower than the value at which the majority of mammals responded at a response score of 6 (i.e. once the received rms sound pressure level is greater than 140 dB re 1 µPa). Considering the lack of data and high level variation of data relating to onset of behavioural effects due to continuous sound, it is recommended that any ranges predicted using this number are viewed as probabilistic and potentially over-precautionary.

2.2.4 The High Energy Seismic Survey (HESS) workshop on the effects of seismic sound on marine mammals concluded that mild behavioural disturbance to impulsive sound would most likely occur at sound levels greater than 140 dB re 1 µPa (rms) (HESS, 1997). This workshop drew on multiple studies but recognised that there was some degree of variability in reactions between different studies and mammal groups. This value is similar to the lowest threshold for disturbance of low-frequency cetaceans noted in Southall *et al.* (2007). It is however, considered unlikely that a threshold for the onset of mild disturbance effects could be defined as significant disturbance.

Consequently, this study utilises the NMFS (2005) marine mammal level B harassment threshold of 160 dB re 1 µPa (rms) as a proxy for significant disturbance due to impulsive sound.

2.2.3 Modelling Approach and Assumptions

2.2.1 The propagation and sound exposure calculations were conducted over a range of water column depths in order to determine the likely range for injury and disturbance. It should be noted that the effect of directivity has a strong bearing on the calculated zones for injury and disturbance because a marine mammal could be directly underneath the sound source for greater distances in deep water compared to shallow water.

2.2.2 Exposure modelling was based on the assumption of an animal swimming at a constant speed (1.5 ms^{-1}) in a perpendicular direction away from a moving vessel.

2.2.3 Full details of the noise modelling approach and assumptions can be found in Appendix B.

2.3 Results

2.3.1 Injury

2.3.1 The results of the subsea noise modelling for the multiple survey types (Table 2.4 - Table 2.9) show that the range at which injury could occur for all species is somewhat localised, with a maximum of 244 m (based on worst case sub-bottom profiler PTS SEL) for harbour porpoise as the most sensitive species (with the lowest threshold for injury) (Table 2.6).

2.3.2 Behaviour

2.3.1 The range at which fleeing response (TTS) could occur for all species is 1,870 m (based on worst case sleeve gun TTS SEL) (Table 2.9).

2.3.2 Behavioural effects are also predicted to be limited in extent with likely behavioural disturbance occurring out to a maximum of 1,930 m from the source (based on worst case USBL) (Table 2.7). Distances have not been given for soft start since the benefits of this technique are greater at shorter ranges from the source. This is because at smaller distances the sound level is higher and falls away at a faster rate, so an animal swimming at a constant speed will observe a larger relative reduction in sound compared to if it starts further away.

Table 2.4: Marine Mammal Noise Modelling Results for Multibeam Echo Sounder (Non-impulsive) Surveys and the Summary of Potential Injury and Disturbance Zones in the E1 East Proposed Export Cable Corridor Area.

Survey Type	Potential Effect	Radius of Effect, (m)		
		LF Cetacean (Minke Whale)	HF Cetacean (Bottlenose Dolphin, White-beaked Dolphin, Atlantic White-Sided Dolphin)	VHF Cetacean (Harbour Porpoise)
Multibeam Echo Sounder	PTS: SEL of mammal swimming away from survey vessel	2	48	51
	TTS: SEL of mammal swimming away from survey vessel	31	50	52
	RMS behavioural change	382		

Table 2.5: Marine Mammal Noise Modelling Results for Side Scan Sonar (Non-impulsive) Surveys and the Summary of Potential Injury and Disturbance Zones in the E1 East Proposed Export Cable Corridor Area.

Survey Type	Potential Effect	Radius of Effect (m)		
		LF Cetacean (Minke Whale)	HF Cetacean (Bottlenose Dolphin, White-beaked Dolphin, Atlantic White-Sided Dolphin)	VHF Cetacean (Harbour Porpoise)
Side Scan Sonar	PTS: SEL of mammal swimming away from survey vessel	8	50	51
	TTS: SEL of mammal swimming away from survey vessel	47	50	52
	RMS behavioural change	282		

Table 2.6: Marine Mammal Noise Modelling Results for Sub Bottom Profiler (Non-impulsive) Surveys and the Summary of Potential Injury and Disturbance Zones in the E1 East Proposed Export Cable Corridor Area.

Survey Type	Effect	Radius of Effect (m)		
		LF Cetacean (Minke Whale)	HF Cetacean (Bottlenose Dolphin, White-beaked Dolphin, Atlantic White-Sided Dolphin)	VHF Cetacean (Harbour Porpoise)
Sub Bottom Profiler	PTS: SEL of mammal swimming away from survey vessel	51	55	244
	TTS: SEL of mammal swimming away from survey vessel	51	205	679
	RMS behavioural change	1,382		

Table 2.7: Marine Mammal Noise Modelling Results for Ultra Short Base Line (USBL) (Non-impulsive) Surveys and the Summary of Potential Injury and Disturbance Zones in the E1 East Proposed Export Cable Corridor Area (N/E – not exceeded).

Survey Type	Effect	Radius of Effect (m)		
		LF Cetacean (Minke Whale)	HF Cetacean (Bottlenose Dolphin, White-beaked Dolphin, Atlantic White-Sided Dolphin)	VHF Cetacean (Harbour Porpoise)
Ultra Short Base Line	PTS: SEL of mammal swimming away from survey vessel	N/E	N/E	2

Survey Type	Effect	Radius of Effect (m)		
		LF Cetacean (Minke Whale)	HF Cetacean (Bottlenose Dolphin, White-beaked Dolphin, Atlantic White-Sided Dolphin)	VHF Cetacean (Harbour Porpoise)
	TTS: SEL of mammal swimming away from survey vessel	N/E	N/E	149
	RMS behavioural change	1,930		

Table 2.8: Marine Mammal Noise Modelling Results for Sparker (Impulsive) Surveys and the Summary of Potential Injury and Disturbance Zones in the E1 East Proposed Export Cable Corridor Area (N/E – not exceeded).

Survey Type	Effect	Radius of Effect, m		
		LF Cetacean (Minke Whale)	HF Cetacean (Bottlenose Dolphin, White-beaked Dolphin, Atlantic White-Sided Dolphin)	VHF Cetacean (Harbour Porpoise)
Sparker	PTS: SEL of mammal swimming away from moving vessel	N/E	N/E	9
	TTS: SEL of mammal swimming away from moving vessel	270	N/E	367
	RMS behavioural change (Strong/Mild)	612 / 91		

Table 2.9: Marine Mammal Noise Modelling Results for Sleeve Gun (Impulsive) Surveys and the Summary of Potential Injury and Disturbance Zones in the E1 East Proposed Export Cable Corridor Area (N/E – not exceeded).

Survey Type	Effect	Radius of Effect, m		
		LF Cetacean (Minke Whale)	HF Cetacean (Bottlenose Dolphin, White-beaked Dolphin, Atlantic White-Sided Dolphin)	VHF Cetacean (Harbour Porpoise)
Sleeve Gun	PTS: SEL of mammal swimming away from moving vessel	N/E	N/E	120
	TTS: SEL of mammal swimming away from moving vessel	107	N/E	1,870
	RMS behavioural change (Strong/Mild)	1,049 / 196		

3 CETACEAN RISK ASSESSMENT

3.1 Introduction

3.1.1 Within the coastal waters of the east coast of Scotland, the more commonly recorded cetacean species include the harbour porpoise, bottlenose dolphin, white-beaked dolphin, and minke whale, with Atlantic white-sided dolphin occurring more typically in deeper waters (Table 3.1). A summary of the distribution and abundance for each of the key cetacean EPS is provided below together with an assessment of the risk of injury or disturbance based on the results of the subsea noise assessment (Section 2; Appendix B).

Table 3.1: Summary of Cetacean Species Found in the E1 East Proposed Export Cable Corridor Area. Sources: Weir (2001), Hammond *et al*., (2013), Hammond *et al*., (2021) and Marine Scotland Maps NMPi (2021).

Species	Occurrence in the northern North Sea	Description
Toothed Whales, Dolphins, and Porpoises		
Harbour porpoise *Phocoena phocoena*	Abundant	Abundant and widespread throughout the northern North Sea, most frequently reported cetacean in the North Sea
Bottlenose dolphin *Tursiops truncatus*	Common	Occurs throughout the northern North Sea, the Moray Firth supports the only known remaining resident population in the North Sea
White-beaked dolphin *Lagenorhynchus albirostris*	Abundant	Abundant and widespread throughout the northern North Sea, second most frequently reported cetacean in the North Sea
Atlantic white-sided dolphin *Lagenorhynchus acutus*	Occasional	Occurs typically in deep waters along continental shelf although regularly enters the North Sea over summer months.
Baleen Whales		
Minke whale *Balaenoptera acutorostrata*	Common	Range widely and can be observed throughout the northern North Sea

3.2 Harbour Porpoise

3.2.1 Baseline

3.2.1 The harbour porpoise has a large population and is extensively distributed throughout the North Sea, making it the most abundant cetacean species within the North Sea (Hammond *et al*., 2017; Chevallard *et al*., 2019; Evans and Waggitt, 2020). In general, peak densities of harbour porpoises were found along the Scottish coast during the month of July, coinciding with known calving periods for this species in the area (Gilles *et al*., 2019). Harbour porpoise diets are diverse, vary regionally, and predominantly consist of cephalopods and an assortment of fish species (Ransijn *et al.,* 2019). Historical studies of harbour porpoise in Scottish waters have illustrated that sandeels and whiting dominate the species' diet (Santos and Pierce, 2003; Baines *et al*., 2012; Ransijn *et al*., 2019). Long-term passive acoustic data collected near the Moray Firth, Scotland has shown that harbour porpoises were increasingly detected during sunrise, sunset and throughout the night in deeper areas with muddy substrate, but in shallow, sandy areas during the day, suggesting the importance of multiple habitat types necessary to ensure species success (Williamson *et al*., 2017). According to the Marine Mammal Research Unit (MMRU), harbour porpoises have a typical life expectancy of around 10 years (MMRU, 2021).

3.2.2 The East Coast Marine Mammal Acoustic Study (ECOMMAS) utilised acoustic recorders (C-PODs) to collect data on the relative abundance of harbour porpoises in 30 locations off the east coast of Scotland (NMPi, 2021; Hague *et al*., 2020; Williamson, 2018). Deployments were undertaken twice per year, with data covering the months of April to November (Hague *et al*., 2020). The nearest C-

POD deployments to the E1 East site were those located at Cruden Bay and Stonehaven. Data collected from 2013-2016 illustrated that the greatest presence of harbour porpoise within the vicinity of the E1 East site was detected at Fraserburgh and Spey Bay, situated approximately 60.4 km and 99.2 km northeast of Cruden Bay, and Arbroath, located approximately 53.4 km south of Stonehaven. C-PODs located at Stonehaven had relatively low harbour porpoise detection rates from 2014-2016, further demonstrating the species preference for offshore, deep water habitats along the 20 to 50 m isobath (Chevellard *et al*., 2019; Robinson *et al*., 2007).

3.2.3 Species-specific densities have been based on SCANS III Survey Block R densities (Hammond *et al*., 2021). The abundance estimates for harbour porpoise within Survey Block R were 38,646 individuals, with a density of 0.599 animals/km^2 (Hammond *et al*., 2021). The conservation status of the harbour porpoise in UK waters was assessed as Favourable (JNCC, 2013a) but this has subsequently been revised to Unknown for the latest assessment (JNCC, 2019a).

3.2.4 The E1 East Proposed Export Cable Corridor Area is located within the North Sea Management Unit (NSMU) for harbour porpoise (IAMMWG, 2021). This abundance of harbour porpoise in the NSMU is estimated at 346,601 individuals. Within the UK portion of the NSMU, it is estimated there are 159,632 harbour porpoise (IAMMWG, 2021).

3.2.2 Risk Assessment

3.2.1 Audiogram data for the harbour porpoise indicate that it is responsive to noise at frequencies from 100 Hz – 170 kHz, with peak hearing sensitivity occurring over the frequency range 20 kHz – 150 kHz. Thresholds for SPLs at which injury and behavioural disturbance may be induced are described in Section 2.

3.2.2 The noise assessment (Section 2; Appendix B) showed that a harbour porpoise exposed to subsea noise from the survey equipment may experience permanent auditory injury at a range of up to 244 metres (worst case sub bottom profiler; PTS SEL). Recoverable auditory injury and fleeing response has the potential to occur out to a maximum distance of 1,870 metres (worst case sleeve gun; TTS SEL). Behavioural disturbance has the potential to occur out to a maximum distance of 1,930 m (11.7 km^2) (worst case USBL) (see Appendix A).

3.2.3 The noise modelling demonstrated that without the implementation of mitigation, and for all equipment, less than one harbour porpoise is predicted to have the potential to experience PTS at any one time within the E1 East survey area (see Appendix A).

3.2.4 Due to the small area over which injury could occur and the low number of animals which may be affected, the risk of injury to harbour porpoise is considered to be negligible. It is likely that animals will be displaced from the area of injury risk prior to commencement of the geophysical activities due to audible and visual cues during movement of the boats used to place the survey equipment. Proposed mitigation to further reduce potential for impact is presented in Section 3.7.

3.2.5 Up to seven harbour porpoise may experience TTS (recoverable injury) at any one time within the survey area.

3.2.6 Up to seven harbour porpoise may be disturbed as a result of the survey activities at any one time. Disturbance has the potential to occur over an area of up to 11.7 km^2. This equates to up to 0.002% of the NSMU population, or up to 0.004% of the UK portion of the NSMU population at each of the survey locations (see Appendix A).

3.2.7 Therefore, there is a low risk of disturbance, however an EPS Licence is required in respect of this disturbance for the E1 East proposed geophysical survey.

3.3 Bottlenose Dolphin

3.3.1 Baseline

3.3.1 Scotland is home to a small, resident population of bottlenose dolphin that are protected through a Special Area of Conservation (SAC) in the Moray Firth (Chevellard *et al*., 2019; JNCC, 2021). The Moray Firth comprises the sole, year-round resident population of bottlenose dolphin in the North Sea (BOWL, 2012; Robinson *et al*., 2017). Bottlenose dolphin have also been recorded off of the western Isles of Scotland and are commonly found in inshore and deep coastal waters (Avant, 2008). However, the Moray Firth population has been known to show high site fidelity and the Moray Firth area is understood as their core location (Fernandez-Betelu *et al*., 2019). Bottlenose dolphin have been known to exhibit high flexibility in both their foraging behaviour and habitat use (Fernandez-Betelu *et al*., 2019). Prey availability and prey concentration drive species' habitat preference, with their foraging behaviours known to adapt accordingly (Genov *et al*., 2019; Garagouni *et al*., 2019). Typical prey items in Scottish waters include cod (*Gadus morhua*), saithe (*Pollachius virens*), whiting, salmon (*Salmo salar*) and haddock (*Melanogrammus aeglefinus*) (Santos *et al*., 2001). The majority of female bottlenose dolphins found in the Moray Firth were found to give birth from six to 13 years of age, with calves born predominantly from May to October, peaking during the summer months with increased water temperatures (Robinson *et al*., 2017).

3.3.2 ECOMMAS utilised acoustic recorders (C-PODs) to collect data on the relative abundance of bottlenose dolphins in 30 locations off the east coast of Scotland (NMPi, 2021; Hague *et al*., 2020; Williamson, 2018). Deployments were undertaken twice per year, with data covering the months of April to November (Hague *et al*., 2020). The nearest C-POD deployments are listed in paragraph 3.2.2 above. According to C-POD location data and acoustic occupancy rates collected by Thompson *et al*. (2015), bottlenose dolphins are more likely to be observed in coastal waters, within 5km of the shoreline. Data collected from 2013-2016 illustrated that the greatest presence of bottlenose dolphin were detected at Cromarty, situated approximately 138.9 km northeast of Cruden Bay and 136.1 km northeast of Stonehaven (NMPi, 2021).Species-specific densities have been based on SCANS III Survey Block R densities (Hammond *et al*., 2021). The abundance estimate for bottlenose dolphin within Survey Block R is 1,924 individuals, with a density of 0.030 animals /km^2 (Hammond *et al*., 2021). The conservation status of the bottlenose dolphin in UK waters was assessed as Favourable (JNCC, 2013b) but this has subsequently been revised to Unknown for the latest assessment (JNCC, 2019b). The Moray Firth coastal population of bottlenose dolphin has recently shown signs of increased range extension, occurring off the eastern coast of Scotland and England (Cheney *et al*., 2014; Evans and Waggitt, 2020), with this range typically focused between, but not exclusive to, the Moray Firth and the Firth of Forth (Arso Civil *et al*., 2021).

3.3.3 A study by Cheney *et al*. (2018) estimated that the bottlenose dolphin population on the east coast of Scotland is increasing and varied from 129 (95% CI = 104 to 155) in 2001 to 189 (95% CI = 155 – 216) in 2015, further analysed by Arso Civil *et al*. (2021, with the IAMMWG thus recommending the population in the Coastal East Scotland MU for bottlenose dolphin is taken as 224 individuals (IAMMWG, 2021). Site-specific aerial surveys performed in the nearby area for the Berwick Bank Marine Mammal Technical Report (SSE, 2022) found extremely low abundances of bottlenose dolphins in the area. Specifically, only 7 individuals were sighted over the 2019-21 study period, with a mean number of animals per km of trackline of 0.0001 (±0.0002 95% CI = 0 to 0.0024).

3.3.4 The E1 East Proposed Export Cable Corridor Survey Area is located within the Greater North Sea Management Unit (GNSMU) and the Coastal East Scotland Management Unit (CESMU) for bottlenose dolphin (IAMMWG, 2021). This abundance of bottlenose dolphin in the GNSMU is estimated at 2,022 individuals. Within the UK portion of the GNSMU, it is estimated there are 1,885 bottlenose dolphin. The CESMU is only located within UK waters, up to the 12nm limit. The abundance of bottlenose dolphin in the CESMU is estimated at 224 individuals (IAMMWG, 2021).

3.3.2 Risk Assessment

3.3.1 Audiogram data for the bottlenose dolphin indicate that it is responsive to noise at frequencies from 150 Hz – 160 kHz. Thresholds for SPLs at which injury and behavioural disturbance may be induced are described in Section 2.

3.3.2 The noise assessment (Section 2; Appendix B) showed that a bottlenose dolphin exposed to subsea noise from the survey equipment would be likely to experience permanent auditory injury at a range of up to 55 metres (worst case sub bottom profiler; PTS SEL). Recoverable auditory injury and fleeing response has the potential to occur out to a maximum distance of 205 metres (worst case sub bottom profiler; TTS SEL). Behavioural disturbance has the potential to occur out to a maximum distance of 1,930 m (11.7 km^2) (worst case USBL) (see Appendix B).

3.3.3 The noise modelling demonstrated that without the implementation of mitigation, and for all equipment, less than one bottlenose dolphin is predicted to have the potential to experience PTS at any one time within the E1 East survey area (see Appendix A).

3.3.4 Due to the small area over which injury could occur and the low number of animals which may be affected (<1), the risk of injury to bottlenose dolphin is considered to be negligible. It is likely that animals will be displaced from the area of injury risk prior to commencement of the geophysical activities due to audible and visual cues during movement of the boats used to place the survey equipment. Proposed mitigation to further reduce potential for impact is presented in Section 3.7.

3.3.5 Less than one bottlenose dolphin is predicted to have the potential to experience TTS at any one time within the E1 East survey area.

3.3.6 Less than one bottlenose dolphin may be disturbed as a result of the survey activities at any one time. Disturbance has the potential to occur over an area of up to 11.7 km^2. This equates to up to 0.017% of the GNSMU population, or up to 0.019% of the UK portion of the GNSMU population. With regard to the CESMU, this equates to 0.157% of the population (see Appendix A).

3.3.7 Therefore, there is a low risk of disturbance, however an EPS Licence is required in respect of this disturbance for the E1 East proposed geophysical survey.

3.4 White-beaked Dolphin

3.4.1 Baseline

3.4.1 The white-beaked dolphin is endemic to the North Sea, with an estimated population of nearly 36,000 individuals (IJsseldijk *et al*., 2018). The white-beaked dolphin is the second most common cetacean species present in the North Sea following the harbour porpoise (Schick *et al*., 2020). This species is typically found along continental shelf waters between 50-100 m in depth, predominantly in the western portion of the central and northern North Sea (Hammond *et al*., 2013). Analysis of stomach contents from North Sea white beaked dolphins have illustrated that cod, gobies, haddock, and whiting play an important role in the species diet (Schick *et al*., 2020). Sexual maturity has been found to range between six to 10 years in females and seven to 12 years in males (Schick *et al*., 2020). Although little is known regarding the species reproductive behaviours, calving is believed to take place in summer months from May to September (IJsseldijk *et al*., 2018), coinciding with peak densities found along the Scottish coast (Gilles *et al*., 2019). Temperature has been found to be a critical factor in determining the white-beaked dolphins' distribution. Several authors have emphasised the potential impacts of increased water temperatures due to ramifications of climate change and their effects on prey abundance and distribution, altering white-beaked dolphin habitat and foraging preferences (Macleod *et al*., 2008; Evans and Bjørge, 2013; IJsseldijk *et al*., 2018).

3.4.2 As previously stated, the white-beaked dolphin is the second most common cetacean species observed in the North Sea (Schick *et al*., 2020). Given the known, wide ranging movements of this species, and the southerly location of the E1 East site (Figure 1.1) to the species range, this area of the North Sea likely represents a small portion of the overall area utilised (Hammond *et al*., 2017). Therefore, the habitat affected through the proposed survey of the E1 East Proposed Export Cable Corridor Area will comprise a minor proportion of available habitat for the white-beaked dolphin population.

3.4.3 Species-specific densities have been based on SCANS III Survey Block R densities (Hammond *et al.,* 2021). The abundance estimates for white-beaked dolphin within Survey Block R were 15,694 individuals, with a density of 0.243 animals /km^2 (Hammond *et al*., 2021). The conservation status of the white-beaked dolphin in UK waters was assessed as Favourable (JNCC, 2013c) but this has subsequently been revised to Unknown for the latest assessment (JNCC, 2019c). Large-scale abundance surveys conducted from 1994-2005 have consistently reported similar numbers, suggesting that the population size has remained relatively stable without significant increase or decrease in total population size within the North Sea (Hammond *et al*., 2017; Paxton *et al*., 2016).

3.4.4 The E1 East Proposed Export Cable Corridor Area is located within the Celtic and Greater North Seas Management Unit (CGNSMU) for white-beaked dolphin (IAMMWG, 2021). This abundance of white-beaked dolphin in the CGNSMU is estimated at 43,951 individuals. Within the UK portion of the CGNSMU, it is estimated there are 34,025 white-beaked dolphin (IAMMWG, 2021).

3.4.2 Risk Assessment

3.4.1 Thresholds for SPLs at which injury and behavioural disturbance may be induced in HF cetacean species, such as the white-beaked dolphin are described in Section 2.

3.4.2 The noise assessment (Section 2; Appendix B) showed that a white-beaked dolphin exposed to subsea noise from the survey equipment would be likely to experience permanent auditory injury at a range of up to 55 metres (worst case sub bottom profiler; PTS SEL). Recoverable auditory injury and fleeing response has the potential to occur out to a maximum distance of 205 metres (worst case sub bottom profiler; TTS SEL). Behavioural disturbance has the potential to occur out to a maximum distance of 1,930 m (11.7 km^2) (worst case USBL) (see Appendix B).

3.4.3 The noise modelling demonstrated that without the implementation of mitigation, and for all equipment, less than one white-beaked dolphin is predicted to have the potential to experience PTS at any one time within the E1 East survey area (see Appendix A).

3.4.4 Due to the small area over which injury could occur and the low number of animals which may be affected, the risk of injury to white-beaked dolphin is considered to be negligible. It is likely that animals will be displaced from the area of injury risk prior to commencement of the geophysical survey due to audible and visual cues during movement of the boats used to place the survey equipment. Proposed mitigation to further reduce potential for impact is presented in Section 3.7.

3.4.5 Less than one white-beaked dolphin is predicted to have the potential to experience TTS at any one time within the E1 East survey area.

3.4.6 Up to three white-beaked dolphin may be disturbed as a result of the survey activities at any one time. Disturbance has the potential to occur over an area of up to 11.7 km^2. This equates to up to 0.006% of the CGNSMU population, or up to 0.008% of the UK portion of the CGNSMU population at the survey location (see Appendix A).

3.4.7 Therefore, there is a low risk of disturbance, however an EPS Licence is required in respect of this disturbance for the E1 East proposed geophysical survey.

3.5 Atlantic White-sided Dolphin

3.5.1 Baseline

3.5.1 The Atlantic white-sided dolphin inhabits the North Atlantic as its name implies, and prefers deep oceanic waters along the continental shelf, ranging in depth from 100-500 metres (Evans and Waggitt, 2020; Schick *et al*., 2020). Atlantic white-sided dolphins are known to be highly mobile and can travel long distances as their distribution from the eastern coast of the United States to north of Greenland illustrates (Wall *et al*., 2013). In the UK, the species is known to primarily occur to the north and northwest of Scotland, with observances being rare in the central and northeastern North Sea (Gilles *et al*., 2019). Males are typically larger than females and calving season is known to begin in the early summer months, with the majority of calf sightings ranging from June to September (Weinrich *et al*., 2001; Schick *et al*., 2020). This species is usually observed in large pods, which can comprise up to several thousand individuals (Barnes, 2008). Atlantic white-sided dolphins have been observed working together to herd schools of fish towards the surface and their diets have been found to mainly consist of cod, herring, squid, shrimp, mackerel and sandeels (HWDT, 2021). Additionally, they can often be seen feeding with fin and humpback whales and are known to form mixed groups with other dolphin species (Hammond *et al*., 2019).

3.5.2 The Atlantic white-sided dolphin is abundant throughout its range with approximately 54% of its population coming from the west coast of Scotland (Macleod, 2004; Hammond *et al*., 2019). Given the extensive range of the species, the North Sea is likely to only represent a small portion of the total range and habitat utilised by Atlantic white-sided dolphins (Hammond *et al*., 2017). Additionally, given the species preference for deep oceanic and offshore waters, it is unlikely the E1 East Proposed Export Cable Corridor Area represents a key habitat for the species.

3.5.3 Species-specific densities have been based on SCANS III Survey Block R densities (Hammond *et al*., 2021). The abundance estimate for Atlantic white-sided dolphin within Survey Block R is 644 individuals, with a density of 0.010 animals /km^2 (Hammond *et al*., 2021). The conservation status of the Atlantic white-sided dolphin in UK waters was assessed as Favourable (JNCC, 2013d) but this has subsequently been revised to Unknown for the latest assessment (JNCC, 2019d). The species is known to be widespread and abundant, with population estimates currently exceeding 100,000 individuals (Hammond *et al*., 2019).

3.5.4 The E1 East Proposed Export Cable Corridor Area is located within the Celtic and Greater North Seas Management Unit (CGNSMU) for Atlantic white-sided dolphin (IAMMWG, 2021). The abundance of Atlantic white-sided dolphin in the CGNSMU is estimated at 18,128 individuals. Within the UK portion of the CGNSMU, it is estimated there are 12,293 Atlantic white-sided dolphin (IAMMWG, 2021).

3.5.2 Risk Assessment

3.5.1 Thresholds for SPLs at which injury and behavioural disturbance may be induced in HF cetacean species, such as the Atlantic white-sided dolphin are described in Section 2.

3.5.2 The noise assessment (Section 2; Appendix B) showed that an Atlantic white-sided dolphin exposed to subsea noise from the survey equipment may experience permanent auditory injury at a range of up to 55 metres (worst case sub bottom profiler; PTS SEL). Recoverable auditory injury and fleeing response has the potential to occur out to a maximum distance of 205 metres (worst case sub bottom profiler; TTS SEL). Behavioural disturbance has the potential to occur out to a maximum distance of 1,930 m (11.7 km^2) (worst case USBL) (see Appendix A).

3.5.3 The noise modelling demonstrated that without the implementation of mitigation, and for all equipment, less than one Atlantic white-sided dolphin is predicted to have the potential to experience PTS at any one time within the E1 East survey area. (see Appendix A).

3.5.4 Due to the small area over which injury could occur and the low number of animals which may be affected (<1), the risk of injury to Atlantic white-sided dolphin is considered to be negligible. It is likely that animals will be displaced from the area of injury risk prior to commencement of the geophysical survey due to audible and visual cues during movement of the boats used to place the survey equipment. Proposed mitigation to further reduce potential for impact is presented in Section 3.7.

3.5.5 Less than one Atlantic white-sided dolphin is predicted to have the potential to experience TTS at any one time within the E1 East survey area.

3.5.6 Less than one Atlantic white-sided dolphin may be disturbed as a result of the survey activities. Disturbance has the potential to occur over an area of up to 11.7 km^2. This equates to up to 0.0006% of the CGNSMU population, or up to 0.0009% of the UK portion of the CGNSMU population at each of the survey locations, assuming the surveys take place consecutively (see Appendix A).

3.5.7 Therefore, there is a low risk of disturbance, however an EPS Licence is required in respect of this disturbance for the E1 East proposed geophysical survey.

3.6 Minke Whale

3.6.1 Baseline

3.6.1 The minke whale is the smallest, most abundant baleen whale (mysticete) species observed in UK waters (Robinson *et al*., 2021; Evans and Waggitt, 2020). Recent studies have determined there are approximately 9,000 individuals occurring in the North Sea, with the majority of sightings coming from inshore, shelf waters up to 200 metres in depth along the northern North Sea (Hammond *et al*., 2017; Robinson *et al*., 2021). Studies have shown that minke whale are most commonly sighted in summer months, where the species undergo seasonal movements, illustrating their wide spatial distribution (Gilles *et al*., 2019). However, it is worth noting that while the species has been frequently observed from April to October in coastal waters of the North Sea, sightings have simultaneously been documented year-round (Dolman *et al*., 2013; Reid *et al*., 2003). Off the coast of Scotland, sightings peak from July to August, relating to meso-scale oceanographic features which most likely increase minke whale foraging opportunities in the area (Tetley and Robinson, 2008; Robinson *et al*., 2009). The minke whale diet in Scottish waters primarily consists of sandeels, herring, whiting, and plankton (HWDT, 2021; Pierce *et al*., 2004). It has been evidenced that minke whales undergo large, seasonal migrations between breeding grounds and foraging grounds, although these have not been conclusively identified (Risch *et al.,* 2014; Risch *et al*., 2019). The species' relatively small size and elusive behaviour have resulted in uncertainty regarding their migratory routes and seasonal distributions, making effective conservation and management difficult (Risch *et al*., 2019).

3.6.2 Minke whale is a commonly occurring species off the coast of Scotland and more specifically, in the Moray Firth with significant distributions found along the southern coastline. It's been evidenced that minke whales are observed less frequently in the southern North Sea as compared to the northern and central North Sea (Risch *et al*., 2019). These highly productive waters are home to rich feeding grounds which attract high densities of minke whales during summer and autumn months, resulting in the designation of the Southern Trench Marine Protected Area (MPA) (Robinson *et al*., 2021).

3.6.3 Acoustic recordings were collected from May – November 2016 across 10 recording sites within the Moray Firth and the Eastern coast of Scotland (Risch *et al*., 2019). These recording sites, from north to south include Latheron, Helmsdale, Cromarty, Spey Bay, Fraserburgh, Cruden Bay, Stonehaven, Arbroath, St Andrews, and St Abbs. Minke whale acoustic recordings were present at 70% of the recording locations, with most recordings being evidenced in the central and northern Moray Firth, particularly at Latheron, Helmsdale, and Spey Bay (Risch *et al.,* 2019). Latheron, Helmsdale, and Spey Bay are approximately 126.4 km, 132.3 km, and 103.2 km northeast of the Cruden Bay location, nearest to the E1 East Proposed Export Cable Corridor Area. There were few to no recorded detections along the east coast outside of the Moray Firth (Cruden Bay, Stonehaven, Arbroath, St Andrews and St Abbs) (Risch *et al.,* 2019).

3.6.4 Species-specific densities have been based on SCANS III Survey Block R densities (Hammond *et al*., 2021). The abundance estimate for minke whale within Survey Block R is 2,498 individuals, with a density of 0.039 animals /km^2 (Hammond *et al*., 2021). The conservation status of the minke whale in UK waters was assessed as Favourable (JNCC, 2013e) but this has subsequently been revised to Unknown for the latest assessment (JNCC, 2019e).

3.6.5 The E1 East Proposed Export Cable Corridor Area is located within the Celtic and Greater North Seas Management Unit (CGNSMU) for minke whale (IAMMWG, 2021). The abundance of minke whale in the CGNSMU is estimated at 20,118 individuals. Within the UK portion of the CGNSMU, it is estimated there are 10,288 minke whale (IAMMWG, 2021).

3.6.2 Risk Assessment

3.6.1 The minke whale, a baleen whale, is most sensitive to noise frequencies in the range from 40 Hz to 15 kHz (Ketten and Mountain, unpublished). Thresholds for SPLs at which injury and behavioural disturbance may be induced are described in Section 2.

3.6.2 The noise assessment (Section 2; Appendix B) showed that a minke whale exposed to subsea noise from the survey equipment may experience permanent auditory injury at a range of up to 51 metres (worst case sub bottom profiler; PTS SEL). Recoverable auditory injury and fleeing response has the potential to occur out to a maximum distance of 270 metres (worst case sparker; TTS SEL). Behavioural disturbance has the potential to occur out to a maximum distance of 1,930 m (11.7 km^2) (worst case USBL) (see Appendix A).

3.6.3 The noise modelling demonstrated that without the implementation of mitigation, and for all equipment, less than one minke whale is predicted to have the potential to experience PTS at any one time within the E1 East survey area (see Appendix A).

3.6.4 Due to the small area over which injury could occur and the low number of animals which may be affected (<1), the risk of injury to minke whale is considered to be negligible. It is likely that animals will be displaced from the area of injury risk prior to commencement of the geophysical survey due to audible and visual cues during movement of the boats used to place the survey equipment. Proposed mitigation to further reduce potential for impact is presented in Section 3.7.

3.6.5 Less than one minke whale is predicted to have the potential to experience TTS at any one time within the E1 East survey area.

3.6.6 Less than one minke whale may be disturbed as a result of the survey activities. Disturbance has the potential to occur over an area of up to 11.7 km^2. This equates to up to 0.002% of the CGNSMU population, or up to 0.004% of the UK portion of the CGNSMU population at each of the survey locations, assuming the surveys take place consecutively (see Appendix A).

3.6.7 Therefore, there is a low risk of disturbance, however an EPS Licence is required in respect of this disturbance for the E1 East proposed geophysical survey.

3.7 Mitigation

3.7.1 Marine mammal mitigation activities will be conducted in the field following the JNCC Guidelines for Minimising the Risk of Injury and Disturbance to Marine Mammals from seismic surveys (JNCC, 2017). The following specific mitigation measures are proposed for the planned geophysical surveys.

3.7.2 Dedicated marine mammal observers (MMO) / passive acoustic monitoring (PAM) operatives (potentially dual role for PAM) will operate from the vessel bridge during daylight hours as per current JNCC guidelines (JNCC, 2017). Given the water depth of the E1 East Proposed Export Cable Corridor Area (< 200 metres), monitoring will be carried out with particular attention given to a 500 m exclusion zone around the geophysical survey equipment source and from 30 minutes before start of geophysical equipment, throughout the 20 minute soft-start period until the start of acquisition (therefore ~50 minutes before start of line).

3.7.3 Each time the seismic source is activated, there will be a gradual build -up (or soft-start) of source power over the 20 minute period, as per the soft-start procedures and current JNCC guidelines (JNCC, 2017). This soft-start procedure is utilised while commencing underwater activities to gradually increase the sound intensity over a specific period of time and area. Effectively, this procedure aims to deter marine mammals from the surrounding area prior to full volume being reached so that the noise exposure to marine mammals and the associated risk of injury is reduced and/or mitigated. It should be noted that the MBES, SSS, USBL and SBP equipment is all run at the same time as the 2DUHR (Sparker or Sleeve Gun), therefore, the mitigation measures put in place apply to all pieces of equipment simultaneously.

3.7.4 Towed passive acoustic monitoring (PAM) provides an opportunity to detect and indicate the location of marine mammal vocalisations at sea relative to a towed hydrophone streamer and is useful when visual searching is not possible (i.e. during periods of low visibility or darkness). Marine mammal species are identified by the specific characteristics of the detected click and whistle sounds, the interpretation of which requires a specialised operator. PAM can be used to detect vocalising cetaceans, but it is not applicable for detection of pinnipeds or non-vocalising animals.

3.7.5 The MMO/PAM operative(s) will monitor an agreed mitigation zone and advise if any marine mammals are present within the zone. The standard radius of the mitigation zone is 500 m, estimated from the centre of the noise source location (noting that this exceeds the 244 m maximum modelled unmitigated injury zone as described in Section 2 and Appendix B).

3.7.6 The flexibility of the PAM towing arrangement and ease of deployment/recovery methods must also be considered in relation to existing in-sea equipment in order to ensure that the PAM system can be used without additional risk to vessel personnel and equipment either during geophysical data acquisition or equipment maintenance schedules during typical line changes or periods of poor weather.

3.7.7 It should be noted that PAM in-sea equipment deployment is dependent on operational constraints. Therefore, PAM will be used as practically and continuously as possible. SSER will advise Marine Scotland and NatureScot in the event of any significant periods where PAM is not available. PAM efforts will focus on providing a marine mammal monitoring capability of the area within 500 m of the source array, during the 30-minute monitoring period prior to soft-start at night or during periods of poor visibility.

3.7.8 In the event that marine mammals are detected within the mitigation zone, the procedures outlined in the JNCC (2017) guidance will be followed with respect to delaying the soft start (i.e. there must be a minimum of a 20 minute delay from the time of the last detection within the mitigation zone and the commencement of the soft -start).

4 THREE EPS LICENCING TESTS

4.1 Test 1: Overriding Public Interest

4.1.1 With regard to Test 1 there are several different purposes for which an EPS licence can be granted including, under Regulation 44(2)(e) of the Habitat Regulations, for 'preserving public health or public safety or other imperative reasons of overriding public interest including those of a social or economic nature and beneficial consequences of primary importance for the environment'.

4.1.2 NatureScot Guidance states that, when determining an EPS Licence application, it will be taken into account whether an activity or development is required to meet, or contribute to meeting, a specific need such as maintaining the environment of Scotland's people (including sustainable development and renewable or green energy), complying with national planning policies and supporting economic or social development (including nationally important infrastructure development projects and employment).

4.1.3 While the marine surveys associated with the proposed E1 East Array Area and Proposed Export Cable Corridor Area present a temporary disturbance to a localised marine environment, this work will allow an important addition to Scotland's growing contributions to the UK's renewable energy sector. The UK has an urgent need for new electricity generation capacity due to the closure of coal fired stations, the aging of thermal power stations and the closure of nuclear power programmes. Offshore wind provides the opportunity to deliver this new capacity, not only from a renewable, low carbon resource, but a resource which is indigenous and does not depend upon the geo-economic and geo-political risks attendant with importing fuels.

4.1.4 The UK and Scotland has committed to meeting national and international commitments to greenhouse gas reduction including the Paris Agreement (2016), which sets out a global action plan towards climate neutrality with the aims of stopping the increase in global average temperature to below 2 °C above pre-industrial levels, and to pursue efforts to limit global warming to 1.5 °C. A number of pieces of UK and Scottish legislation have also been enacted with a view to achieving these targets for reduction in greenhouse gasses, including, but not limited to:

- The Climate Change Act 2008, which the UK committed to a net reduction in GHG emissions by 2050 of 80% against the 1990 baseline;
- The Energy Act 2013 which makes provisions to incentivise investment in low carbon electricity generation, ensure security of supply, and help the UK meet its emission reduction and renewables targets. And
- The Climate Change (Emissions Reduction Targets) (Scotland) Act 2019 which amends the Climate Change (Scotland) Act 2009, and introduces binding targets on the Scottish Government to reduce net Scottish greenhouse gas emissions by at least 100% by 2045 from 1990 levels:

4.1.5 As the UK follows these legislation and policies to meet its national and international commitments to greenhouse gas reduction, additional demands will be placed on domestic electricity supply as use of, for example, electric vehicles, increases. The project will provide additional support to the UK government's national and international commitments to reduce greenhouse gases, which will bring long-term benefits. The UK currently aims to reach their zero emissions target by 2050 and a new plan is aiming for at least 68% reduction in GHG emissions by the end of the decade, compared to 1990 levels. The UK has committed to reducing emissions by the fastest rate of any major economy and in doing so, aims to create and support 250,000 jobs whilst eradicating contributions to climate change.

4.1.6 ScotWind offers the deployment of a technology in a location with a recognised wind resource and to deliver a low-cost, low-carbon supply of electricity at a time when the UK urgently needs new generation capacity to maintain a secure, affordable supply of power. The proposed development will also provide multiple opportunities of employment over the course of the project's lifetime.

4.1.7 If the works do not proceed, the progression of the ScotWind offshore developments would not be possible, making it more difficult for the UK to reach its ambitions net zero goals and the positive contribution to the local economy and job market.

4.2 Test 2: No Satisfactory Alternatives

4.2.1 Regulation 44(3)(a) of the Habitat Regulations 1994 requires the Scottish Ministers to be satisfied that there is no satisfactory alternative before an EPS Licence can be issued for the Licensable Operations.

4.2.2 In terms of the route selection process, a detailed study was undertaken to identify and appraise options for the marine cable routes to the landfall locations. The study identified and collated information on the offshore technical and environmental constraints within a broad study area, using public and commercial sources. Each constraint was then ranked and route optioneering carried out.

4.2.3 A software package was used for route optioneering which combines engineering and environmental constraints to generate feasible route options. A Black/Red/Amber/Green (BRAG) assessment was then carried, for the different possible route options to landfall, which evaluated the key risks and opportunities identified for each route. This considered issues such as archaeology, seabed conditions, UXO, third party infrastructure, military zones, dredging sites, environmentally designated areas and other sea users. A 500 m buffer was set around the route centreline. This process helped to establish a preferred route corridor, for each landfall connection, with reduced potential environmental impact and consenting risk as well as technical risks.

4.2.4 SSER has detailed the following two options that describe the possible alternatives that were considered and those that were considered unsuitable:

4.2.5 Option 1: Do not undertake the geophysical survey works or use subsurface positional equipment, resulting in excessive project risk and potential abandonment of the project.

4.2.6 Option 2: To undertake the geophysical survey works and use subsurface positional equipment, in conjunction with undertaking a Marine Mammal / EPS Risk Assessment. The EPS Risk Assessment will identify, quantify, and determine a mitigation strategy for the works such that the conservation status of EPS & Marine Mammals present in the works area or in adjacent waters where a disturbance could be perceived, are protected through the use of mitigation tools such as the use of MMO and PAM following the JNCC seismic guidelines.

4.2.7 SSER has determined that Option 2 will be progressed, as the survey activities will provide SSER with an in depth understanding of E1 East potential cable corridors, while maintaining FCS of cetaceans within the works or adjacent area.

4.2.8 If the works do not proceed, as previously stated, it would make the UK’s ambitious target to reach net zero by 2050 more difficult to attain, resulting in the underutilisation of a strong and renewable resource off the Scottish coast.

4.3 Test 3: Favourable Conservation Status (FCS)

4.3.1 Regulation 44(3)(b) of the Habitat Regulations 1994 requires the regulatory authority to be satisfied that the licensed activities must not be detrimental to the maintenance of the population of species concerned at FCS in their natural range. The EU Habitats Directive includes the definitions for FCS below:

The “conservation status” of a species means, “the sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations […]”

The “favourable conservation status” of a species means:

> *“population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable component of its natural habitats, and*

the natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future, and

there is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis."

4.3.2 The risk assessment (Section 3) has identified five cetacean species which have the potential to occur in the vicinity of the E1 East Proposed Export Cable Corridor Area and for which effects from the Licensable Operation must be assessed against FCS. The species to which this licence application applies are:

- Harbour porpoise,
- Bottlenose dolphin,
- White-beaked dolphin,
- Atlantic white-sided dolphin, and
- Minke whale.

4.3.2 Harbour Porpoise

FCS of Harbour Porpoise

4.3.1 The noise modelling assessment (Section 2; Appendix B) demonstrated that, for very high-frequency cetaceans (without mitigation), less than one individual has the potential to experience PTS (permanent auditory injury) as a result of the proposed geophysical survey, which is equivalent to less than 3.23×10^{-5} % of the NSMU population, or 7.02×10^{-5} % of the UK portion of the NSMU (NMFS, 2018). Up to seven individuals may have the potential to experience TTS (recoverable injury) as a result of the proposed geophysical survey, which is the equivalent to less than 0.002% of the NSMU population, or 0.004% of the UK portion of the NSMU. The likelihood of an animal experiencing PTS or TTS will be reduced with the implementation of mitigation measures as detailed in Section 3.7 (JNCC, 2017). Modelling indicated that disturbance could occur out to a distance of up to 1,930 m over an area of up to 11.7 km^2 and has the potential to affect up to seven harbour porpoise at any one time. This is the equivalent of less than 0.002% of the NSMU, or 0.004% of the UK portion of the NSMU (IAMMWG 2021).

4.3.2 Given that mitigation measures will be implemented to avoid auditory injury, the remaining behavioural effects will be spatially limited and are therefore predicted to affect very small numbers of animals in the context of the wider population. As such, the North Sea harbour porpoise population is likely to continue "maintaining itself on a long-term basis as a viable element of its natural habitats", as defined by the first FCS test.

4.3.3 The proposed geophysical survey will be temporary, taking place over 60 days for the E1 East Proposed Export Cable Corridor Area and will be carried out over a small area (up to 1,126.1 km^2), with only a small proportion of that total area affected at any one time in the context of the NSMU (IAMMWG, 2021). The use of geophysical survey equipment is not expected to create a barrier to movement for any EPS and is therefore not expected to reduce the range of the local harbour porpoise population, with the "natural range of the species neither being reduced nor likely to be reduced for the foreseeable future", as defined by the second FCS status test.

4.3.4 Harbour porpoise are highly mobile utilising habitats over a wide area. Any habitat likely to be affected therefore will constitute a very small proportion of the available habitat to the harbour porpoise population. The survey area is not likely to represent a key habitat in the context of the wider region. As such, it is predicted that the third FCS test, namely that "there is, and will probably continue to be, a sufficiently large habitat to maintain harbour porpoise populations on a long-term basis", will be satisfied.

4.3.3 Bottlenose Dolphin

FCS of Bottlenose Dolphin

4.3.1 The noise modelling assessment (Section 2; Appendix B) demonstrated that, for HF cetaceans (without mitigation), less than one individual has the potential to experience PTS (permanent auditory injury) as a result of the proposed geophysical survey, which is equivalent to less than 1.48×10^{-5} % of the GNSMU population, or 1.59×10^{-5} % of the UK portion of the GNSMU. With regard to the CESMU, which is located in UK waters only, this equates to 1.34×10^{-4} % of the population (IAMMWG 2021; NMFS, 2018). Less than one individual may have the potential to experience TTS (recoverable injury) as a result of the proposed geophysical survey, which is the equivalent to less than 1.96×10^{-4} % of the GNSMU population, or 2.1×10^{-4} % of the UK portion of the GNSMU. With regard to the CESMU, which is located in UK waters only, this equates to 1.77×10^{-3} % of the population (IAMMWG 2021).

4.3.2 The likelihood of an animal experiencing PTS or TTS will be reduced with the implementation of mitigation measures as detailed in Section 3.7 (JNCC, 2017).

4.3.3 Modelling indicated that disturbance could occur out to a distance of up to 1,930 m over an area of up to 11.7 km^2 and has the potential to affect less than one animal at any one time. This is the equivalent of less than 0.017% of the GNSMU, or 0.019% of the UK portion of the GNSMU. With regard to the CESMU, which is located in UK waters only, this equates to 0.157% of the population (IAMMWG 2021).

4.3.4 Given that mitigation measures will be implemented to avoid auditory injury, the remaining behavioural effects will be spatially limited, and are therefore predicted to affect very small numbers of animals in the context of the wider population. As such, the Greater North Sea bottlenose dolphin population and the Coastal East Scotland bottlenose dolphin population are likely to continue "maintaining itself on a long-term basis as a viable element of its natural habitats", as defined by the first FCS test.

4.3.5 The proposed geophysical survey will be temporary, taking place over 60 days for the E1 East Proposed Export Cable Corridor Area and will be carried out over a small area (total: up to 1,126.1 km^2; within 12nm zone: up to 502.7 km^2), with only a small proportion of that total area affected at any one time) in the context of the GNSMU and CESMU (IAMMWG, 2021). The use of geophysical survey equipment is not expected to create a barrier to movement for any EPS and is therefore not expected to reduce the range of the local bottlenose dolphin population, with the "natural range of the species neither being reduced nor likely to be reduced for the foreseeable future", as defined by the second FCS status test.

4.3.6 Bottlenose dolphin have been known to exhibit flexibility in their habitat use and those off the east coast of Scotland demonstrate high site fidelity to the Moray Firth SAC. Any habitat likely to be affected therefore will constitute a very small proportion of the available habitat to the bottlenose dolphin population. The survey area is not likely to represent a key habitat in the context of the wider region. As such, it is predicted that the third FCS test, namely that "there is, and will probably continue to be, a sufficiently large habitat to maintain bottlenose dolphin populations on a long-term basis", will be satisfied.

4.3.4 White-beaked Dolphin

FCS of White-beaked Dolphin

4.3.1 The noise modelling assessment (Section 2; Appendix B) demonstrated that, for HF cetaceans without mitigation, less than one individual has the potential to experience PTS (permanent auditory injury) as a result of the proposed geophysical survey, which is equivalent to less than 5.53×10^{-6} % of the CGNSMU population, or 7.14×10^{-6} % of the UK portion of the CGNSMU (NMFS, 2018). Less than one individual may have the potential to experience TTS (recoverable injury) as a result of the proposed geophysical survey, which is the equivalent to less than 7.30 x 10^{-5} % of the CGNSMU population, or 9.43 x 10^{-5} % of the UK portion of the CGNSMU. The likelihood of an animal experiencing PTS or TTS will be reduced with the implementation of mitigation measures as detailed in Section 3.7 (JNCC, 2017). Modelling indicated that disturbance could occur out to a distance of up to 1,930 m over an area of up to 11.7 km^2 and has the potential to affect up to three animals at any one time. This is the equivalent of less than 0.006% of the CGNSMU, or 0.008% of the UK portion of the CGNSMU (IAMMWG 2021).

4.3.2 Given that mitigation measures will be implemented to avoid auditory injury the remaining behavioural effects will be spatially limited and are therefore predicted to affect very small numbers of animals in the context of the wider population. As such, the Celtic and Greater North Sea white-beaked dolphin population is likely to continue "maintaining itself on a long-term basis as a viable element of its natural habitats", as defined by the first FCS test.

4.3.3 The proposed geophysical survey will be temporary, taking place over 60 days for the E1 East Proposed Export Cable Corridor Area and will be carried out over a small area (up to 1,126.1 km^2), with only a small proportion of that total area affected at any one time) in the context of the CGNSMU (IAMMWG, 2021). The use of geophysical survey equipment is not expected to create a barrier to movement for any EPS and is therefore not expected to reduce the range of the local white-beaked dolphin population, with the "natural range of the species neither being reduced nor likely to be reduced for the foreseeable future", as defined by the second FCS status test.

4.3.4 The white-beaked dolphin is a highly mobile and wide-ranging species encountered in the North Sea. Any habitat likely to be affected therefore will constitute a very small proportion of the available habitat to the white-beaked dolphin population. The survey area is not likely to represent a key habitat in the context of the wider region. As such, it is predicted that the third FCS test, namely that "there is, and will probably continue to be, a sufficiently large habitat to maintain white-beaked dolphin populations on a long-term basis", will be satisfied.

4.3.5 Atlantic White-sided Dolphin

FCS of Atlantic White-sided Dolphin

4.3.1 The noise modelling assessment (Section 2; Appendix B) demonstrated that, for HF cetaceans without mitigation, less than one individual has the potential to experience PTS (permanent auditory injury) as a result of the proposed geophysical survey, which is equivalent to less than 5.52 x 10^{-7} % of the CGNSMU population, or 8.13 x 10^{-7} % of the UK portion of the CGNSMU (NMFS, 2018). Less than one individual may have the potential to experience TTS (recoverable injury) as a result of the proposed geophysical survey, which is the equivalent to less than 7.28 x 10^{-6} % of the CGNSMU population, or 1.07 x 10^{-5} % of the UK portion of the CGNSMU. The likelihood of an animal experiencing PTS or TTS will be reduced with the implementation of mitigation measures as detailed in Section 3.7 (JNCC, 2017). Modelling indicated that disturbance could occur out to a distance of up to 1,930 m over an area of up to 11.7 km^2 and has the potential to affect less than one animal at any one time. This is the equivalent of less than 0.0006% of the CGNSMU, or 0.0009% of the UK portion of the CGNSMU (IAMMWG 2021).

4.3.2 Given that mitigation measures will be implemented to avoid auditory injury the remaining behavioural effects will be spatially limited and are therefore predicted to affect very small numbers of animals in the context of the wider population. As such, the Celtic and Greater North Sea Atlantic white-sided dolphin population is likely to continue "maintaining itself on a long-term basis as a viable element of its natural habitats", as defined by the first FCS test.

4.3.3 The proposed geophysical survey will be temporary, taking place over 60 days for the E1 East Proposed Export Cable Corridor Area and will be carried out over a small area (up to 1,126.1 km^2) with only a small proportion of that total area affected at any one time) in the context of the CGNSMU (IAMMWG, 2021). The use of geophysical survey equipment is not expected to create a barrier to movement for any EPS and is therefore not expected to reduce the range of the local Atlantic white-sided dolphin population, with the "natural range of the species neither being reduced nor likely to be reduced for the foreseeable future", as defined by the second FCS status test.

4.3.4 The Atlantic white-sided dolphin is known to be highly mobile and can travel long distances as their distribution from the eastern coast of the United States to north of Greenland illustrates. Any habitat likely to be affected therefore will constitute a very small proportion of the available habitat to the Atlantic white-sided dolphin population. The survey area is not likely to represent a key habitat in the context of the wider region. As such, it is predicted that the third FCS test, namely that "there is, and will probably continue to be, a sufficiently large habitat to maintain Atlantic white-sided dolphin populations on a long-term basis", will be satisfied.

4.3.6 Minke Whale

FCS of Minke Whale

4.3.1 The noise modelling assessment (Section 2; Appendix B) demonstrated that, for LF cetaceans without mitigation, less than one individual has the potential to experience PTS (permanent auditory injury) as a result of the proposed geophysical survey, which is equivalent to less than 1.55 x 10^{-6} % of the CGNSMU population, or 3.03 x 10^{-6} % of the UK portion of the CGNSMU (NMFS, 2018). Less than one individual may have the potential to experience TTS (recoverable injury) as a result of the proposed geophysical survey, which is the equivalent to less than 4.44 x 10^{-5} % of the CGNSMU population, or 4.32 x 10^{-7} % of the UK portion of the CGNSMU. The likelihood of an animal experiencing PTS or TTS will be reduced with the implementation of mitigation measures as detailed in Section 3.7 (JNCC, 2017). Modelling indicated that disturbance could occur out to a distance of up to 1,930 m over an area of up to 11.7 km^2 and has the potential to affect less than one animal at any one time. This is the equivalent of less than 0.002% of the CGNSMU, or 0.004% of the UK portion of the CGNSMU (IAMMWG 2021).

4.3.2 Given that mitigation measures will be implemented to avoid auditory injury the remaining behavioural effects will be spatially limited and are therefore predicted to affect very small numbers of animals in the context of the wider population. As such, the Celtic and Greater North Sea minke whale population is likely to continue "maintaining itself on a long-term basis as a viable element of its natural habitats", as defined by the first FCS test.

4.3.3 The proposed geophysical survey will be temporary, taking place over 60 days for the E1 East Proposed Export Cable Corridor Area and will be carried out over a small area (up to 1,126.1 km^2), with only a small proportion of that total area affected at any one time) in the context of the CGNSMU (IAMMWG, 2021). The use of geophysical survey equipment is not expected to create a barrier to movement for any EPS and is therefore not expected to reduce the range of the local minke whale population, with the "natural range of the species neither being reduced nor likely to be reduced for the foreseeable future", as defined by the second FCS status test.

4.3.4 The minke whale is known to have a large spatial distribution, undergoing seasonal movements between foraging and breeding grounds. Any habitat likely to be affected therefore will constitute a very small proportion of the available habitat to the minke whale population. The survey area is not likely to represent a key habitat in the context of the wider region. As such, it is predicted that the third FCS test, namely that "there is, and will probably continue to be, a sufficiently large habitat to maintain minke whale populations on a long-term basis", will be satisfied.

5 CONCLUSIONS

5.1.1 The Applicant understands that in order for an EPS licence to be granted for the specific purposes set out in the Conservation (Natural Habitats) Regulations 1994 (as amended), the regulator would need to be satisfied that the Application passes each of the three tests namely: (1) Overriding public interest; (2) No satisfactory alternatives; and (3) Favourable conservation status. This document, in support of an Application for an EPS licence, has sought to demonstrate compliance with these three tests.

5.1.2 The proposed survey will contribute to long-term strategic economic development and regeneration, in addition to reducing GHG emissions and aiming to mitigate the ramifications of climate change, therefore the Licensable Operations fulfil the requirements of Test 1: Overriding Public Interest. The Licensable Operations are a solution to a fundamental and essential step required for the sustainable construction of the proposed project, and the option of 'do nothing' is not considered to be a realistic option. As such it can be demonstrated that the Licensable Operations fulfil the requirements of Test 2: No Satisfactory Alternatives.

5.1.3 The Applicant has sought to demonstrate that, should the Project Consents be granted, the activities would not be detrimental to the maintenance of the FCS of EPS likely to occur within the zone of potential impact of the Project. Those EPS included harbour porpoise, bottlenose dolphin, white-beaked dolphin, Atlantic white-sided dolphin and minke whale. Project specific noise modelling predicted that, in the absence of mitigation, permanent injury (PTS) could occur out to a maximum of 244 m across all species, temporary injury/fleeing response (TTS) out to a maximum of 1,870 m across all species, and disturbance out a maximum range of 1,930 m across all species.

5.1.4 The assessment found that in the absence of mitigation, less than one individual of each species has the potential to experience PTS at any one time. Up to seven individual harbour porpoise have the potential to experience TTS at any one time.

5.1.5 The risk of injury (permanent or temporary) to marine mammals from the proposed geophysical survey activities will be mitigated following JNCC mitigation guidelines (JNCC, 2017).

5.1.6 Up to seven harbour porpoise and up to three white-beaked dolphin have the potential to experience disturbance at any one time. The most sensitive species was harbour porpoise where up to two individuals may experience strong disturbance at any one time. These numbers constitute very small proportions of the relevant management unit populations.

5.1.7 Based on the output of noise modelling, in conjunction with available data on relevant populations, habitat use and natural range, it was demonstrated that for all five species, the number of animals affected in the context of the wider MU populations will be very small and therefore unlikely to significantly affect the population as a whole; the populations of EPS in the vicinity of the survey area will continue to maintain themselves on a long-term basis as a viable component of their natural habitats. In addition, it was demonstrated that for all five EPS, the Licensable Operations are not predicted to create a barrier to movement for EPS and are therefore not likely to reduce the range of populations, with the natural range of each species neither being reduced nor likely to be reduced for the foreseeable future. Finally, it was demonstrated that any habitat likely to be affected by the Licensable Operations will constitute a very small proportion of the available habitat to these EPS and therefore it is predicted that there is, and will probably continue to be, a sufficiently large habitat to maintain EPS populations on a long-term basis. As such the Applicant has demonstrated that the Licensable Operations fulfil the requirements of Test 3: Favourable Conservation Status.

REFERENCES

Arso Civil, M., Quick, N., Mews, S., Hague, E. Cheney, B.J., Thompson, P.M. and Hammond, P.S. (2021). Improving understanding of bottlenose dolphin movements along the east coast of Scotland. Final report. Report number SMRUCVAT-2020-10 provided to European Offshore Wind Deployment Centre (EOWDC), March 2021.

Avant, P. 2008. *Tursiops truncatus* Bottle-nosed dolphin. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 21-10-2021]. Available from: https://www.marlin.ac.uk/species/detail/1674.

Baines, M. E. and P. G. H. Evans (2012) Atlas of the Marine Mammals of Wales. CCW Monitoring Report No. 68. 2nd Edition. 139pp.

Barnes, M.K.S. 2008. Lagenorhynchus acutus Atlantic white-sided dolphin. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 22-10-2021]. Available from: https://www.marlin.ac.uk/species/detail/116.

Cheney, B., Corkrey, R., Durban, J.W., Grellier, K., Hammond, P.S., Uslas-Villanueva, V, Janik, V.M., Lusseau, S.M., Parsons, K.M., Quick, N.J., Wilson, B. and Thompson, P.M. (2014) Long-term trends in the use of a protected area by small cetaceans in relation to changes in population status. Global Ecology and Conservation, 2, 118–128.

Cheney, B., Graham, I. M., Barton, T., Hammond, P. S. and Thompson, P. M. (2018). Site Condition Monitoring of bottlenose dolphins within the Moray Firth Special Area 288 of Conservation: 2014-2016. Scottish National Heritage Research Report No 1021.

Chevallard, P., Culloch, R., Edwards, E., Davies, I. and Brookes, K., 2019. East Coast Marine Mammal Acoustic Survey (ECOMMAS).

Dolman, S. J., Hodgins, N. K., Macleod, C. D., Pierce, G. J. & Weir, C. R. Harbour porpoises (Phocoena phocoena) and minke whales (Balaenoptera acutorostrata) observed during land-based surveys in The Minch, north-west Scotland. J. Mar. Biol. Assoc. UK 94, 1185–1194 (2013).

Evans, P. and Waggitt, J., 2020. Impacts of climate change on Marine Mammals, relevant to the coastal and marine environment around the UK.

Evans, P.G.H. & A. Bjørge 2013. Impacts of climate change on marine mammals. Marine Climate Change Impacts Partnership (MCCIP) Science Review 2013: 134-148.

Fernandez-Betelu, O., Graham, I.M., Cornulier, T. and Thompson, P.M., 2019. Fine scale spatial variability in the influence of environmental cycles on the occurrence of dolphins at coastal sites. Scientific reports, 9(1), pp.1-12.

Garagouni, M., Pirotta, E., Ingram, S.N. and Rogan, E., 2019. Habitat use of a resident bottlenose dolphin population in the Shannon Estuary. Habitat preferences and movement patterns of bottlenose dolphins at, p.99.

Genov, T., Centrih, T., Kotnjek, P. and Hace, A., 2019. Behavioural and temporal partitioning of dolphin social groups in the northern Adriatic Sea. Marine biology, 166(1), pp.1-14.

Gilles, A., Galatius, A., Aloha, M., Authier, M., Brasseur, S., Carlsson, A., Carlström, J., Chaudry, F., Culloch, R.M., Evans, P.G. and Geelhoed, S.C.V., 2019. Working Group on Marine Mammal Ecology (WGMME).

Hague, E.L., Sinclair, R.R. and Sparling, C.E., 2020. Regional baselines for marine mammal knowledge across the North Sea and Atlantic areas of Scottish waters. Scottish Marine and Freshwater Science.

Hammond, P.S., Bearzi, G., Bjørge, A., Forney, K., Karczmarski, L., Kasuya, T., Perrin, W.F., Scott, M.D., Wang, J.Y., Wells, R.S. and Wilson, B., 2019. Lagenorhynchus acutus. The IUCN Red List of Threatened Species 2008: e. T11141A3255721.

Hammond, P.S., Lacey, C., Gilles, A., Viquerat, S., Börjesson, P., Herr, H., Macleod, K., Ridoux, V., Santos, M.B., Scheidat, M., Teilmann, J., Vingada, J. and Øien, N. (2017). Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. May 2017, 40 pp.

Hammond, P.S., Lacey, C., Gilles, A., Viquerat, S., Börjesson, P., Herr, H., Macleod, K., Ridoux, V., Santos, M.B., Scheidat, M., Teilmann, J., Vingada, J. and Øien, N. (2021). Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. May 2017, 40 pp.

Hammond, P.S., Macleod, K., Berggren, P., Borchers, D.L., Burt, L., Cañadas, A., Desportes, G., Donovan, G.P., Gilles, A., Gillespie, D. and Gordon, J. (2013) Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. Biological Conservation, 164, pp.107-122.

Hebridean Whale and Dolphin Trust (HWDT), 2021. *Atlantic white-sided dolphin*. Available at: https://hwdt.org/atlantic-white-sided-dolphin. Accessed on: 22 October 2021.

Hebridean Whale and Dolphin Trust (HWDT), 2021. *Minke Whale*. Available at: https://hwdt.org/minke-whale Accessed on: 22 October 2021.

High Energy Seismic Survey (HESS) (1997). Summary of Recommendations Made by the Expert Panel at the HESS Workshop on the Effects of Seismic Sound on Marine Mammals In Pepperdine University, Malibu, California.

IJsseldijk, L.L., Brownlow, A., Davison, N., Deaville, R., Haelters, J., Keijl, G., Siebert, U. and ten Doeschate, M.T., 2018. Spatiotemporal analysis in white-beaked dolphin strandings along the North Sea coast from 1991-2017. Lutra, 61(1), pp.153-163.

IAMMWG. 2021. Updated abundance estimates for cetacean Management Units in UK waters. JNCC Report No.680, JNCC Peterborough, ISSN 0963-8091.

JNCC (2013a) European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC): Third Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2007 to December 2012 Conservation status assessment for S1351 harbour porpoise (*Phocoena phocoena*).

JNCC (2013b) European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC): Third Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2007 to December 2012 Conservation status assessment for S1349 bottlenose dolphin (*Tursiops truncatus*).

JNCC (2013c) European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC): Third Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2007 to December 2012 Conservation status assessment for S2032 white-beaked dolphin (*Lagenorhynchus albirostris*).

JNCC (2013d) European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC): Third Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2007 to December 2012 Conservation status assessment for S2031 Atlantic white-sided dolphin (*Lagenorhynchus acutus*).

JNCC (2013e) European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC): Third Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2007 to December 2012 Conservation status assessment for S2618 minke whale (*Balaenoptera acutorostrata*).

JNCC (2017) Guidelines for minimising the risk of injury to marine mammals from geophysical surveys, JNCC, Aberdeen, April 2017.

JNCC (2019a) European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC): Fourth Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2013 to December 2018 Conservation status assessment for S1351 harbour porpoise (*Phocoena phocoena*).

JNCC (2019b) European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC): Fourth Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2013 to December 2018 Conservation status assessment for S1349 bottlenose dolphin (*Tursiops truncatus*).

JNCC (2019c) European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC): Fourth Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2013 to December 2018 Conservation status assessment for S2032 white-beaked dolphin (*Lagenorhynchus albirostris*).

JNCC (2019d) European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC): Fourth Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2013 to December 2018 Conservation status assessment for S2031 Atlantic white-sided dolphin (*Lagenorhynchus acutus*).

JNCC (2019e) European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC): Third Report by the United Kingdom under Article 17 on the implementation of the Directive from January 2013 to December 2018 Conservation status assessment for S2618 minke whale (*Balaenoptera acutorostrata*).

JNCC (2021). *Moray Firth Designated Special Area of Conservation (SAC).* Available at: https://sac.jncc.gov.uk/site/UK0019808. Accessed on: 21 October 2021.

Ketten, D.R. and Mountain, D., (Unpublished) Modelling minke whale hearing. Report to E&P Sound and Marine Life Programme. Available from: http://www.soundandmarinelife.org/library/project-reports.aspx

MacLeod, C.D Weir, C.R., Santos, M.B. and Dunn, T.E. (2008). Temperature-based summer habitat partitioning between white-beaked and common dolphins around the United Kingdom and Republic of Ireland. Journal of the Marine Biological Association of the UK, 88: 1193-1198.

Macleod, K. 2004. Abundance of Atlantic white-sided dolphin (*Lagenorhynchus acutus*) during summer off northwest Scotland. Journal of Cetacean Research and Management 6(1): 33-40.

Marine Mammal Research Unit. (2021). *Harbour porpoise biology*. Available at: https://mmru.ubc.ca/biology/harbour-porpoise-biology/. Accessed on: 21 October 2021.

National Marine Fisheries Service (NMFS) (2005). *Scoping Report for NMFS EIS for the National Acoustic Guidelines on Marine Mammals.* National Marine Fisheries Service.

NMFS (2018). “Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts.” National Marine Fisheries Service (NOAA).

National Marine Plan Inspectorate (NMPi), 2021. *Marine Scotland*. Available at: https://marinescotland.atkinsgeospatial.com/nmpi/default.aspx?availablelayers=1535. Accessed on: 21 October 2021.

Paxton, C.G.M., L. Scott-Hayward, M. Mackenzie, E. Rexstad & L. Thomas 2016. Revised Phase III Data Analysis of Joint Cetacean Protocol Data Resource. JNCC Report & Advisory Note 517. JNCC, Peterborough, UK.

Pierce, G. J., Santos, M. B., Reid, R. J., Patterson, I. A. P. and Ross, H. M. (2004) "Diet of minke whales Balaenoptera acutorostrata in Scottish (UK) waters with notes on strandings of this species in Scotland 1992–2002," Journal of the Marine Biological Association of the United Kingdom. Cambridge University Press, 84(6), pp. 1241–1244. doi: 10.1017/S0025315404010732h.

Ransijn, J.M., Booth, C. and Smout, S.C., 2019. JNCC Report No. 633.

Reid, J.B., Evans, P.G.H. and Northridge, S.P. (2003). Atlas of Cetacean distribution in northwest European waters, Joint Nature Conservation Committee (JNCC), Peterborough.

Richardson, William John, Denis H. Thomson, Charles R. Greene, Jr., and Charles I. Malme. 1995. Marine Mammals and Noise. Academic Press.

Risch, D., Castellote, M., Clark, C.W., Davis, G.E., Dugan, P.J., Hodge, L.E., Kumar, A., Lucke, K., Mellinger, D.K., Nieukirk, S.L. and Popescu, C.M., 2014. Seasonal migrations of North Atlantic minke whales: novel insights from large-scale passive acoustic monitoring networks. Movement ecology, 2(1), pp.1-17.

Risch, D., Norris, T., Curnock, M. and Friedlaender, A., 2019. Common and Antarctic minke whales: Conservation status and future research directions. Frontiers in Marine Science, 6, p.247.

Robinson, K. P., Tetley, M. J. & Mitchelson-Jacob, E. G. The distribution and habitat preference of coastally occurring minke whales (Balaenoptera acutorostrata) in the outer southern Moray Firth, northeast Scotland. J. Coast. Conservation 13, 39–48 (2009).

Robinson, K.P., Bamford, C.C., Brown, W.J., Culloch, R.M., Dolan, C.J., Hall, R., Russell, G., Sidiropoulos, T., Spinou, E., Sim, T.M. and Stroud, E., 2021. Ecological habitat partitioning and feeding specialisations of coastal minke whales (Balaenoptera acutorostrata) using a designated MPA in northeast Scotland. bioRxiv.

Robinson, K.P., Baumgartner, N., Eisfeld, S.M., Clark, N.M., Culloch, R.M., Haskins, G.N., Zapponi, L., Whaley, A.R., Weare, J.S. and Tetley, M.J. (2007). The summer distribution and occurrence of cetaceans in the coastal waters of the outer southern Moray Firth in northeast Scotland (UK). Lutra 50(11): 13-26.

Robinson, K.P., Sim, T.M., Culloch, R.M., Bean, T.S., Cordoba Aguilar, I., Eisfeld, S.M., Filan, M., Haskins, G.N., Williams, G. and Pierce, G.J., 2017. Female reproductive success and calf survival in a North Sea coastal bottlenose dolphin (Tursiops truncatus) population. PLoS One, 12(9), p.e0185000.

Santos, M. B., Pierce, G. J., Reid, R. J., Patterson, I. A. P., Ross, H. M., and Mente, E. (2001). Stomach contents of bottlenose dolphins (*Tursiops truncatus*) in Scottish waters. Journal of the Marine Biological Association of the United Kingdom, 81(5), 873-878.

Santos, M.B. & Pierce, G.J. 2003. The diet of harbour porpoise (Phocoena phocoena) in the northeast Atlantic. Oceanography and Marine Biology: an Annual Review 41: 355-390.

Schick, L., IJsseldijk, L.L., Grilo, M.L., Lakemeyer, J., Lehnert, K., Wohlsein, P., Ewers, C., Prenger-Berninghoff, E., Baumgärtner, W., Gröne, A. and Kik, M.J., 2020. Pathological findings in white-beaked dolphins (Lagenorhynchus albirostris) and Atlantic white-sided dolphins (Lagenorhynchus acutus) from the South-Eastern North Sea. Frontiers in veterinary science, 7, p.262.

Senior, B., Bailey, H., Lusseau, D., Foote A., and Thompson, P.M. (2008). Anthropogenic noise in the Moray Firth SAC; potential sources and impacts on bottlenose dolphins. Scottish Natural Heritage Commissioned Report No.265 (ROAME No. F05LE02).

Southall, Brandon L., Ann E. Bowles, William T. Ellison, James J. Finneran, Roger L. Gentry, Charles R. Greene Jr, David Kastak, *et al*. 2007. "Marine Mammal Noise-Exposure Criteria: Initial Scientific Recommendations." Aquatic Mammals 33 (4): 411–521.

Southall, Brandon L., James J. Finneran, Colleen Reichmuth, Paul E. Nachtigall, Darlene R. Ketten, Ann E. Bowles, William T. Ellison, Douglas P. Nowacek, and Peter L. Tyack. 2019. "Marine Mammal Noise

Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects.” Aquatic Mammals 45 (2): 125–232.

SSE Renewables (2022) Berwick Bank Wind Farm Offshore Environmental Impact Assessment Appendix 10:1 Marine Mammal Technical Report. Report (unpublished).

Tetley, M. J., Mitchelson-Jacob, E. G. & Robinson, K. P. The summer distribution of coastal minke whales (Balaenoptera acutorostrata) in the southern outer Moray Firth, NE Scotland, in relation to co-occurring mesoscale oceanographic features. Remote Sensing.

Thompson, P.M., Brookes, K.L., Graham, I.M., Barton, T.R., Needham, K., Bradbury, G. and Merchant, N.D. (2013). Short-term disturbance by a commercial two-dimensional seismic survey does not lead to long-term displacement of harbour porpoises. Proc R Soc B 280: 20132001. http://dx.doi.org/10.1098/rspb.2013.2001.

Thompson, P. M., Brookes, K. L. and Cordes, L. S. (2015). Integrating passive acoustic and visual data to model spatial patterns of occurrence in coastal dolphins. ICES Journal of Marine Science, Volume 72, Issue 2, Pages 651–660, https://doi.org/10.1093/icesjms/fsu110.

Wall, D., Murray, C., O’Brien, J., Kavanagh, L., Wilson, C., Ryan, C., Glanville, B., Williams, D., Enlander, I., O’Connor, I., McGrath, D., Whooley, P., Berrow, S. (2013) Atlas of the distribution and relative abundance of marine mammals in Irish offshore waters 2005 – 2011. Irish Whale and Dolphin Group, Kilrush, Co. Clare, 63pp.

Weinrich MT, Belt CR, Morin D. Behavior and ecology of the Atlantic white-sided dolphin (*Lagenorhynchus Acutus*) in coastal New England waters. Mar Mamm Sci. (2001) 17:231–48. doi: 10.1111/j.1748-7692.2001.tb01268.x

Williamson, L., 2018. Spatio-temporal variation in harbour porpoise distribution and activity (Doctoral dissertation, University of Aberdeen).

Williamson, L.D., Brookes, K.L., Scott, B.E., Graham, I.M. and Thompson, P.M., 2017. Diurnal variation in harbour porpoise detection potential implications for management. Marine Ecology Progress Series, 570, pp.223-232.

Appendix A

EPS Calculation Tables

Apx Table 1: Number of Animals Potentially Affected by PTS (Auditory Injury) During the E1 East Proposed Export Cable Corridor Area Geophysical Survey (N/A = Not Applicable).

Species	Density estimate (animals/ km^2)[1]	MU population	MU population (UK portion)	Abundance within Survey Area	Threshold	Area of sea affected in zone of injury (km^2)	Number of animals potentially within zone of injury	Proportion of MU population (%)	Proportion of MU population (UK portion) (%)
MULTIBEAM ECHOSOUNDER									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	PTS (SEL)	0.007	<1	3.86×10^{-7}	5.69×10^{-7}
Bottlenose dolphin	0.030	2,022 (GNS MU)	1,885 (GNS MU)	19[2]	PTS (SEL)	0.007	<1	1.04×10^{-5}	1.11×10^{-5}
		-	224 (CES MU)	16[3]	PTS (SEL)	0.007	<1	-	9.38×10^{-5}
Harbour porpoise	0.599	346,601	159,632	675	PTS (SEL)	0.008	<1	1.38×10^{-6}	3×10^{-6}
Minke whale	0.039	20,118	10,288	44	PTS (SEL)	1×10^{-5}	<1	1.94×10^{-9}	3.79×10^{-9}
White-beaked dolphin	0.243	43,951	34,025	274	PTS (SEL)	0.007	<1	3.87×10^{-6}	5×10^{-6}
SIDE SCAN SONAR									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	PTS (SEL)	0.008	<1	4.41×10^{-7}	6.51×10^{-7}
Bottlenose dolphin	0.030	2,022 (GNS MU)	1,885 (GNS MU)	19	PTS (SEL)	0.008	<1	1.19×10^{-5}	1.27×10^{-5}
		-	224 (CES MU)	16	PTS (SEL)	0.008	<1	-	1.07×10^{-4}
Harbour porpoise	0.599	346,601	159,632	675	PTS (SEL)	0.008	<1	1.38×10^{-6}	3×10^{-6}

[1] Data taken from SCANS III surveys (Hammond, 2017)

[2] Abundance of Bottlenose dolphin (GNS MU) in the survey area has been calculated as follows: (total survey area – survey area within 12nm) x density of animals

[3] Abundance of Bottlenose dolphin (CES MU) in the survey area has been calculated as follows: survey area within 12nm x density of animals

Species	Density estimate (animals/ km^2)[1]	MU population	MU population (UK portion)	Abundance within Survey Area	Threshold	Area of sea affected in zone of injury (km^2)	Number of animals potentially within zone of injury	Proportion of MU population (%)	Proportion of MU population (UK portion) (%)
Minke whale	0.039	20,118	10,288	44	PTS (SEL)	2×10^{-4}	<1	3.88×10^{-8}	7.58×10^{-8}
White-beaked dolphin	0.243	43,951	34,025	274	PTS (SEL)	0.008	<1	4.42×10^{-6}	5.71×10^{-6}
SUB BOTTOM PROFILER									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	PTS (SEL)	0.01	<1	5.52×10^{-7}	8.13×10^{-7}
Bottlenose dolphin	0.030	2,022 (GNS MU)	1,885 (GNS MU)	19	PTS (SEL)	0.01	<1	1.48×10^{-5}	1.59×10^{-5}
		-	224 (CES MU)	16	PTS (SEL)	0.01	<1	-	1.34×10^{-4}
Harbour porpoise	0.599	346,601	159,632	675	PTS (SEL)	0.187	<1	3.23×10^{-5}	7.02×10^{-5}
Minke whale	0.039	20,118	10,288	44	PTS (SEL)	0.008	<1	1.55×10^{-6}	3.03×10^{-6}
White-beaked dolphin	0.243	43,951	34,025	274	PTS (SEL)	0.01	<1	5.53×10^{-6}	7.14×10^{-6}
USBL									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	PTS (SEL)	N/A	N/A	N/A	N/A
Bottlenose dolphin	0.030	2,022 (GNS MU)	1,885 (GNS MU)	19	PTS (SEL)	N/A	N/A	N/A	N/A
		-	224 (CES MU)	16	PTS (SEL)	N/A	N/A	-	N/A
Harbour porpoise	0.599	346,601	159,632	675	PTS (SEL)	1×10^{-5}	<1	1.73×10^{-9}	3.75×10^{-9}
Minke whale	0.039	20,118	10,288	44	PTS (SEL)	N/A	N/A	N/A	N/A
White-beaked dolphin	0.243	43,951	34,025	274	PTS (SEL)	N/A	N/A	N/A	N/A
SPARKER									

Species	Density estimate (animals/ km²)[1]	MU population	MU population (UK portion)	Abundance within Survey Area	Threshold	Area of sea affected in zone of injury (km²)	Number of animals potentially within zone of injury	Proportion of MU population (%)	Proportion of MU population (UK portion) (%)
Atlantic white-sided dolphin	0.010	18,128	12,293	12	PTS (SEL)	N/A	N/A	N/A	N/A
Bottlenose dolphin	0.030	2,022 (GNS MU)	1,885 (GNS MU)	19	PTS (SEL)	N/A	N/A	N/A	N/A
		-	224 (CES MU)	16	PTS (SEL)	N/A	N/A	-	N/A
Harbour porpoise	0.599	346,601	159,632	675	PTS (SEL)	3×10^{-4}	<1	5.18×10^{-8}	1.13×10^{-7}
Minke whale	0.039	20,118	10,288	44	PTS (SEL)	N/A	N/A	N/A	N/A
White-beaked dolphin	0.243	43,951	34,025	274	PTS (SEL)	N/A	N/A	N/A	N/A
SLEEVE GUN (10 CU.IN.)									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	PTS (SEL)	N/A	N/A	N/A	N/A
Bottlenose dolphin	0.030	2,022	1,885	19	PTS (SEL)	N/A	N/A	N/A	N/A
		-	224 (CES MU)	16	PTS (SEL)	N/A	N/A	-	N/A
Harbour porpoise	0.599	346,601	159,632	675	PTS (SEL)	0.045	<1	7.78×10^{-6}	1.69×10^{-5}
Minke whale	0.039	20,118	10,288	44	PTS (SEL)	N/A	N/A	N/A	N/A
White-beaked dolphin	0.243	43,951	34,025	274	PTS (SEL)	N/A	N/A	N/A	N/A

Apx Table 2: Number of Animals Potentially Affected by TTS During the E1 East Proposed Export Cable Corridor Area Geophysical Survey (N/A = Not Applicable).

Species	Density estimate (animals/ km^2)[4]	MU population	MU population (UK portion)	Abundance within Survey Area	Threshold	Area of sea affected in zone of injury (km^2)	Number of animals potentially within zone of injury	Proportion of MU population (%)	Proportion of MU population (UK portion) (%)
MULTIBEAM ECHOSOUNDER									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	TTS (SEL)	0.008	<1	4.41×10^{-7}	6.51×10^{-7}
Bottlenose dolphin	0.030	2,022	1,885	19	TTS (SEL)	0.008	<1	1.19×10^{-5}	1.27×10^{-5}
		-	224 (CES MU)	16	TTS (SEL)	0.008	<1	-	1.07×10^{-4}
Harbour porpoise	0.599	346,601	159,632	675	TTS (SEL)	0.008	<1	1.38×10^{-6}	3×10^{-6}
Minke whale	0.039	20,118	10,288	44	TTS (SEL)	0.003	<1	5.82×10^{-7}	1.14×10^{-6}
White-beaked dolphin	0.243	43,951	34,025	274	TTS (SEL)	0.008	<1	4.42×10^{-6}	5.71×10^{-6}
SIDE SCAN SONAR									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	TTS (SEL)	0.008	<1	4.41×10^{-7}	6.51×10^{-7}
Bottlenose dolphin	0.030	2,022	1,885	19	TTS (SEL)	0.008	<1	1.19×10^{-5}	1.27×10^{-5}
		-	224 (CES MU)	16	TTS (SEL)	0.008	<1	-	1.07×10^{-4}
Harbour porpoise	0.599	346,601	159,632	675	TTS (SEL)	0.008	<1	1.38×10^{-6}	3×10^{-6}
Minke whale	0.039	20,118	10,288	44	TTS (SEL)	0.007	<1	1.36×10^{-6}	2.65×10^{-6}
White-beaked dolphin	0.243	43,951	34,025	274	TTS (SEL)	0.008	<1	4.42×10^{-6}	5.71×10^{-6}

[4] Data taken from SCANS III surveys (Hammond, 2017)

Species	Density estimate (animals/ km^2)[4]	MU population	MU population (UK portion)	Abundance within Survey Area	Threshold	Area of sea affected in zone of injury (km^2)	Number of animals potentially within zone of injury	Proportion of MU population (%)	Proportion of MU population (UK portion) (%)
SUB BOTTOM PROFILER									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	TTS (SEL)	0.132	<1	7.28×10^{-6}	1.07×10^{-5}
Bottlenose dolphin	0.030	2,022	1,885	19	TTS (SEL)	0.132	<1	1.96×10^{-4}	2.1×10^{-4}
		-	224 (CES MU)	16	TTS (SEL)	0.132	<1	-	1.77×10^{-3}
Harbour porpoise	0.599	346,601	159,632	675	TTS (SEL)	1.448	<1	2.5×10^{-4}	5.43×10^{-4}
Minke whale	0.039	20,118	10,288	44	TTS (SEL)	0.008	<1	1.55×10^{-6}	3.03×10^{-6}
White-beaked dolphin	0.243	43,951	34,025	274	TTS (SEL)	0.132	<1	7.3×10^{-5}	9.43×10^{-5}
USBL									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	TTS (SEL)	N/A	N/A	N/A	N/A
Bottlenose dolphin	0.030	2,022	1,885	19	TTS (SEL)	N/A	N/A	N/A	N/A
		-	224 (CES MU)	16	TTS (SEL)	N/A	-	N/A	N/A
Harbour porpoise	0.599	346,601	159,632	675	TTS (SEL)	0.07	<1	1.21×10^{-5}	2.63×10^{-5}
Minke whale	0.039	20,118	10,288	44	TTS (SEL)	N/A	N/A	N/A	N/A
White-beaked dolphin	0.243	43,951	34,025	274	TTS (SEL)	N/A	N/A	N/A	N/A
SPARKER									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	TTS (SEL)	N/A	N/A	N/A	N/A
Bottlenose dolphin	0.030	2,022	1,885	19	TTS (SEL)	N/A	N/A	N/A	N/A

Species	Density estimate (animals/ km^2)[4]	MU population	MU population (UK portion)	Abundance within Survey Area	Threshold	Area of sea affected in zone of injury (km^2)	Number of animals potentially within zone of injury	Proportion of MU population (%)	Proportion of MU population (UK portion) (%)
		-	224 (CES MU)	16	TTS (SEL)	N/A	-	N/A	N/A
Harbour porpoise	0.599	346,601	159,632	675	TTS (SEL)	0.423	<1	7.31×10^{-5}	1.59×10^{-4}
Minke whale	0.039	20,118	10,288	44	TTS (SEL)	0.229	<1	4.44×10^{-5}	4.32×10^{-7}
White-beaked dolphin	0.243	43,951	34,025	274	TTS (SEL)	N/A	N/A	N/A	N/A
SLEEVE GUN (10 CU.IN.)									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	TTS (SEL)	N/A	N/A	N/A	N/A
Bottlenose dolphin	0.030	2,022	1,885	19	TTS (SEL)	N/A	N/A	N/A	N/A
		-	224 (CES MU)	16	TTS (SEL)	N/A	-	N/A	N/A
Harbour porpoise	0.599	346,601	159,632	675	TTS (SEL)	10.986	6.58	1.9×10^{-3}	4.12×10^{-3}
Minke whale	0.039	20,118	10,288	44	TTS (SEL)	0.036	<1	6.98×10^{-6}	1.36×10^{-5}
White-beaked dolphin	0.243	43,951	34,025	274	TTS (SEL)	N/A	N/A	N/A	N/A

Apx Table 3: Number of Animals Potentially Affected by Disturbance During the E1 East Proposed Export Cable Corridor Area Geophysical Survey

Species	Density estimate (animals/ km^2)[5]	MU population	MU population (UK portion)	Abundance within Survey Area	Threshold	Area of sea affected within zone of disturbance (km^2)	Number of animals potentially within zone of disturbance	Proportion of MU population (%)	Proportion of MU population (UK portion) (%)
MULTIBEAM ECHOSOUNDER									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	Disturbance	0.458	<1	2.53×10^{-5}	3.73×10^{-5}
Bottlenose dolphin	0.030	2,022 (GNS MU)	1,885 (GNS MU)	19	Disturbance	0.458	<1	6.8×10^{-4}	7.29×10^{-4}
		-	224 (CES MU)	16	Disturbance	0.458	<1	-	6.13×10^{-3}
Harbour porpoise	0.599	346,601	159,632	675	Disturbance	0.458	<1	7.92×10^{-5}	1.72×10^{-4}
Minke whale	0.039	20,118	10,288	44	Disturbance	0.458	<1	8.88×10^{-5}	1.74×10^{-4}
White-beaked dolphin	0.243	43,951	34,025	274	Disturbance	0.458	<1	2.53×10^{-4}	3.27×10^{-4}
SIDE SCAN SONAR									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	Disturbance	0.25	<1	1.38×10^{-5}	2.03×10^{-5}
Bottlenose dolphin	0.030	2,022 (GNS MU)	1,885 (GNS MU)	19	Disturbance	0.25	<1	3.71×10^{-4}	3.98×10^{-4}
		-	224 (CES MU)	16	Disturbance	0.25	<1	-	3.35×10^{-3}
Harbour porpoise	0.599	346,601	159,632	675	Disturbance	0.25	<1	4.32×10^{-5}	9.38×10^{-5}
Minke whale	0.039	20,118	10,288	44	Disturbance	0.25	<1	4.85×10^{-5}	9.48×10^{-5}
White-beaked dolphin	0.243	43,951	34,025	274	Disturbance	0.25	<1	1.38×10^{-4}	1.79×10^{-4}

[5] Data taken from SCANS III surveys (Hammond, 2017)

Species	Density estimate (animals/ km²)[5]	MU population	MU population (UK portion)	Abundance within Survey Area	Threshold	Area of sea affected within zone of disturbance (km²)	Number of animals potentially within zone of disturbance	Proportion of MU population (%)	Proportion of MU population (UK portion) (%)
SUB BOTTOM PROFILER									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	Disturbance	6	<1	3.31×10^{-4}	4.88×10^{-4}
Bottlenose dolphin	0.030	2,022 (GNS MU)	1,885 (GNS MU)	19	Disturbance	6	<1	8.9×10^{-3}	9.55×10^{-3}
		-	224 (CES MU)	16	Disturbance	6	<1	-	8.02×10^{-2}
Harbour porpoise	0.599	346,601	159,632	675	Disturbance	6	3.59	1.04×10^{-3}	2.25×10^{-3}
Minke whale	0.039	20,118	10,288	44	Disturbance	6	<1	1.16×10^{-3}	2.27×10^{-3}
White-beaked dolphin	0.243	43,951	34,025	274	Disturbance	6	1.46	3.32×10^{-3}	4.29×10^{-3}
USBL									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	Disturbance	11.7	<1	6.46×10^{-4}	9.52×10^{-4}
Bottlenose dolphin	0.030	2,022 (GNS MU)	1,885 (GNS MU)	19	Disturbance	11.7	<1	1.74×10^{-2}	1.86×10^{-2}
		-	224 (CES MU)	16	Disturbance	11.7	<1	-	1.57×10^{-1}
Harbour porpoise	0.599	346,601	159,632	675	Disturbance	11.7	7.01	2.02×10^{-3}	4.39×10^{-3}
Minke whale	0.039	20,118	10,288	44	Disturbance	11.7	<1	2.27×10^{-3}	4.44×10^{-3}
White-beaked dolphin	0.243	43,951	34,025	274	Disturbance	11.7	2.84	6.47×10^{-3}	8.36×10^{-3}
SPARKER									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	Strong disturbance	1.177	<1	6.49×10^{-5}	9.57×10^{-5}
					Mild disturbance	0.026	<1	1.43×10^{-6}	2.12×10^{-6}

Species	Density estimate (animals/ km^2)[5]	MU population	MU population (UK portion)	Abundance within Survey Area	Threshold	Area of sea affected within zone of disturbance (km^2)	Number of animals potentially within zone of disturbance	Proportion of MU population (%)	Proportion of MU population (UK portion) (%)
Bottlenose dolphin	0.030	2,022 (GNS MU)	1,885 (GNS MU)	19	Strong disturbance	1.177	<1	1.75×10^{-3}	1.87×10^{-3}
					Mild disturbance	0.026	<1	3.86×10^{-5}	4.14×10^{-5}
		-	224 (CES MU)	16	Strong disturbance	1.177	<1	-	1.58×10^{-2}
					Mild disturbance	0.026	<1	-	3.48×10^{-4}
Harbour porpoise	0.599	346,601	159,632	675	Strong disturbance	1.177	<1	2.03×10^{-4}	4.42×10^{-4}
					Mild disturbance	0.026	<1	4.49×10^{-6}	9.76×10^{-6}
Minke whale	0.039	20,118	10,288	44	Strong disturbance	1.177	<1	2.28×10^{-4}	4.46×10^{-4}
					Mild disturbance	0.026	<1	5.04×10^{-6}	9.86×10^{-6}
White-beaked dolphin	0.243	43,951	34,025	274	Strong disturbance	1.177	<1	6.51×10^{-4}	8.41×10^{-4}
					Mild disturbance	0.026	<1	1.44×10^{-5}	1.86×10^{-5}
SLEEVE GUN (10 CU.IN.)									
Atlantic white-sided dolphin	0.010	18,128	12,293	12	Strong disturbance	3.457	<1	1.91×10^{-4}	2.81×10^{-4}
					Mild disturbance	0.121	<1	6.67×10^{-6}	9.84×10^{-6}
Bottlenose dolphin	0.030	2,022 (GNS MU)	1,885 (GNS MU)	19	Strong disturbance	3.457	<1	5.13×10^{-3}	5.5×10^{-3}
					Mild disturbance	0.121	<1	1.8×10^{-4}	1.93×10^{-4}
		-	224 (CES MU)	16	Strong disturbance	3.457	<1	-	4.63×10^{-2}

Species	Density estimate (animals/ km^2)[5]	MU population	MU population (UK portion)	Abundance within Survey Area	Threshold	Area of sea affected within zone of disturbance (km^2)	Number of animals potentially within zone of disturbance	Proportion of MU population (%)	Proportion of MU population (UK portion) (%)
					Mild disturbance	0.121	<1	-	1.62×10^{-3}
Harbour porpoise	0.599	346,601	159,632	675	Strong disturbance	3.457	2.07	5.97×10^{-4}	1.3×10^{-3}
					Mild disturbance	0.121	<1	2.09×10^{-5}	4.54×10^{-5}
Minke whale	0.039	20,118	10,288	44	Strong disturbance	3.457	<1	6.7×10^{-4}	1.31×10^{-3}
					Mild disturbance	0.121	<1	2.35×10^{-5}	4.59×10^{-5}
White-beaked dolphin	0.243	43,951	34,025	274	Strong disturbance	3.457	<1	1.91×10^{-3}	2.47×10^{-3}
					Mild disturbance	0.121	<1	6.69×10^{-5}	8.64×10^{-5}

Appendix B

Noise Modelling Report

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SSE ScotWind E1 (East) Geophysical Survey Subsea Noise Assessment

Document Control

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Table of Contents

1 Introduction

This report presents the results of a desktop study considering the potential effects of underwater noise on the marine environment from geophysical surveys associated with the proposed ScotWind area E1 (East) and associated cable route. Predominant water depths across the E1 East survey area range between approximately 60 m to 85 m Lowest Astronomical Tide (LAT), whilst water depths along the cable routes typically range between 50 m to 70 m across the majority of the corridors, reducing to a few metres or less at landfall.

The location of the survey area is shown in Figure 1.1.

Noise is readily transmitted underwater and there is potential for sound emissions from the surveys to affect marine mammals. At long ranges the introduction of additional noise could potentially cause short-term behavioural changes, for example to the ability of cetaceans to communicate and to determine the presence of predators, food, underwater features and obstructions. At close ranges and with high noise source levels, permanent or temporary hearing damage may occur, while at very close range, gross physical trauma is possible. This report provides an overview of the potential effects due to underwater noise from the proposed survey on the surrounding marine environment.

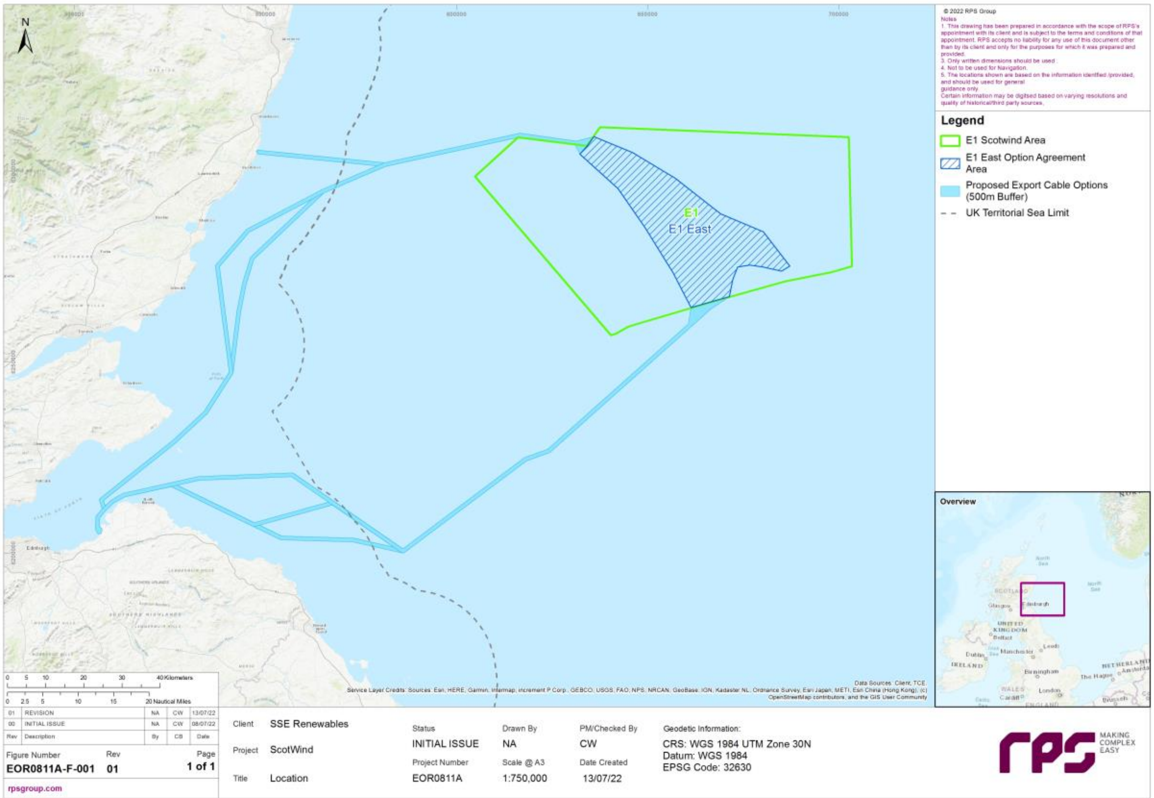

Figure 1.1: Location of Survey Areas

2 Acoustic Concepts and Terminology

Sound travels through the water as vibrations of the fluid particles in a series of pressure waves. The waves comprise a series of alternating compressions (positive pressure) and rarefactions (negative pressure). Because sound consists of variations in pressure, the unit for measuring sound is usually referenced to a unit of pressure, the Pascal (Pa). The decibel (dB) scale is used to conveniently communicate the large range of acoustic pressures encountered, with a known pressure amplitude chosen as a reference value (i.e., 0 dB). In the case of underwater sound, the reference value (P_{ref}) is taken as 1 µPa, whereas the airborne sound is usually referenced to a pressure of 20 µPa. To convert from a sound pressure level referenced to 20 µPa to one referenced to 1 µPa, a factor of 20 log (20/1) i.e., 26 dB has to be added to the former quantity. Thus 60 dB re 20 µPa is the same as 86 dB re 1 µPa, although differences in sound speeds and different densities mean that the decibel level difference in sound intensity is much more than the 26 dB when converting pressure from air to water. All underwater sound pressure levels in this report are quantified in dB re 1 µPa.

There are several descriptors used to characterise a sound wave. The difference between the lowest pressure variation (rarefaction) and the highest-pressure variation (compression) is called the peak to peak (or pk-pk) sound pressure level. The difference between the highest variation (either positive or negative) and the mean pressure is called the peak pressure level. Lastly, the root mean square (rms) sound pressure level is used as a description of the average amplitude of the variations in pressure over a specific time window. Decibel values reported should always be quoted along with the P_{ref} value employed during calculations. For example, the measured SPL_{rms} value of a sound may be reported as 100 dB re 1 µPa. These descriptions are shown graphically in Figure 2.1.

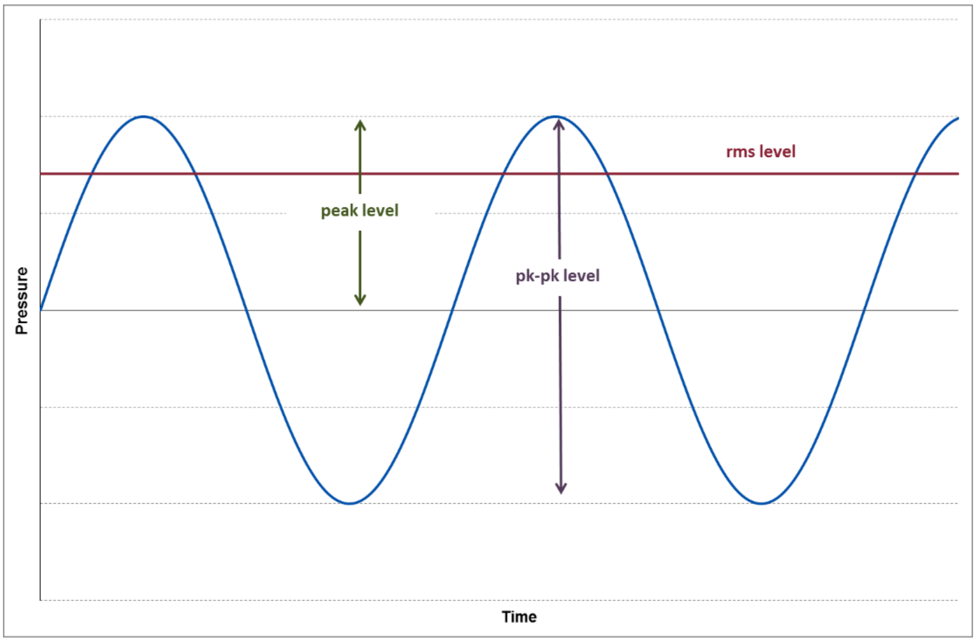

Figure 2.1: Graphical representation of acoustic wave descriptors

The rms sound pressure level (SPL) is defined as follows:

$$SPL_{rms} = 10log_{10}\left(\frac{1}{T}\int_{0}^{T}\left(\frac{p^2}{p_{ref}^2}\right)dt\right)$$

The magnitude of the rms sound pressure level for an impulsive sound (such as that from a seismic source array) will depend upon the integration time, T, used for the calculation (Madsen 2005). It has become customary to utilise the T90 time period for calculating and reporting rms sound pressure levels. This is the interval over which the cumulative energy curve rises from 5% to 95% of the total energy and therefore contains 90% of the sound energy.

Another useful measure of sound used in underwater acoustics is the Sound Exposure Level, or SEL. This descriptor is used as a measure of the total sound energy of an event or a number of events (e.g., over the course of a day) and is normalised to one second. This allows the total acoustic energy contained in events lasting a different amount of time to be compared on a like for like basis[1]. The SEL is defined as follows:

$$SEL = 10log_{10}\left(\int_0^T \left(\frac{p^2(t)}{p_{ref}^2 t_{ref}}\right) dt\right)$$

The frequency, or pitch, of the sound is the rate at which the acoustic oscillations occur in the medium (air/water) and is measured in cycles per second, or Hertz (Hz). When sound is measured in a way which approximates to how a human would perceive it using an A-weighting filter on a sound level meter, the resulting level is described in values of dBA. However, the hearing faculty of marine mammals is not the same as humans, with marine mammals hearing over a wider range of frequencies and with a different sensitivity. It is therefore important to understand how an animal's hearing varies over its entire frequency range to assess the effects of anthropogenic sound on marine mammals. Consequently, use can be made of frequency weighting scales (m-weighting) to determine the level of the sound in comparison with the auditory response of the animal concerned. A comparison between the typical hearing response curves for fish, humans and marine mammals is shown in Figure 2.2. (It is worth noting that hearing thresholds are sometimes shown as audiograms with sound level on the y axis rather than sensitivity, resulting in the graph shape being the inverse of the graph shown).

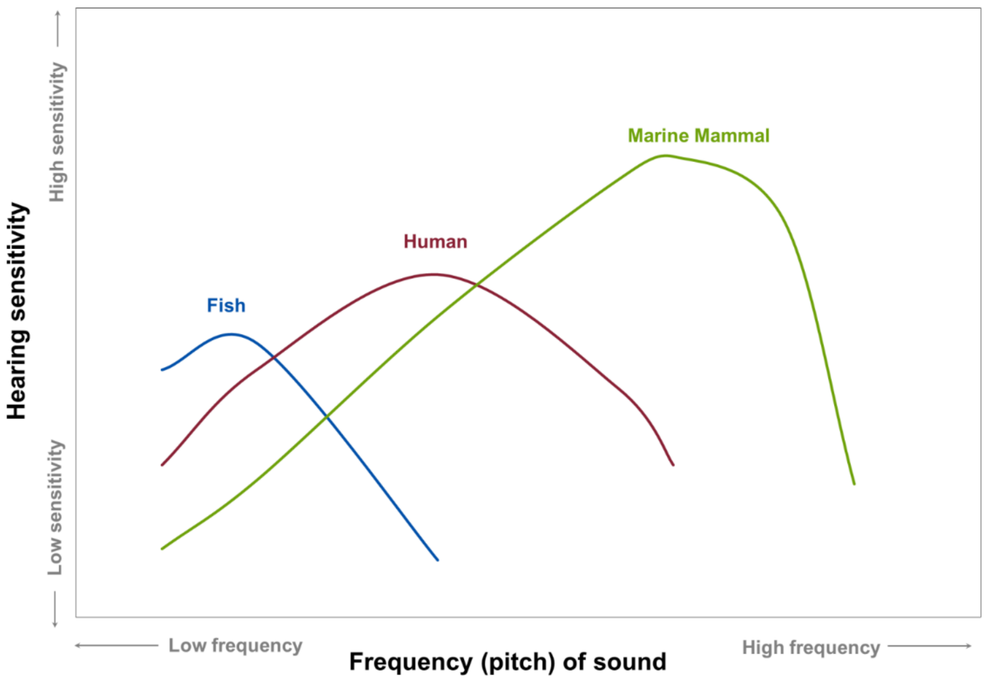

Figure 2.2: Comparison between hearing thresholds of different animals

1 Historically, use was primarily made of rms and peak sound pressure level metrics for assessing the potential effects of sound on marine life. However, the SEL is increasingly being used as it allows exposure duration and the effect of exposure to multiple events to be considered.

Other relevant acoustic terminology and their definitions used in the report are detailed below.

1/3rd octave bands

The broadband acoustic power (i.e., containing all the possible frequencies) emitted by a sound source, measured/modelled at a location within the survey region is generally split into and reported in a series of frequency bands. In marine acoustics, the spectrum is generally reported in standard 1/3rd octave band frequencies, where an octave represents a doubling in sound frequency.

Source level (SL)

The source level is the sound pressure level of an equivalent and infinitesimally small version of the source (known as *point source*) at a hypothetical distance of 1 m from it. The source level may be combined with the transmission loss (TL) associated with the environment to obtain the received level (RL) in the *far field* of the source. The far field distance is chosen so that the behaviour of the distributed source can be approximated to that of a point source. Source levels do not indicate the real sound pressure level at 1 m.

Transmission loss (TL)

TL at a frequency of interest is defined as the loss of acoustic energy as the signal propagates from a hypothetical (point) source location to the chosen receiver location. The TL is dependent on water depth, source depth, receiver depth, frequency, geology, and environmental conditions. The TL values are generally evaluated using an acoustic propagation model (various numerical methods exist) accounting for the above dependencies.

Received level (RL)

The RL is the sound level of the acoustic signal recorded (or modelled) at a given location, that corresponds to the acoustic pressure/energy generated by a known active sound source. This considers the acoustic output of a source and is modified by propagation effects. This RL value is strongly dependant on the source, environmental properties, geological properties and measurement location/depth. The RL is reported in dB either in rms or peak-to-peak SPL, and SEL metrics, within the relevant third-octave band frequencies. The RL is related to the SL as

$$RL = SL - TL$$

where TL is the transmission loss of the acoustic energy within the survey region.

The directional dependence of the source signature and the variation of TL with azimuthal direction α (which is strongly dependent on bathymetry) are generally combined and interpolated to report a 2-D plot of the RL around the chosen source point up to a chosen distance.

3 Acoustic Assessment Criteria

3.1 Marine Mammals

Underwater noise has the potential to affect marine life in different ways depending on its noise level and characteristics. Richardson *et al*. (1995) defined four zones of noise influence which vary with distance from the source and level. These are:

- **The zone of audibility:** this is the area within which the animal can detect the sound. Audibility itself does not implicitly mean that the sound will have an effect on the marine mammal.
- **The zone of masking:** this is defined as the area within which noise can interfere with detection of other sounds such as communication or echolocation clicks. This zone is very hard to estimate due to a paucity of data relating to how marine mammals detect sound in relation to masking levels (for example, humans can hear tones well below the numeric value of the overall noise level).
- **The zone of responsiveness:** this is defined as the area within which the animal responds either behaviourally or physiologically. The zone of responsiveness is usually smaller than the zone of audibility because, as stated previously, audibility does not necessarily evoke a reaction.
- **The zone of injury / hearing loss:** this is the area where the sound level is high enough to cause tissue damage in the ear. This can be classified as either temporary threshold shift (TTS) or permanent threshold shift (PTS). At even closer ranges, and for very high intensity sound sources (e.g., underwater explosions), physical trauma or even death are possible.

For this study, it is the zones of injury and disturbance (i.e., responsiveness) that are of concern (there is insufficient scientific evidence to properly evaluate masking). To determine the potential spatial range of injury and disturbance, a review has been undertaken of available evidence, including international guidance and scientific literature. The following sections summarise the relevant thresholds for onset of effects and describe the evidence base used to derive them.

Sound propagation models can be constructed to allow the received noise level at different distances from the source to be calculated. To determine the consequence of these received levels on any marine mammals which might experience such noise emissions, it is necessary to relate the levels to known or estimated impact thresholds. The injury criteria proposed by Southall *et al* (2019). are based on a combination of linear (i.e., un-weighted) peak pressure levels and mammal hearing weighted sound exposure levels (SEL). The hearing weighting function is designed to represent the bandwidth for each hearing group within which acoustic exposures can have auditory effects. The categories include:

- **low-frequency (LF) cetaceans** (i.e., marine mammal species such as baleen whales);
- **high-frequency (HF) cetaceans** (i.e., marine mammal species such as dolphins, toothed whales, beaked whales and bottlenose whales);
- **very high-frequency (VHF) cetaceans** (i.e., marine mammal species such as true porpoises, river dolphins and pygmy/dwarf sperm whales and some oceanic dolphins, generally with auditory centre frequencies above 100 kHz);
- **phocid pinnipeds (PCW)** (i.e., true seals; hearing in air is considered separately in the group PCA); and
- **other marine carnivores (OCW)** (including otariid pinnipeds (e.g., sea lions and fur seals), sea otters and polar bears; in-air hearing considered separately in the group OCA).

These weightings have therefore been used in this study and are shown in Figure 3.1.

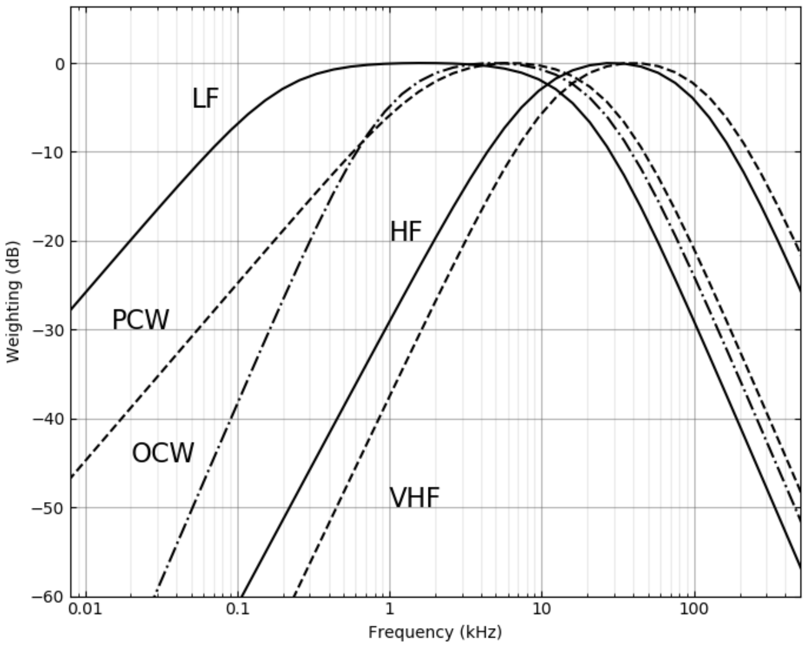

Figure 3.1: Hearing weighting functions for pinnipeds and cetaceans (Southall et al., 2019)

Injury criteria are proposed in Southall *et al* (2019) are for two different types of sound as follows:

- **Impulsive sounds** which are typically transient, brief (less than 1 second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay (ANSI 1986; NIOSH 1998; ANSI 2005). This category includes sound sources such as seismic surveys, impact piling and underwater explosions; and
- **Non-impulsive sounds** which can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent and typically do not have a high peak sound pressure with rapid rise/decay time that impulsive sounds do (ANSI 1995; NIOSH 1998). This category includes sound sources such as continuous running machinery, sonar and vessels.

The relevant criteria proposed by Southall *et al*. (2019) are as summarised in Table 3.1.

Table 3.1: Summary of PTS onset acoustic thresholds (Southall et al. 2019)

Hearing Group	Parameter	Impulsive	Non-impulsive
Low-frequency (LF) cetaceans	Peak, unweighted	219	-
	SEL, LF weighted	183	199
High-frequency (HF) cetaceans	Peak, unweighted	230	-
	SEL, MF weighted	185	198
Very High-frequency (VHF) cetaceans	Peak, unweighted	202	-
	SEL, HF weighted	155	173
Phocid Carnivores in Water (PCW)	Peak, unweighted	218	-
	SEL, PW weighted	185	201
Other Marine Carnivores in Water (OCW)	Peak, unweighted	232	-
	SEL, OW weighted	203	219

These updated marine mammal injury criteria were published in March 2019 (Southall *et al*. 2019). The paper utilised the same hearing weighting curves and thresholds as presented in the preceding regulations document NMFS (2018) with the main difference being the naming of the hearing groups and introduction of additional thresholds for animals not covered by NMFS (2018). A comparison between the two naming conventions is shown in Table 3.2.

For avoidance of doubt, the naming convention used in this report is based upon those set out in Southall *et al* (2019). Consequently, this assessment utilises criteria which are applicable to both NMFS (2018) and Southall *et al*. (2019).

Table 3.2: Comparison of hearing group names between NMFS 2018 and Southall 2019

NMFS (2018) hearing group name	Southall *et al*. (2019) hearing group name
Low frequency cetaceans (LF)	Low-frequency cetaceans (LF)
Mid frequency cetaceans (MF)	High-frequency cetaceans (HF)
High frequency cetaceans (HF)	Very high-frequency cetaceans (VHF)
Phocid pinnipeds in water (PW)	Phocid carnivores in water (PCW)

Beyond the area in which injury may occur, the effect on marine mammal behaviour is the most important measure of impact. Significant (i.e., non-trivial) disturbance may occur when there is a risk of animals incurring sustained or chronic disruption of behaviour or when animals are displaced from an area, with subsequent redistribution being significantly different from that occurring due to natural variation.

Therefore, this assessment adopts a conservative approach and uses the US National Marine Fisheries Service (NMFS 2005a) Level B harassment thresholds for impulsive and non-impulsive sounds. Level B Harassment is defined as having the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild. This description of non-trivial disturbance has therefore been used as the basis for onset of behavioural change in this assessment.

The (NMFS 2005) guidance sets the marine mammal level B harassment threshold for continuous noise at 120 dB re 1 µPa (rms). This value sits approximately mid-way between the range of values identified in Southall *et al*. (2007) for continuous sound but is lower than the value at which the majority of mammals responded at a response score of 6 (i.e. once the received rms sound pressure level is greater than 140 dB re 1 µPa). Taking into account the paucity and high level variation of data relating to onset of behavioural effects due to continuous sound, it is recommended that any ranges predicted using this number are viewed as probabilistic and possibly over-precautionary.

The High Energy Seismic Survey workshop on the effects of seismic sound on marine mammals (HESS 1997) concluded that **mild** behavioural disturbance to impulsive sound would most likely occur at sound levels greater than 140 dB re 1 µPa (rms). This workshop drew on several studies but recognised that there was some degree of variability in reactions between different studies and mammal groups. This value is similar to the lowest threshold for disturbance of low-frequency cetaceans noted in Southall *et al*. (2007). It is, however, considered unlikely that a threshold for the onset of mild disturbance effects could be defined as significant disturbance. Consequently, this study utilises the NMFS (2005) marine mammal level B harassment threshold of 160 dB re 1 µPa (rms) as a proxy for significant disturbance due to impulsive sound.

4 Assessment Methodology

4.1 Source Levels

Underwater noise sources are usually quantified in dB re 1 µPa, as if measured at a hypothetical distance of 1 m from the source (the Source Level). In practice, it is not usually possible to measure at 1 m from a source, but this metric allows comparison and reporting of different source levels on a like-for-like basis. In reality, for a large sound source this imagined point at 1 m from the acoustic centre does not exist. Furthermore, the energy is distributed across the source and does not all emanate from this imagined acoustic centre point. Therefore, the stated sound pressure level at 1 m does not actually occur for large sources. In the acoustic near-field (i.e. close to the source), the sound pressure level will be significantly lower than the value predicted by the SL.

It is understood that a number of sonar based survey types will potentially be used for the survey. Sound source data for the types of equipment likely to be used has been provided by manufacturers.

During the survey a transmitter emits an acoustic signal directly toward the sea bed (or alongside, at an angle to the seabed, in the case of side scan and MBES techniques). The equipment likely to be used can typically work at a range of signal frequencies, depending on the distance to the bottom and the required resolution. The signal is highly directional and acts as a beam, with the energy narrowly concentrated within a few degrees of the direction in which it is aimed. The signal is emitted in pulses, the length of which can be varied as per the survey requirements. The characteristics for each sonar based survey device modelled in this assessment are summarised in Table 4.1 and impulsive device parameters are summarised in Table 4.2.

Table 4.1: Sonar based survey equipment parameters used in assessment

Survey type	Unit	Frequency, kHz	Source level, dB re 1 µPa re 1 m (rms)	Pulse rate, s-1	Pulse width, ms	Beam width
Multibeam Echo Sounder	Norbit iWBMS	400 kHz	225	60	0.5	0.9º x 1.9º
Side Scan Sonar	Edgetech 6205s	230 kHz (LF) 550 kHz (HF)	210	15	15	0.54º (LF) 0.36º (HF)
Parametric Sub Bottom Profiler	Innomar SES 2000 Standard	100 kHz (primary) 4, 5, 6, 8, 10, 12 kHz selectable secondary frequencies	248	50	0.07 – 1.5	2.0º
USBL	Sonardyne 8300 /	19–34 kHz	202	1	5	Omni

Table 4.2: Impulsive survey equipment parameters used in assessment

Source	Equipment	Source level, dB re 1 µPa re 1 m (peak)	Source SEL, dB re 1 µPa^{2}s re 1 m	Source level, dB re 1 µPa re 1 m (rms)	T90, ms
TI Sleeve Gun	TI sleeve gun 10CU	224	195	214	13.5
Sparker	Geosource 200-400	219	182	214	0.7

The pulse rate has been used to calculate the SEL, which is normalised to one second, from the rms sound pressure level. Directivity corrections were calculated based on the transducer dimensions and ping frequency and taken from manufacturer's datasheets. It is important to note that directivity will vary significantly with frequency, but that these directivity values have been used in line with the modelling assumptions stated above.

Propagation Modelling

Increasing the distance from the sound source usually results in the level of sound becoming lower, due primarily to the spreading of the sound energy with distance, analogous to the way in which the ripples in a pond spread after a stone has been thrown in, in combination with attenuation due to absorption of sound energy by molecules in the water. This latter mechanism is more important for higher frequency sound than for lower frequencies.

The way that the sound spreads (geometrical divergence) will depend upon several factors such as water column depth, pressure, temperature gradients, salinity as well as water surface and bottom (i.e. seabed) conditions. Thus, even for a given locality, there are temporal variations to the way that sound will propagate. However, in simple terms, the sound energy may spread out in a spherical pattern (close to the source) or a cylindrical pattern (much further from the source), although other factors mean that decay in sound energy may be somewhere between these two simplistic cases.

In acoustically shallow waters[2] in particular, the propagation mechanism is coloured by multiple interactions with the seabed and the water surface (Lurton 2002; Etter 2013; Urick 1983; Kinsler *et al*. 1999). Whereas in deeper waters the sound will propagate further without encountering the surface or bottom of the sea, in shallower waters the sound may be reflected from either or both boundaries (potentially more than once).

At the sea surface, the majority of sound is reflected back in to the water due to the difference in acoustic impedance (i.e. sound speed and density) between air and water. Scattering of sound at the surface of the sea can be an important factor with respect to the propagation of sound. In an ideal case (i.e. for a perfectly smooth sea surface), the majority of sound wave energy will be reflected back into the sea. For rough seas, however, much of the sound energy is scattered (e.g. Eckart 1953; Fortuin 1970; Marsh, Schulkin, and Kneale 1961; Urick and Hoover 1956). Scattering can also occur due to bubbles near the surface such as those generated by wind or fish. Scattering my also result from the presence of suspended solids in the water such as particulates and marine life. Scattering is more pronounced for higher frequencies than for low frequencies and is dependent on the sea state (i.e. wave height). However, the various factors affecting this mechanism are complex.

Because surface scattering results in differences in reflected sound, its effect will be more important at longer ranges from the source sound and in acoustically shallow water (i.e. where there are multiple reflections between the source and receiver). The degree of scattering will depend upon the sea state/wind speed, water depth, frequency of the sound, temperature gradient, angle of incidence and range from source. It should be noted that variations in propagation due to scattering will vary temporally within an area primarily due to different sea-states / wind speeds at different times. However, over shorter ranges (e.g. several hundred meters or less) the sound will experience fewer reflections and so the effect of scattering should not be significant.

When sound waves encounter the bottom, the amount of sound reflected will depend on the geoacoustic properties of the bottom (e.g. grain size, porosity, density, sound speed, absorption coefficient and roughness) as well as the angle of incidence and frequency of the sound (Cole 1965; Hamilton 1970; Mackenzie 1960; McKinney and Anderson 1964; Etter 2013; Lurton 2002; Urick 1983). Thus, bottoms comprising primarily mud or other acoustically soft sediment will reflect less sound than acoustically harder bottoms such as rock or sand. This effect will also depend on the profile of the bottom (e.g. the depth of the sediment layer and how the geoacoustic properties vary with depth below

[2] *Acoustically, shallow water conditions exist whenever the propagation is characterised by multiple reflections with both the sea surface and bottom (Etter 2013). Consequently, the depth at which water can be classified as acoustically deep or shallow depends upon numerous factors including the sound speed gradient, water depth, frequency of the sound and distance between the source and receiver.*

the sea floor). The effect is less pronounced at low frequencies (a few kHz and below). A scattering effect (similar to that which occurs at the surface) also occurs at the bottom (Essen 1994; Greaves and Stephen 2003; McKinney and Anderson 1964; Kuo 1992), particularly on rough substrates (e.g. pebbles).

Another phenomenon is the waveguide effect, which means that shallow water columns do not allow the propagation of low frequency sound (Urick 1983; Etter 2013). The cut-off frequency of the lowest mode in a channel can be calculated based on the water depth and knowledge of the sediment geoacoustic properties. Any sound below this frequency will not propagate far due to energy losses through multiple reflections.

Another important factor is the sound speed gradient. Changes in temperature and pressure with depth mean that the speed of sound varies throughout the water column. This can lead to significant variations in sound propagation and can also lead to sound channels, particularly for high frequency sound. Sound can propagate in a duct-like manner within these channels, effectively focussing the sound, and conversely they can also lead to shadow zones. The frequency at which this occurs depends on the characteristics of the sound channel but, for example, a 25 m thick layer would not act as a duct for frequencies below 1.5 kHz. The temperature gradient can vary throughout the year and thus there will be potential variation in sound propagation depending on the season.

Sound energy is also absorbed due to interactions at the molecular level converting the acoustic energy into heat. This is another frequency dependent effect with higher frequencies experiencing much higher losses than lower frequencies.

There are several methods available for modelling the propagation of sound between a source and receiver ranging from very simple models which simply assume spreading according to a 10 log (r) or 20 log (r) relationship (as discussed above) to full acoustic models (e.g. ray tracing, normal mode, parabolic equation, wavenumber integration and energy flux models). In addition, semi-empirical models are available which lie somewhere in between these two extremes in terms of complexity.

In choosing which propagation model to employ, it is important to ensure that it is fit for purpose and produces results with a suitable degree of accuracy for the application in question, taking into account the context (as detailed in Monitoring Guidance for Underwater Noise in European Seas Part III, NPL Guidance and Farcas *et al*., 2016). Thus, in some situations (e.g. low risk due to underwater noise, range dependent bathymetry is not an issue, non-impulsive sound) a simple (N log R) model will be sufficient, particularly where other uncertainties outweigh the uncertainties due to modelling. On the other hand, some situations (e.g. very high source levels, impulsive sound, complex source and propagation path characteristics, highly sensitive receivers and low uncertainties in assessment criteria) warrant a more complex modelling methodology.

The first step in choosing a propagation model is therefore to examine these various factors, such as set out below:

- balancing of errors / uncertainties;
- range dependant bathymetry;
- frequency dependence; and
- source characteristics.

For impulsive sound, such as that produced by a seismic survey source, the sound propagation is rather more complex than can be modelled using a simple N log (R) relationship. For example, as discussed previously, the rms sound pressure level of an impulsive sound wave will depend upon the integration window used. An additional phenomenon occurs where the seismic waveform elongates with distance from the source due to a combination of dispersion and multiple reflections. This temporal “smearing” can significantly affect the peak pressure level and reduces the rms amplitude with distance (because the rms window is longer). Another important factor affecting the received sound pressure level from geophysical surveys is the source directivity characteristics. Sound sources are designed so that the majority of acoustic energy is directed downwards towards the ocean bottom. Therefore, the amount of energy emitted horizontally will be significantly less than directed downwards. This is a frequency dependent effect and is more pronounced at higher frequencies than at lower frequencies.

Sound propagation modelling for this assessment was therefore based on an established, peer reviewed, range dependent sound propagation model which utilises the semi-empirical model developed by Rogers (1981). The model provides a robust balance between complexity and technical rigour over a wide range of frequencies, has been validated by numerous field studies and has been benchmarked against a range of other models. The following inputs are required for the model:

- third-octave band source sound level data;
- range (distance from source to receiver);
- water column depth (input as bathymetry data grid);
- sediment type;
- sediment and water sound speed profiles and densities;
- sediment attenuation coefficient; and
- source directivity characteristics.

The propagation loss is calculated using the formula:

$$TL = 15log_{10}R + 5\log_{10}(H\beta) + \frac{\beta R\theta_L^2}{4H} - 7.18 + \alpha_w R$$

Where R is the range, H the water depth, β the bottom loss, $\theta_L$the limiting angle and α_w the absorption coefficient of sea water (α_w is a frequency dependant term which is calculated based on Ainslie and McColm, 1998).

The limiting angle, θ_L is the larger of θ_g and θ_c where θ_g is the maximum grazing angle for a skip distance and θ_c is the effective plane wave angle corresponding to the lowest propagating mode.

$$\theta_g = \sqrt{\frac{2Hg}{c_w}} \qquad \theta_c = \frac{c_w}{2fH}$$

where g is the sound speed gradient in water and f is the frequency.

The bottom loss β is approximated as:

$$\beta \approx \frac{0.477(\rho_s/\rho_w)(c_w/c_s)K_s}{[1-(c_w/c_s)^2]^{3/2}}$$

where ρ_s is the density of sediment, ρ_w the density of water, c_s the sound speed in the sediment, c_w the sound speed in water and K_s is the sediment attenuation coefficient.

The propagation model also takes into account the depth dependent cut-off frequency for propagation of sound (i.e. the frequency below which sound does not propagate):

$$f_{cut-off} = \frac{c_w}{4h\sqrt{1-\frac{c_w^2}{c_s^2}}}$$

where c_s and c_w are the sound propagation speeds in the substrate and water.

The propagation and sound exposure calculations were conducted over a range of water column depths in order to determine the likely range for injury and disturbance. It should be noted that the effect of directivity has a strong bearing on the calculated zones for injury and disturbance because a marine mammal could be directly underneath an array for greater distances in deep water compared to shallow water.

It should be borne in mind that noise levels (and associated range of effects) will vary depending on actual conditions at the time (day-to-day and season-to-season) and that the model predicts a typical worst case scenario. Taking into account factors such as animal behaviour and habituation, any injury and disturbance ranges should be viewed as indicative and probabilistic ranges to assist in understanding potential impacts on marine life rather than lines either side of which an impact definitely will or will not occur. (This is a similar approach to that adopted for airborne noise where a typical worst case is taken, though it is known that day to day levels may vary to those calculated by 5 - 10 dB depending on wind direction etc.).

Exposure Calculations

As well as calculating the un-weighted rms and peak sound pressure levels at various distances from the source, it is also necessary to calculate the SEL for a mammal using the relevant hearing weightings described above taking into account the number of pulses to which it is exposed. For operation of the source array, the SEL sound data for a single pulse was utilised, along with the maximum number of "pulses" expected to be received by marine mammals in order to calculate cumulative exposure.

Exposure modelling was based on the assumption of a mammal swimming at a constant speed in a perpendicular direction away from a moving vessel (see Figure 4.1).

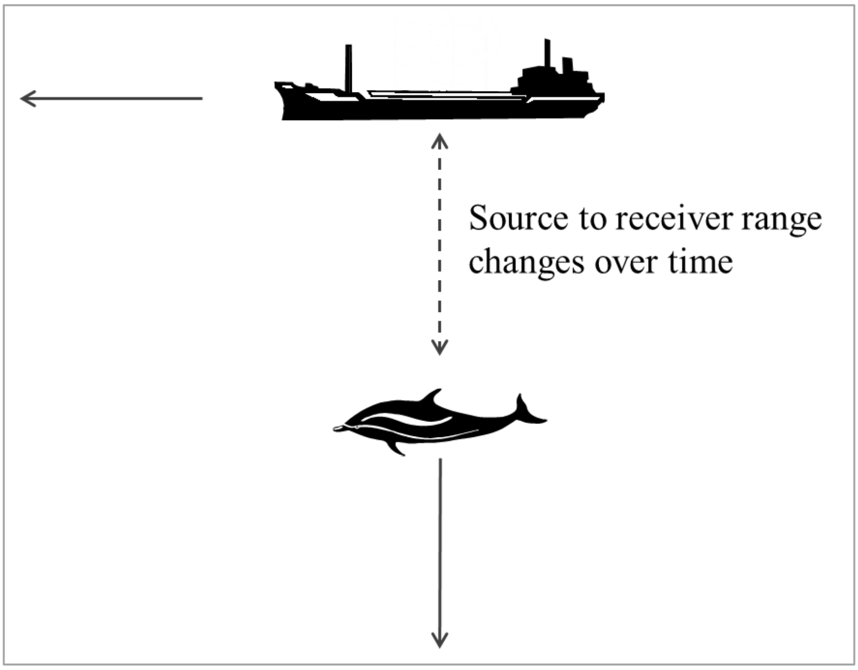

Figure 4.1 Sound exposure modelling

The above case was modelled for a range of start distances (initial or closest passing distance between the animal and vessel) in order to calculate cumulative exposure for a range of scenarios. In each case, the pulses to which the mammal is exposed in closest proximity to the vessel dominate the sound exposure. This is due to the logarithmic nature of sound energy summation.

In order to carry out the swimming mammal calculation, it has been assumed that a mammal will swim away from the noise source at an average speed of 1.5 ms^{-1}. The calculation considers each pulse to be established separately resulting in a series of discrete SEL values of decreasing magnitude (see Figure 4.2).

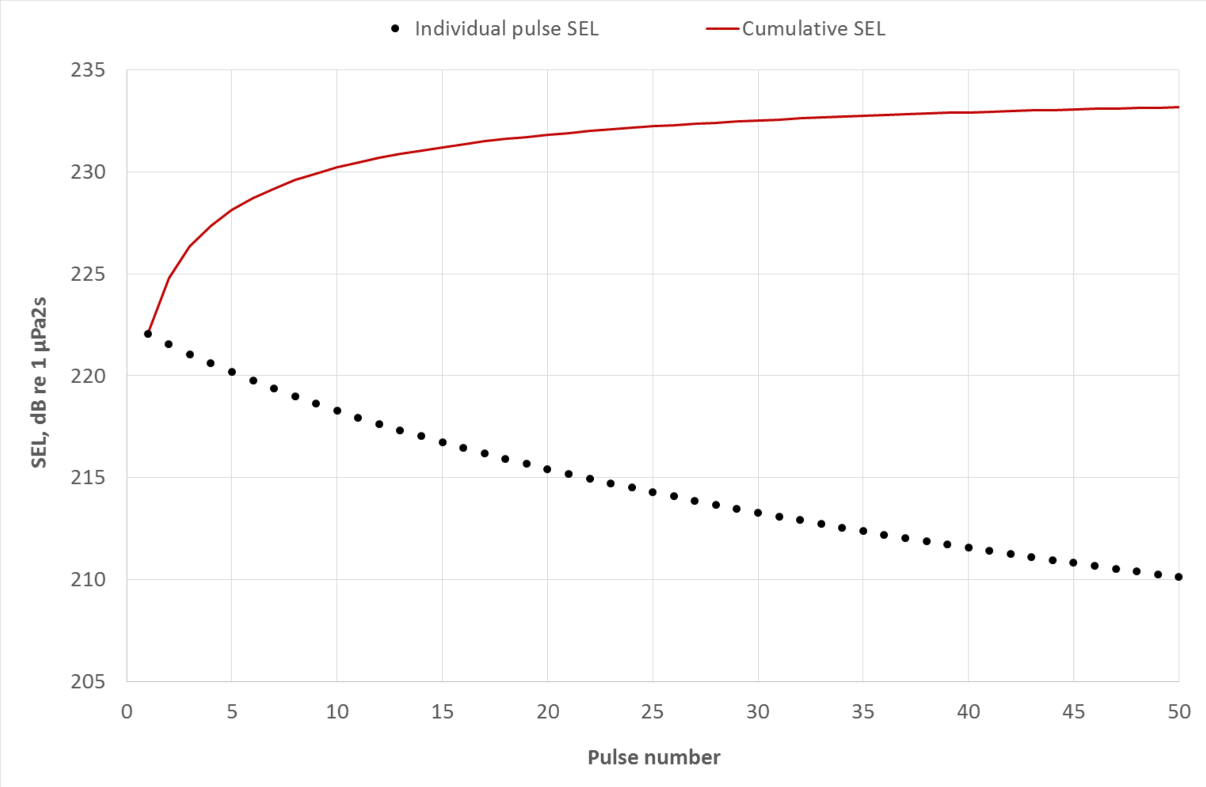

Figure 4.2 Discrete "pulse" SEL and cumulative SEL

As a mammal swims away from the source, the noise will become progressively quieter; the cumulative SEL is worked out by logarithmically adding the SEL to which the mammal is exposed as it travels away from the source. This calculation was used to estimate the approximate minimum start distance for a marine mammal in order for it to be exposed to sufficient sound energy to result in the onset of potential injury. It should be noted that the sound exposure calculations are based on the simplistic assumption that the animal will continue to swim away at a fairly constant relative speed. The real world situation is more complex and the animal is likely to move in a more complex manner. Swim speeds of marine mammals have been shown to be up to 5 ms^{-1} (e.g. cruising minke whale 3.25 ms-1 (Cooper *et al*., 2008) and harbour porpoise up to 4.3 ms^{-1} (Otani *et al*., 2000)). The more conservative swim speed of 1.5 ms^{-1} used in this assessment allows some headroom to account for the potential that the marine mammal might not swim directly away from the source, could change direction or does not maintain a fast swim speed over a prolonged period.

5 Results and Conclusions

5.1 Sonar Based Surveys

Based on the results of the noise modelling the radii of effect for injury and disturbance to marine mammals are presented in Table 5.1. It should be noted that the injury ranges are limited to approximate water depth in the area. Sonar based systems have very strong directivity which effectively means that there is only potential for injury when a marine mammal is directly underneath (or within the "beam" of) the sound source. Once the animal moves outside of the main beam then there is no potential for injury. The same is true in many cases for TTS where an animal is only exposed to enough energy to cause TTS when inside the direct beam of the sonar. For this reason, many of the TTS and PTS ranges are similar (i.e. limited by the depth of the water).

Table 5.1: Marine mammal noise modelling results for sonar based surveys

Survey type	Effect	Area	Radius of Effect, m				
			LF Cetacean	HF Cetacean	VHF Cetacean	PCW	OCW
Multibeam Echo Sounder	PTS: SEL of mammal swimming away from moving vessel	E1E array area	2 m	65 m	74 m	6 m	N/E
		Cable routes	2 m	48 m	51 m	6 m	N/E
	TTS: SEL of mammal swimming away from moving vessel	E1E array area	35 m	73 m	74 m	55 m	5 m
		Cable routes	31 m	50 m	52 m	44 m	5 m
	RMS behavioural change	E1E array area	374 m				
		Cable routes	382 m				
Side Scan Sonar	PTS: SEL of mammal swimming away from moving vessel	E1E array area	8 m	73 m	74 m	22 m	N/E
		Cable routes	8 m	50 m	51 m	21 m	N/E
	TTS: SEL of mammal swimming away from moving vessel	E1E array area	64 m	73 m	74 m	72 m	19 m
		Cable routes	47 m	50 m	52 m	50 m	18 m
	RMS behavioural change	E1E array area	322 m				
		Cable routes	282 m				
Sub Bottom Profiler	PTS: SEL of mammal swimming away from moving vessel	E1E array area	74 m	76 m	310 m	74 m	N/E
		Cable routes	51 m	55 m	244 m	51 m	46 m
	TTS: SEL of mammal swimming away from moving vessel	E1E array area	74 m	220 m	546 m	77 m	74 m
		Cable routes	51 m	205 m	679 m	54 m	51 m
	RMS behavioural change	E1E array area	1,338 m				
		Cable routes	1,382 m				
USBL	PTS: SEL of mammal swimming away from moving vessel	E1E array area	N/E	N/E	2 m	N/E	N/E
		Cable routes	N/E	N/E	2 m	N/E	N/E
	TTS: SEL of mammal swimming away from moving vessel	E1E array area	N/E	N/E	151 m	N/E	N/E
		Cable routes	N/E	N/E	149 m	N/E	N/E
	RMS behavioural change	E1E array area	1,926 m				
		Cable routes	1,930 m				

5.2 Impulsive Source Surveys

Based on the results of the noise modelling the radii of effect for injury and disturbance to marine mammals due to impulsive sound sources are presented in Table 5.2.

Table 5.2: Marine mammal noise modelling results for impulsive sound source surveys

Survey type	Effect	Area	Radius of Effect, m				
			LF Cetacean	HF Cetacean	VHF Cetacean	PCW	OCW
Sparker	PTS: SEL of mammal swimming away from moving vessel	E1E array area	N/E	N/E	9 m	N/E	N/E
		Cable routes	N/E	N/E	9 m	N/E	N/E
	TTS: SEL of mammal swimming away from moving vessel	E1E array area	240 m	N/E	328 m	42 m	N/E
		Cable routes	270 m	N/E	367 m	47 m	N/E
	RMS behavioural change (Strong / mild)	E1E array area	565 m / 82 m				
		Cable routes	612 m / 91 m				
Sleeve Gun	PTS: SEL of mammal swimming away from moving vessel	E1E array area	N/E	N/E	120 m	N/E	N/E
		Cable routes	N/E	N/E	120 m	N/E	N/E
	TTS: SEL of mammal swimming away from moving vessel	E1E array area	107 m	N/E	1,767 m	27 m	N/E
		Cable routes	107 m	N/E	1,870 m	27 m	N/E
	RMS behavioural change (Strong / mild)	E1E array area	1,012 m / 196 m				
		Cable routes	1,049 m / 196 m				

References

Ainslie, Michael A., and James G. McColm. 1998. “A Simplified Formula for Viscous and Chemical Absorption in Sea Water.” The Journal of the Acoustical Society of America 103 (3): 1671–72.

Brekhovskikh, Leonid Maksimovich, and I͡Uriĭ Lysanov. 2003. Fundamentals of Ocean Acoustics.

Cole, B. F. 1965. “Marine Sediment Attenuation and Ocean-Bottom-Reflected Sound.” The Journal of the Acoustical Society of America 38 (2): 291–97.

Cooper, Lisa Noelle, Nils Sedano, Stig Johansson, Bryan May, Joey D. Brown, Casey M. Holliday, Brian W. Kot, and Frank E. Fish. 2008. “Hydrodynamic Performance of the Minke Whale (Balaenoptera Acutorostrata) Flipper.” Journal of Experimental Biology 211 (12): 1859–67.

Eckart, Carl. 1953. “The Scattering of Sound from the Sea Surface.” The Journal of the Acoustical Society of America 25 (3): 566–70.

Essen, H.-H. 1994. “Scattering from a Rough Sedimental Seafloor Containing Shear and Layering.” The Journal of the Acoustical Society of America 95 (3): 1299–1310.

Etter, Paul C. 2013. Underwater Acoustic Modeling and Simulation. CRC Press.

Farcas, Adrian, Paul M. Thompson, and Nathan D. Merchant. 2016. “Underwater Noise Modelling for Environmental Impact Assessment.” Environmental Impact Assessment Review 57: 114–22.

Fortuin, Leonard. 1970. “Survey of Literature on Reflection and Scattering of Sound Waves at the Sea Surface.” The Journal of the Acoustical Society of America 47 (5B): 1209–28.

Greaves, Robert J., and Ralph A. Stephen. 2003. “The Influence of Large-Scale Seafloor Slope and Average Bottom Sound Speed on Low-Grazing-Angle Monostatic Acoustic Scattering.” The Journal of the Acoustical Society of America 113 (5): 2548–61.

Hamilton, Edwin L. 1970. “Reflection Coefficients and Bottom Losses at Normal Incidence Computed from Pacific Sediment Properties.” Geophysics 35 (6): 995–1004.

HESS. 1997. “Summary of Recommendations Made by the Expert Panel at the HESS Workshop on the Effects of Seismic Sound on Marine Mammals.” In . Pepperdine University, Malibu, California.

Kinsler, Lawrence E., Austin R. Frey, Alan B. Coppens, and James V. Sanders. 1999. “Fundamentals of Acoustics.” Fundamentals of Acoustics, 4th Edition, by Lawrence E. Kinsler, Austin R. Frey, Alan B. Coppens, James V. Sanders, Pp. 560. ISBN 0-471-84789-5. Wiley-VCH, December 1999. 1.

Kuo, Edward YT. 1992. “Acoustic Wave Scattering from Two Solid Boundaries at the Ocean Bottom: Reflection Loss.” Oceanic Engineering, IEEE Journal Of 17 (1): 159–70.

Lurton, Xavier. 2002. An Introduction to Underwater Acoustics: Principles and Applications. Springer Science & Business Media.

Mackenzie, K. V. 1960. “Reflection of Sound from Coastal Bottoms.” The Journal of the Acoustical Society of America 32 (2): 221–31.

Madsen, P. T. 2005. “Marine Mammals and Noise: Problems with Root Mean Square Sound Pressure Levels for Transients.” The Journal of the Acoustical Society of America 117: 3952.

Marsh, H. Wysor, M. Schulkin, and S. G. Kneale. 1961. “Scattering of Underwater Sound by the Sea Surface.” The Journal of the Acoustical Society of America 33 (3): 334–40.

McKinney, C. Mo, and C. D. Anderson. 1964. “Measurements of Backscattering of Sound from the Ocean Bottom.” The Journal of The Acoustical Society of America 36 (1): 158–63.

NMFS. 2005a. “Scoping Report for NMFS EIS for the National Acoustic Guidelines on Marine Mammals.” National Marine Fisheries Service.

NMFS. 2005b. “Scoping Report for NMFS EIS for the National Acoustic Guidelines on Marine Mammals.” National Marine Fisheries Service.

NMFS. 2018. “2018 Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0).” NOAA Technical Memorandum NMFS-OPR-59. National Oceanic and Atmospheric Administration.

Otani, Seiji, Yasuhiko Naito, Akiko Kato, and Akito Kawamura. 2000. “DIVING BEHAVIOR AND SWIMMING SPEED OF A FREE-RANGING HARBOR PORPOISE, PHOCOENA.” Marine Mammal Science 16 (4): 811–14.

Popper, Arthur N., Anthony D. Hawkins, Richard R. Fay, David A. Mann, Soraya Bartol, Thomas J. Carlson, Sheryl Coombs, *et al*. 2014. ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report Prepared by ANSI-Accredited Standards Committee S3/SC1 and Registered with ANSI. Springer.

Richardson, William John, Denis H. Thomson, Charles R. Greene, Jr., and Charles I. Malme. 1995. Marine Mammals and Noise. Academic Press.

Rogers, P. H. 1981. “Onboard Prediction of Propagation Loss in Shallow Water.” DTIC Document.

Southall, Brandon L., Ann E. Bowles, William T. Ellison, James J. Finneran, Roger L. Gentry, Charles R. Greene Jr, David Kastak, *et al*. 2007. “Marine Mammal Noise-Exposure Criteria: Initial Scientific Recommendations.” Aquatic Mammals 33 (4): 411–521.

Southall, Brandon L., James J. Finneran, Colleen Reichmuth, Paul E. Nachtigall, Darlene R. Ketten, Ann E. Bowles, William T. Ellison, Douglas P. Nowacek, and Peter L. Tyack. 2019. “Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects.” Aquatic Mammals 45 (2): 125–232.

Urick, Robert J. 1983. Principles of Underwater Sound. McGraw-Hill.

Urick, Robert J., and Robert M. Hoover. 1956. “Backscattering of Sound from the Sea Surface: Its Measurement, Causes, and Application to the Prediction of Reverberation Levels.” The Journal of the Acoustical Society of America 28 (6): 1038–42.