MALIN SEA WIND

Geophysical Survey European Protected Species & Marine Wildlife Supporting Information Report

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Prepared by:

RPS

<Redacted>
Senior Consultant

Imagination House
Station Road
Chepstow, Monmouthshire NP16 5PB

T +44 1483 746 500
E <Redacted>

Prepared for:

ESB

<Redacted>
Senior Offshore Ecology Coordinator

One Dublin Airport Central
Dublin Airport
Cloghran,
Co. Dublin
K67 XF72

E <Redacted>

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GLOSSARY

Term	Definition
Baseline Environment	The existing conditions as represented by the latest available survey and desktop data which is used as a benchmark to assess the impacts of the proposed surveys.
Cetaceans	Aquatic mammals constituting the infraorder Cetacea (whales, dolphins, porpoises).
Continuous Sound	As defined in the National Physical Laboratory (NPL) 2014 guidelines (NPL, 2014), continuous sounds are sounds where the acoustic energy is spread over a significant time, typically many seconds, minutes or even hours. The amplitude of the sound may vary throughout the duration, but the amplitude does not fall to zero for any significant time. The sound may contain broadband noise and tonal (narrowband) noise at specific frequencies. Examples of continuous sound include ship noise, operational noise from machinery including marine renewable energy devices, and noise from drilling.
Decibel (dB)	Expression of the ratio of one value of a power quantity to another (reference value) on a logarithmic scale. The reference value should be stated.
Impulsive Sound	Typically transient, brief (less than one 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.
L_P (Peak Level, Peak Pressure Level)	The maximal sound pressure level of an event, formally: “ten times the base-ten logarithm of the maximal squared pressure divided by the reference pressure squared” or “twenty time the base-ten logarithm of the peak sound pressure divided by the reference pressure, where the peak sound pressure is the maximal deviation from ambient pressure”. Defined in ISO 18405:2017, 3.2.2.1
Management Unit	Marine mammal Management Unit (MUs) for marine mammals in UK waters, which provide an indication of the spatial scales at which impacts of plans and projects alone, cumulatively and in combination, need to be assessed for the key cetacean species in UK waters. For cetaceans, these management units are defined by the Inter-Agency Marine Mammal Working Group. For seal species (harbour and grey seal), the Special Committee on Seals (SCOS) provided advice on seal MUs.
Neritic	A region of the ocean that spans from the coastline to the edge of the continental shelf, sometimes referred to as the coastal or sublittoral zone.,
Non-impulsive (Sound Source)	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 vibro-piling, running machinery, some sonar and vessels.
Permanent Threshold Shift	An irreversible loss of hearing sensitivity.
Pinnipeds	Infraorder of marine mammals including true and eared seals, sealions and walrus.
Root-Mean-square Sound Pressure	Square root of the integral over a specified time interval of squared sound pressure, divided by the duration of the time interval, for a specified frequency range.
Sound Exposure Level	Ten times the logarithm to the base 10 of the ratio of sound exposure to the specified reference value in decibels. The reference value in underwater acoustics is 1 $\mu Pa^2 s$.
Non-impulsive (Sound Source)	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 vibro-piling, running machinery, some sonar and vessels.
Temporary Threshold Shift	Temporary loss of hearing as a result of exposure to sound over time. Exposure to high levels of sound over relatively short time periods will cause the same amount of TTS as exposure to lower levels of sound over longer time periods. The mechanisms underlying TTS are not well understood, but there may be some temporary damage to the sensory cells. The duration of TTS varies depending on the nature of the stimulus, but there is generally recovery of full hearing over time.

ABBREVIATIONS

Acronym	Description
CMACS	Centre for Marine and Coastal Studies
CGNS	Celtic and Greater North Seas
CWSH	Coastal West Scotland and Hebrides
DAERA	Department for Agriculture, Environment and Rural Affairs
DECC	The Department of Energy and Climate Change
EEZ	European Exclusive Zone
EPS	European Protected Species
ESB	Energy Supply Board
HF	High Frequency
HWDT	Hebridean Whale and Dolphin Trust
FCS	Favourable Conservation Status
GHG	Greenhouse Gas
IAMMWG	Inter-Agency Marine Mammal Working Group
INTOG	Innovation and Targeted Oil and Gas
JNCC	Joint Nature Conservation Committee
LF	Low Frequency
OWF	Offshore Wind Farm
MBES	Multibeam Echosounder
OW	Oceanic Waters
MMO	Marine Mammal Observer
MS-LOT	Marine Scotland - Licensing Operations Team
MU	Management Unit
NBN	National Biodiversity Network
NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NRW	Natural Resources Wales
OCA	Other Marine Carnivores in Air
PAM	Passive Acoustic Monitoring
OCA	Phocid Carnivores in Air
PCW	Phocid Carnivores in Water
PTS	Permanent Threshold Shift
rms	Root mean square
RoI	Republic of Ireland
SAC	Special Area of Conservation
SBP	Parametric Sub-bottom Profiler
SCOS	Special Committee on Seals
SPL	Sound Pressure Level
SSS	Side Scan Sonar
TTS	Temporary Threshold Shift
VHF	Very High Frequency
WCI	West Coast of Ireland
ZoI	Zone of Influence

UNITS

Unit	Description
dB	Decibel
Hz	hertz
J	Joules
kHz	Kilo-hertz
kn	Knot
km	Kilo-metre
km^2	Kilo-metre squared
L_E	Same as SEL
L_P	Peak Level, Peak Pressure Level
m	Metres
m/s	Metres per second
ms	Millisecond
nm	Nautical miles
Pa	Pascal – Acoustic pressure
μPa	Micro-pascal
SEL	Sound exposure level
SPL	Sound pressure level
°C	Degrees Celcius

1 INTRODUCTION

1.1 Project Overview

The Malin Sea Wind offshore wind farm (OWF) is being explored by the Electricity Supply Board (ESB) for development as a floating offshore wind farm. The Malin Sea Wind OWF has been awarded through the Innovation and Targeted Oil and Gas (INTOG) seabed leasing process, run by Crown Estate Scotland. The leasing process aims to drive cost reduction in the offshore wind sector by enabling the deployment of new and innovative technologies, and to harness wind energy to decarbonise the oil and gas sector. The Malin Sea Wind OWF is an innovation project that is aiming to have a 100 MW generating capacity from circa 6 turbines.

To progress concept development, a detailed geophysical survey is needed of the Malin Sea Wind Array Area in 2024. The survey for the Offshore Cable Corridor is to take place in 2025. RPS has been contracted by ESB (‘the Client’) to prepare and support delivery of marine European Protected Species (EPS) and Marine Wildlife Risk Assessments for this survey, which will be the first dedicated geophysical surveys for the Malin Sea Wind Array Area. These proposed surveys cover the Malin Sea Wind Array Area (plus an addition buffer for potential survey line turns), the survey for the Offshore Cable Corridor is to take place in 2025 and associated EPS and Marine Wildlife Risk Assessments will be applied for separately.

The Malin Sea Wind Array Area is located in the western approach to the North Channel, in the Scottish Exclusive Economic Zone (EEZ) approximately 23 km southeast of Islay (Scotland) and approximately 25 km north from Portrush (Northern Ireland) (Figure 1.1). At the time of writing, no proposed cable landfall locations have been confirmed.

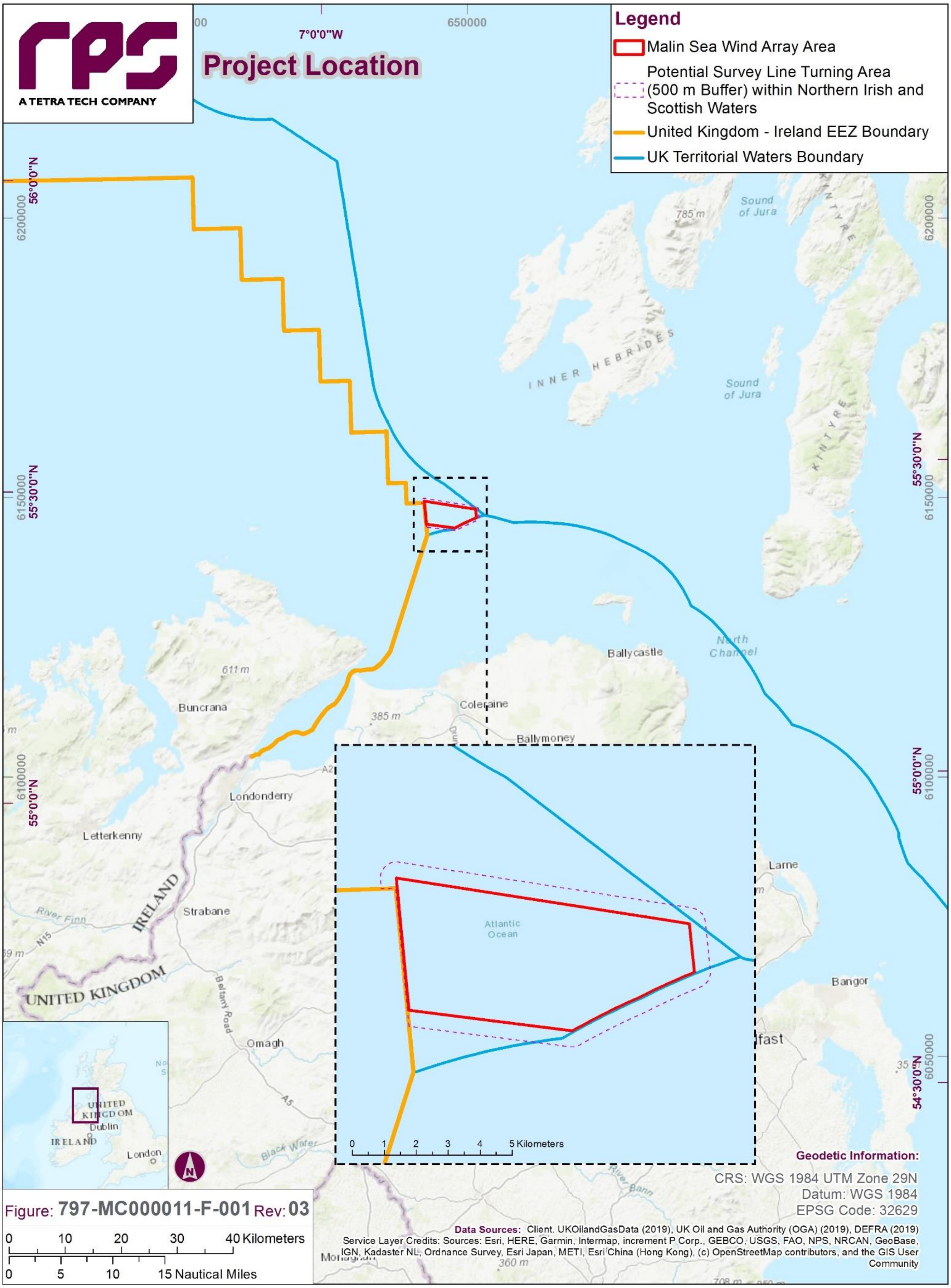

Figure 1.1: Malin Sea Wind Array Area (red polygon) location

1.2 Purpose of the document

As some marine species in the UK are protected under law (see Section 2) as EPS, marine licence applicants must demonstrate that risks of injury and disturbance have been duly assessed in the vicinity of the surveys. Whilst the Malin Sea Wind Array Area is fully located in Scottish offshore waters (i.e. outside the 12 nm boundary), it is located directly on the boundary of Northern Irish waters. Due to this proximity it is anticipated that survey line turns (based upon an estimated 500m buffer) may cross into Scottish territorial waters and Northern Irish waters (see Figure 1.1 and Appendix B), and so the legislative regime of both nations must be considered regarding marine EPS (in this case cetaceans) as well as those species (basking sharks, marine turtles and seals) protected under related wildlife laws (outlined in Section 2).

This EPS and Marine Wildlife Risk Assessment covers the geophysical surveys for the Malin Sea Wind Array Area only. Further details on the survey methods are presented in the survey design section of this report (Section 1.3). As the survey vessel's line turns will likely cross the territorial boundary into Northern Irish waters, EPS and basking shark licences will be sought from the Marine Directorate (for Scottish waters) and an EPS and Wildlife licence will be sought from the Department for Agriculture, Environment and Rural Affairs (DAERA) in Northern Ireland.

This report summarises the legislative context (Section 2) with respect to marine EPS identified in the Malin Sea Wind Array Area (Section 3) and provides an overview of the licensable operations (i.e. noise-producing survey activities) (Sections 1.4 and 4.1) that will be undertaken as part of the geophysical surveys. It describes the proposed survey activities, the survey equipment likely to be used and associated noise levels, uses the results of underwater noise modelling of the sound sources to assesses the risk of auditory injury or disturbance to marine EPS likely to be present in the Malin Sea Wind Array Area's Zone of Influence (ZoI), and proposes mitigation measures (where needed) to reduce those risks to acceptable levels within the relevant legislative context (Section 2). Where risks that cannot be mitigated are identified, information will be provided to support EPS and/or marine wildlife licence application(s) (Section 5).

1.3 Survey Design

The proposed geophysical surveys are expected to be conducted as outlined in Table 1.1.

Table 1.1: Proposed timings of Malin Sea Wind Array Area geophysical surveys

Survey Component	Indicative Survey Area	Territorial Jurisdiction	Anticipated Duration & Timing
Malin Sea Wind Array Area	31.4 km^2	Scottish waters (EEZ) (array area) Scottish territorial waters (survey line turns), Northern Irish waters survey line turns).	9 – 22 days (including anticipated weather downtime) Survey is due to commence 1st June 2024 and will be completed no later than 31st October 2024.

Depths in the Malin Sea Wind Array Area are generally from 50 to 140 m, with the surface sediment being mainly fine gravel to medium gravel.

Detailed geophysical surveys are required to develop the Malin Sea Wind Farm's design envelope, and aim to:

- Map the seabed and sub-surface to optimise positioning of moorage/anchoring and cable routing within the application area and to enable assessment of cable burial depth;
- Plan the scope and positioning of the geotechnical sampling programme in the application area;
- Identify marine habitat areas from which to plan the benthic survey;
- Identify sensitive marine habitats that may need to be avoided during geotechnical and environmental sampling and infrastructure installation; and
- Provide the geophysical data from which a marine archaeological assessment can be undertaken as part of the consenting process.

1.4 Survey Equipment

The Malin Sea Wind Array Area will be surveyed using a variety of towed geophysical survey equipment, deployed from sea-going vessels offshore. The number and specification of survey vessels and equipment will depend on the appointed contractor. In the absence of specifics, this report has been prepared using industry standard vessels and survey apparatus (Table 1.2).

Vessels

The proposed surveys will likely be undertaken by a combination of offshore survey vessels with potential logistical support from guard vessels. As survey vessel specifications are yet to be confirmed by the survey contractor, the noise emitted from a representative vessel (Table 4.1) has been used in the preparation of this report.

The Client has specified that the vessel(s) shall have a minimum transit speed of 10 knots and shall be capable of surveying for extended periods at 4-5 knots. Both smaller survey vessels (c.17 m; 12-hour operations) and larger (c.80 m; 24-hour operations) vessels are being considered.

Geophysical survey equipment

The Malin Sea Wind Array Area will be surveyed using a range of geophysical survey techniques. As well as the vessels which emit continuous non-impulsive sound, the noise emitting survey equipment likely to be used in the survey is outlined in Table 1.2. These sound sources are described in detail in section 4.1 below and represent the Licensable Operations in the context of EPS / Wildlife licence applications, as they have the potential to cause direct or indirect effects (including injury or disturbance) on marine mammals, basking shark and marine turtles. Noise levels from representative equipment covering these specification ranges are detailed in Table 4.1.

Table 1.2: Description of geophysical survey apparatus and the Client's specifications

Apparatus	Specifications	Description
Side Scan Sonar (SSS)	Dual frequency with low and high nominal frequencies of 200 kHz and 900 kHz.	An impulsive sound source used to generate an accurate image of the seabed; this uses an acoustic beam to obtain a sonic image of a narrow area of seabed to either side of the instrument by measuring the amplitude of back-scattered return signals.
Multibeam Echosounder (MBES)	A dual head system. Nominal frequencies from 200 kHz to 400 kHz Swath coverage of 120°. Ping rate min 40 Hz.	An impulsive sound source used to record the two-way travel time of a high frequency pulse emitted by a transducer to obtain detailed maps of the seafloor showing water depths.
Parametric Sub-bottom Profiler (P-SBP)	Minimum penetration: 30 m. Frequency between 1 kHz and 20 kHz. The survey speed at which P-SBP surveys are undertaken shall normally be maintained at 4.0 knots (±10%). e.g., Innomar SES 2000	An impulsive sound source used to characterise layers of sediment or rock under the seafloor; they use a transducer which emits a sound pulse vertically downwards towards the seafloor, and a receiver which records the return of the pulse once it has been reflected off the seafloor.
Sparker Sub-bottom Profiler (S-SBP)	UHRS (Ultra High-Resolution Seismic survey) min frequencies of 1-20 kHz	Similar to P-SBP, an impulsive sound source that emits acoustic/seismic energy in short bursts that penetrate the seabed with the responding echoes providing information about the subsurface sediment structure and geology beneath the water column.
Ultra short baseline (USBL)	Frequency range 20 kHz – 34 kHz	An impulsive sound source used for acoustic positioning.

Whilst magnetometer systems will also likely be used on the survey, these are not scoped into the remit of this assessment as they do not produce significant levels of underwater noise.

1.5 Designated Sites

Relevant designated sites identified in the vicinity of the survey area are shown in Table 1.3 and Figure 1.2. The underwater noise modelling results (section 4.2 and Appendix A) indicate that the potential for behavioural disturbance from continuous noise exists to a radius of 10 km from the source (i.e. the survey vessel). All designated sites identified Table 1.3 and Figure 1.2 are located beyond 10 km from the Malin Sea Wind Array Area, the closest designated site being the Skerries and Causeway Special Area of Conservation (SAC) designated for harbour porpoise.

Given that harbour porpoise and other protected features of the designated sites listed in Table 1.3 are wide ranging and highly mobile species there is the potential for protected features to be present within the Malin Sea Wind Array Area. However, considering that mitigation measures (section 4.4) will be implemented to avoid auditory injury, any behavioural effects are predicted to affect very small numbers of animals in the context of the wider populations. The proposed geophysical survey will be short-term, taking place over a maximum of 22 days and will be carried out over a small area (31.4 km^2). In addition, considering the distances to the designated sites (>16 km), it is not anticipated that the geophysical survey will result in adverse impacts on the relevant features of the designated sites shown in Table 1.3 and Figure 1.2.

Table 1.3: List of designated sites within 100 km of Malin Sea Wind Array area with relevant protected features.

Designated Site	Protected Feature	Distance to Malin Sea Wind Array Area (km)	Distance to the Potential Survey Line Turn Area (500 m buffer) (km)
Skerries and Causeway SAC	Harbour porpoise	16.3	15.8
South-East Islay Skerries SAC	Harbour seal	36.9	36.4
Nave Island	Grey seal	52.5	52.0
Inner Hebrides and the Minches SAC	Harbour porpoise	58.3	57.8
Craighouse Small Isles & Lowlandman's Bay	Harbour seal	62.8	62.3
S Oronsay	Grey seal	63.9	63.4
Sanda & Sheep Island	Grey seal and harbour seal	66.2	65.7
Oronsay Strand	Grey seal	68.2	67.7
The Maidens SAC	Grey seal	73.2	71.5
Sea of Hebrides MPA	Basking shark Minke whale	76.9	76.4
Outer Loch Tarbert	Harbour seal	77.5	77.0
Horn Head and Rinclevan SAC	Grey seal	80.4	80.4
Yellow Rock	Harbour seal	83.0	82.5
North Channel SAC	Harbour porpoise	87.6	85.9
Soa (Mull)	Grey seal	92.3	91.8
Rubha nan Sgarbh	Harbour seal	93.6	93.1
Sound of Pladda Skerries	Grey seal and harbour seal	97.7	97.2

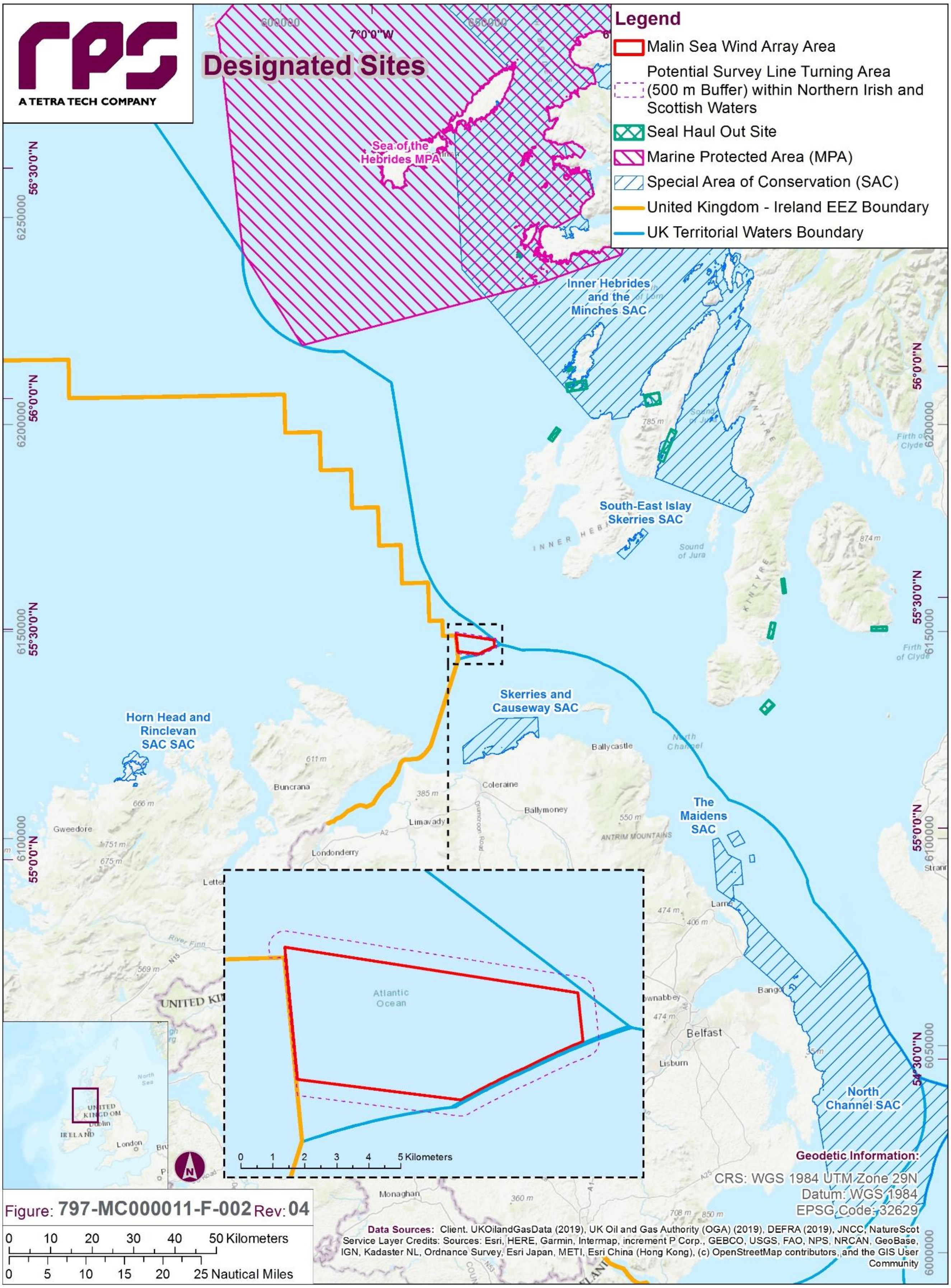

Figure 1.2: Map of relevant designated sites near to the Malin Sea Wind Array Area

2 LEGISLATIVE CONTEXT

Under UK and European law, some marine species are afforded protection from activities that may cause injury or disturbance. These species include (amongst others[1]):

- cetaceans (whales, dolphins and porpoise) and marine turtles, labelled as EPS under Annex IV of the European Commission Habitats Directive (92/43/EEC)(the "Habitats Directive"); transposed individually into UK law under the devolved administrations as described in Sections 2.1 and 2.2;
- basking sharks, protected under the Wildlife and Countryside Act 1981 (as amended) in Scotland and under Schedule 5 of The Wildlife (Northern Ireland) Order 1985 (as amended) (the Wildlife Order) in Northern Ireland; and
- seals under Schedule 5 of The Wildlife (Northern Ireland) Order 1985 (as amended) (the Wildlife Order) in Northern Ireland, and under the Marine (Scotland) Act 2010.

Whilst the entirety of the Malin Sea Wind Array Area is located in Scottish waters along the boundary with Northern Ireland, given the devolved administrations, the legislative regime varies slightly between Scotland and Northern Ireland for waters within 12 nautical miles (nm) (see 2.1 and 2.2). Beyond 12 nm, the Conservation of Offshore Marine Habitats and Species Regulations 2017 (the "Offshore Marine Regulations") applies in both UK administrations by implementing the species protection requirements of the Habitats Directive.

2.1 Scotland

In Scotland the Habitats Directive is transposed into UK law by the Conservation (Natural Habitats) Regulations 1994 (as amended) (the "Habitats Regulations"), which mandates protection for EPS out to 12 nm. As mentioned above, the Offshore Marine Regulations apply beyond 12 nm. These two pieces of legislation make it an offence to deliberately or recklessly disturb, injure, capture or kill EPS. In brief, marine activities should not be detrimental to the population maintenance of the species concerned, with particular emphasis on breeding or resting areas across their natural range.

EPS licensing makes it possible to permit certain activities (e.g. geophysical surveys) that would otherwise be illegal. Marine Directorate - Licensing Operations Team (MD-LOT) (on behalf of the Scottish Ministers) is the licensing authority for marine casework and is generally advised by NatureScot for applications within 12 nm and the Joint Nature Conservation Committee (JNCC) for those beyond 12 nm. However, the Malin Sea Wind project is an INTOG project and it is understood that NatureScot is the advisory body for INTOG associated activities within both inshore and offshore waters. For licences to be granted, the licensing authority need to be satisfied that the following criteria are met:

1. Test 1 (Overriding Public Interest Test): If the competent authority is satisfied that, there being no alternative solutions, the Malin Sea Wind Array Area must be carried out for imperative reasons of overriding public interest, which may be of a social or economic nature (Regulation 44(2));
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
3. Test 3 (Favourable Conservation Status [FCS] Test): The Licensable Operations will not be detrimental to the maintenance of the population of the species concerned at an FCS in their natural range (Regulation 44(3)(b)).

EPS that need to be considered for the Malin Sea Wind Array Area's geophysical survey licence are discussed in Section 3. 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.

In addition to EPS, basking sharks are protected from disturbance in Scotland under the Wildlife and Countryside Act 1981 (as amended), with a licence from MD-LOT being obligatory for commercial activities such as geophysical surveys. The conditions for granting consent to a project are similar to those required for

[1] Only those protected species susceptible to disturbance and injury from underwater noise are considered for the purposes of this assessment.

an EPS licence, starting with the application covering a licensable purpose followed by a justification that there are no satisfactory alternatives and that the licensable actions will not be detrimental to the maintenance of the population of the species concerned at FCS in their natural range.

Article 1(i) of the Habitats Directive defines FCS of a species. The FCS of each EPS considered for this licence has been presented in the species-specific risk assessments in Section 5.3.

2.2 Northern Ireland

In Northern Ireland, the Habitats Directive is transposed into Northern Irish law under the Conservation (Natural Habitats, etc.) Regulations (Northern Ireland) 1995. This protects EPS in the same way as detailed for Scotland in Section 2.1, with the licensing authority being the Department for Agriculture, Environment and Rural Affairs (DAERA).

In addition to EPS, seals and basking sharks are protected at all times under Schedule 5 of The Wildlife (Northern Ireland) Order 1985 (as amended) (the Wildlife Order). These species are discussed further in Section 3. A Wildlife Licence may be issued where DAERA's Marine and Fisheries Division is satisfied that there is no satisfactory alternative to the activity and that the activity will not be detrimental to the maintenance of the population of the species concerned.

2.3 Guidance

The JNCC, Natural England and Natural Resources Wales (NRW) (previously Countryside Council for Wales) have produced draft guidance concerning the Habitat Regulations and protection of marine EPS from injury and disturbance in the UK offshore marine area (JNCC *et al.*, 2010). The guidance document provides an example of a preventative approach to ensuring the strict protection of EPS in their natural range as required by Article 12 of the Habitats Directive. Additional guidance also provides an interpretation of the regulations in greater detail for seismic surveys (JNCC, 2017), including mitigation measures designed to reduce the risk of deliberate injury to marine mammals. Relevant measures are incorporated as part of the consenting regimes for geophysical activities within the UK waters.

The 2010 guidance defines disturbance as significant when "it is likely to be detrimental to the animals of an EPS or significantly affect their local abundance or distribution". It also highlights that "trivial disturbance" should not be considered as a disturbance offence under Article 12. Trivial disturbance is described as "sporadic disturbances without any likely negative impact on the animals such as that resulting in short term behavioural reactions which is not likely to result in an offence being committed" (JNCC *et al.*, 2010).

3 SPECIES BASELINE INFORMATION

A summary of the distribution and abundance for each of the key protected species likely to be found within the survey area and surrounding waters is provided below. This information has been used to inform the assessment of risk of injury or disturbance based on the results from the subsea noise modelling (Section 4.1). A summary of the key data sources is provided in Table 3.1. For the purpose of this section, the most recent baseline survey data identified has been used to report the protected species densities.

Table 3.1: Key data sources used to provide baseline of protected marine species within the Malin Sea Wind Array Area

Data Source	Date	Description	Reference
SCANS IV distribution maps for cetaceans	Most recent surveys conducted during summer 2022 (published 09/2023)	Estimates of distributions of cetaceans given for spatial blocks around the UK from aerial and sighting surveys. The Malin Sea Wind Array Areais located in the general vicinity of survey area CS-F.	Gilles *et al.,* 2023
ObSERVE surveys	Surveys conducted in the summer and winter of 2015 and 2016 (published 2018)	Aerial surveys of cetaceans (and seabirds) in Irish waters: records of occurrence, distribution and abundance in 2015-2017.	Rogan *et al.,* 2018
Atlas of Cetacean Distribution in North-West European Waters	Cetacean distribution	Provides information on the distribution of cetacean species that are known to have occurred in the waters off north-west Europe in the last 25 years.	Reid, Evans and Northridge, 2003
Sea Mammal Research Unit, St. Andrews	2018	Aerial thermal-imaging surveys of harbour and grey seals in Northern Ireland	Morris and Duck, 2018a
Sea Mammal Research Unit, St. Andrews	2018	Aerial Thermal-Imaging Survey of Seals in Ireland	Morris and Duck, 2018b
Sea Mammal Research Unit, St. Andrews	2020	Habitat-based predictions of at-sea distribution for grey and harbour seals in the British Isles.	Carter *et al.,* 2020
Sea Mammal Research Unit, St. Andrews; Special Committee on Seals (SCOS)	2022	Annual scientific advice on matters related to the management of seal populations, includes population estimates.	SCOS, 2022
Inter-Agency Marine Mammal Working Group (IAMMWG)	2022	Updated abundance estimates for cetacean Management Units in UK waters.	IAMMWG, 2022

3.1 Key Protected Species

The marine protected species relevant to this assessment (i.e. those susceptible to disturbance from underwater noise) that are most commonly documented in the North Channel, west coast of Scotland, north-western Irish Sea and surrounding areas are presented in the following sections). It should be noted that the monitoring success of marine wildlife sightings (ship or aerial) surveys are highly dependent on abiotic factors (sea state, visibility, re-sightings and seasonality of survey effort etc.), and whilst they are indicative of presence/absence distributions, it can be tenuous to model absolute abundance or densities. Where density estimates have been made for geographic areas (or species management units) of approximate relevance to the, the highest estimates are typically utilised for conservative risk assessments in the interest of adhering to the precautionary principle.

Cetaceans

Harbour porpoise

Harbour porpoise *Phocoena phocoena* are the most commonly observed cetacean species in UK waters, with high densities in the Irish Sea and its northern and southern channels (Wall *et al.,* 2013). Sightings occur year-round throughout the Irish Sea (Baines and Evans, 2009), with a tendency for higher abundance in summer (Rogan *et al.,* 2018). This species prefers habitats where depths range from 5-150 m in highly sloped regions (Booth *et al*., 2013; Buttifant, 2021). Water depth and hydrodynamic variables have been found to have the greatest influence on the distribution of the species within the Irish Sea (Heinänen and Skov, 2015).

Modelled predictions of harbour porpoise density within the vicinity of the Malin Sea Wind Array Area range from 0.2010 animals per km^2 (SCANS IV survey block CS-F) to group sightings comprising 1-5 individuals at any one place/time (ObSERVE IV, north-eastern survey reaches). The IAMMWG estimated abundance of harbour porpoise at 28,936 with the western Scotland (WS) management unit (MU) (comprising ICES divisions 6a and b), which is a large area, however the species is largely confined to the continental shelf in waters <200 m (IAMMWG, 2022).

Bottlenose dolphins

The bottlenose dolphin *Tursiops truncatus* is relatively common in the Irish Sea, especially in south-eastern reaches where a semi-resident populations exists in Cardigan Bay (Baines and Evans, 2009, CMACS, 2005). Whilst reportings are sparser in the direct vicinity of the Malin Sea Wind Array Area, this is located within their natural distribution. Population estimates for the location of the Malin Sea Wind Array Area are vague at best, given the Project's location on the intersection of three MUs, which have the following abundance estimates (IAMMWG, 2022):

- 45 animals in the Coastal West Scotland and Hebrides (CWSH) MU (approximately two thirds of the Malin Sea Wind array areas is located within this MU);
- 70,249 animals in the Oceanic Waters (OW) MU; and
- West Coast of Ireland (WCI) MU (no estimate available).

The CWSH MU value (45 animals) has been used in this assessment (Section4.3) as more detailed population modelling considering multiple MUs in combination are beyond the scope of this report. However, it is recognised that given the location of the Project (i.e. at the intersection of multiple MUs) considering the CWSH MU in isolation is a shortfall of this assessment due to the highly mobile nature of this species. Comparative figures using the OW MU abundance (70,249 animals) have been provided (Table 4.7 and section 4.3) to consider some form of movement of individuals between the MUs. The SCANS IV density estimate for the survey area most relevant to the Project (CS-F) is 0.0425 Bottlenose dolphins per km^2 (Gilles *et al.,* 2023).

Most sightings of bottlenose dolphin in UK waters take place between July and September, with a secondary peak in April (Reid *et al.*, 2003). The species often occurs in small groups in coastal areas, moving further offshore during winter months to feed on benthic and pelagic fish species (CMACS, 2005). In coastal waters, bottlenose dolphin have been found to prefer headlands, river estuaries, or sandbanks, where there is typically uneven bottom relief and/or stong tidal currents (Reid *et al*., 2003). There are numerous recent bottlenose dolphin sightings recorded in the vicinity of the Project by members of the public (HWDT, 2024).

Common dolphins

The common / short-beaked dolphin *Delphinus delphis* have a large population in UK waters, predominantly occurring offshore and at the southern end of the Irish Sea (Waggitt *et al.*, 2020). They tend to favour coastal, shelf, slope and deep-water habitats with geologic features such as underwater ridges and seamounts where upwelling occurs, increasing nutrient concentrations and supporting higher productivity (NOAA, 2022). Whilst not uncommon, they are less frequently observed nearshore (JNCC, 2003; Mackney and Gimenez, 2006).

Sightings in the Irish Sea also occur along the west coast of Scotland, Ireland and to the southwest of England (Reid *et al.*, 2003). Infrequent sightings in the Irish Sea typically occur between June and September (CMACS, 2005). They have been recorded in Irish waters all year round, but strong seasonal shifts in their distribution have been noted, with winter inshore movements onto the Celtic Shelf and into the western English Channel and St. George's Channel resulting in pronounced concentrations (Northridge *et al.*, 2004). A single MU, the Celtic and Greater North Seas (CGNS), has been defined for common dolphin, with an estimated population of 57,417 animals (IAMMWG, 2022).

Prey species tend to be pelagic fish such as mackerel, sardine and sprat. Research undertaken to analyse short-beaked common dolphin foraging habits illustrated that the species is abundant in both neritic and oceanic habitats, suggesting highly variable habitat preferences and associated foraging strategies (CMACS, 2005).

The SCANS IV survey density estimate (area CS-F) is 0.0544 common dolphins per km^2 (Gilles *et al.,* 2023). Sightings of common dolphin were rare in the vicinity of the Malin Sea Wind Array Area on the ObSERVE surveys, but large pods (anything from individual to super pods in the hundreds) were sighted off the west coasts of Ireland and Scotland (Rogan *et al.,* 2018). Finally, they have been sighted in the North Channel by the Irish Whale and Dolphin Group and the HWDT and are noted on regional tourist board websites.

Risso's dolphins

Risso's dolphin *Grampus griseus* are frequently sighted in the northern Irish Sea (The Department of Energy and Climate Change (DECC), 2016). They tend to prefer shelf-edge offshore waters in depths ranging from 400 to 1,000 m (NOAA, 2022; Waggitt *et al.*, 2020). They have been found to predominantly be a nocturnal forager, targeting deep dwelling benthic organisms (Visser *et al.*, 2021). However, Risso's dolphin is known to perform 'prey switching' between deeper diving for squid and shallow water foraging. The species will often feed at night to benefit from vertical migration of squid as they can then stay nearer surface to breathe and conserve energy (Benoit-Bird *et al.*, 2019).

A single MU, the CGNS, has been defined for Risso's dolphin, with an estimated population of 8,687 animals (IAMMWG, 2022). The SCANS IV estimated density of Risso's dolphin in the vicinity of the Malin Sea Wind Array Area (CS-F) is very low at 0.0027 individuals per km^2 (Gilles *et al.,* 2023). The ObSERVE surveys reported seeing them in offshore waters off the west coast of the Ise of Islay (Rogan *et al.,* 2018). Risso's dolphin are considered likely to be present year-round within the vicinity of the Malin Sea Wind Array Area, with a higher prevalence during summer months (Waggitt *et al.*, 2020).

Minke Whale

Minke whale *Balaenoptera acutorostrata* are found throughout the Irish Sea and Celtic Deep, occurring predominantly during summer months (DECC, 2016; NatureScot, 2019; Waggitt *et al.*, 2020). This seasonal variation within the Irish Sea has been linked to changes in oceanographic conditions and prey availability (Baines and Evans, 2012). The lesser sandeel *Ammodytes marinus* is known to have both spawning and nursery grounds between Scotland and Northern Ireland and are a key food source for minke whale (Reeves *et al*., 2002).

Minke whale are most commonly seen alone or in small groups (Reeves *et al.*, 2002), and numerous sightings have been reported by the HWDT and Ireland's Marine Atlas (IMA) in the Northern Channel near the Malin Sea Wind Array Area (HWDT, 2024; IMA, 2024). The SCANS IV density estimate is 0.0137 minke whale per km^2 for survey area CS-F (Gilles *et al.,* 2023), whilst Evans and Waggitt (2023) present a higher modelled density of 0.03 individuals per km^2. The greatest number of minke whale sightings from dedicated surveys occur in the St George's Channel westwards from Pembrokeshire across the Celtic Deep to County Wexford, and from County Dublin north-eastwards to around the Isle of Man, where densities of up to > 5 animals per km have been recorded(Evans and Waggit, 2023). A single MU, the CGNS, has been defined for minke whale, with an estimated population of 10,288 animals (IAMMWG, 2022).

Other

Other cetacean species that appear in the literature, but for which abundance estimates are less defined in the vicinity of the Malin Sea Wind Array Area are:

- White-beaked dolphin *Lagenorhynchus albirostris;*

- Atlantic white-sided dolphin *Lagenorhynchus acutus;*
- Striped dolphin *Stenella coeruleoalba* – often mistaken with common dolphin *Delphinus delphis;*
- Killer whale Orcinus orca;
- Long-finned pilot whale *Globicephala melas;*
- Humpback whale *Megaptera novaeangliae; and*
- Fin whale *Balaenoptera physalus.*

Specific risk assessments have not been included for these species given the sparsity of data. Therefore, it is considered good practice to have a Marine Mammal Observer (MMO) onboard during noise-emitting survey/construction activities so that commencement of activities may be delayed if needed and to contribute to the evidence-base for these species.

Pinnipeds

Harbour seal

Harbour seal *Phoca vitulina*, often referred to as the common seal (despite being less common than the grey seal *Halichoerus grypus*), are widely distributed across the Northern Hemisphere and British Isles. Their densities are found to be substantially higher near to haul-out areas and sites of approximately 30 m water depth (Aarts *et al.*, 2016).

Thompson *et al*. (2019) estimated the population sizes of harbour seals at haul-out locations in the UK during their annual moult and found clear evidence of their presence in the North Channel where the Project is located. There are known haul-out sites with large numbers (>1000 animals) in the southern parts of the Isle of Islay (Thompson *et al.,* 2019). The count estimates for the zones relevant to this Malin Sea Wind Array Area, Northern Ireland and West Scotland, were 948 and 15,184 grey seals, respectively (Thompson *et al*., 2019). The latter figure is not dissimilar to the West Scotland MU figure of 15,600 animals (SCOS, 2022).

The presence of harbour seals in the inshore areas of the Malin Sea Wind Array Area are also reported by Carter *et al*. (2019) and Morris and Duck (2018) and given the abundance of suitable haul-out areas bordering the North Channel it is considered likely that this species will be encountered during survey works.

Carter *et al.* (2019) estimated numbers of at-sea harbour seals in 5x5 km grid cells, based on haul-outs in the British Isles. SCOS provide annual updates to inform management of seal populations, with the latest density estimate of at-sea harbour seals within the vicinity of the Project being 3.302 harbour seal per 25 km^2 (SCOS, 2022).

Grey seal

Grey seals *Halichoerus grypus* are found in coastal waters around the UK and northern Europe, mainly inhabiting the exposed rocky northern and western coasts of Scotland, Ireland and Wales (Marlin, 2024). The population of the British Isles represents about 38% of the world population (Carter *et al.,* 2019), of which 90% breed in Scotland (Duck, 2002 cited in Marlin, 2024).

In August 2018, Morris and Duck (2018a) used aerial thermal imaging to count grey seal populations in Northern Ireland and concluded a population of 505 animals. An equivalent study for the Republic of Ireland (RoI) counted 3,698 grey seals (Morris and Duck, 2018b). In the north region, area 7 (Malin Head to Northern Ireland border) of the RoI survey, 205 individuals were counted (Morris and Duck, 2018b), whilst 53 were counted between the RoI border to Magilligan Point (area 17) (Morris and Duck, 2018a). A sizeable population of grey seals (circa 100 animals) is also reported on Rathlin Island.

SCOS (2022) estimate 4,174 grey seals within the West Scotland MU, which is used for the purposes of this assessment along with the latest density estimate of at-sea seals; 1.038 grey seal per 25 km^2 in the vicinity of the Malin Sea Wind Array Area (SCOS, 2022).

Basking shark

Estimating the abundance of marine species like basking shark *Cetorhinus maximus* can be challenging due to their migratory patterns and the size of their habitats. They are found in the Irish Sea and have been observed on the surface in summer and spring months near to the Isle of Man and further north, with the species typically undergoing a north-south migration through the Irish Sea ((Sims *et al.*, 2008); Wilson *et al*., 2020). Large numbers of basking shark are known to aggregate around Tiree, Coll and the Skerryvore reefs (Marine Scotland, 2024), with the areas widely considered hotspots.

Marine Scotland (2024) modelling based on Paxten *et al.* (2014) provides an estimated density of basking shark in the approximate area of the Malin Sea Wind Array Area of 0.1-0.2 animals per km^2 for sightings data between 2000-2012.

The Irish Basking Shark Group is a dedicated group which studies the distribution of the species in Irish Seas; they have an abundance of ongoing projects, including the Malin Head Survey. Results suggest that the species could be present in the Malin Sea Wind Array Area. Furthermore, data from individual sighting reported by Bloomfield and Solandt (2008) show that basking sharks have been sighted abundantly in the North Channel.

Leatherback turtles

Leatherback turtle *Dermochelys coriacea* have been sighted in the Irish Sea between July and September, and further north between August and October (Pierpoint, 2000), however their occurrence is considered rare. Sightings data from the year 2000 reported 26 individuals in August in the Irish Sea and suggested that the species passes through the channel during autumn (Pierpoint, 2000). More recently, Hanley *et al*. (2013) recorded 16 leatherback turtles in Manx waters between 2001 and 2011. There are also visual observation records of leatherback turtles in the North Channel, recorded through citizen science and compiled in the National Biodiversity Network (NBN) atlas (NBN, 2023). This shows some recordings of the species in the North Channel, including within the general Project area.

Generally, leatherback turtle occurrence in NI is considered rare (King, 2009), typically occurring as a result of a current taking them off their usual route. Due to their rare incidence, marine turtles will not be considered further in this risk assessment. However, should any marine turtles be encountered during the survey works, best practice should be followed including:

- Following the UK Turtle Code, which gives guidance on how to report, approach, handle and rescue individuals (Marine Conservation Society, 2023).

4 RISK ASSESSMENT

Anthropogenic underwater noise is readily transmitted into the underwater environment and has the potential to adversely affect marine mammals and basking shark (Richardson, *et al.,* 2013). In particular, cetaceans are capable of generating and detecting sound, and depend on sound for feeding, predator avoidance, communication and navigation (Bailey *et al.,* 2010). Five zones of noise influence have been described by Richardson and Würsig (1997), which vary with the distance from the source (see Appendix A):

- The zone of audibility;
- The zone of masking;
- The zone of responsiveness;
- The zone of temporary hearing loss, this hearing loss is typically classified as Temporary Threshold Shift (TTS);
- The zone of injury / permanent hearing loss, this hearing loss is typically classified as Permanent Threshold Shift (PTS).

At close range to a high-level noise source, permanent or temporary hearing damage may occur to marine species, while at very close range gross physical trauma and even death is possible. At long ranges (several km) the introduction of any additional noise could, for the duration of the activity, potentially cause behavioural changes, for example to the ability of species to communicate and to determine the presence of predators, food, underwater features, and obstructions.

This assessment considers the zones of auditory injury and disturbance with the relevant thresholds for the onset of effects, compared to the modelled noise level of the geophysical survey. Sound generated by geophysical surveys can be a major contributor to low frequency sound within the hearing ranges of some marine mammals, and therefore has the potential to impact some species (NRW, 2020).Compared to studies on the effects of seismic surveys (which generally employ airguns for oil and gas exploration purposes), there is a comparative evidence-gap on the effects from geophysical surveys. However, similarities are often drawn given the impulsive nature of both types of surveys. The species at risk from the noise generated by the geophysical survey are outlined in section 3, and the potential impacts to these species are described in section 4.3. These are based on the Southall *et al.,* (2019), Popper *et al.,* (2014) and NOAA (2018) framework for assessing impact from noise on marine mammals and fish.

The primary purpose of the underwater noise risk assessment is to predict the likely range of onset for potential physiological and behavioural effects due to increased anthropogenic noise as a result of the geophysical survey works.

4.1 Underwater Noise Modelling

Sound Sources

The geophysical survey for the Malin Sea Wind Array Area (section 1.3) will produce underwater noise that has the potential to disturb or injure sensitive and protected marine fauna such as EPS and basking shark. A subsea noise assessment (Appendix A) was carried out to predict the ranges of effect from the different noise-producing survey equipment specified by the Client (section 1.4). Industry standard representative geophysical survey equipment criteria were used to inform this assessment, with specifications outlined in Table 4.1.

Table 4.1: Summary of Noise Sources and Activities Included in the Subsea Noise Assessment.

Equipment	Source level sound pressure level [SPL] (as used in model)	Primary decidecade bands (-20 dB width)	Source model details	Impulsive/non-impulsive
Survey vessel (based on "quiet" vessel)	177 dB SPL	10-2000 Hz	Based on RV Celtic Explorer[2] travelling at 5 knots	Non-impulsive
Side scan sonar	158 dB SPL (equivalent spherical level)	200 kHz & 800 kHz	Based on 90th percentile level from popular SSS models (e.g., EdgeTech, C_MAX and Klein Systems).	Impulsive
Multibeam echosounder (Reson Seabat T51R & Kongsberg EM 2040-4 MKII or equivalent	194 dB SPL (equivalent spherical level)	200 kHz – 400 kHz	Model based on frequency modulated tone bursts, but representative for constant frequency tone bursts, von Hann window, ping rate determined by local depth.	Impulsive
Parametric sub-bottom profiler (Innomar SES 2000)	Primary: 202 dB SPL Secondary: 172 dB SPL	85 kHz – 115 kHz & 4 kHz – 15 kHz	Model based on frequency modulated tone bursts, but representative for constant frequency tone bursts, von Hann window, ping rate determined by local depth. Source level used for modelling adjusted for beam pattern and local sediment properties.	Impulsive
Sparker type sub-bottom profiler	185 dB SPL	630 – 5000 Hz	Model based on similar sources.	Impulsive
Ultra Short Baseline (USBL) positioning system	180 dB SPL	19,000 – 34,000 Hz	3 x 8 ms pulses per second. Based on the "Sonardyne Ranger" and "Sonardyne Mini Ranger 2.	Impulsive

The sound sources assessed were separated into two distinct types:

- Impulsive sounds which are typically transient, brief (less than one second), broadband, and consist of high peak sound pressure with rapid rise time and rapid decay American National Standards Institute (ANSI, 1986; National Institute for Occupational Safety and Health (NIOSH), 1998; ANSI, 2005). This category includes sound sources such as seismic surveys, impact piling and underwater explosions.
- Non-impulsive (continuous) sounds which can be broadband, narrowband or tonal, momentary or prolonged, continuous or intermittent and typically do not have the 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 vibro-piling, running machinery, some sonar and vessels.

Modelling Assumptions and Approach

The noise modelling assessment predicted the ranges for potential injury (Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS)) and behavioural disturbance for marine mammals and basking shark based on the recommended criteria for the different hearing groups (section 4.2). The assessment criteria used in this assessment were developed based on a review of available evidence including national and international guidance and scientific literature.

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 across the varying conditions in the Malin Sea Wind Array Area. It should be noted that direction has a strong bearing on the calculated zones for injury and

[2] The R/V Celtic Explorer, travelling at 5 kn, is assumed to be representative for a suitable vessel for carrying out the geophysical survey, with research/survey vessels up to 80 m long being within the bounds of the noise modelling.

disturbance because a marine mammal could be directly underneath the sound source for greater distances in deep water compared to shallow water.

As a marine mammal or fish swims away from the sound source, the noise it experiences will become progressively more attenuated. Sound exposure calculations (presented in Appendix A) were used in this assessment 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 or to estimate if a set exclusion zone is sufficient for an activity (e.g. will an exclusion zone of 500 m be sufficient to prevent exceeding a limit).

Exposure modelling was based on the simplistic assumptions of:

1. a marine mammal swimming at a constant speed of 1.5 ms^{-1}; and
2. a fish swimming at a constant speed of 0.5 ms^{-1},

in a perpendicular direction away from a moving vessel. The real-world situation is more complex, and the animal is likely to move in a more complex manner.

The main assumptions for the validity of the results presented were:

- final equipment configuration is not louder than the presented equipment (Table 4.1).
- increasing the locations sampled would lead to a spread in results resembling a normal distribution, allowing statistical methods to be employed for upper bound estimates (90th percentile estimates).
- the survey vessel will travel at a suitable speed while surveying limited by the acquisition rate of the equipment, here assumed to be 5 kn = 2.5 ms^{-1}.

Six types of results are presented (Table 4.6 and Table 4.8) to inform this assessment:

1. **“90th percentile starting range for a fleeing animal”:**
   This range is based on the estimated true 90th percentile rage using the mean and standard deviation from the five sites to estimate true 90th percentile. This category assumed no soft start.
2. **“90th percentile starting range for a fleeing animal, with soft start of 15 minutes”:**
   Same as “1” but with a soft start where equipment has 10 dB lower source level for 15 minutes prior to survey start.
3. **90th percentile starting range for a fleeing animal, with soft start of 20 minutes”:**
   Same as “1” but with a soft start where equipment has 10 dB lower source levels for 20 minutes prior to survey start.
4. **“90th percentile starting range for a fleeing animal, with soft start of 30 minutes”:**
   Same as “1” but with a soft start where equipment has 10 dB lower source level for 30 minutes prior to survey start.
5. **“Peak level risk range”:**
   The range of acute risk of impact from peak pressure levels associated with the peak pressure level from the impulsive sources.
6. **“Behavioural response range”:**
   The range at which the behavioural limit for marine mammals (160 dB SPL for impulsive, 120 dB SPL for non-impulsive) or fish (150 dB SPL) is exceeded. Note that the behavioural limits are unweighted and will therefore be dominated by the low frequency part of the emitted noise, with all hearing groups bar Low Frequency (LF)probably unable to hear the noise to this range or be impacted in any way by its presence.

4.2 Impacts of Underwater Noise

The following section assesses the potential impacts on the relevant EPS, basking sharks and seals from sound produced during the Malin Sea Wind Array Area geophysical survey (see section 4.3). The introduction of additional man-made sound has the potential to result in disturbance or injury, by affecting an animal’s ability to feed, avoid predators, communicate, and navigate the marine environment (Nieukirk *et al.,* 2004; Richardson, *et al*., 2013). The impacts include short-term behavioural changes, temporary or permanent auditory damage, and mortality (Southall *et al*., 2019). However, if the frequency resulting from the underwater sound source does not exceed the hearing thresholds of the marine species, they may not experience any effect from this exposure (Carroll *et al.,* 2017). The assessment considers the impact ranges around the vessel and the geophysical survey equipment (rather than the entire survey area). Further details on the approach to underwater noise modelling is detailed in Appendix A.

Hearing Sensitivity

Marine Mammals

Hearing sensitivity varies between marine mammals and fish, and therefore they have varying sensitivities to noise and susceptibility to noise-induced impacts (NOAA, 2018). Moreover, their reactions to sound have been shown to depend on sound source level, propagation conditions, ambient noise and individual differences (such as age, sex, habitat and previous habituation to noise) (Richardson *et al.,* 1995).

In order to assess the impacts of underwater noise on these species, they are classed into functional hearing groups (Southall *et al*., 2007; Southall *et al.,* 2019). NOAA Fisheries have produced marine mammal acoustic technical guidance, which provides thresholds for the onset of PTS and TTS in marine mammal hearing for all underwater sound sources. These are based on the assumption that, outside of their hearing ranges, it is unlikely that a species will experience an auditory impact.

The hearing weighting function is designed to represent the sensitivity for each group within which acoustic exposures can have auditory effects. The categories include:

- Low Frequency (LF) cetaceans: marine mammal species such as baleen whales (e.g. minke whale);
- High Frequency (HF) cetaceans: marine mammal species such as dolphins, toothed whales, beaked whales and bottlenose whales (e.g. bottlenose dolphin);
- Very High Frequency (VHF) cetaceans: 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) (e.g. harbour porpoise);
- Phocid Carnivores in Water (PCW): true seals, earless seals (e.g. harbour seal and grey seal), hearing in air is considered separately in the group Other Marine Carnivores in Air (OCA);
- Other Marine Carnivores in Water: including otariid pinnipeds (e.g. sea lions and fur seals), sea otters and polar bears; air hearing considered separately in the group OCA; and
- Sirenians: Manatees and dugongs. This group is only represented in the NOAA guidelines.

It should be noted that not all the above categories of marine mammal will be present in the area relevant to the Malin Sea Wind Array Area geophysical survey. The classifications of the more commonly recorded EPS species in the vicinity of the Malin Sea Wind Array Area, according to these criteria is displayed below in Table 4.2.

Basking Shark

Basking sharks are a protected marine species which are also considered in this risk assessment. The species are classified by Popper, *et al*., 2014 as group 1 fish (fish with no swim bladder). Basking sharks have only an inner ear and no swim bladder, meaning that they are only sensitive to particle motion (Chapuis *et al*., 2019). Therefore, they are sensitive to low frequency sounds only (between 20 Hz and 1500 Hz), with their hearing sensitivity peaking between 200 and 600 Hz (Carroll, *et al*., 2017) (Table 4.2).

Table 4.2: Functional marine hearing groups for marine mammals and basking shark potentially present in the survey area. Hearing group classification and estimated auditory band width taken from NOAA Marine Mammal Acoustic Technical Guidance (NOAA, 2018), Southall *et al* (2019) Marine Mammal Noise Exposure Criteria & Popper *et al* (2014)

Species	Hearing Group	Estimated auditory bandwidth
Harbour porpoise	VHF	275 Hz to 160 kHz
Bottlenose dolphin	HF	150 Hz to 160 kHz
Common dolphin	HF	150 Hz to 160 kHz
Risso’s dolphin	HF	150 Hz to 160 kHz
Minke whale	LF	7 Hz to 35 kHz

Harbour seal	PCW	50 Hz to 86 kHz
Grey seal	PCW	50 Hz to 86 kHz
Basking shark	Group 1 fish	20 Hz to 1500 Hz (Peak between 200 and 600 Hz)

Assessment Method for Potential Injury

This section summarises the assessment method for potential for injury impacts to species of marine mammal and fish in the survey area. For this study, it is the zones of injury (PTS) that are of primary interest, along with estimates of behavioural impact ranges. The zone of injury in this study is classified as the distance over which a marine mammal can suffer PTS leading to non-reversible auditory injury.

Injury thresholds are based on a dual criteria approach using both un-weighted L_P (maximal instantaneous SPL) and cumulative exposure based on marine mammal hearing weighted sound exposure level (SEL). The hearing weighting function is designed to represent the sensitivity for each group within which acoustic exposures can have auditory effects. To determine the potential spatial range of injury and behavioural change, a review has been undertaken of available evidence, including international guidance and scientific literature.

Both the criteria for impulsive and non-impulsive sound are relevant for this study given the nature of the sound sources used during the survey. The relevant PTS and TTS criteria proposed by Southall *et al.* (2019) are summarised in Table 4.3.

Table 4.3: PTS and TTS onset acoustic thresholds (Southall *et al*., 2019)

Hearing Group	Parameter	Impulsive [dB]		Non-impulsive [dB]	
		PTS	TTS	PTS	TTS
Low frequency (LF) cetaceans	L_P, (unweighted)	219	213	-	-
	SEL, (LF weighted)	183	168	199	179
High frequency (HF) cetaceans	L_P, (unweighted)	230	224	-	-
	SEL, (MF weighted)	185	170	198	178
Very high frequency (VHF) cetaceans	L_P, (unweighted)	202	196	-	-
	SEL, (HF weighted)	155	140	173	153
Phocid carnivores in water (PCW)	L_P, (unweighted)	218	212	-	-
	SEL, (PW weighted)	185	170	201	181

Basking shark falls into the Popper *et al.,* (2014) classification as a Group 1 fish (fish with no swim bladder). Dual metrics are presented for this hearing group with respect to different physiological injury criteria as set out below (Table 4.4). Further details regarding the injury criteria are presented in Section 2.4 of the underwater noise technical report (Appendix A).

Table 4.4: Criteria for onset of injury to group 1 fish (e.g. basking shark) due to impulsive sound

Type of animal	Impulsive [dB]				Non-impulsive [dB]	
	Unit	Mortality and potential mortal injury	Recoverable injury (PTS)	TTS	Recoverable injury (PTS)	TTS
Fish: no swim bladder (particle motion detection)	SEL	219[1]	216[1]	186[1]	222	210
	L_P	213[1]	213[1]	193[2]	-	-

[1] (Popper *et al*., 2014)
[2] (Worcester, 2006)
[3] (WSDOT, 2011)

Assessment Method for Potential Behavioural Disturbance

Scientific literature shows that responses to disturbance vary between and within species and depend on the individual characteristics (body size, condition, sex and personality) and extrinsic factors (environmental context, repeated exposure, prior experience and acclimatisation) (Harding, *et al.,* 2019). These factors will affect whether an individual exhibits an aversive response to sound, particularly in an area with high sound levels from to human activities.

Typically, a 'strong disturbance' is one which has the potential to disturb an animal in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering (NMFS, 2005; JNCC, 2010). The NOAA define strong disturbance in all marine mammals as Level B harassment and for impulsive sound suggests a threshold of 160 dB re 1 μPa (root mean square (rms)) (Table 4.5). This threshold meets the criterion defined by JNCC (2010a) as a 'non-trivial' (i.e. significant) disturbance and is equivalent to the Southall *et al.,* (2007) severity score of five or more on the behavioural response scale. Outside of this threshold, behavioural responses are considered trivial, and unlikely to significantly impact the marine animal, or its population status in the wild. For example, these responses often include minor changes in swimming speed, direction and/or dive profile, modification of vocal behaviour and minor changes to respiratory rate (Southall, *et al.,* 2007). For mild disturbance, a precautionary level of 140 dB re 1 μPa (rms) is used to indicate the onset of low-level marine mammal disturbance effects for all mammal groups for impulsive sound.

For vessel noise (continuous sound), NOAA (2019) guidance sets the marine mammal level B behavioural disturbance threshold for continuous noise at 120 dB re 1 μPa (rms), which sits approximately mid-way between the range of values identified in Southall *et al*. (2007). Based upon NOAA criteria, disturbance thresholds in this assessment for marine mammals were 120 dB SPL and 160 dB $L_{E\ single\ impulse}$ or 1-second L_E for non-impulsive and impulsive sound, respectively (Table 4.5).

Criteria for the onset of behavioural effects for fish were 150 dB SPL for fish with no swim bladder (basking sharks) for both impulsive and non-impulsive sound sources. For fish species, these behavioural changes could include the elicitation of a startle response, disruption of feeding, or avoidance of an area. The underwater noise modelling (see Appendix A) notes that levels exceeding this threshold are not expected to cause direct permanent injury but may indirectly affect the individual fish (such as by impairing predator detection) (Hastings, 2002; Worcester, 2006). Note that the non-impulsive threshold can often be lower than ambient noise for coastal waters with some human activity, meaning that response ranges determined using this limit will tend to be higher than actual ranges. Also, as the levels are unweighted, the ranges will be dominated by low-frequency noise, which is outside the hearing range of most hearing groups.

Table 4.5: Disturbance criteria for marine mammals used in this study based on NOAA Level B behavioural disruption (NOAA, 2018)

Effect	Non-Impulsive Threshold	Impulsive Threshold
Disturbance (all marine mammals)	120 dB SPL	160 dB $L_{E\ single\ impulse}$ or 1-second L_E
Disturbance (to all fishes)	150 [SPL]*	160 dB L_P

*This is based on the impulsive criteria.

4.3 Assessment of Potential Impacts

Assessment of Potential Injury Impacts

Instantaneous injury (PTS) based on the L_P metric could occur out to a maximum range of 15 m across all marine mammal species and basking shark with the largest range predicted for the VHF hearing group (harbour porpoise) (Table 4.6). A standard 500 m mitigation zone is recommended for geophysical surveys (JNCC, 2017) and therefore this is determined to be sufficient to reduce the risk of instantaneous injury to negligible. Further details on mitigation are presented in Section 4.4.

The underwater noise modelling also predicted a risk of injury from cumulative exposure where all geophysical survey activities could occur at the same time. The largest range of up to 990 m was predicted for the VHF hearing group (harbour porpoise). A soft start can be employed to reduce the risk over this range. Table 4.6, which provides a summary of the minimal starting ranges for fleeing animals to avoid TTS/PTS, demonstrates how a 20 minute soft start would reduce the injury range from cumulative SEL to below 500 m (i.e. the JNCC guideline (see section 4.4 for further details) Therefore, by adhering to either or both mitigation methods, there is little acute risk for a member of the VHF group to exceed its auditory limits. In addition, harbour porpoise are very sensitive to noise, including the presence of vessels, and display avoidance movements in response to impulsive noise sources, such as seismic surveys (Thompson, *et al*., 2013). Consequently, it is considered unlikely that an animal would remain in the vicinity of the survey vessel during the noise-producing activities. Therefore, injury is ultimately deemed unlikely.

The HF hearing group (bottlenose and Risso's dolphin) have risk ranges for PTS <10 m for instantaneous injury from L_P (<50 m for cumulative exposure from SEL), whilst remaining hearing groups including Group 1 fish (basking shark) have PTS risk ranges <10 m. Applying the 500 m exclusion zone described above would likely result in little to no risk of injury for these groups.

To demonstrate the efficacy of a 20-minute soft start the numbers of animals potentially affected by PTS and TTS and the corresponding percentage of the relevant MU populations are also presented in Table 4.7. The impact area (km^2) has been combined with the density of individuals in the area (individuals per km^2) to determine how many animals may be affected by underwater noise from these surveys (Table 4.7). As described above, implementation of a 500 m mitigation zone will fully mitigate the risk of PTS and therefore it is concluded that no animals will be permanently injured.

Table 4.6: Summary of minimal auditory injury starting ranges for fleeing animals.

Condition	LF (TTS / PTS) [m]	HF (TTS / PTS) [m]	VHF (TTS / PTS) [m]	PCW (TTS / PTS) [m]	OCW (TTS / PTS) [m]	Fish (TTS / PTS) [m]
90th percentile (unmitigated)	1100 / <10	290 / 46	4200 / 990	340 / <10	<10 / <10	150 / <10
90th percentile 15 min soft start (-10 dB)	350 / <10	100 / <10	4200 / 540	14 / <10	<10 / <10	33 / <10
90th percentile 20 min soft start (-10 dB)	150 / <10	100 / <10	4200 / 490	11 / <10	<10 / <10	32 / <10
90th percentile 30 min soft start (-10 dB)	75 / <10	100 / <10	4200 / 460	<10 / <10	<10 / <10	31 / <10
Peak level range (max from all sites)	<10	<10	25 / 15	<10	<10	<10

Table 4.7: Number of animals potentially affected by PTS and TTS during the proposed geophysical survey (number of animals was rounded to the nearest whole number; N/E = Threshold not exceeded, N/A = not applicable).

Species	Density estimate (animals/km²) from Gilles *et al.* (2023)/Carter *et al.* (2022)	Relevant MU	MU population from IAMMWG (2022)/SCOS (2022)	Threshold	Starting ranges (km)		Area of sea affected (km²)		Number of animals potentially affected		Proportion of MU population (%)	
					No soft start	With 20 minute soft start	No soft start	With 20 minute soft start	No soft start	With 20 minute soft start	No soft start	With 20 minute soft start
Harbour porpoise	0.201	West Scotland	28,936	PTS (SEL)	0.99	0.49	3.08	0.75	1	0	0.00213884	0.00052396
				TTS (SEL)	4.2	4.2	55.42	55.42	11	11	0.03849515	0.03849515
Bottlenose Dolphin	0.0425	Coastal West Scotland and Hebrides	45	PTS (SEL)	0.046	<0.01	0.01	0.0003	0	0	0.00062783	0.00002967
				TTS (SEL)	0.29	0.1	0.26	0.03	0	0	0.02495297	0.00296706
		Oceanic waters	70249	PTS (SEL)	0.046	<0.01	0.01	0.0003	0	0	0.00000040	0.00000002
				TTS (SEL)	0.29	0.1	0.26	0.03	0	0	0.00001598	0.00000190
Common Dolphin	0.0544	Celtic and Greater North Seas	57,417	PTS (SEL)	0.046	<0.01	0.01	0.0003	0	0	0.00000063	0.00000003
				TTS (SEL)	0.29	0.1	0.26	0.03	0	0	0.00002503	0.00000298
Risso's Dolphin	0.0027	Celtic and Greater North Seas	8,687	PTS (SEL)	0.046	<0.01	0.01	0.0003	0	0	0.00000021	0.00000001
				TTS (SEL)	0.29	0.1	0.26	0.03	0	0	0.00000821	0.00000098
Minke whale	0.0137	Celtic and Greater North Seas	10,288	PTS (SEL)	0.01	<0.01	0.0003	0.0003	0	0	0.00000004	0.00000004
				TTS (SEL)	1.1	<0.15	3.80	0.07	0	0	0.00050620	0.00000941
Grey seal	0.042	West Scotland	4174	PTS (SEL)	0.01	<0.01	0.0003	0.0003	0	0	0.00000032	0.00000032
				TTS (SEL)	0.34	0.01	0.36	0.0003	0	0	0.00036543	0.00000032

Species	Density estimate (animals/km^2) from Gilles *et al.* (2023)/Carter *et al.* (2022)	Relevant MU	MU population from IAMMWG (2022)/SCOS (2022)	Threshold	Starting ranges (km)		Area of sea affected (km^2)		Number of animals potentially affected		Proportion of MU population (%)	
					No soft start	With 20 minute soft start	No soft start	With 20 minute soft start	No soft start	With 20 minute soft start	No soft start	With 20 minute soft start
Harbour seal	0.132	West Scotland	15600	PTS (SEL)	0.01	<0.01	0.0003	0.0003	0	0	0.00000027	0.00000027
				TTS (SEL)	0.34	<0.01	0.36	0.0003	0	0	0.00011169	0.00000027

Assessment of Potential Behavioural Disturbance Impacts

Behavioural response ranges are 200 m and 420 m for marine mammals and fish (i.e. basking shark) respectively for the impulsive noise. These ranges fall within the 500 m mitigation zone and therefore with standard industry measures implemented (MMOs and PAM) it is unlikely for there to be any animals within the impact range. However, the non-impulsive noise behavioural response range for marine mammals extends to 10 km meaning the behaviour of protected EPS may be disrupted within a 314.2 km^2 area surrounding the survey.

There are limited studies directly investigating the temporary disturbance impacts from impulsive noise sources from geophysical surveys. However, there are an abundance of studies on the effects of multi-array seismic surveys on marine mammals which can be useful in supporting predictions of behavioural responses of marine mammals to geophysical survey sources in general, given the overlap of parameters that typically characterise sound sources (i.e. transmission frequency, source level, pulse duration); these findings are summarised below.

Temporary disturbance may have implications on survival and fitness and population-level consequences, particularly for species such as harbour porpoise, which have been shown to forage almost constantly (24 hours a day) to meet their high energy and metabolic requirements, and therefore may be more vulnerable to anthropogenic disturbance (Wisniewska *et al*., 2016). However, several studies suggest that to some extent, marine mammals would be able to adapt their behaviour to reduce impacts on survival and reproduction rates and tolerate elevated levels of underwater sound during site investigation surveys. Marine mammals are also deemed to have a high tolerance to behavioural disturbance, and studies suggest that disturbance is unlikely to be ecologically significant for marine mammals.

For example, harbour porpoise behavioural responses were investigated in response to a commercial two-dimensional seismic airgun survey in the North Sea, conducted over 10 days using an airgun array (impulsive sound source). The results demonstrated that prolonged survey noise did not lead to broad scale displacement of harbour porpoise (Thompson *et al.,* 2013). Furthermore, Nabe-Nielsen *et al.* (2014) found that in response to noise from wind turbines and ships, the impacts on harbour porpoise were minor, and sound was found to have no effect on the survival or resilience of the population. Furthermore, a study by Sarnocińska *et al.* (2020) indicated that although there was temporary displacement and change in harbour porpoise echolocation behaviour in response to a 3D seismic survey, prolonged use of seismic survey sound did not lead to broader-scale displacement into higher-risk habitats. Similar conclusions were also drawn from a ten-month study of overt responses to seismic exploration in humpback whale, sperm whale (*Physeter macrocephalus*) and Atlantic spotted dolphin (*Stenella frontalis*)*,* which demonstrated no evidence of prolonged or large-scale displacement of these mammal species from the region during the survey (Weir, 2008). A study by Kates Varghese *et al*. (2020) on behavioural responses specifically to MBES surveys found that the only marine mammal metric that changed was vocalisation rate and concluded that these changes in behaviour were unlikely to be biologically significant.

In addition, the marine mammal species assessed are mobile species, and likely to move away from loud sources of sound. Under the JNCC *et al.,* (2010) guidance (which applies to offshore waters beyond 12 nm and to Northern Irish waters), these survey works are considered to be a 'trivial' disturbance (unlikely to result in population-level effects). Furthermore, the mitigation applied in the survey to reduce the potential injury impacts of sound, although not dealing with disturbance directly, will also assist in reducing the potential for disturbance effects.

Under the Marine Scotland (2020) guidance there is, however, a risk of disturbance to EPS in inshore Scottish waters. As the modelled behavioural response range for marine mammals cannot be fully mitigated, this will be taken forward to assess against the three EPS licencing tests (Section 5).

A summary of minimal starting ranges for disturbance is provided below in Table 4.8, the numbers of animals potentially affected by disturbance and the corresponding percentage of the relevant MU populations are also presented in Table 4.9.

Table 4.8: Summary of minimal disturbance starting ranges for fleeing animals.

Condition	LF, HF, VHF, PCW and OCW [m]	Fish [m]
Behavioural response range	200 (impulsive) 10,000 (non-impulsive)	420

Table 4.9 Number of animals potentially affected by disturbance during the Malin Sea Wind Array Area geophysical survey

Species	Density estimate (animals/km^2) from Gilles *et al.* (2023)/Carter *et al.* (2022)	Relevant MU	MU population from IAMMWG (2022)/ SCOS (2022)	Sound Source	Disturbance range (km)	Area of sea affected (km^2)	Number of animals potentially affected	Proportion of MU population (%)
Harbour porpoise	0.201	WS	28,936	Impulsive	0.2	0.1	<1	0.00009
				Non-impulsive	10	314.2	63	0.21823
Bottlenose Dolphin	0.0425	CWSH	45	Impulsive	0.2	0.1	<1	0.01187
				Non-impulsive	10	314.2	13	29.67060
		OW	70,249	Impulsive	0.2	0.1	<1	0.00001
				Non-impulsive	10	314.2	13	0.01901
Common Dolphin	0.0544	CGNS	57,417	Impulsive	0.2	0.1	<1	0.00001
				Non-impulsive	10	314.2	17	0.02977
Risso's Dolphin	0.0027	CGNS	8,687	Impulsive	0.2	0.1	<1	0.00000
				Non-impulsive	10	314.2	1	0.00976
Minke whale	0.0137	CGNS	10,288	Impulsive	0.2	0.1	<1	0.00002
				Non-impulsive	10	314.2	4	0.04183
Grey seal	0.042	WS	4174	Impulsive	0.2	0.1	<1	0.00013
				Non-impulsive	10	314.2	13	0.31612
Harbour seal	0.132	WS	15600	Impulsive	0.2	0.1	<1	0.00011
				Non-impulsive	10	314.2	41	0.26583

Species-Specific Risk Assessment

Harbour porpoise

The most sensitive species likely to be present in the survey area is the harbour porpoise, which has an estimated auditory band width of 275 Hz to 160 kHz. Thresholds for which injury and behavioural disturbance may be induced are described in Table 4.7 and Table 4.9.

The noise assessment (Appendix A) showed that a harbour porpoise exposed to underwater noise from the survey equipment may experience instantaneous auditory injury based on L_P at a range of up to 15 m (PTS) which can be fully mitigated within a standard 500 m mitigation zone. There is also a risk of cumulative exposure (SEL) out to 990 m and the application of a 20 minute soft start will effectively reduce this range to within the 500 m mitigation zone. Recoverable auditory injury (TTS) and fleeing response has the potential to occur out to a maximum distance of 25 m (instantaneous injury) or 4,200 m (SEL). Behavioural disturbance has the potential to occur out to a maximum distance of 10 km (see Appendix A).

The noise modelling demonstrated that even without the implementation of mitigation, and for all equipment, no more than one harbour porpoise is predicted to have the potential to experience PTS at any one time within the Malin Sea Wind Array Area (see Table 4.7; Appendix A).

Due to the small area over which injury could occur and the low number of animals which may be affected, even without mitigation 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 4.4.

Up to 11 harbour porpoise individuals may experience TTS (recoverable injury) at any one time within the survey area (Table 4.7).

Up to 63 harbour porpoise individuals may be experience behavioural disturbance as a result of the survey activities at any one time. This equates to up to 0.218% of the WS MU population. Disturbance has the potential to occur over an area of up to 314 km^2 (Table 4.9).

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

Bottlenose dolphin

Thresholds at which injury and behavioural disturbance may be induced in HF cetacean species, such as the common dolphin are described in Table 4.7 and Table 4.9.

The noise assessment (Appendix A) showed that a bottlenose dolphin exposed to underwater noise from the survey equipment would be likely to experience permanent auditory injury at a range of <10 m (based on L_P) or up to 46 m (cumulative SEL). Recoverable auditory injury (TTS) and fleeing response has the potential to occur out to a maximum distances of <10 m or 290 m for L_P or cumulative SEL respectively. Behavioural disturbance has the potential to occur out to a maximum distance of 10 km (see Table 4.8; Appendix A).

The noise modelling provided the impact ranges associated with the sound sources which may be used for the surveys and allowed for the calculation of the impact area. Less than one bottlenose dolphin is predicted to have the potential to experience PTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7). 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 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 surveys due to audio and visual cues from boat movements. Less than one bottlenose dolphin is predicted to have the potential to experience TTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7). Proposed mitigation to further reduce potential for impact is presented in section 4.4.

Common dolphin

Thresholds at which injury and behavioural disturbance may be induced in HF cetacean species, such as the common dolphin are described in Table 4.7 and Table 4.9.

The noise assessment (Appendix A) showed that a common dolphin exposed to subsea noise from the survey equipment would be likely to experience permanent auditory injury at a range of <10 m (based on L_P) or up to 46 m (cumulative SEL). Recoverable auditory injury (TTS) and fleeing response has the potential to occur out to a maximum distance of <10 m or 290 m for L_P or cumulative SEL respectively. Recoverable auditory injury and fleeing response has the potential to occur out to a maximum distance of 290 m (worst case TTS SEL without mitigation). Behavioural disturbance has the potential to occur out to a maximum distance of 10 km (see Table 4.8; Appendix A).

Less than one common dolphin is predicted to have the potential to experience PTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7). 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 common 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 surveys due to audio and visual cues during movement of the boats. Less than one common dolphin is predicted to have the potential to experience TTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7). Proposed mitigation to further reduce potential for impact is presented in section 4.4.

Risso’s dolphin

Thresholds for at which injury and behavioural disturbance may be induced in HF cetacean species, such as the Risso’s dolphin are described in Table 4.7 and Table 4.9.

The noise assessment (Appendix A) showed that a Risso’s dolphin exposed to subsea noise from the survey equipment would be likely to experience permanent auditory injury at a range of <10 m (based on L_P) or up to 46 m (cumulative SEL). Recoverable auditory injury (TTS) and fleeing response has the potential to occur out to a maximum distances of <10 m or 290 m for L_P or cumulative SEL respectively. Behavioural disturbance has the potential to occur out to a maximum distance of 10 km (see Table 4.8; Appendix A).

Less than one Risso’s dolphin is predicted to have the potential to experience PTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7). 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 Risso’s 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 and geotechnical surveys due to audio and visual cues during movement of the boats. Less than one Risso’s dolphin is predicted to have the potential to experience TTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7). Proposed mitigation to further reduce potential for impact is presented in section 4.4.

Minke whale

The minke whale, a baleen whale, is most sensitive to noise frequencies in the range from 40Hz to 15kHz (Ketten and Mountain, unpublished). Thresholds at which injury and behavioural disturbance may be induced are described in Table 4.7 and Table 4.9.

The noise assessment (Appendix A) showed that a minke whale exposed to underwater noise from the survey equipment may experience permanent auditory injury at a range of <10m for both L_P and cumulative SEL. Recoverable auditory injury (TTS) and fleeing response has the potential to occur out to a maximum distances of <10 m or 1,100 m for L_P and cumulative SEL respectively. Behavioural disturbance has the potential to occur out to a maximum distance of 10 km (see Table 4.9; Appendix A).

Less than one minke whale is predicted to have the potential to experience PTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7). 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 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 audio and visual cues during movement of the boats. Less than one minke whale is predicted to have the potential to experience TTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7). Proposed mitigation to further reduce potential for impact is presented in section 4.4.

Grey seal

Grey seals are likely to be present in the survey area and have an estimated auditory band width of 50Hz to 86kHz. Thresholds at which injury and behavioural disturbance may be induced are described in Table 4.7 and Table 4.9.

The noise assessment (Appendix A) showed that grey seals exposed to underwater noise from the survey equipment may experience permanent auditory injury at a range of <10 m for both L_P and cumulative SEL. Recoverable auditory injury (TTS) and fleeing response has the potential to occur out to a maximum distances of <10 m or 340 m for L_P and cumulative SEL respectively. Behavioural disturbance also has the potential occur out to a range of 10 km as a result of the geophysical survey (Table 4.8; Appendix A).

Less than one grey seal is predicted to have the potential to experience PTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7; Appendix A). 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 grey seal is considered to be negligible. It is likely that animals will be displaced from the area of injury prior to commencement of the geophysical survey due to audio and visual cues during movement of the boats. Less than one grey seal is predicted to have the potential to experience TTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7; Appendix A). Proposed mitigation to further reduce potential for impact is presented in section 4.4.

Harbour seal

Harbour seals are likely to present in the survey area and have the same auditory band width as grey seals of 50Hz to 86kHz. Thresholds at which injury and behavioural disturbance may be induced are described in Table 4.7 and Table 4.9.

The noise assessment (Appendix A) showed that harbour seals exposed to underwater noise from the survey equipment may experience permanent auditory injury at a range of <10 m for both L_P and cumulative SEL. Recoverable auditory injury (TTS) and fleeing response has the potential to occur out to a maximum distances of <10 m or 340 m for L_P and cumulative SEL respectively. Behavioural disturbance also has the potential to occur out to a range of 10 km as a result of the geophysical survey (Table 4.8; Appendix A).

Less than one harbour seal is predicted to have the potential to experience PTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7; Appendix A). 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 seal 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 audio and visual cues during movement of the boats. Less than one harbour seal is predicted to have the potential to experience TTS at any one time within the impact area during the surveys with or without a soft start (Table 4.7; Appendix A). Proposed mitigation to further reduce potential for impact is presented in section 4.4.

Basking shark

The hearing range of basking sharks is not known, however, five other elasmobranchs have been found to have a hearing range between 20Hz to 1kHz with greatest sensitivities at lower frequencies (Mickle *et al.* 2020). Therefore, it is unlikely this species will be affected by the noise produced during these surveys, especially considering there is no evidence of sound causing mortality or stress in this species. In addition, this species is highly mobile and so significant adverse impacts to this species are considered unlikely. Despite the unlikelihood of being affected by noise, JNCC guidelines and best practice still advise to reduce the pressures associated with acoustic surveys, to ensure to the highest degree of confidence that basking sharks are not disrupted (JNCC 2017).

The noise assessment (Appendix A) showed that basking sharks exposed to underwater noise from the survey equipment may experience permanent auditory injury at a range of <10 m whilst TTS could occur out to maximum of 150 m. The behavioural response range of 420 m for basking shark (see Table 6-2 in Appendix A) is relatively low and will be mitigated by the measures (Section 4.4) used to manage PTS injury.

Cumulative Impacts

Cumulative impacts are those which can occur from survey operations occurring over a similar area at the same time, at different times (i.e. if species is still in recovery following TTS), and from numerous simultaneous human activities which produce sound in combination with each other.

The survey is due to take place in the North Channel for 9 to 22 days (allowing for downtime). The North Channel is one of the principal maritime gateways in the UK, contributing to the European Spatial Development Perspectives, and with several important ports nearby it is a busy maritime space. However, since there is no residual risk (following application of mitigation measures) of injury to marine protected species from this survey alone, there is no potential for cumulative injury effects.

Whilst there is a residual behavioural response range of 10 km for marine mammals around the survey operations at any one time, there are no known surveys or other human activities out of the ordinary creating additional underwater noise within this 10 km ZoI. The behavioural disturbance impacts are considered short-term and reversible, so cumulative effects are not considered further in this assessment.

Summary of Risk of Injury and Behavioural Disturbance

Since the risk of injury can be mitigated effectively through the adoption of a 500 m mitigation zone and a 20 minute soft start, see section 4.4), there is considered to be no residual risk to cetacean EPS, protected marine mammals, or basking shark.

For disturbance, it is possible that cetacean EPS, protected marine mammals and basking sharks may experience some limited behavioural effects. These effects are unlikely to result in any significant disturbance or displacement for these species. In addition, it is expected that, since marine mammals are mobile species, they will be able to adapt their behaviour to reduce effects to some extent, for example through avoidance behaviour. However, an EPS Licence is required in respect of this disturbance for the Malin Sea Wind Array Area proposed geophysical survey.

4.4 Mitigation

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.

A 30-minute search to establish the absence of marine mammals and basking shark is required before start of geophysical equipment. Dedicated and experienced marine mammal observers (MMO)/passive acoustic monitoring (PAM) operatives[3] (potentially dual role for PAM) will operate from the vessel bridge during daylight hours as per current JNCC guidelines (JNCC 2017).

Where equipment allows, a 20-minute soft-start period will be employed prior to the start of the survey, during which there will be a gradual build-up (or soft-start) of source power over the 20-minute period with power reduced to 10% of modelled power, 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. Not all the geophysical equipment has soft start capability, however, application of a 20-minute soft start using the sparker SBP and parametric SBP is considered sufficient to cover the full frequency range of the geophysical survey equipment. Therefore, these two devices will be activated first with the remaining equipment activated after the 20-minute soft start period.

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[3] Note, it is a prerequisite that all MMOs working in the UK Continental Shelf (UKCS) have attended a JNCC-approved course. Whilst some MMO courses may include a basic introduction to acoustic detection techniques, dedicated PAM courses are available, and specialist trained PAM operatives are needed to set up and deploy the equipment and to interpret detected sounds. Newly qualified PAM operators are generally not advised to work in isolation (i.e. they are not the sole PAM operative on board a vessel) for their first five PAM jobs. JNCC guidance states that they should work alongside experienced personnel (with a minimum of 20 weeks of experience) who can act as mentors while they gain experience of deploying PAM and implementing the latest guidelines.

The search for absence within 500 m will still commence 30 minutes prior to the commencement of the soft-start thus there will circa 1 hour lead time until the start of acquisition.

For breaks of <10 minutes there is no requirement for soft-start and the survey will recommence at the same level provided no marine mammals/basking shark have been detected in the mitigation zones during the break; and for breaks of >10 minutes the full mitigation procedure (as described above) will be adopted including pre-survey monitoring and soft-start.

PAM provides an opportunity to detect and indicate the location of marine mammal vocalisations at sea relative to a hydrophone 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 such as basking shark. When conditions are optimal, visual MMO searches are considered to be the most effective monitoring method for marine mammals. PAM should be used as a substitute for visual observations when the full extent of the mitigation zone cannot be seen (JNCC, 2023). JNCC Guidance for The Use of Passive Acoustic Monitoring in UK Waters for Minimising the Risk of Injury to Marine Mammals from Offshore Activities (JNCC, 2023) provides further guidance on specific circumstances when PAM should be utilised.

The MMO/PAM operative(s) will monitor an agreed mitigation zone and advise if any marine mammals are present within the zone. If marine mammals are detected, the soft-start should be delayed until their passage and the soft-start should be commenced again once 20 minutes have elapsed since the last sighting in the mitigation zone.

It is standard practice for MMOs to transcribe their deck forms and provide a report to the relevant regulatory body (Marine Scotland/DAERA) and JNCC to encourage assessment of compliance with licence conditions and to ensure the activities minimised the potential for harm. MMO feedback and data improves industry practices and seeks to enhance protection of marine wildlife. The flexibility of the PAM system and ease of deployment/recovery methods will also be considered in relation to existing in-sea equipment 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. If PAM is unavailable and conditions do not permit for successful visual observation, it is generally advised to delay until conditions improve (JNCC, 2023).

It should be noted that PAM in-sea equipment deployment is dependent on operational constraints. PAM will only be deployed when practical during periods of low visibility when MMO visual observation is restricted.. JNCC's 2023 guidance on the use of PAM notes that "*while there are benefits to deploying PAM 24-hours a day, real-time monitoring of detections is only needed during the pre-activity search and soft-start (unless specified otherwise in a consent or licence)"*. The Applicant will advise Marine Directorate Scotland and NatureScot or the Department of Agriculture, Environment and Rural Affairs (DAERA) 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.

5 THREE EPS LICENCING TESTS

5.1 Test 1: Overriding Public Interest

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’.

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 or supporting economic or social development (including nationally important infrastructure development projects and employment).

The Malin Sea Wind Array Area geophysical survey presents 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 does not depend upon the geo-economic and geo-political risks attendant with importing fuels.

The UK has committed to meeting national and international commitments to greenhouse gas (GHG) reduction including the Paris Agreement (2016), which sets out a global action plan towards climate neutrality with the aims of limiting 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 GHGs, including, but not limited to:

- The Climate Change Act 2008, under which the UK committed to a net reduction in GHG emissions of 80% against the 1990 baseline by 2050. Strengthened in 2019[4] to a 100% reduction (net zero) in GHG emissions, with the legal duty extending to the devolved administrations;
- 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 GHG emissions by at least 100% by 2045 from 1990 levels.

As the UK follows these policies and pieces of legislation, additional demands will be placed on domestic electricity supply as use of, for example, electric vehicles, increases. The Malin Sea Wind OWF will provide additional support to the UK government’s national and international commitments to reduce GHG, 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.

The Malin Sea Wind OWF 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 Malin Sea Wind OWF will also provide multiple opportunities of employment over the course of the project’s lifetime.

If the Malin Sea Wind Array Area geophysical survey does not proceed, the progression of the Malin Sea Wind OWF’s 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] Climate Change Act 2008 (2050 Target Amendment) Order 2019

5.2 Test 2: No Satisfactory Alternatives

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

The Malin Sea Wind OWF has been awarded through the INTOG seabed leasing process, run by Crown Estate Scotland, which aimed to attract investment and innovation in OWF projects whilst supporting the decarbonisation of North Sea Oil and gas platforms. Identification and selection of sites for seabed leasing involved extensive modelling and assessment from spatial planning exercise, strategic/environmental impact assessment, technical feasibility (considering factors like water depth, wind resources, and seabed conditions as well as supporting infrastructure and grid connectivity), stakeholder consultations, and economic viability / cost-benefit analysis – with sites chosen that offered a balance between cost-effectiveness and environmental benefits.

At this stage, given that the leasing process in which the Malin Sea Wind OWF was identified involved rigorous assessments, stakeholder engagement, and strategic criteria to identify optimal sites that promote both energy innovation and decarbonization, it is hard to promote any satisfactory alternatives that can meet societal energy demands whilst reducing environmental impacts.

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. This report has aimed to promote best practices that minimise impacts on EPS and protected species to allow the work to be undertaken in an environmentally sound and conscientious manner.

5.3 Test 3: Favourable Conservation Status (FCS)

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*.”

The species baseline information of this report (section 3) has identified five species of cetacean (besides those excluded from assessment due to sparsity of evidence) that have the potential to occur in the vicinity of the Malin Sea Wind Array 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,
- Common dolphin;
- Risso’s dolphin; and
- Minke whale.

The noise modelling assessment (Appendix A) determined that a 10 km behavioural response range remained for marine mammals from non-continuous noise that could not be mitigated for. The aim of this section is to assess the likely impact of this disturbance on the FCS of the above cetaceans.

Harbour Porpoise

The noise modelling assessment (Appendix A) demonstrated that, for VHF cetaceans (without mitigation), one individual has the potential to experience PTS as a result of the proposed geophysical survey, which is equivalent to 0.002 % of the WS population (IAMMWG, 2022). The likelihood of an animal experiencing PTS will be reduced with the implementation of mitigation measures as detailed in section 4.4 (JNCC, 2017). The noise modelling indicated that disturbance could occur out to a distance of up to 10 km, which is equivalent to an area of up to 314 km^2 and has the potential to affect up to 63 harbour porpoise at any one time. This is the equivalent of less than 0.22% of the WS MU.

Given that mitigation measures will be implemented to avoid auditory injury, the remaining behavioural effects are predicted to affect very small numbers of animals in the context of the wider population. As such, the regional 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.

The proposed geophysical survey will be short-term, taking place over a maximum of 22 days and will be carried out over a small area (31.4 km^2), with only a small proportion of that total area affected at any one time in the context of the WS MU. 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 (reported as "Favourable" in the most recent FCS status assessment), 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.

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 habitats available 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.

Bottlenose Dolphin

The noise modelling assessment (Appendix A) demonstrated that, for HF cetaceans (without mitigation), less than one individual has the potential to experience PTS as a result of the proposed geophysical survey, which is equivalent to less than 0.0006 % of the CWSH population. The likelihood of an animal experiencing PTS will be reduced with the implementation of mitigation measures as detailed in section 4.4(JNCC, 2017).

Mitigation measures will be implemented to avoid auditory injury. As noted above, behavioural effects may extend to 10 km for non-impulsive sound resulting in the potential for 13 animals to experience behavioural effects at any one time. The IAMMWG (2022) abundance estimate provided a population estimate of 45 animals, which results in the potential for 29% of the CWSH MU to experience behavioural effects. However, it should be noted that due to the location of the Malin Sea Array Area at the intersection of three MUs, it is likely that animals will move between the MUs and that animals from the other MUs (WCI MU and OCW MU) are likely to be present within the survey area. Using the OWC MU abundance of 70,249 animals, the disturbance range of 10 km has the potential to affect 13 animals which corresponds to 0.01% of the MU population. It should also be acknowledged that these numbers are worst case for non-impulsive sound sources (vessel noise) only, with disturbance from impulsive sound sources being limited to within 0.2 km (see Table 4.9).The non-impulsive threshold (120 dB SPL) can often be lower than ambient noise for coastal waters with some human activity, meaning that ranges determined using this limit will tend to be higher than actual ranges. Also, as the levels are unweighted, the ranges will be dominated by low-frequency noise, therefore for species such as bottlenose dolphin (HF hearing group) this is considered to be outside of their hearing range. In addition, the geophysical surveys will be short-term, taking place over a maximum of 22 days and will be carried out over a small area (31.4 km^2). Although some animals may be disturbed during the survey, animals are expected to return to the area immediately after the surveys have ceased. On this basis, the proposed geophysical surveys are not anticipated to prevent the bottlenose dolphin population from continuing to "maintain itself on a long-term basis as a viable element of its natural habitats", as defined by the first FCS test.

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 population (reported as "Favourable" in the most recent FCS status assessment), 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.

Bottlenose dolphin have been known to exhibit flexibility in their habitat use and therefore any habitat likely to be affected will constitute a very small proportion of the habitat available 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.

Common Dolphin

The noise modelling assessment (Appendix A) demonstrated that, for HF cetaceans without mitigation, less than one individual has the potential to experience PTS as a result of the proposed geophysical survey, which is equivalent to 0.0000006% of the CGNS MU population. 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 0.00003% of the CGNS MU population. The likelihood of an animal experiencing PTS or TTS will be reduced with the implementation of mitigation measures as detailed in section 4.4 (JNCC, 2017).

The underwater noise modelling indicated that disturbance could occur out to a distance of up to a maximum of 10 km over an area of up to 314 km^2 (for non-impulsive sound only) and has the potential to affect up to 17 animals at any one time, representing the equivalent of less than 0.03% of the CGNS MU (IAMMWG 2022). For impulsive sound, disturbance could occur out to a distance of 0.2 km, which has the potential to affect less than one animal at any one time, representing the equivalent of less than 0.00001% CGNS MU (IAMMWG 2022).

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 a very small numbers of animals in the context of the wider population. As such, the CGNS common 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.

The proposed geophysical survey will be short-term, taking place over a maximum of 22 days and will be carried out over a small area (up to 31.4 km^2), with only a small proportion of that total area affected at any one time) in the context of the CGNS MU (IAMMWG, 2022). 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 common dolphin population (reported as "Favourable" in the most recent FCS status assessment), 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.

The common dolphin is a highly mobile and wide-ranging species encountered along the west coast of Scotland, Ireland and to the southwest of England (Reid *et al.*, 2003). Any habitat likely to be affected therefore will constitute a very small proportion of the habitat available 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 common dolphin populations on a long-term basis", will be satisfied.

Risso's Dolphin

The noise modelling assessment (Appendix A) demonstrated that, for HF cetaceans without mitigation, less than one individual has the potential to experience PTS as a result of the proposed geophysical survey, which is equivalent to less than 0.0000002% of the CGNS MU population. 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 0.000008% of the CGNS MU population. The likelihood of an animal experiencing PTS or TTS will be reduced with the implementation of mitigation measures as detailed in section 4.4 (JNCC, 2017).

The underwater noise modelling indicated that disturbance could occur out to a distance of up to a maximum of 10 km over an area of up to 314 km^2 (for non-impulsive sound only) and has the potential to affect less than one animal at any one time, representing the equivalent of less than 0.01% of the CGNS MU (IAMMWG 2022). For impulsive sound, disturbance could occur out to a distance of 0.2 km, which has the potential to affect less than one animal at any one time, representing the equivalent of less than 0.000004% CGNS MU (IAMMWG 2022).

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 Risso's 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.

The proposed geophysical survey will be short-term, taking place over a maximum of 22 days and will be carried out over a small area (up to 31.4 km^2), with only a small proportion of that total area affected at any one time) in the context of the CGNS MU (IAMMWG, 2022). 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 Risso's dolphin population (reported as "Favourable" in the most recent FCS status assessment), 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.

The Risso's dolphin is known to be highly mobile and can travel long distances as illustrated by their presence in all temperate and tropical waters around the world. Any habitat likely to be affected therefore will constitute a very small proportion of the habitat available to the Risso's 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 Risso's dolphin populations on a long-term basis", will be satisfied.

Minke Whale

The noise modelling assessment (Appendix A) demonstrated that, for LF cetaceans without mitigation, less than one individual has the potential to experience PTS as a result of the proposed geophysical survey, which is equivalent to less than 0.00000004% of the CGNS MU population. 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 0.0005% of the CGNS MU population. The likelihood of an animal experiencing PTS or TTS will be reduced with the implementation of mitigation measures as detailed in section 4.4 (JNCC, 2017).

The underwater noise modelling indicated that disturbance could occur out to a distance of up to a maximum of 10 km over an area of up to 314 km^2 (for non-impulsive sound only) and has the potential to affect 4 animals at any one time, representing the equivalent of less than 0.04% of the CGNS MU (IAMMWG 2022). For impulsive sound, disturbance could occur out to a distance of 0.2 km, which has the potential to affect less than one animal at any one time, representing the equivalent of less than 0.00002% CGNS MU (IAMMWG 2022).

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 CGNS 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.

The proposed geophysical survey will be short-term, taking place over a maximum of 22 days and will be carried out over a small area (up to 31.4 km^2), with only a small proportion of that total area affected at any one time) in the context of the CGNS MU (IAMMWG, 2022). 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 (reported as "Favourable" in the most recent FCS status assessment), 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.

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 habitat available 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.

6 CONCLUSION

Table 6.1 provides an overview of the conclusions and associated justifications for which licences are required in both Scottish and Northern Irish territorial waters.

Table 6.1: Licence application conclusions

Relevant licence applications	Relevant legislation	Is a licence being applied for?	Justification
MD-LOT			
EPS licence (inshore waters)	The Conservation (Natural Habitats, &c.) Regulations 1994 (as amended)	Yes	Guidance from Scottish Government (2020) states, where an activity is likely to cause disturbance or injury to an EPS, an EPS licence is required to undertake the activity legally. For non-impulsive sound sources (vessel noise only), disturbance could occur out to a maximum range of 10 km. The Malin Sea Wind Array Area is located entirely within offshore waters (but with a small overlap with possible survey turn lines with Scottish territorial waters); however the 10 km disturbance range would incur a 171.8 km^2 overlap with Scottish inshore waters based upon the Array Area). In the absence of guidance regarding the licensing for an activity in offshore waters that could cause a disturbance in inshore waters, a precautionary approach has been adopted. **Therefore, it is concluded that a licence is required.**
EPS licence (offshore waters)	The Conservation of Offshore Marine Habitats and Species Regulations 2017	Yes	For activities taking place in Scottish waters beyond 12nm (the offshore marine area), The Marine Directorate refers to the JNCC (2010) guidance disturbance effects from these surveys on EPS are considered to qualify as 'trivial disturbance' (as defined by JNCC *et al.* (2010) "sporadic disturbances without any likely negative impact on the animals" as trivial disturbance) and are therefore unlikely to significantly impact the marine animal, or its population status in the wild. Considering this guidance, it is predicted that an EPS licence for Scottish waters beyond 12nm is not required, however due to project related time constraints a precautionary approach has been adopted and a licence application has been completed and submitted to MD-LOT, to avoid delays where feasible. **It is anticipated that a licence will not be required, however a licence application has been completed and submitted to MD-LOT to avoid delays where feasible.**

Relevant licence applications	Relevant legislation	Is a licence being applied for?	Justification
Basking shark licence	Wildlife and Countryside Act 1981	Yes	Guidance from the Scottish Government (2023) states that if an activity taking place in the Scottish Territorial Sea (0-12 nm) is likely to cause to disturbance or injury to basking sharks, a licence is required to undertake activity legally. The Malin Sea Wind Array Area is located outside of Scottish territorial waters (but with a small overlap with possible survey turn lines with Scottish territorial waters), and potential disturbance could extend out to 420 m which would overlap with Scottish territorial waters. In the absence of guidance regarding the licensing for an activity in offshore waters that could cause a disturbance in inshore waters, a precautionary approach has been adopted. **On a precautionary basis, it is concluded that a licence is required.**
Seal licence	Under the Marine (Scotland) Act 2010	No	With the implementation of mitigation measures outlined in section 4.4, the proposed geophysical survey will not "intentionally or recklessly to kill, injure or take any seal". **Therefore, it is concluded that a licence is not required.**
DAERA			
EPS licence	The Conservation (Natural Habitats, etc.) Regulations (Northern Ireland) 1995 (as amended)	Yes	In Northern Irish waters, the potential disturbance effects from these surveys on EPS are considered to qualify as 'trivial disturbance' (as defined by JNCC *et al.* (2010) as "sporadic disturbances without any likely negative impact on the animals") and are therefore unlikely to significantly impact the marine animal, or its population status in the wild. Considering this guidance, it is predicted that an EPS licence for Northern Irish waters is not required, however, due to project related time constraints a precautionary approach has been adopted and a licence application has been completed and submitted to DAERA to avoid delays where feasible. **It is anticipated that a licence will not be required, however a licence application has been completed and submitted to DAERA to avoid delays where feasible.**

Relevant licence applications	Relevant legislation	Is a licence being applied for?	Justification
Wildlife licence	Wildlife (Northern Ireland) Order 1985	Yes	Disturbance from the proposed geophysical survey may occur out to 10 km for seals (non-impulsive sound source) and 420 m for basking shark. A wildlife licence is required if a proposal “could disturb or remove protected wildlife or damage protected resting places in Northern Ireland”. **Therefore, it is concluded that a licence is required.**

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.

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.

The Applicant has sought to demonstrate that, should the Malin Sea Wind Array Area geophysical survey 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 Malin Sea Wind Array Area geophysical survey. Those EPS included harbour porpoise, bottlenose dolphin, common dolphin, Risso’s dolphin and minke whale.

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 small and therefore unlikely to significantly affect the population as a whole. The numbers of bottlenose dolphin potentially disturbed equates to a larger proportion of the CWSH MU, however as outlined above and in section 4.3 , it is considered that this will be lower in reality due to the location of the Malin Sea Array Area (i.e., on the intersection of multiple MUs) and level of precaution built into the underwater noise modelling presented in Appendix A. 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 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.

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Appendix A: Malin Sea Wind Array Area Geophysical Survey Underwater Noise Technical Report

MALIN SEA WIND GEOPHYSICAL SURVEY

UNDERWATER NOISE TECHNICAL REPORT

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Subsea Noise Technical Report
A03
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Approval for issue

Prepared by:

RPS

RPS-Environment

West Pier Business Campus
Dun Laoghaire
Co. Dublin
A96 N6T7

Prepared for:

ESB

<Redacted>
Senior Offshore Ecology Coordinator

One Dublin Airport Central
Dublin Airport
Cloghran,
Co. Dublin
K67 XF72

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Glossary

Term	Meaning
Decibel (dB)	A relative scale most commonly used for reporting levels of sound. The actual sound measurement is compared to a fixed reference level and the "decibel" value is defined to be $10 \cdot \log_{10}$(“actual”/”reference”), where (“actual”/”reference”) is a power ratio. The standard reference for underwater sound pressure is 1 micro-Pascal (µPa), while 20 micro-Pascals is the standard for airborne sound. The dB symbol is often followed by a second symbol identifying the specific reference value (i.e. re 1 µPa).
Grazing angle	A glancing angle of incidence (the angle between a ray incident on a surface and the line perpendicular to the surface).
Permanent Threshold Shift (PTS)	A total or partial permanent loss of hearing caused by some kind of acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the ear, and thus a permanent reduction of hearing acuity.
Temporary Threshold Shift (TTS)	Temporary loss of hearing as a result of exposure to sound over time. Exposure to high levels of sound over relatively short time periods will cause the same amount of TTS as exposure to lower levels of sound over longer time periods. The mechanisms underlying TTS are not well understood, but there may be some temporary damage to the sensory cells. The duration of TTS varies depending on the nature of the stimulus, but there is generally recovery of full hearing over time.
Sound Exposure Level (SEL)	The cumulative sound energy in an event, formally: “ten times the base-ten logarithm of the integral of the squared pressures divided by the reference pressure squared”. Equal to the often seen “L_E” or “dB SEL” quantity. Defined in: ISO 18405:2017, 3.2.1.5
Sound Pressure level (SPL)	The average sound energy over a specified period of time, formally: “ten times the base-ten logarithm of the arithmetic mean of the squared pressures divided by the squared reference pressure”. Equal to the deprecated “RMS level”, “dB_{rms}” and to Leq if the period is equal to the whole duration of an event. Defined in ISO 18405:2017, 3.2.1.1
Peak Level, Peak Pressure Level (L_P)	The maximal sound pressure level of an event, formally: “ten times the base-ten logarithm of the maximal squared pressure divided by the reference pressure squared” or “twenty time the base-ten logarithm of the peak sound pressure divided by the reference pressure, where the peak sound pressure is the maximal deviation from ambient pressure”. Defined in ISO 18405:2017, 3.2.2.1
Source Level (SL)	Here taken to mean the level (SEL/SPL/L_P) at 1 meter range. If not otherwise stated it’s assumed the source is omnidirectional (equal level in all directions). For sources larger than 1 m in radius the Source Level is back-calculated to 1 m.
decidecade	Used to refer to a step in frequency, similar to “one-third-octave”, defined as a ratio of $10^{0.1} \approx 1.259$ (one third octave is 21/3 ≈ 1.260). Used interchangeably with “3rd octave”.

Acronyms

Term	Meaning
ADD	Acoustic Deterrent Device
LF	Low Frequency (Cetaceans)
HF	High Frequency (Cetaceans)
VHF	Very High Frequency (Cetaceans)
MF	Mid Frequency (Cetaceans) – **DEPRECATED** only for reference to NOAA/NMFS 2018 groups
OW/OCW	Otariid pinnipeds/Other Carnivores in water (refers to the same weighting and animal groups)
PW/PCW	Phocid pinnipeds
NMFS	National Marine Fisheries Service
RMS	Root Mean Square
SEL	Sound Exposure Level, [dB]
SPL	Sound Pressure Level, [dB]
L_P	Peak Pressure Level, [dB]
SL	Source Level [dB]
TTS	Temporary Threshold Shift
PTS	Permanent Threshold Shift
SSS	Side scan sonar – Towed sonar device typically positioned 10-15 m above the sediment, main purpose is to characterise the sediment surface texture.
MBES	Multi beam echosounder – Uses multiple narrow beams to measure the depth across a swath below the vessel.
SBP	Sub Bottom Profiler – Any device/system that uses acoustics to record echoes from within the sediment, examples include seismic arrays, sparkers, boomers, chirpers, pingers and associated recorder array.
USBL	Ultra Short Baseline Array – Small array of at least 4 hydrophones and a pinger to measure positions of equipment under water.
UHRS	Ultra High-Resolution Seismic survey – Usually a sparker driven sub bottom characterisation system.
c.	Circa, i.e., approximately

Units

Unit	Description
dB	Decibel (Sound)
Hz	Hertz (Frequency)
kHz	Kilohertz (Frequency)
kJ	Kilojoule (Energy)
km	Kilometre (Distance)
km^2	Kilometre squared (Area)
m	Metre
ms	Millisecond (10^{-3} seconds) (Time)
ms^{-1} or m/s	Metres per second (Velocity or speed)

Unit	Description
kn	Knots (speed), 1 kn = 0.514… m/s, 1 m/s = 1.944 kn
µPa	Micro Pascal
Pa	Pascal (Pressure: newton/m²)
psu	Practical Salinity Units (parts per thousand of equivalent salt in seawater, weight-based)
kg/m³	Specific density (of water, sediment or air)
Z	Acoustic impedance [kg/(m²·s) or (Pa·s)/m³]

Units will generally be enclosed in square brackets e.g.: “[m/s]”

1 INTRODUCTION

This Subsea Noise Technical Report presents the results of a desktop study considering the potential short-term effects of underwater sound on marine animals from the proposed geophysical survey (The Survey), in relation to the Malin Sea Wind project (Proposed Development) Array Area (AA) c. 25-30 km north off the coast of County Londonderry/Derry in Northern Ireland and c. 22 km south-west of Islay in Scotland. The array area covers c. 32 km^2 (c. 8.5 km east-west x 3.8 km south-north). The array area varies in depths from 50 to 160 m, and the surface sediment is medium to fine gravel.

Sound is readily transmitted into the underwater environment and there is potential for the sound emissions from anthropogenic sources to adversely affect the environment. In this document the sound from the Proposed Development is compared to absolute thresholds of received sound by marine mammals and fishes. Near a sound source with high sound levels, permanent or temporary hearing damage may occur, while at a very close range gross physical trauma is possible. At long ranges (several kms) the introduction of any additional sound could cause behavioural changes, changes to the ability of species to communicate and to determine the presence of predators, food, underwater features, and obstructions.

This report provides an overview of the potential effects due to underwater noise from the Proposed Development on the surrounding marine environment based on the Southall et al. 2019 and Popper et al. 2014 frameworks for assessing impact from sound on marine mammals and fishes, focussing on effects related to hearing impact.

Consequently, the primary purpose of the underwater noise assessment is to predict the likely range of onset for potential physiological and behavioural effects due to increased anthropogenic noise as a result of the Proposed Development.

2 ASSESSMENT CRITERIA

2.1 General

To determine the potential spatial range of injury and disturbance, assessment criteria have been developed based on a review of available evidence including national and international guidance and scientific literature. The following sections summarise the relevant assessment criteria and describe the evidence base used to derive them.

Underwater sound has the potential to affect marine life in different ways depending on its sound level and characteristics. Assessment criteria generally separate sound into two distinct types, as follows:

- **Impulsive sounds** which are typically transient, momentary (less than one 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 from sound sources such as seismic surveys, impact piling and underwater explosions.
  Additionally included here are sounds under 1 second in duration with a weighted kurtosis over 40 (see note below*).

- **Non-impulsive** (and continuous) sounds which can be broadband, narrowband or tonal, momentary, brief or prolonged, continuous or intermittent and typically do not have a high peak sound pressure with rapid rise/decay time like impulsive sounds (ANSI 1995; NIOSH 1998).
  This category includes sound from sound sources such as vibro-piling, running machinery, some sonar equipment and vessels. Additionally included here are sounds over 1 second in duration with a weighted kurtosis under 40 (see note below*).

* Note that the European Guidance: "Monitoring Guidance for Underwater Noise in European Seas, Part II: Monitoring Guidance Specifications" (MSFD Technical Subgroup on Underwater Noise, 2014) includes sonar as impulsive sources (see Section 2.2). However, the guidance suggests that *"all loud sounds of duration less than 10 seconds should be included"* as impulsive.
This contradicts research on impact from impulsive sounds suggesting that a limit for "impulsiveness" can be set at a kurtosis[1] of 40 (Martin, et al., 2020).
This latter criterion has been used for classification of impulsive versus non-impulsive for sonars and similar sources. The justification for departing from the MSFD criterion is that the Southall et al. 2019 and the Popper et al. 2014 framework limits are based on the narrower definition of impulsive as given in "**Impulsive sounds**" above.

The acoustic assessment criteria for marine mammals and fish in this report has followed the latest international guidance (based on the best available scientific information), that are widely accepted for assessments in the UK, Europe and worldwide (Popper, et al., 2014; Southall, et al., 2019).

The notable exception is the Irish guidance which currently uses older TTS thresholds set out by Southall et al. in 2007 (Brandon L. Southall, 2007). For comparison, the TTS threshold for the VHF group[2] under

[1] Statistical measure of the asymmetry of a probability distribution.

[2] VHF group chosen as it is the most sensitive group in relation to this assessment.

Southall et al. 2007 is 183 dB SEL (with the 2007 weighting), while the newer, Southall et al. 2019 PTS threshold for the VHF group is 155 dB SEL (with the 2019 weighting).

The Survey takes part wholly inside UK waters and is assessed in line with the relevant guidance for this region (PTS thresholds as given in Southall et al. 2019).

Richardson *et al.* (1995) defined four zones of sound influence which vary with distance from the source and received sound level, to this a fifth zone has been added: the “zone of temporary hearing loss”.

These five zones are:

- **The zone of audibility**: This is defined as the area within which the animal can detect the sound. Audibility itself does not implicitly mean that the sound will affect the animal.

- **The zone of masking**: This is defined as the area within which sound 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 animals detect sound in relation to masking levels (for example, humans can hear tones well below the numeric value of the overall sound level). Continuous sounds will generally have a greater masking potential than intermittent sound due to the latter providing some relative quiet between sounds. Masking only occurs of there is near-overlap in sound and signal, such that a loud sound at e.g., 1000 Hz will not be able to mask a signal at 10,000 Hz[3].

- **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. For most species there is very little data on response, but for species like harbour porpoise there exists several studies showing a relationship between received level and probability of response (Graham IM, 2019; Sarnoci´nska J, 2020; BOOTH, 2017; Benhemma-Le Gall A, 2021).

- **The zone of temporary hearing loss**: The area where the sound level is sufficient to cause the auditory system to lose sensitivity temporarily, causing loss of “acoustic habitat”: the volume of water that can be sensed acoustically by the animal. This hearing loss is typically classified as Temporary Threshold Shift (TTS).

- **The zone of injury / permanent hearing loss**: This is the area where the sound level is sufficient to cause permanent hearing loss in an animal. This hearing loss is typically classified as Permanent Threshold Shift (PTS). At even closer ranges, and for very high intensity sound sources (e.g., underwater explosions), physical trauma or acute mortal injuries are possible.

To determine the potential spatial range of injury and behavioural change, 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.

[3] The exact limit of how near a noise can get to the signal in frequency before causing masking will depend on the receivers auditory frequency resolution ability, but for most practical applications noise and signal frequencies will need to be within 1/3rd octave to start to have a masking effect.

For this study the thresholds associated with permanent hearing loss/permanent threshold shift (PTS) is of primary interest, along with estimates of behavioural impact ranges.

2.2 Thresholds for Marine mammals

Thresholds are based on a dual criteria approach using both un-weighted L_P (maximal instantaneous SPL) and marine mammal hearing weighted SEL. The hearing weighting function is designed to represent the sensitivity for each group within which acoustic exposures can have auditory effects. The categories include:

- **Low Frequency (LF) cetaceans**:
  Marine mammal species such as baleen whales (e.g., minke whale *Balaenoptera acutorostrata*).

- **High Frequency (HF) cetaceans**:
  Marine mammal species such as dolphins, toothed whales, beaked whales and bottlenose whales (e.g., bottlenose dolphin *Tursiops truncatus* and white-beaked dolphin *Lagenorhynchus albirostris*).

- **Very High Frequency (VHF) cetaceans**:
  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) (e.g. harbour porpoise *Phocoena phocoena*).

- **Phocid Carnivores in Water (PCW)**:
  True seals, earless seals (e.g., harbour seal *Phoca vitulina* and grey seal *Halichoreus grypus*); hearing in air is considered separately in the group PCA.

- **Other Marine Carnivores in Water (OCW)**:
  Including otariid pinnipeds (e.g., sea lions and fur seals), sea otters and polar bears; air hearing considered separately in the group Other Marine Carnivores in Air (OCA).

- **Sirenians (SI)**:
  Manatees and dugongs. This group is only represented in the NOAA guidelines.

The weightings are shown in Figure 2-1. It should be noted that not all the above categories of marine mammal will be present in the area relevant to the Proposed Development, but all criteria are presented in this report for completeness.

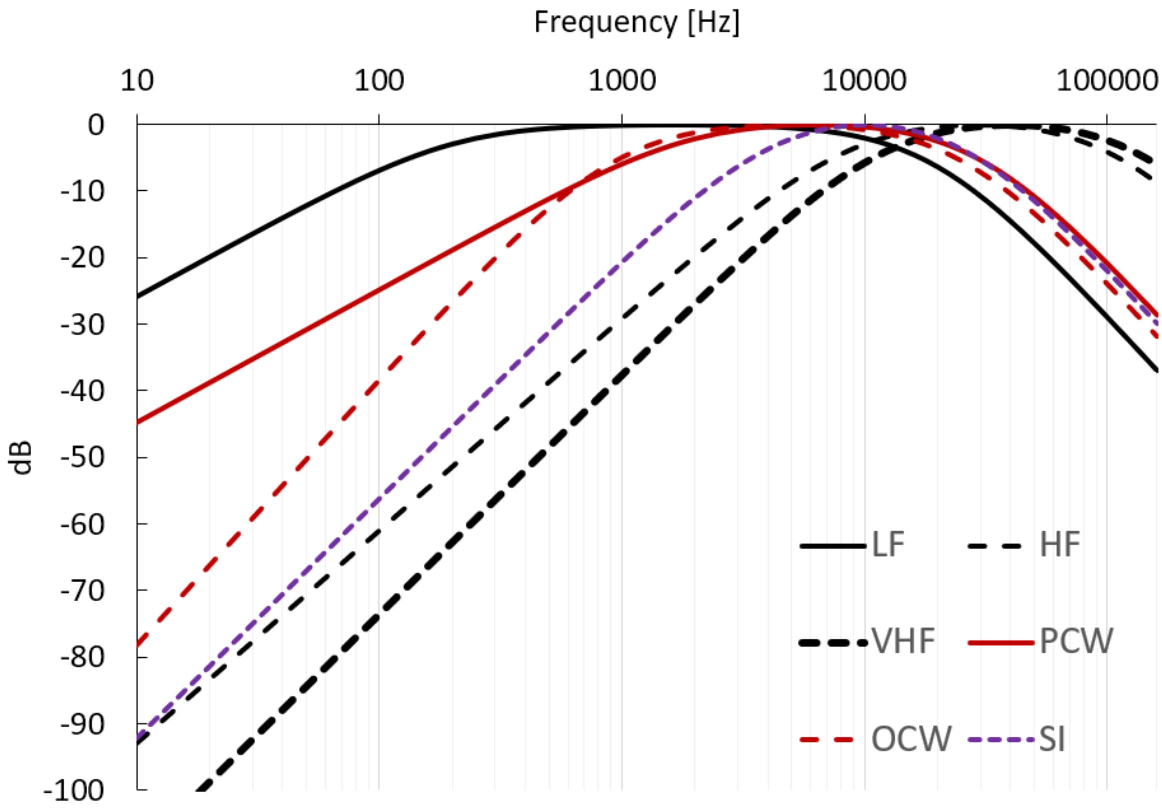

Figure 2-1. Hearing weighting functions for marine mammals (Southall *et al*., 2019).

Both the criteria for impulsive and non-impulsive sound are relevant for this study given the nature of the sound sources used during the The Survey. The relevant PTS and TTS thresholds proposed by Southall *et al*. (2019) are summarised in Table 2-1.

Table 2-1: PTS and TTS onset acoustic thresholds (Southall *et al., 2019*; Tables 6 and 7)

Hearing Group	Parameter	Impulsive [dB]		Non-impulsive [dB]	
		PTS	TTS	PTS	TTS
Low frequency (LF) cetaceans	L_P, (unweighted)	219	213	-	-
	SEL, (LF weighted)	183	168	199	179
High frequency (HF) cetaceans	L_P, (unweighted)	230	224	-	-
	SEL, (MF weighted)	185	170	198	178
Very high frequency (VHF) cetaceans	L_P, (unweighted)	202	196	-	-
	SEL, (HF weighted)	155	140	173	153
Phocid carnivores in water (PCW)	L_P, (unweighted)	218	212	-	-
	SEL, (PW weighted)	185	170	201	181
Other marine carnivores in water (OCW)	L_P, (unweighted)	232	226	-	-
	SEL, (OW weighted)	203	188	219	199
Sirenians (SI) (NOAA only)	L_P, (unweighted)	226	220	-	-
	SEL, (OW weighted)	190	175	206	186

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 2-2.

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 2-2: Comparison of Hearing Group Names between NMFS (2018) and Southall *et al.* (2019)

NMFS (2018) hearing group name	Southall *et al*. (2019) hearing group name
Low-frequency cetaceans (LF)	LF
Mid-frequency cetaceans (MF)	HF
High-frequency cetaceans (HF)	VHF
Phocid pinnipeds in water (PW)	PCW
Otariid pinnipeds in water (OW)	OCW
Sirenians (SI)	Not included

2.3 Disturbance to Marine Mammals

Disturbance thresholds for marine mammals are summarised in Table 2-3. Note that the non-impulsive threshold can often be lower than ambient sound for coastal waters with some human activity, meaning that ranges determined using this threshold will tend to be higher than actual ranges. However, the levels are unweighted and ranges to threshold will be dominated by low-frequency sound, which for most hearing groups is outside their hearing range. For hearing groups with lower limits this can mean that their range to TTS/PTS is *larger* than the range to the behavioural threshold, e.g., the PTS threshold for impulsive sound for the VHS group is 155 dB SEL, while the behavioural threshold is 160 dB SPL. For a typical scenario, for 1 second's exposure (SEL compares directly to SPL) that means the range the range to the behavioural threshold will be c. twice the range to the PTS threshold (a difference of 5 dB). This is just one of the reasons why this behavioural threshold should be interpreted with caution.

Table 2-3: Disturbance Criteria for Marine Mammals Used in this Study based on Level B harassment of NMFS (National Marine Fisheries Service, 2005)

Effect	Non-Impulsive Threshold	Impulsive Threshold
Disturbance (all marine mammals)	120 dB SPL	160 dB SEL $_{single\ impulse}$ or 1-second SEL

2.4 Injury and Disturbance to Fish and Sea Turtles

The injury criteria used in this noise assessment are given in Table 2-4 and Table 2-5 for impulsive sounds and continuous sound respectively. L_P and SEL criteria presented in the tables are unweighted. Physiological effects relating to injury criteria are described below (Popper, et al., 2014):

- **Mortality and potential mortal injury**: either immediate mortality or tissue and/or physiological damage that is sufficiently severe (e.g., a barotrauma) that death occurs sometime later due to decreased fitness. Mortality has a direct effect on animal populations, especially if it affects individuals close to maturity.

- **Recoverable injury ("PTS" in tables and figures)**: Tissue damage and other physical damage or physiological effects, that are recoverable, but which may place animals at lower levels of fitness, may render them more open to predation, impaired feeding and growth, or lack of breeding success, until recovery takes place.

The PTS term is used here to describe this, more serious impact, even though it is not strictly permanent for fish. This is to better reflect the fact that this level of impact is perceived as serious and detrimental to fish.

- **Temporary Threshold Shift (TTS)**: Short term changes (minutes to few hours) in hearing sensitivity may, or may not, reduce fitness and survival. Impairment of hearing may affect the ability of animals to capture prey and avoid predators, and cause deterioration in communication between individuals, affecting growth, survival, and reproductive success. After termination of a sound that causes TTS, normal hearing ability returns over a period that is variable, depending on many factors, including the intensity and duration of sound exposure.

Popper et al. 2014 does not set out specific TTS thresholds for L_P and disturbance thresholds for impulsive sound for fishes. Therefore publications: "Washington State Department of Transport Biological Assessment Preparation for Transport Projects Advanced Training Manual" (WSDOT, 2011) and "Canadian Department of Fisheries and Ocean Effects of Seismic energy on Fish: A Literature review" (Worcester, 2006) on effects of seismic sound on fish are used to determine thresholds for these:

- The criteria presented in the Washington State Department of Transport Biological Assessment Preparation for Transport Projects Advanced Training Manual (WSDOT, 2011). The manual suggests an un-weighted sound pressure level of 150 dB SPL (assumed to be duration of 95 % of energy) as the criterion for onset of behavioural effects, based on work by (Hastings, 2002). Sound pressure levels in excess of 150 dB SPL are expected to cause temporary behavioural changes, such as elicitation of a startle response, disruption of feeding, or avoidance of an area. The document notes that levels exceeding this threshold are not expected to cause direct permanent injury but may indirectly affect the individual fish (such as by impairing predator detection). It is important to note that this threshold is for onset of potential effects, and not necessarily an ‘adverse effect’ threshold. The threshold is implemented here as either single impulse SEL or 1 second SEL, whichever is greater.

- The report from the Canadian Department of Fisheries and Ocean “Effects of Seismic energy on Fish: A Literature review on fish” (Worcester, 2006) found large differences in response between experiments. Onset of behavioural response varied from 107-246 dB L_P , the 10^{th} percentile level for behavioural response was 158 dB L_P.

Given the large variations in the data, we have rounded the value to 160 dB L_P as the behavioural threshold for fishes for impulsive sound, and 150 dB SPL for non-impulsive sound.

Table 2-4: Criteria for onset of injury to fish and sea turtles due to impulsive sound

Type of animal	Unit	Mortality and potential mortal injury [dB]	Recoverable injury (PTS) [dB]	TTS [dB]	Behavioural [dB]
Fish: no swim bladder (particle motion detection)	SEL	219[1]	216[1]	186[1]	150[3]
	L_P	213[1]	213[1]	193[2]	160[2]
Fish: where swim bladder is not involved in hearing (particle motion detection)	SEL	210[1]	203[1]	186[1]	150[3]
	L_P	207[1]	207[1]	193[2]	160[2]
Fish: where swim bladder is involved in hearing (primarily pressure detection)	SEL	207[1]	203[1]	186	150[3]
	L_P	207[1]	207[1]	193[2]	160[2]
Sea turtles	SEL	210[1]	(*Near*) High (*Intermediate*) Low (*Far*) Low	-	-
	L_P	207[1]		-	-
Eggs and larvae	SEL	210[1]	(*Near*) Moderate (*Intermediate*) Low (*Far*) Low	-	-
	L_P	207[1]		-	-

[1] (Popper *et al.*, 2014)
[2] (Worcester, 2006)
[3] (WSDOT, 2011)

Where Popper et al. 2014 present thresholds as “>” 207 or “>>” 186, we have ignored the “greater than” and used the threshold level as given.

Relevant thresholds for fishes relating to PTS, TTS, and behaviour are given in Table 2-5. Note that for the behaviour threshold we have used the impulsive threshold as basis for the continuous sound threshold, in absence of better evidence.

Table 2-5: Criteria for fish due to non-impulsive sound from Popper *et al*., 2014.

Type of animal	Unit	Mortality and potential mortal injury	Recoverable injury (PTS) [dB]	TTS [dB]	Behavioural [dB]
All fishes	SEL	-	222	210	150 [SPL]*

*This is based on the impulsive criteria.

3 METHOD, ENVIRONMENT & SITE

The following section is based on the information given in the document "Malin Sea Wind Marine Wildlife Licensing Scope_Updated.pdf", created 2023-12-11, as well as written communication with the client and their representatives.

3.1 Array Area

The array area covers c. 32 km² of the sea 25-30 km north of the coast of county Londonderry/Derry and c. 22 km south -west of Islay in Scotland. Depths are generally from 50 to 140 m (Figure 3-1) with the surface sediment being mainly medium gravel to fine gravel.

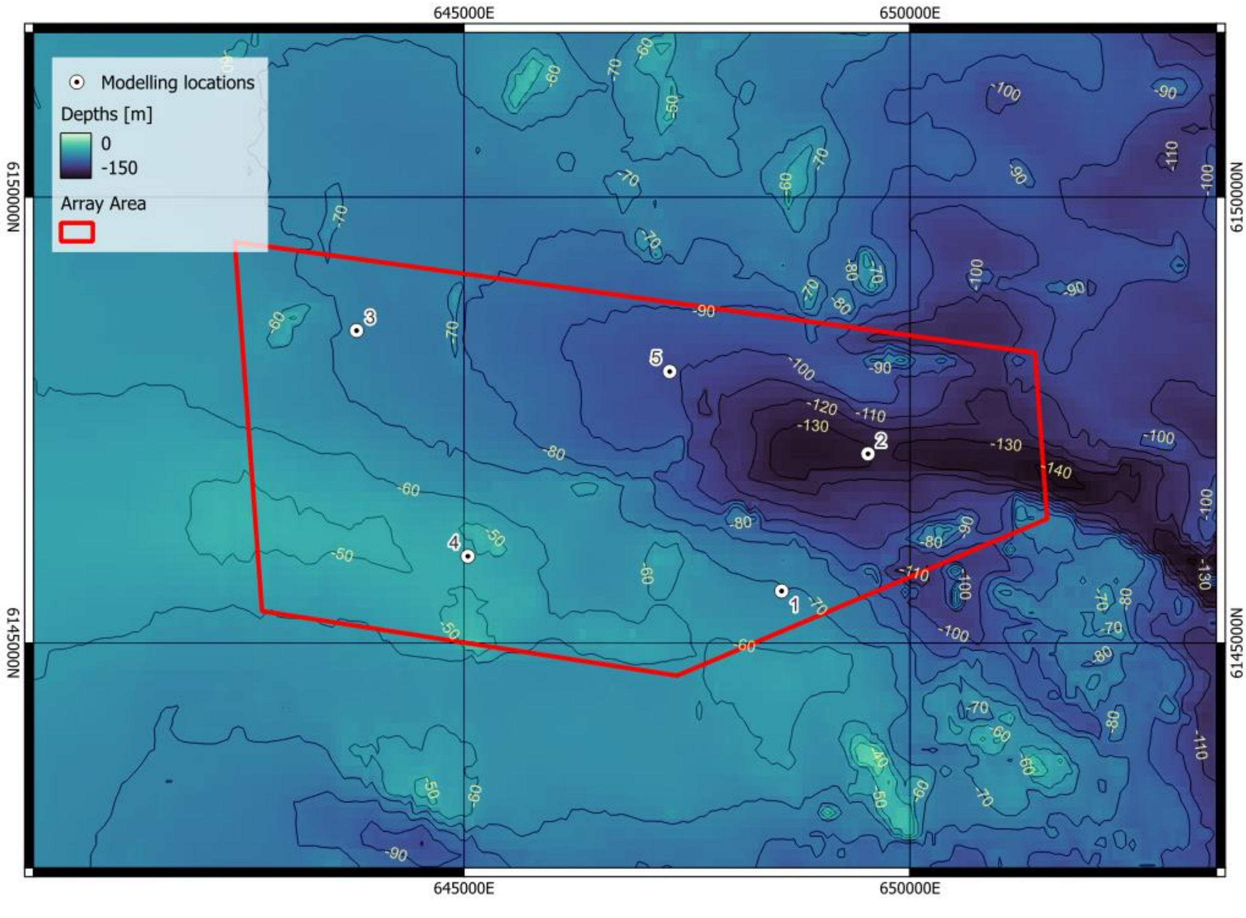

Figure 3-1. The Array Area (red line) and modelled locations (points). Background map: EMODnet Bathymetry (European Commision, 2024).

3.2 Survey Method

The proposed survey is a geophysical survey, focussed on characterising the structure of the seabed and underlying layers, through use of sonar equipment relying on reflected sound.

The survey vessel will travel at a suitable speed while surveying limited by the acquisition rate of the equipment, here assumed to be 5 kn = 2.5 m/s.

Representative survey equipment is presented in Table 4-1, with the modelled source being the combination of all active sources during the survey (band-wise logarithmic sum).

Further details on the expected equipment to be used (or representative equipment) can be found in Section 4, “Source Sound Levels”.

3.3 Source locations

Modelling was based on locations within the array area selected in a guided randomized way to ensure good spatial spread and representation of all conditions present[4] in the array area (Table 3-1):

Table 3-1: Modelled source locations

Site	Sediment type [Folk/ISO]	Depth [m]	Source easting (UTM 29N)	Source Northing (UTM 29N)
1	Gravel/medium gravel	70	648556	6145578
2	Gravel/medium gravel	131	649524	6147116
3	sandy Gravel/fine gravel	72	643791	6148499
4	sandy Gravel/fine gravel	51	645038	6145968
5	sandy Gravel/fine gravel	99	647301	6148039

3.4 Water Properties

Water properties were determined from historical data for the area. Where a range of values are expected, the value leading to the lowest transmission loss was chosen for a more conservative assessment. This also covers seasonal variation.

- Temperature: 13 degrees – maximal temperature given by Met Eireann for the north Irish Sea[5].
- Salinity: 35 psu.
- Soundspeed profile: Assumed uniform given high mixing as a result of tidal flows. A uniform soundspeed profile is conservative compared to the likely downward refracting soundspeed profiles seen during summer months, causing increased loss to the sediment (higher temperature in the surface leads to higher soundspeeds).

[4] Using GIS with criteria for minimal distance between points and representation of all sediment types and depths.

[5] https://www.met.ie/climate/average-monthly-sea-temperature-at-malin-head/

3.5 Sediment Properties

Sediment properties are taken from EMODnet[6] "Folk 16-class Classification", nautical charts[7] and British Geological Survey (British Geological Survey, 2023). A sediment model (Ainslie, 2010) was used to derive the acoustic properties of the sediments from the grain size.

Table 3-2: Sediment properties

Site	Sediment type (Folk 16)	ISO 14688-1:2017	Density [kg/m³]	Soundspeed [m/s]	Grain size [mm] (nominal)
1	Gravel	Medium gravel	2967	2224	11.2
2	Gravel	Medium gravel	2967	2224	11.2
3	sandy Gravel	Fine gravel	2657	2065	3.55
4	sandy Gravel	Fine gravel	2657	2065	3.55
5	sandy Gravel	Fine gravel	2657	2065	3.55

[6] https://emodnet.ec.europa.eu/ sediment model "Folk 7-class" classification.

[7] https://fishing-app.gpsnauticalcharts.com/i-boating-fishing-web-app/fishing-marine-charts-navigation.html

4 SOURCE SOUND LEVELS

Underwater sound sources are usually quantified in dB scale with values generally referenced to 1 μPa pressure amplitude as if measured at a hypothetical distance of 1m from the source (called the Source Level). In practice, it is not usually possible to measure at 1m from a source, but the 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 1m from the acoustic centre does not exist, and source levels "at 1 m" will be higher than any level observed in the real world as the energy is distributed across the source and is not emitted from single point. Therefore, the stated sound pressure level at 1 m does not 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 back-calculated source level (SL).

4.1 Source models

The sound sources and activities investigated during this assessment are summarised in Table 4-1. Source locations are given in Table 3-1.

Note that source levels vary depending on the location of The Survey due to two factors:

1. The ping rate, and therefore the SPL and SEL of the sound source varies with the local depth.

2. Due to differences in sediment, the angle at which the sediment will tend to reflect sound back into the water column efficiently, changes. As we use this information to derive practical source levels for highly directional sources, this will change with sediment type.

Sonars and echosounder generally use tone pulses of either constant frequency or as a frequency sweep, these pulses are typically windowed to limit "spectral leakage[8]". We assume use of a Von Hann window (sometimes "Hanning") which gives effective attenuation of frequencies outside the intended frequencies. This means that while a sonar with centre a frequency of 200 kHz is well above the hearing range of any mammal, there will be energy at 100 kHz c. 50 dB lower than the source level at 200 kHz. This is accounted for in the assessment.

Highly directional sources with narrow beams (sonars and echosounders) will tend to ensonify only a narrow cone of water at any given time. For multibeam echosounders or side scan sonars the beam(s) sweeps though the water, side to side, to get wider sediment coverage. For this type of sonar, we have converted the source to an omnidirectional source with the same acoustic energy as the original but represented as an omnidirectional source (think of a torch illuminating only a small spot on a beach ball, compared to the same light spread all over the surface). This simplifies the calculation process (but yields identical results) and means that we account for the probabilistic nature of an animal being "ensonified" by the source.

For beams only directed vertically down, such as subbottom profilers we account for the directivity in the beam as well as the ability of the sediment to reflect the sound emitted, so that we can account for the fact that primarily a narrow cone directly below the source is ensonified with high sound levels, and also that a significant attenuation occurs in the sediment where sound enters at steep angles. In practice we

[8] Acoustic phenomenon where a sharp change in pressure produces sound in a wide frequency range (similar to an ideal impulse) outside the intended frequencies.

use the angle with the highest level after accounting for directivity combined with sediment loss to a range of 100 m.

4.1.1 Vessel

The R/V Celtic Explorer, travelling at 5 kn, is assumed to be representative for a suitable vessel for carrying out the geophysical survey, with research/survey vessels up to 80 m long being within the bounds of this model. Broadband level of the vessel is 177 dB SPL with decidecade band levels given in Figure 4-1 (maximal band level is 167 dB SPL at the 40 Hz band). Smaller vessels will have lower emitted levels and are thus covered by this assessment.

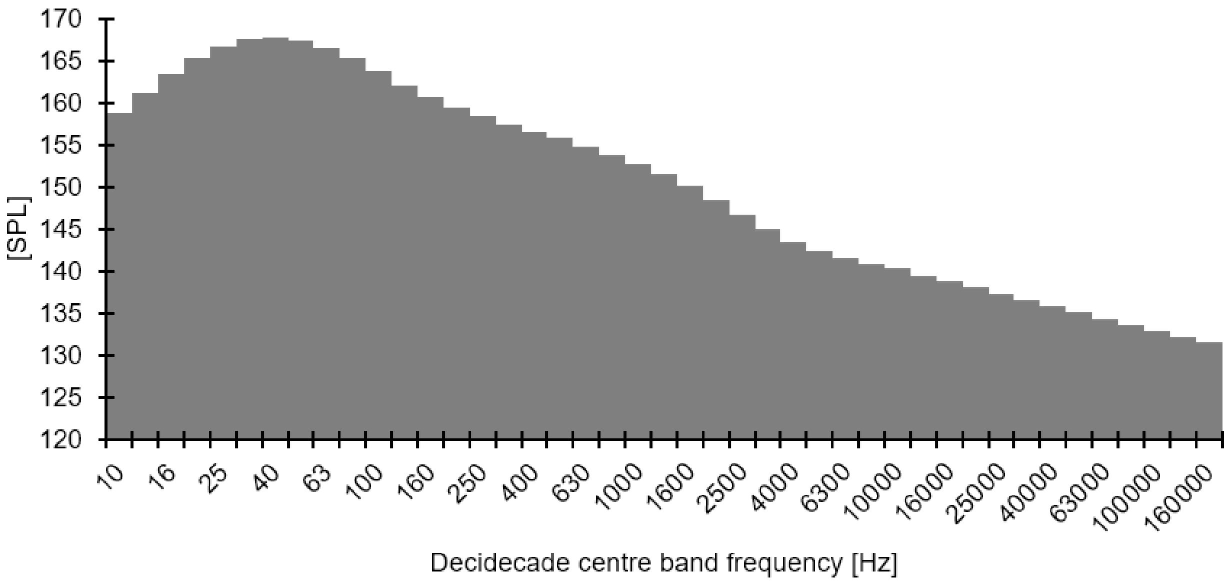

Figure 4-1. Vessel source band levels. Broadband level: 177 dB SPL. Based on the R/V Celtic Explorer travelling at 5 kn.

4.1.2 Side Scan Sonar (SSS)

No specific model of side scan sonar (SSS) has been determined for The Survey, except for specification of the equipment being dual-frequency and with nominal frequencies at 200 kHz and 900 kHz. To address this uncertainty a generic SSS model has been generated from seven commonly used SSS systems (from EdgeTech, C_MAX and Klein Systems). We have used the 90th percentile level as the representative level. In-beam levels for this source is 203 dB SPL, while the equivalent spherical broadband level is 158 dB SPL (Figure 4-2). This difference is due to the very narrow beams of SSS systems (0.5-2 degrees) which means that while the sound level is high in the beam, the mean sound level in a surrounding sphere is much smaller.

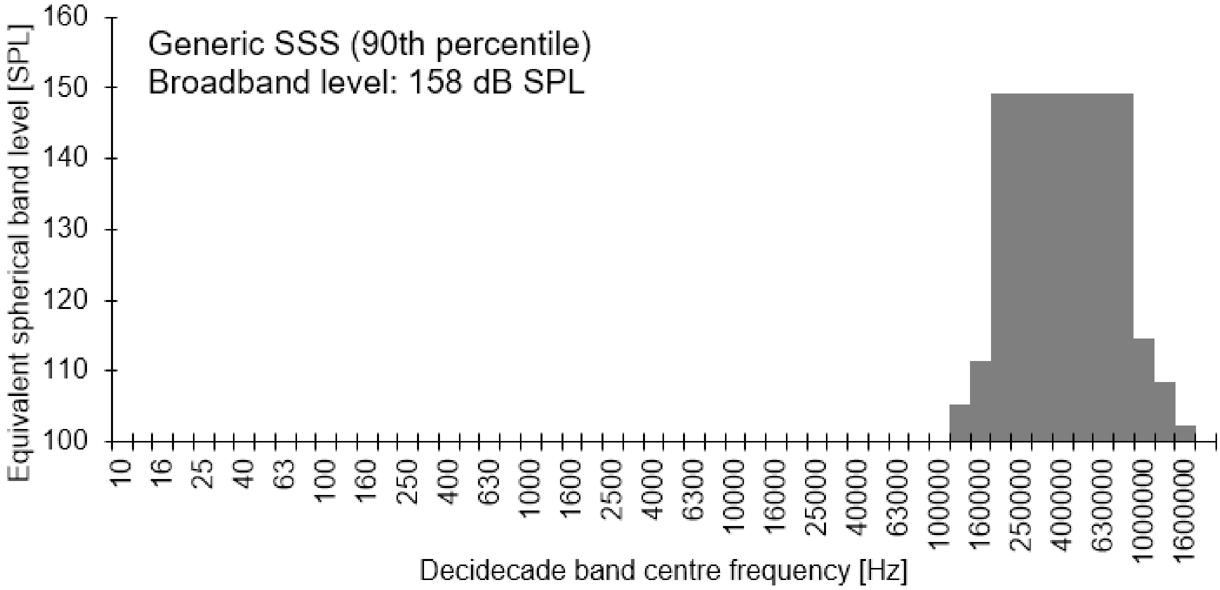

Figure 4-2. SSS source band levels as equivalent spherical/omnidirectional levels.

4.1.3 Multibeam Echosounder (MBES)

No specific model of multibeam echosounder (MBES) has been specified for The Survey, except for the requirement for a dual head, min 40 Hz ping rate and nominal frequencies from 200 kHz to 400 kHz. To address this uncertainty a generic MBES model has been generated from 23 commonly used MBES systems (from Reason Teledyne, R2 Sonic & Kongsberg). We have used the 90th percentile level as the representative level. In-beam levels for this source is 238 dB SPL, while the equivalent spherical level is 194 dB SPL. Band levels are presented in Figure 4-3.

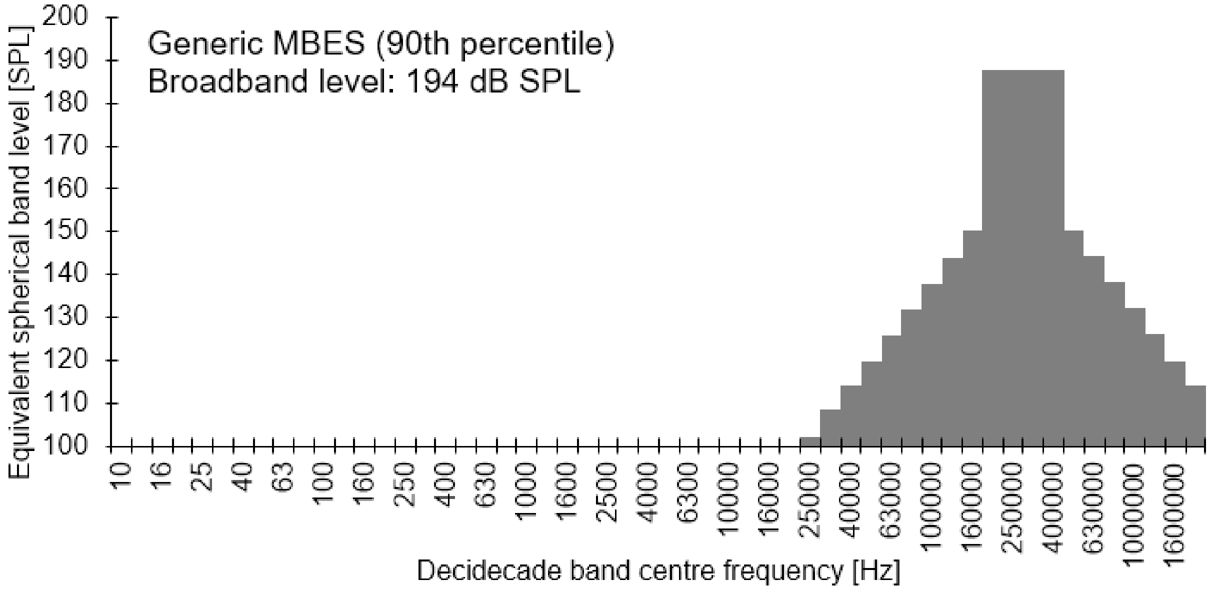

Figure 4-3. MBES source band levels as equivalent spherical/omnidirectional levels.

4.1.4 Parametric Sub-bottom Profiler (P-SBP)

The Survey intends to use the Innomar SES 2000 "parametric" sub-bottom profiler, meaning it uses two higher frequencies ("primary frequencies") to generate an interference pattern at lower frequencies ("secondary frequencies"). This means that the secondary beam can be made extraordinarily narrow, leading to a much smaller sound impact (Figure 4-4**)**. We account for these differences in beam pattern by including the sediment reflection loss at high incidence angles (see APPENDIX A, Figure 8-3) to reduce the effective source level accordingly.

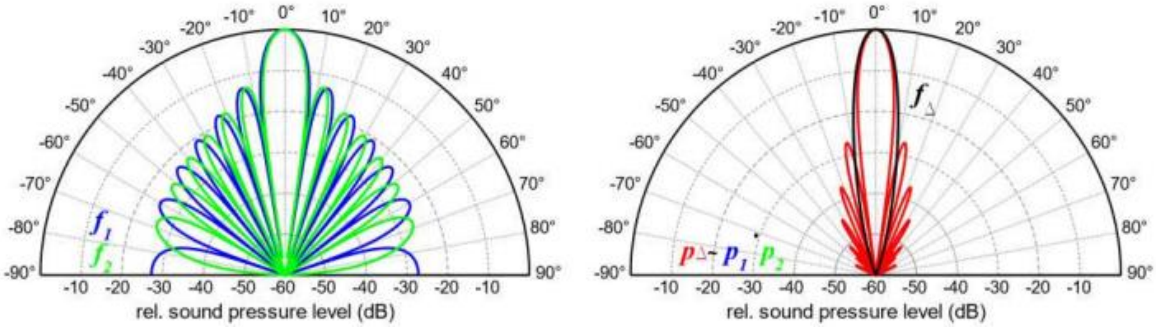

Figure 4-4. Example of a beam pattern on an Innomar SES 2000. Primary frequencies left (f1 & f2), the interference pattern between the primary frequencies means that the beam pattern for the secondary frequency (right plot) is very narrow (Source: Innomar technical note TN-01).

The source level for the P-SBP is split into two regions according to the nominal frequencies, accounting for some spectral leakage (Figure 4-5) and assuming the full range of frequencies is used during The Survey (a conservative assumption).

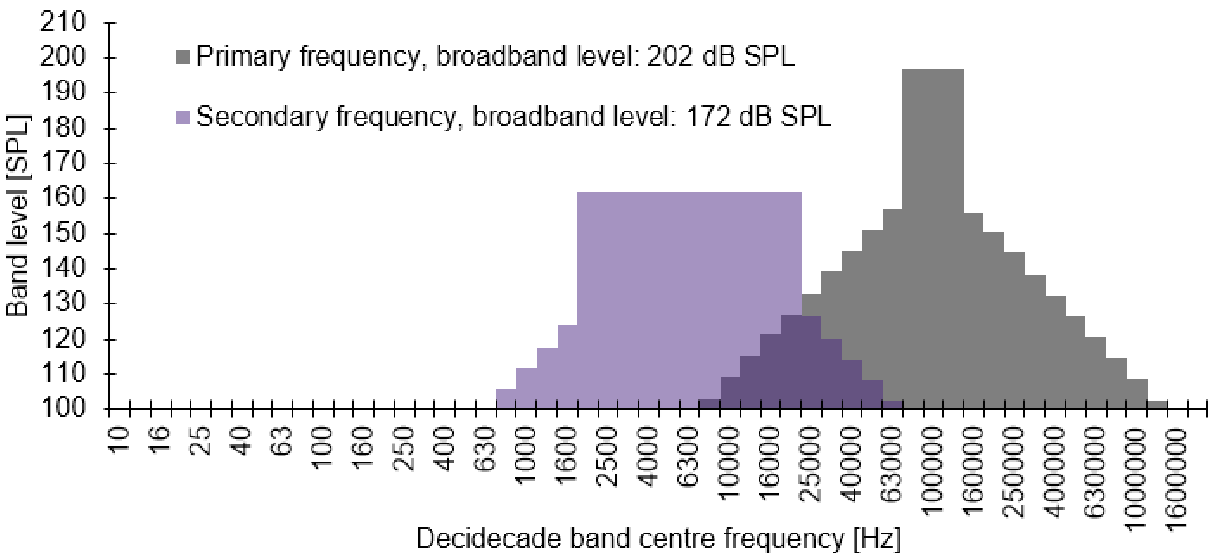

Figure 4-5. Parametric subbottom profiler source band levels as equivalent spherical/omnidirectional levels. Primary frequencies 85 kHz – 115 kHz, secondary frequencies 2 kHz – 22 kHz.

4.1.5 Sparker Sub-bottom Profiler (S-SBP)

No specific model for the UHRS (Ultra High-Resolution Seismic survey) has been specified, so a suitable model for the depths at the array area was based on the maximal depth (140 m) and the 1-20 kHz frequency range given. Energies are modelled to 1000 Joules and a 400-tip arrangement.

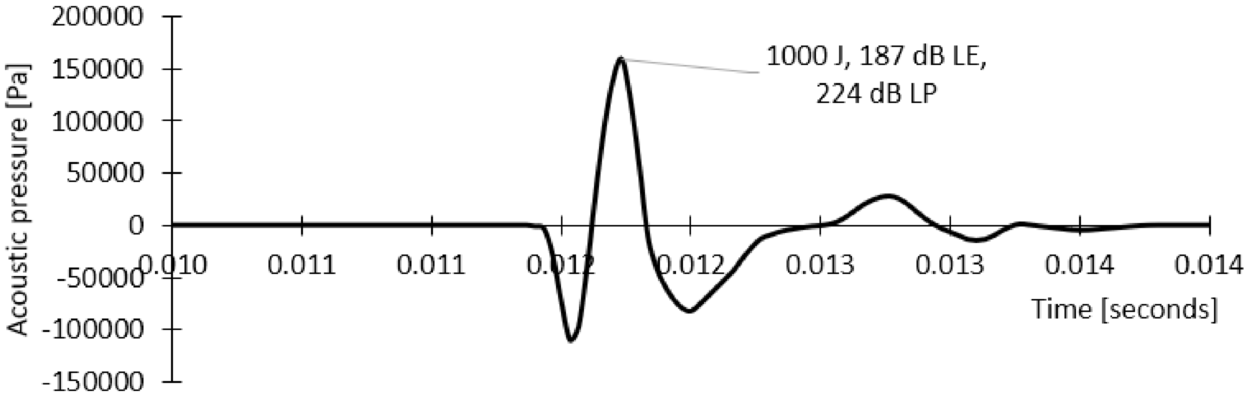

Figure 4-6. Example of typical waveform for a sparker

The single shot SEL for the sparker is 187 dB $SEL_{single\ shot}$ and peak level is 224 dB L_P (Figure 4-6). The broadband level is 185 dB SPL when firing once per second. Band levels outside the 200-5000 Hz range were extrapolated to match published information (Figure 4-7).

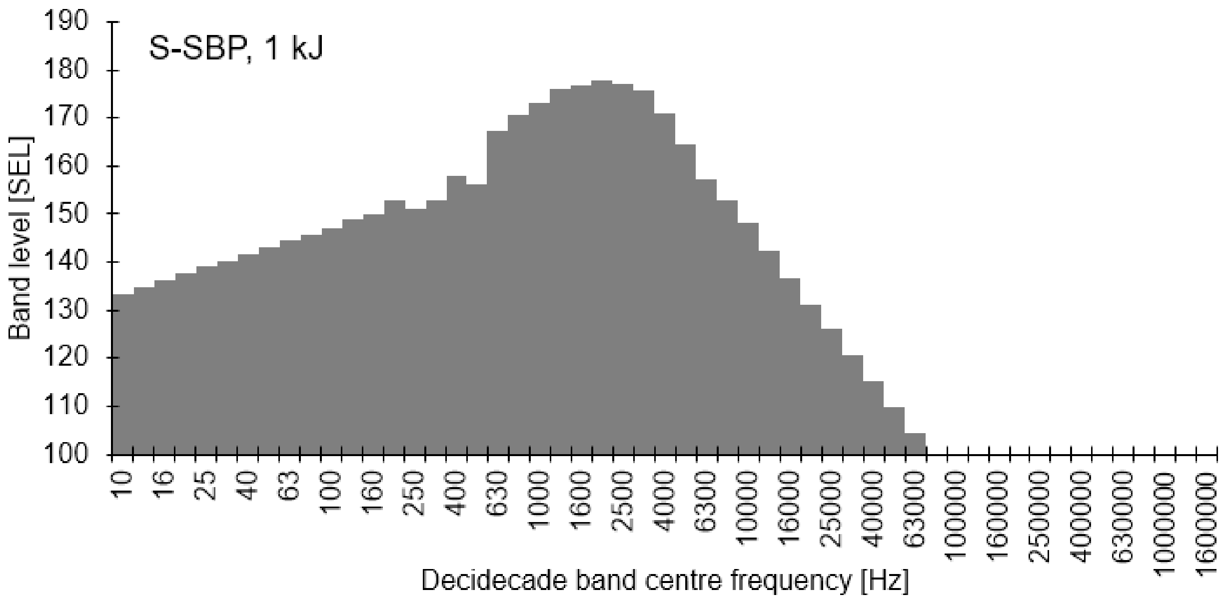

Figure 4-7. Sparker (UHRS) typical single shot band levels as SEL.

4.1.6 Altimeter (possible equipment)

To obtain accurate altitude measurements for deployed equipment (SSS or magnetometer), a separate altimeter can be used on-board the deployed equipment. Altimeters typically have a nominal output frequency at 500 kHz, which means that even with considerable spectral leakage there will be insignificant energy at frequencies relevant to marine life.

4.1.7 Ultra short baseline (USBL)

The USBL (Ultra Short Baseline positioning system) source is based on the “Sonardyne Ranger” and “Sonardyne Mini Ranger 2”. With a broadband SPL of 180 dB in the frequency range 20 kHz – 34 kHz.

4.2 Combined Sound Source

The sound sources described in Section 4.1 were added logarithmically to produce a “combined” sound source that represents the survey vessel’s sound signature while actively surveying during the survey. Decidecade band levels are presented in Figure 4-8. This combined source has all levels given as SPL, meaning impulsive source have been converted from single impulse SEL to SPL given the impulse repetition rate as given by the local depths.

Table 4-1: Summary of Sound Sources and Activities Included in the Subsea Noise Assessment

Equipment	Source level [SPL] (as used in model)	Primary decidecade bands (-20 dB width)	Source model details	Impulsive/non-impulsive
Survey vessel (based on “quiet” vessel)	177 dB SPL	10-2000 Hz	Based on RV Celtic explorer travelling at 5 kn (details in section 4.1.1)	Non-impulsive
Side scan sonar	158 dB SPL (equivalent spherical level)	200 kHz & 800 kHz	Based on the 90th percentile level from popular SSS models	Impulsive
Multibeam echosounder (Reson Seabat T51R & Kongsberg EM 2040-4 MKII or equivalent)	194 dB SPL (equivalent spherical level)	200 kHz – 400 kHz	Model based on frequency modulated tone bursts, but representative for constant frequency tone bursts, von Hann window, ping rate determined by local depth.	Impulsive
Parametric sub-bottom profiler (Innomar SES 2000)	Primary: 202 dB SPL Secondary: 172 dB SPL	85 kHz – 115 kHz & 4 kHz – 15 kHz	Manufacturer. Model based on frequency modulated tone bursts, but representative for constant frequency tone bursts, von Hann window, ping rate determined by local depth. Source level used for modelling adjusted for	Impulsive

Equipment	Source level [SPL] (as used in model)	Primary decidecade bands (-20 dB width)	Source model details	Impulsive/non-impulsive
			beam pattern and local sediment properties.	
Sparker type sub-bottom profiler	185 dB SPL	630 – 5000 Hz	Model based on similar sources.	Impulsive
Ultra Short Baseline (USBL) positioning system	180 dB SPL	19,000 – 34,000 Hz	Manufacturer. 3 x 8 ms pulses per second.	Impulsive

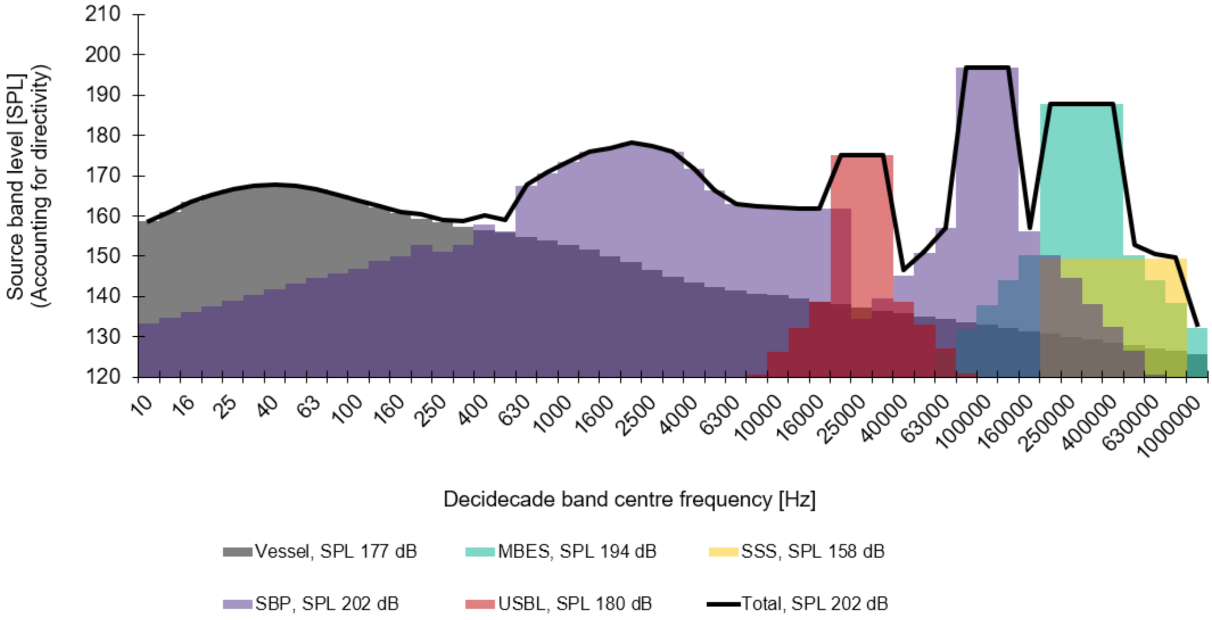

Figure 4-8. Overview of sound sources as SPL at 1 m. Combined source (black solid line) represents source during active survey.

The vessel is assumed to move at 5 knots during the surveying (limited by the temporal resolution of the survey equipment).

The maximal impulsive sound generated by any of the considered sources (after accounting vertical directivity) is the sparker type SBP with a peak pressure level of 224 dB L_P (section 4.1.5).

5 SOUND PROPAGATION MODELLING METHODOLOGY

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 $10 \cdot \log_{10}$(range) or $20 \cdot \log_{10}$(range) relationship 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 (e.g., (Rogers, 1981; Weston, 1971)).

5.1 Semi-empirical models

For simpler scenarios where the sediment is relatively uniform and mostly flat or where greater detail in modelling is not warranted, due to uncertainty in model input or where the source level is relatively low compared to the receiver sensitivity, the speed of these simpler models is preferred over the higher accuracy of numerical models and are routinely used for these types of assessments. For this assessment we have used the "Rogers'" model (Rogers, 1981). This produces very similar output to the also regularly applied "Weston" model (Weston, 1971), but Roger's produces a smoother transition between spherical/cylindrical spreading, mode-stripping and single mode regions of the loss and would normally be preferred unless comparing to earlier work done using the Weston model. Both models are compared to measurements in the papers describing them and are both capable of accurate modelling in acoustically simpler scenarios[9]. We have presented a comparison between Rogers' and Weston's model here for a 30m deep scenario to show the similarities in the transmission losses they predict. We prefer the Rogers' model as it is more conservative for lower frequencies, as it does not have "sharp" steps between different propagation regions.

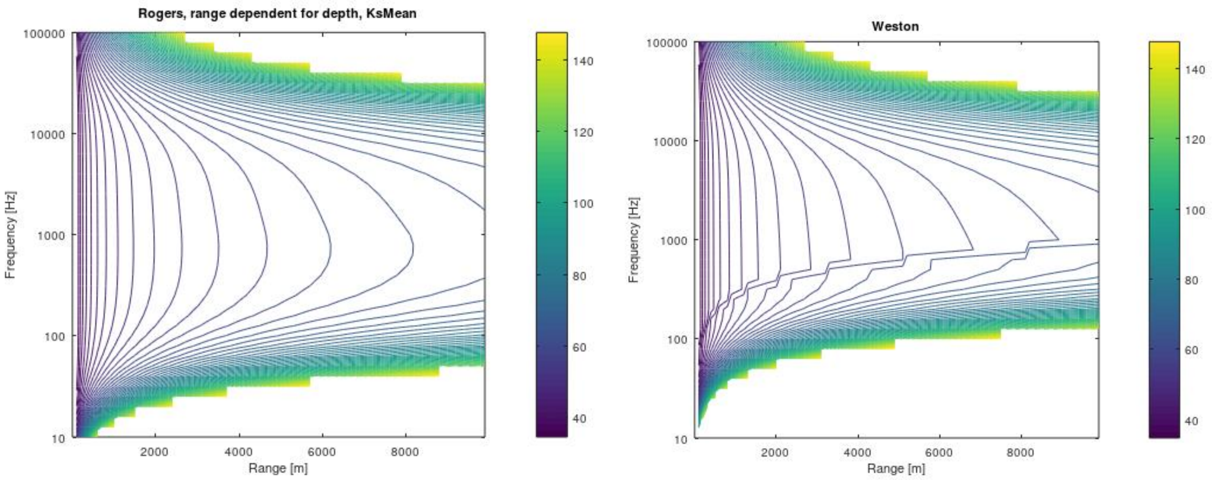

Figure 5-1. Comparison of two semi-empirical models over a sandy bottom at 30 m depth. Transmission loss in dB versus range and frequency.

[9] Simpler meaning shallow in relation to the wavelengths and with no significant sound speed gradient in the water column.

These semi-empirical models will tend to underestimate the transmission losses (overestimating the imapct) primarily due to the omission of surface roughness, wind effects and shear waves in the sediment.

5.2 Analytical models

For the impulsive sources we have used the dBSea software's ray tracing solver dBSeaRay as this accounts for the full waveform propagation of the impulsive. This means including surface and bottom reflections as well as time-of-arrival in the calculations, as these are important to include to correctly estimate the effects of constructive and destructive interference. dBSea solvers are validated against a range of opensource solvers for so-called "standard scenarios" that have agreed solutions[10].

5.3 Exposure Calculations (dB SEL)

To compare modelled levels with the two impact assessment frameworks (Southall et al. 2019 & Popper et al. 2014) it's necessary to calculate received levels as exposure levels, SEL, weighted for marine mammals, and unweighted for fishes. For ease of implementation, sources have generally been converted to an SPL source level, meaning converting to SEL from SPL or from a number of events is relatively easy:

To convert from SEL to SPL the following relation can be used:

$$SEL = \mathrm{SPL} + 10 \cdot Log_{10}(t_2 - t_1) \quad (1)$$

Or where it's inappropriate to convert to SPL by relating to the number of events as:

$$SEL_{\,n\ events} = SEL_{\,single\ event} + 10 \cdot Log_{10}(n) \quad (2)$$

As a marine mammal swims away from the sound source, the sound it experiences will become progressively more attenuated; the cumulative, fleeing SEL is derived 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 or if a set exclusion zone is sufficient for an activity (e.g., will an exclusion zone of 500 m be sufficient to prevent exceeding a threshold). It should be noted that the sound exposure calculations are based on the simplistic and conservative assumption that the animal will continue to swim away at a constant relative speed. The real-world situation is more complex, and the animal is likely to move away faster and potentially in a more complex manner.

Reported swim speeds are summarised in Table 5-1 along with the source papers for the assumptions. For this assessment, we used a swim speed of 1.5 m/s for marine mammals and 0.5m/s for fishes.

For very long fleeing durations the ambient sound itself can exceed the thresholds, e.g., ambient sound of 105 dB, weighted for the VHF group, will exceed the TTS threshold of 140 dB SEL after 1 hour's exposure[11]. We here consider fleeing durations of 2 hours (7200 seconds, allowing 10800 m of fleeing), meaning that weighted levels of 102 dB SPL will exceed the VHF group TTS threshold in the fleeing model.

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[10] https://www.dbsea.co.uk/validation/

[11] 105 dB SPL + 10*$\log_{10}$(3600 seconds) = 140.3 dB SEL, TTS limits for VHF group is 140 dB SEL.

Table 5-1: Swim speed examples from literature

Species	Hearing Group	Swim Speed (m/s)	Source Reference
Harbour porpoise	VHF	1.5	Otani *et al.,* 2000
Harbour seal	PCW	1.8	Thompson, 2015
Grey seal	PCW	1.8	Thompson, 2015
Minke whale	LF	2.3	Boisseau *et al.,* 2021
Bottlenose dolphin	HF	1.52	Bailey and Thompson, 2010
White-beaked dolphin	HF	1.52	Bailey and Thompson, 2010
Basking shark	Group 1 fish	1.0	Sims, 2000
All other fish groups	All fish groups	0.5	Popper *et al.,* 2014

It is highlighted that the SEL exposure calculation is inherently conservative as it makes the assumption that the sound sources are actively continuously and do not account for any breaks in activity during the surveys. Further, the sound criteria described in the Southall *et al*. (2019) guidelines assume that the animal flees at a steady speed (see above) and does not recover hearing between periods of activity. It is likely that both the intervals between operations could allow some recovery from temporary hearing threshold shifts for animals exposed to the sound (von Benda-Beckmann *et al.* 2022) and, therefore, the assessment of sound exposure level is highly precautionary and should be treated with caution.

6 RESULTS AND ASSESSMENT

Results are presented here based on the range to a threshold as given in chapter 2, Assessment Criteria. Risk ranges are given for the estimated 90th percentile value. This value is based on the calculated 90th percentile, given mean and standard deviation of the modelling results.

Main assumptions for the validity of the results:

- Final equipment configuration is not louder than the presented equipment (Table 4-1).
- Increasing the locations sampled would lead to a spread in results resembling a normal distribution, allowing statistical methods to be employed for upper bound estimates (90th percentile estimates).

Six types of results are presented to inform this assessment:

1. **“90th percentile starting range for a fleeing animal”:**
   This range is based on the estimated true 90th percentile rage using the mean and standard deviation from the modelled sites to estimate true 90th percentile.
2. **“90th percentile starting range for a fleeing animal, with soft start of 15 minutes”:**
   Same as “1” but with a soft start where equipment has 10 dB lower source level for 15 minutes prior to survey start.
3. **“90th percentile starting range for a fleeing animal, with soft start of 20 minutes”:**
   Same as “1” but with a soft start where equipment has 10 dB lower source levels for 20 minutes prior to survey start.
4. **“90th percentile starting range for a fleeing animal, with soft start of 30 minutes”:**
   Same as “1” but with a soft start where equipment has 10 dB lower source level for 30 minutes prior to survey start.
5. **“Peak level risk range”:**
   The range of acute risk of impact from peak pressure levels associated with the peak pressure level from the impulsive sources.
6. **“Behavioural response range”:**
   The range at which the behavioural threshold for the marine mammals (160 dB SPL for impulsive, 120 dB SPL for non-impulsive) or the fishes (150 dB SPL) is exceeded. Note that the behavioural thresholds are unweighted and will therefore be dominated by the low frequency part of the emitted sound, with all hearing groups bar LF probably unable to hear the sound to this range or be impacted in any way by its presence.

6.1 Results Summary

For **cumulative sound** the main hearing group driving mitigation range is the VHF group, with risk ranges for PTS to approximately 990 m. The HF hearing group have risk ranges for PTS to below 50 m, remaining hearing groups have risk ranges <10 m.

For **peak pressure levels** the largest risk range is for the VHF group, with a PTS risk range of ca. 25 m.

6.2 Results Details

Note that the risk range used for the assessment is the 90^{th} percentile range, a statistical approximation based on the results from the modelled scenarios. This is to account for the uncertainty when only modelling a subset of possible scenarios and represents a more robust and often more conservative estimate than simply choosing the largest risk range[12].

Starting ranges to avoid PTS for fleeing animals of the VHF group extend to approximately 990 m for the unmitigated case, with the remaining groups having ranges below 50 m. Behavioural response ranges are 200 m and 420 m for marine mammals and fishes respectively for the impulsive sound[13]. Behavioural response range for marine mammals is 10 km for the non-impulsive sound.

Ranges below 10 (the spatial resolution of the model) are given as “<10 m”.

Table 6-1: Geophysical Survey – summary of minimal starting ranges for fleeing animals.

Condition	LF (TTS / PTS) [m]	HF (TTS / PTS) [m]	VHF (TTS / PTS) [m]	PCW (TTS / PTS) [m]	OCW (TTS / PTS) [m]	Fish (TTS / PTS) [m]
90^{th} percentile (No soft start)	1100 / <10	290 / 46	4200 / 990	340 / <10	<10 / <10	150 / <10
90^{th} percentile 15 min soft start (-10 dB)	350 / <10	100 / <10	4200 / 540	14 / <10	<10 / <10	33 / <10
90^{th} percentile 20 min soft start (-10 dB)	150 / <10	100 / <10	4200 / 490	11 / <10	<10 / <10	32 / <10
90^{th} percentile 30 min soft start (-10 dB)	75 / <10	100 / <10	4200 / 460	<10 / <10	<10 / <10	31 / <10
Peak level range (max from all sites)	<10	<10	25 / 15	<10	<10	<10
Behavioural response range	200 (impulsive)[13] 10,000 (non-impulsive)					420

[12] E.g.: With 5 ranges: 500, 600, 550, 490 & 620 m, the mean is 552 m, the standard deviation is 58 m and the 90th percentile of the corresponding normal distribution is 626 m. This differs from the 90^{th} percentile of the raw results, which would be 612 m.

[13] The behavioural range for impulsive noise for the VHF group (200 m) is much smaller than the range to PTS (c. 1 km).

6.2.1 Mitigation

6.2.1.1 Zone of Absence – Marine Mammal Observer

For instantaneous injury due to peak pressure the modelling found that the risk of injury across all species fell within a standard 500 m mitigation range.

The modelling did not assume absence of marine mammals within a 500 m range prior to survey start but given the modelled risk ranges for the VHF group extend to 990 m for cumulative exposure based on the SEL threshold the risk of injury can be further reduced using a soft start. The soft start should reflect the sound sources employed during the geophysical surveys. To cover the frequency range of sensitive species a soft start can be applied for the sparker SBP and parametric SBP prior to the surveys.

6.2.1.2 Soft start – 20 minutes with lower output

As an alternative to a 1000 m exclusion zone prior to survey start a 20-minute soft start, where acoustic output is reduced by at least 10 dB (either by reducing power to 10 % or reducing ping-rate to a tenth) a 30-minute search by a certified MMO to establish likely absence of marine mammals within just 500 m (as opposed to ca. 1000 m) will suffice to mitigate risk of inducing PTS.

Where not all equipment can be reduced in power or firing rate to achieve a soft start, this can be switched off, while the equipment capable of performing a soft start will perform this function. The equipment used during soft start needs to be similar to the final (full power) stage to be meaningful. It is suggested that the sparker can be run at lower power (10 %) or at lower firing rate (10 %) in combination with a reduction in either power or ping rate to 10 % for the parametric subbottom profiler.

6.2.2 Equipment limitations

Final equipment configuration is not louder than the presented equipment (Table 4-1).

7 CONCLUSION

Under the assumptions laid out for the survey method, the sound sources used, and the mitigation applied, the sound arising from the surveys is unlikely to cause permanent injury to marine mammals and fishes (including basking shark).

While there is little risk of exceedance of the injury thresholds (PTS) with the proposed mitigation in place, we note that the survey uses high-powered sound sources (USBL, sparker, sub bottom profiler, multibeam echosounder & side scan sonar) that, while not likely to cause auditory harm, are likely to exceed the behavioural response thresholds as well as temporary hearing impact thresholds to c. 4.2 km for harbour porpoises and c. 1.1 km for the LF group (with other groups below 350 m) . Note here that the assessment is based on the worst-case estimates for sound sources (most conservative), with the realised impacts likely to be smaller.

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Appendix A – Acoustic Concepts and Terminology

Sound travels through water as vibrations of the fluid particles in a series of pressure waves. The waves comprise a series of alternating compressions (positive pressure variations) and rarefactions (negative pressure fluctuations). Because sound consists of variations in pressure, the unit for measuring sound is usually referenced to a unit of pressure, the Pascal (Pa). The unit usually used to describe sound is the decibel (dB) and, in the case of underwater sound, the reference unit is taken as 1 μPa, one micro-pascal, whereas 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, a sound pressure of 60 dB re 20 μPa is the same as 86 dB re 1 μPa, although care also needs to be taken when converting from in air sound to in water sound levels due to the different sound speeds and densities of the two mediums resulting in a conversion factor of approximately 62 dB for comparing intensities (watt/m²), see Table 8-1 , below.

Table 8-1: Comparing sound quantities between air and water.

	Constant intensity		Constant pressure	
Properties	**Air**	**Water**	**Air**	**Water**
Soundspeed (C) [m/s]	340	1500	340	1500
Density (ρ) [kg/m³]	1.293	1026	1.293	1026
Acoustic impedance (Z=C·ρ) [kg/(m²·s) or (Pa·s)/m³]	440	1539000	440	1539000
Sound intensity (I=p²/Z) [Watt/m²]	1	1	22.7469	0.0065
Sound pressure (p=(I*Z)^½) [Pa]	21	1241	100	100
Particle velocity (I/p) [m/s]	0.04769	0.00081	0.22747	0.00006
dB re 1 μPa²	146.4	**181.9**	160.0	**160.0**
dB re 20 μPa²	**120.4**	155.9	**134.0**	134.0
Difference dB re 1 μPa² & dB re 20 μPa²	**61.5**		**26.0**	

All underwater sound pressure levels in this report are described in dB re 1 μPa². In water, the sound source strength is defined by its sound pressure level in dB re 1 μPa², referenced back to a representative distance of 1m from an assumed (infinitesimally small) point source. This allows calculation of sound levels in the far-field. For large, distributed sources, the actual sound pressure level in the near-field will be lower than predicted.

There are several descriptors used to characterise a sound wave. The difference between the lowest pressure deviation (rarefaction) and the highest pressure deviation (compression) from ambient is the peak to peak (or pk-pk) sound pressure (L_{P-P} for the level in dB), Note that L_{P-P} can be hard to measure consistently, as the maximal duration between the lowest and highest pressure deviation is not standardised. The difference between the highest deviation (either positive or negative) and the ambient pressure is called the peak pressure (L_P for the level in dB). Lastly, the average sound pressure is used as a description of the average amplitude of the variations in pressure over a specific time window (SPL for the level in dB). SPL is equal to the L_{eq} when the time window for the SPL is equal to the time window for the total duration of an event. The cumulative sound energy from pressure is the integrated squared pressure over a given period (SEL for the level in dB). These descriptions are shown graphically in Figure 8-1 and reflect the units as given in ISO 18405:2017, "Underwater Acoustics – Terminology".

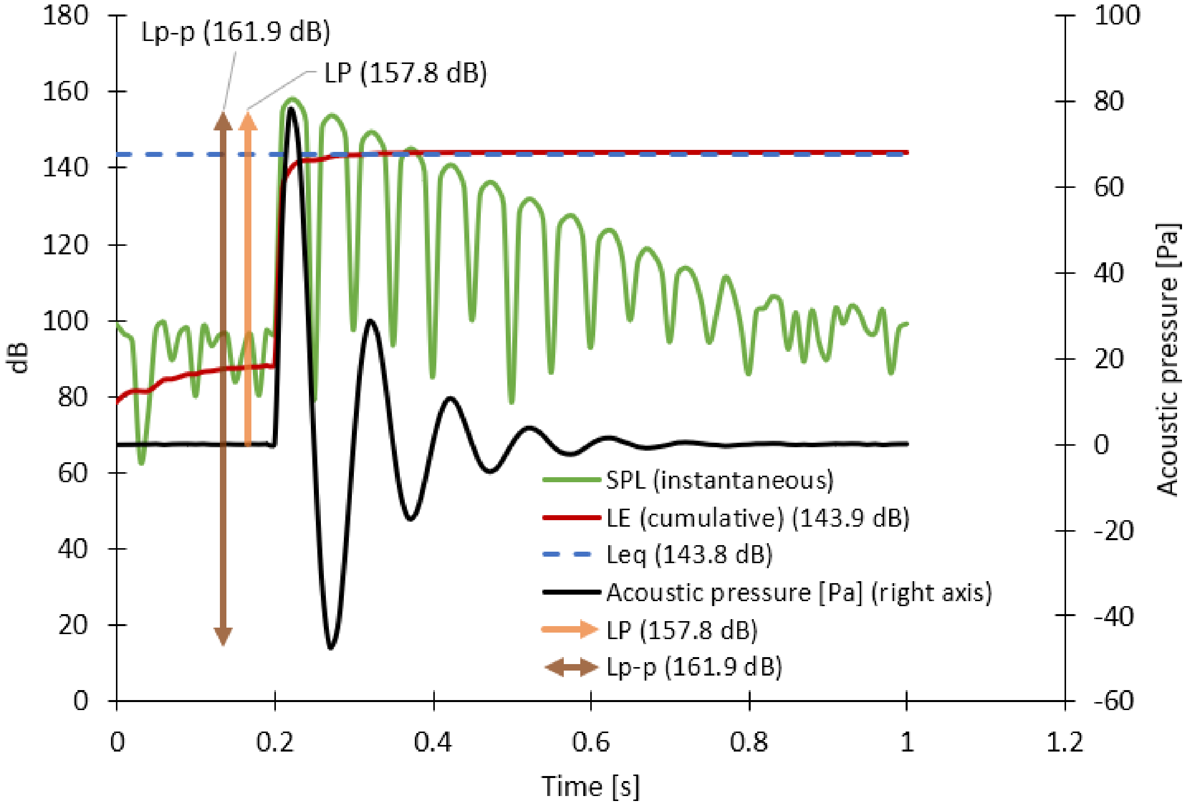

Figure 8-1. Graphical representation of acoustic wave descriptors ("LE" = SEL).

The sound pressure level (SPL[14]) is defined as follows (ISO 18405:2017, 3.2.1.1):

$$SPL = 10 \cdot Log_{10}\left(\frac{\overline{p^2}}{1 \cdot 10^{-12} Pa}\right) \tag{1}$$

Here $\overline{p^2}$ is the arithmetic mean of the squared pressure values. Note that L_P is simply the instantaneous SPL (ISO 18405:2017, 3.2.2.1).

The peak sound pressure level, L_P, is the instantaneous decibel level of the maximal deviation from ambient pressure and is defined in (ISO 18405:2017, 3.2.2.1) and can be calculated as:

$$L_P = 10 \cdot Log_{10}\left(\frac{max(p^2)}{1 \cdot 10^{-12} Pa}\right)$$

[14] Equivalent to the commonly seen "RMS-level".

Another useful measure of sound used in underwater acoustics is the Exposure Level, or SEL. This descriptor is used as a measure of the total sound energy of a single event or a number of events (e.g. over the course of a day). This allows the total acoustic energy contained in events lasting a different amount of time to be compared on a like for like basis. Historically, use was primarily made of SPL and L_P 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 over e.g. a 24-hour period to be taken into account. The SEL is defined as follows (ISO 18405:2017, 3.2.1.5):

$$SEL = 10 \cdot Log_{10}\left(\frac{\int_{t_1}^{t_2} p(t)^2 dt}{1 \cdot 10^{-12} Pa}\right) \quad (2)$$

To convert from SEL to SPL the following relation can be used:

$$SEL = \mathrm{SPL} + 10 \cdot Log_{10}(t_2 - t_1) \quad (3)$$

Converting from a single event to multiple events for L_E:

$$SEL_{n\ events} = SEL_{single\ event} + 10 \cdot Log_{10}(n) \quad (4)$$

The frequency, or pitch, of the sound is the rate at which these oscillations occur 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 dB(A). However, the hearing faculties of marine mammals and fish are not the same as humans, with marine mammals hearing over a wider range of frequencies, fish over a typically smaller range of frequencies and both with different sensitivities. It is therefore important to understand how an animal's hearing varies over the entire frequency range to assess the effects of sound on marine life. Consequently, use can be made of frequency weighting scales 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 8-2. Note 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. It is also worth noting that some fish are sensitive to particle velocity rather than pressure, although paucity of data relating to particle velocity levels for anthropogenic sound sources means that it is often not possible to quantify this effect.

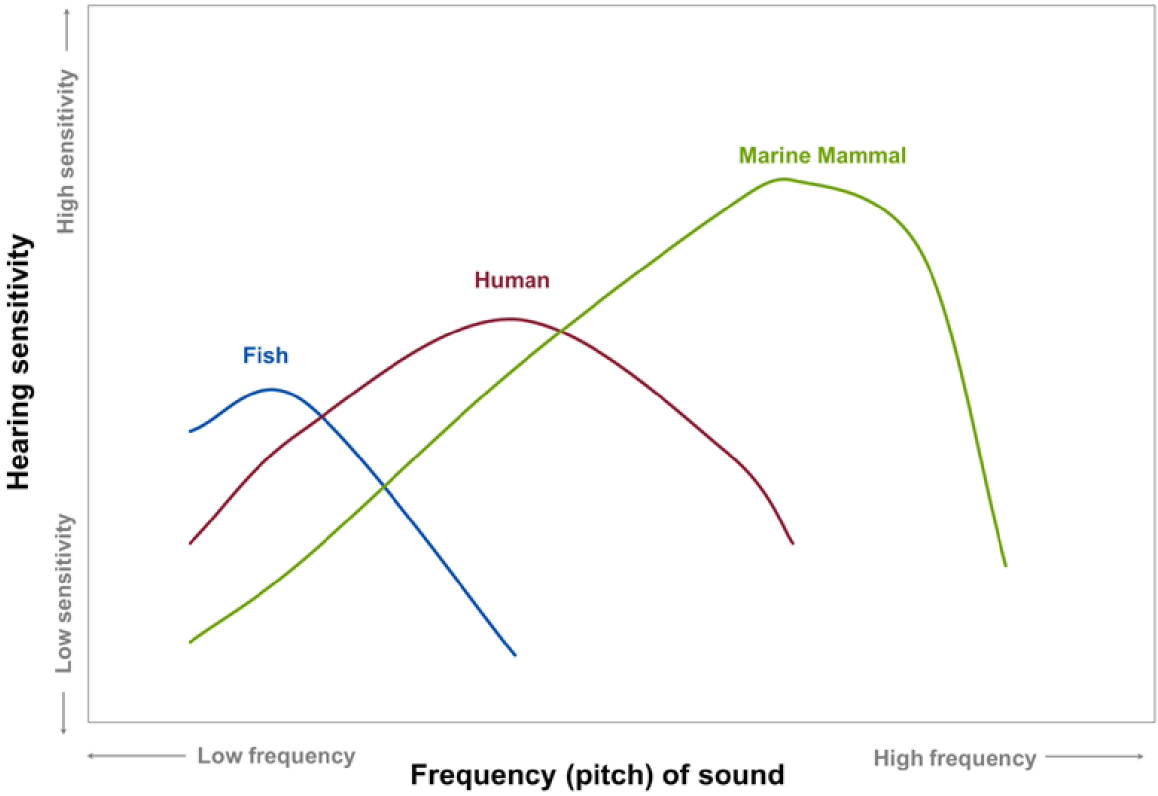

Figure 8-2. Comparison between hearing thresholds of different marine animals and humans.

Review of Sound Propagation Concepts

Increasing the distance from the sound source usually results in the level of sound getting 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.

The way that the sound spreads will depend upon several factors such as water column depth, pressure, temperature gradients, salinity, as well as water surface and 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, with no boundaries) or a cylindrical pattern (much further from the source, bounded by the surface and the sediment), although other factors mean that decay in sound energy may be somewhere between these two simplistic cases.

In acoustically shallow waters[15] in particular, the propagation mechanism is coloured by multiple interactions with the seabed and the water surface (Lurton, 2002; Etter, 2013; Urick, 1983; Brekhovskikh

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[15] Acoustically, shallow water conditions exist whenever the propagation is characterised by multiple reflections with both the sea surface and seabed (Etter, 2013). Consequently, the depth at which water can be classified as acoustically deep or shallow depends upon numerous factors including the sound

and Lysanov 2003, 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 is reflected many times by the surface and sediment.

At the sea surface, the majority of sound is reflected back into the water due to the difference in acoustic impedance (i.e. sound speed and density) between air and water. However, scattering of sound at the surface of the sea is an important factor with respect to the propagation of sound from a source. 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. However, for rough waters, much of the sound energy is scattered (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 or due to 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. Generally, the scattering effect at a particular frequency depends on the physical size of the roughness in relation to the wavelength of the frequency of interest.

As 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 water surface smoothness/wind speed, water depth, frequency of the sound, temperature gradient, grazing angle and range from source. Depending upon variations in the aforementioned factors, significant scattering could occur at sea state 3 or more for higher frequencies (e.g. 15 kHz or more). It should be noted that variations in propagation due to scattering will vary temporally (primarily due to different sea-states/wind speeds at different times) and that more sheltered areas (which are more likely to experience calmer waters) could experience surface scattering to a lesser extent, and less frequently, than less sheltered areas which are likely to encounter rougher waters. However, over shorter ranges (e.g. within 10-20 times the water depth) the sound will experience fewer reflections and so the effect of scattering should not be significant. Consequently, over the likely distances over which injury will occur, this effect is unlikely to significantly affect the injury ranges presented in this report, and not including this effect will overestimate the impact.

When sound waves encounter the seabed, the amount of sound reflected will depend on the geoacoustic properties of the seabed (e.g. grain size, porosity, density, sound speed, absorption coefficient and roughness) as well as the grazing angle (see Figure 8-3) and frequency of the sound (Cole, 1965; Hamilton, 1970; Mackenzie, 1960; McKinney and Anderson, 1964; Etter, 2013; Lurton, 2002; Urick, 1983). Thus, seabeds comprising primarily of mud or other acoustically soft sediment will reflect less sound than acoustically harder seabeds such as rock or sand. This effect also depends on the profile of the seabed (e.g. the depth of the sediment layers and how the geoacoustic properties vary with depth below the sea floor). The sediment interaction is less pronounced at higher frequencies (a few kHz and above) where interaction is primarily with the top few cm of the sediment (related to the wavelength). A scattering effect (similar to that which occurs at the surface) also occurs at the seabed (Essen, 1994; Greaves and Stephen, 2003; McKinney and Anderson, 1964; Kuo, 1992), particularly on rough substrates (e.g. pebbles and larger).

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speed gradient, water depth, sediment type, frequency of the sound and distance between the source and receiver.

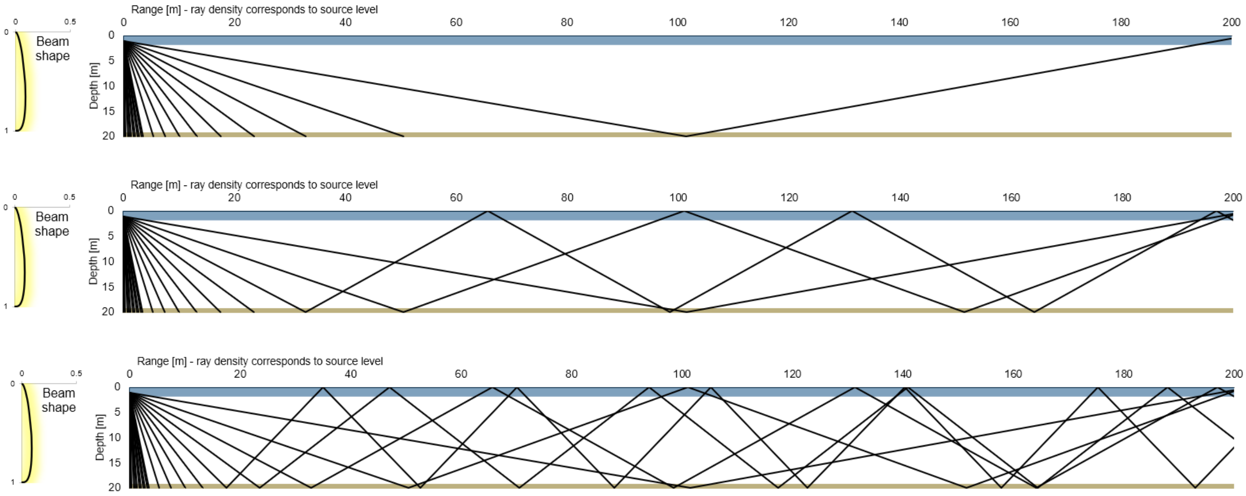


Figure 8-3. Schematic of the effect of sediment on sources with narrow beams.

Sediments range from fine silt (top panel), sand (middle panel), and gravel (lower panel). The density of "rays" indicate difference in effective propagation angle from the source, with acoustically harder sediments (gravel) having better reflection at steeper angles leading to more "rays" being effectively propagated (no significant bottom attenuation) in the waveguide. Beam shape indicated in left chart, with the black line showing the same received level.

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. The cut-off frequency as a function of water depth is shown in Figure 8-4 for a range of seabed types. Thus, for a water depth of 10m (i.e. shallow waters typical of coastal areas and estuaries) the cut-off frequency would be approximately 70Hz for sand, 115Hz for silt, 155Hz for clay and 10Hz for bedrock.

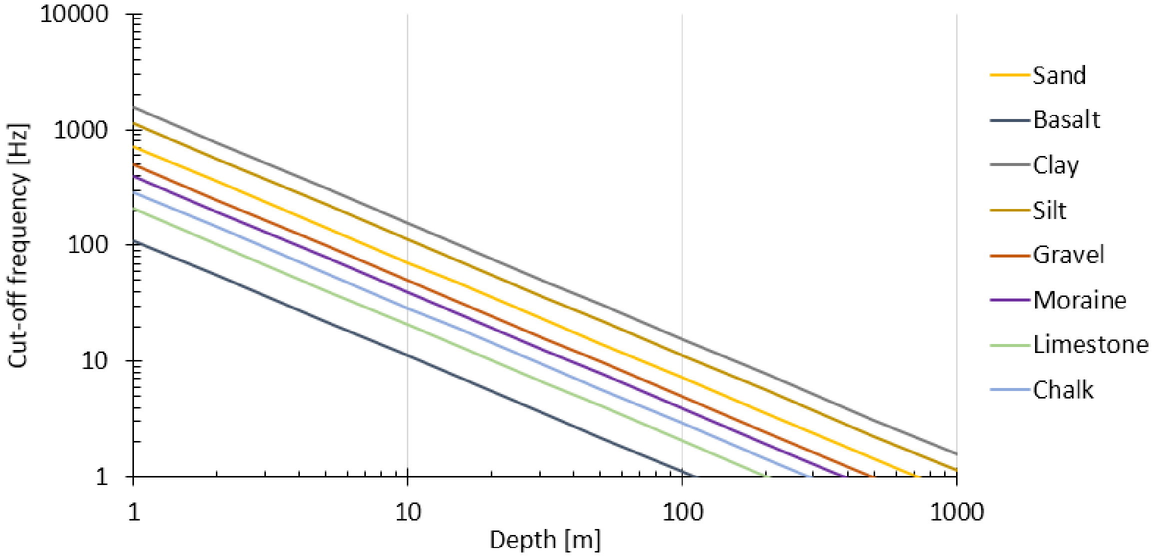


Figure 8-4. Lower cut-off frequency as a function of depth for a range of seabed types.

Changes in the water temperature and the hydrostatic 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 25m thick layer would not act as a duct for frequencies below 1.5kHz. The temperature gradient can vary throughout the year and thus there will be potential variation in sound propagation depending on the season.

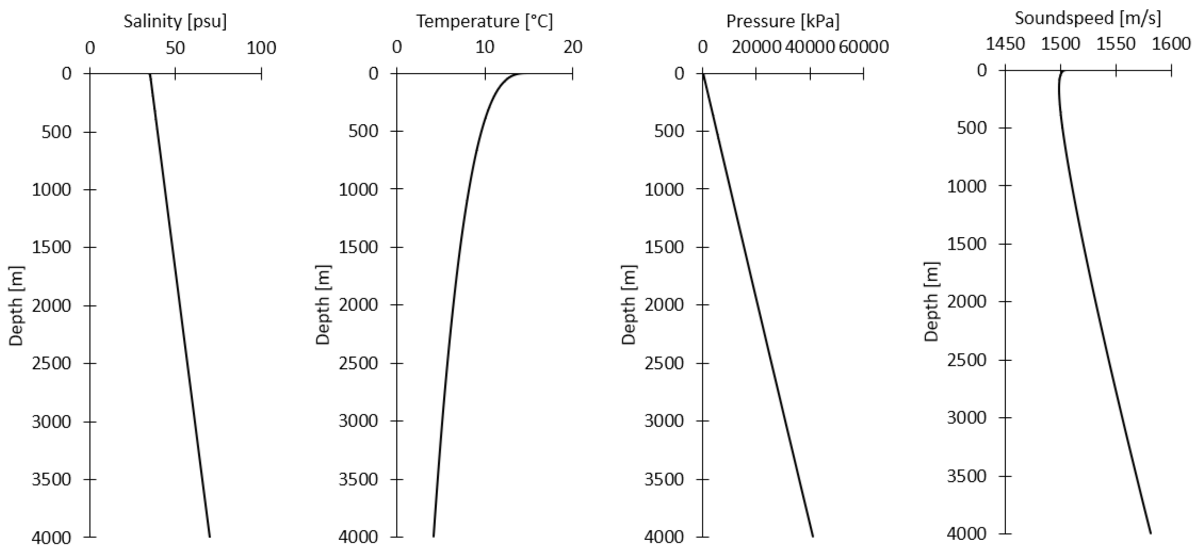


Figure 8-5. Soundspeed profile as a function of salinity, temperature and pressure.

Wind can make a significant difference to the soundspeed in the uppermost layers as the introductions of bubbles decreases the soundspeed and refracts (bends) the sound towards the surface, where the increased roughness and bubbles from the wind will cause increased transmission loss.

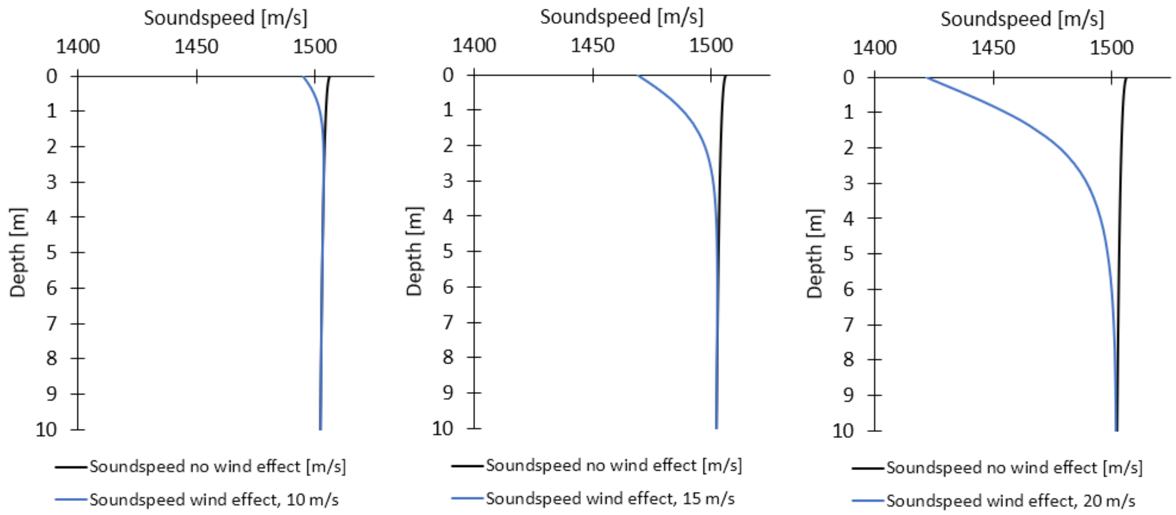


Figure 8-6. Effect of wind (at 10 m height) on upper portion of soundspeed profile.

Sound energy can also be 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. This is shown in Figure 8-7 where the variation of the absorption (sometimes called volume attenuation) is shown for various salinities and temperatures. As the effect is proportional to the wavelength, colder water, with slower soundspeed/period and being slightly more viscous, will have more absorption. Higher salinity slightly decreases absorption at low frequencies (mostly due to increase in soundspeed and wavelength/period), but much higher absorption at higher frequencies where interaction with pressure sensitive molecules of magnesium sulphite and boric acid increase the conversion acoustic energy to heat.

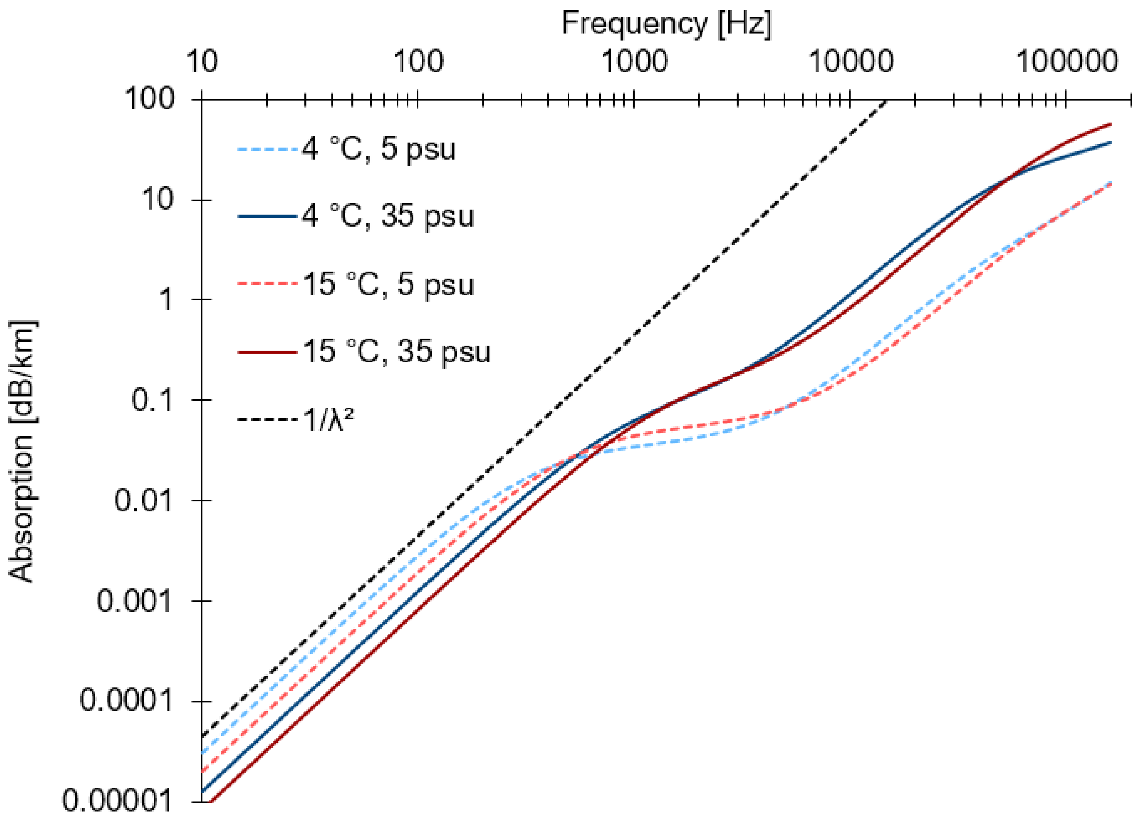
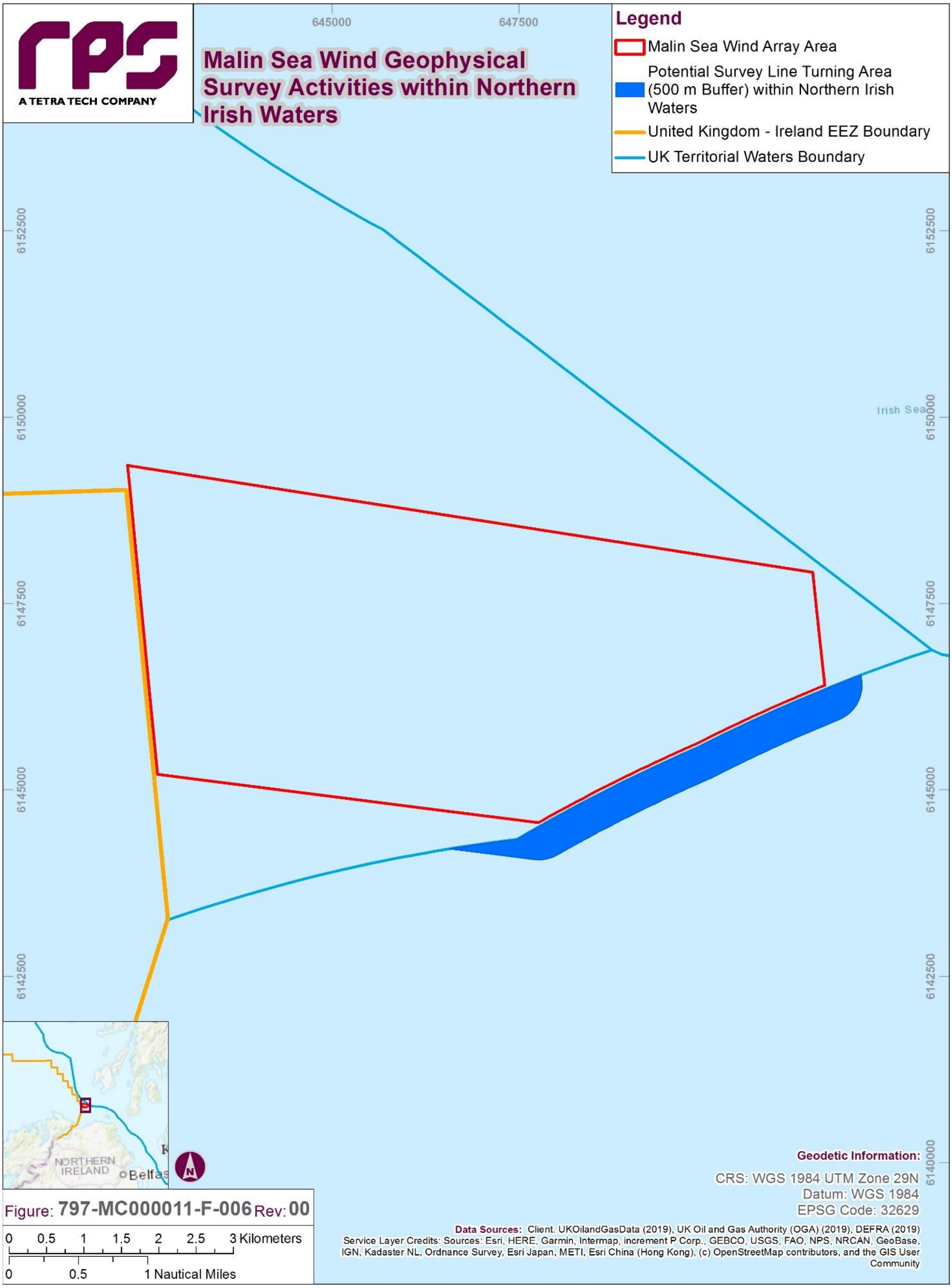
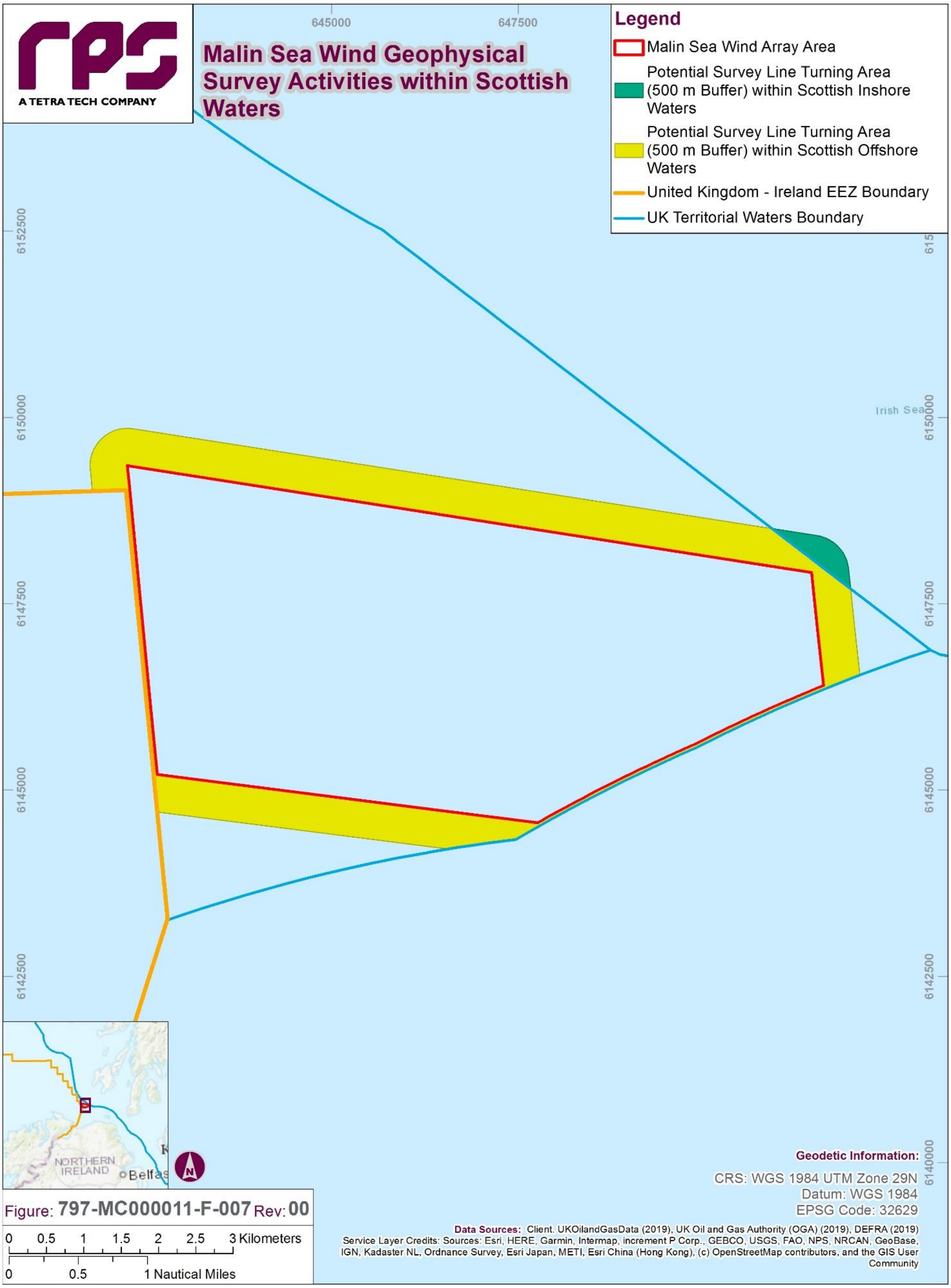


Figure 8-7. Absorption loss coefficient (dB/km) for various salinities and temperature.

Appendix B: Potential Survey Line Turning Area within Northern Irish and Scottish Waters



Apx Figure 1: Potential Survey Line Turning Area within Northern Irish



Apx Figure 2: Potential Survey Line Turning Area within Scottish Waters