EPS and Basking Shark Risk Assessment for Survey Operations – Orkney Section

Report | Orkney Islands

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Abbreviations

dB	decibel
EPS	European Protected Species
HF	high frequency
Hz	Hertz
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
LF	low frequency
LLAUV	Low-Logistics Autonomous Underwater
kHz	kilohertz
km	kilometre
MBES	Multibeam Echosounder
nm	Nautical mile
NOAA	National Oceanic and Atmospheric Administration
PAM	passive acoustic monitoring
PCW	phocid carnivores in water
PHF	primary high frequencies
PTS	permanent threshold shift
RAMMS	Rapid Airborne Multibeam Mapping System
SAC	Special Area of Conservation
SBP	Sub-bottom Profiler
SEL	sound exposure level
SHF	secondary high frequencies
SLF	secondary low frequencies
SMWWC	Scottish Marine Wlidlife Watching Code
SPA	Special Protection Area
SPL	Sound pressure level
SSS	Sidescan Sonar

TTS	Temporary threshold shift
USBL	Ultra-short baseline
VHF	very high frequency

1. Introduction

1.1 Project Overview

Fugro GB Marine Limited (Fugro), on behalf of Global Marine Group (GMG), proposes to undertake geophysical and geotechnical survey operations to inform the installation of a number of submarine cables around the Orkney Islands. Proposed survey routes are shown in Figure 1.1.

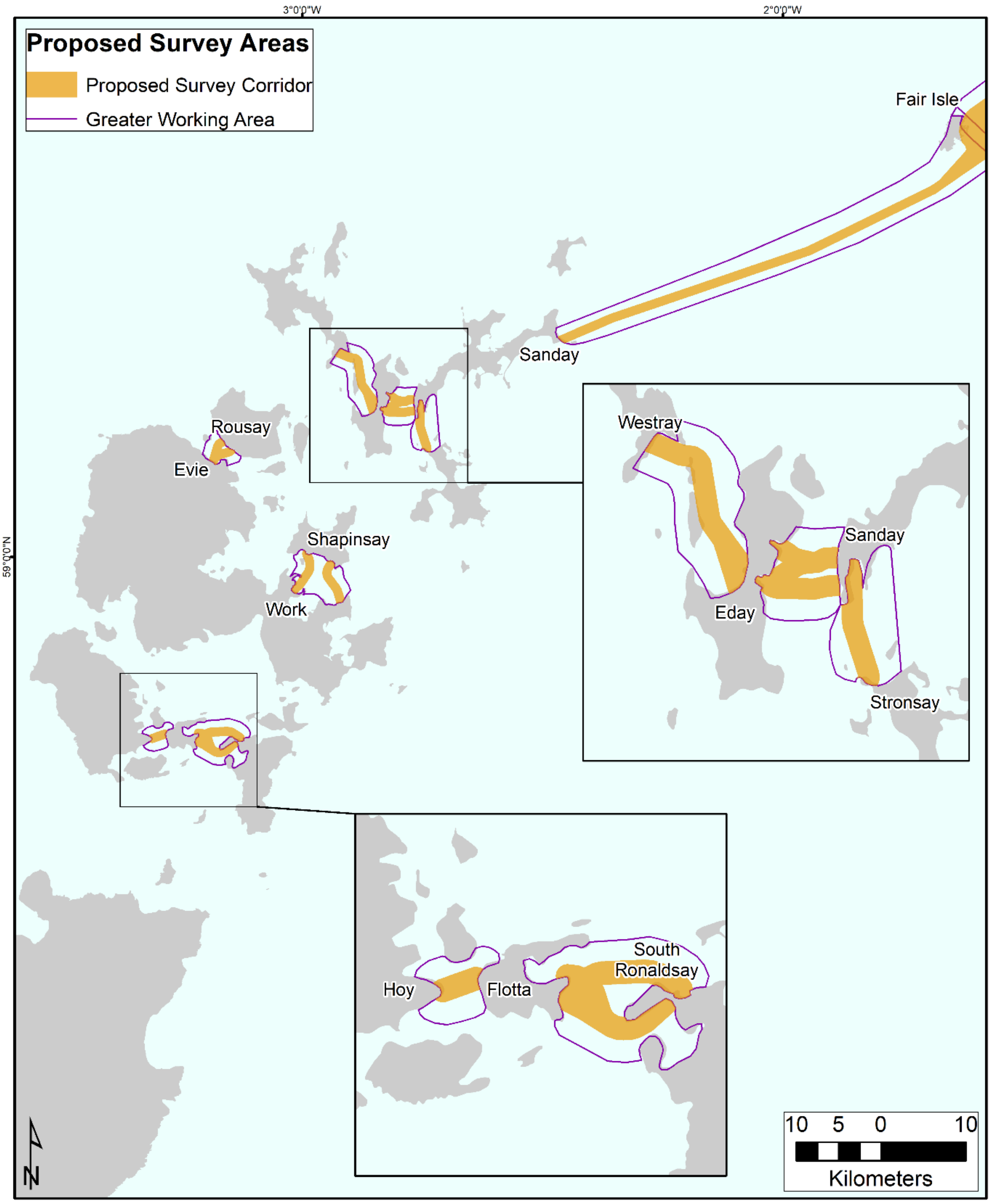

Figure 1.1: Proposed survey areas around the Orkney Islands

The wider project will comprise surveying 16 cable segments between 32 landing sites around the Inner Hebrides, Orkney and Shetland Islands. Within the Orkney islands, the proposed surveys will cover 8 cable segments between 16 landings sites (Table 1.1).

Table 1.1: Proposed cable survey route segments

Inner Hebrides Cable Survey Routes	Orkney Cable Survey Routes	Shetland Cable Survey Routes
Colonsay to Mull	Sanday to Fair Isle	Mainland to Yell
Iona to Mull	Eday to Sanday	Yell to Unst
Mainland to Lismore	Eday to Westray	Shetland mainland to Fair Isle
Mainland to Eigg	Sanday to Stronsay	Shetland mainland to Whalsay
	Orkney mainland to Rousay	
	Orkney mainland to Shapinsay	
	Hoy to Flotta	
	Flotta to South Ronaldsay	

Survey operations for the entire campaign are expected to take up to 175 days, and to take place between May and September 2021. The survey routes amongst the Orkney Islands (covered in this EPS and Basking Shark Risk Assessment) are proposed to be undertaken in June and July, taking approximately 34 days to complete.

The survey aims to provide comprehensive data to the client which will enable GMG to select the most appropriate installation route for the cables, select appropriate protection for the cables and define the most suitable type of cable to be selected. Furthermore, the surveys will be used to calculate the true horizontal distance allowing GMG to determine the correct length of cable to be manufactured.

This document represents the risk assessment prepared in support for a licence application to disturb or injure marine European Protected Species (EPS) or basking sharks for the Orkney islands work scope. Separate risk assessments have been prepared for the Inner Hebrides and Shetland cable routes.

1.2 Vessels

The proposed survey operations will be undertaken by an offshore survey vessel, and two inshore survey vessels as well as airborne bathymetric LiDAR and topography. The survey vessels detailed below are indicative and alternative vessels of a similar specification may be used for logistical reasons.

1.2.1 Offshore Survey Vessel

The offshore survey operations will be undertaken by the MV Fugro Frontier (Figure 1.2). The vessel will be utilised for survey operations in water depths of 20 m LAT or greater. The offshore vessel requires a minimum of 1 km clearance from the coast to allow for safe line turns. Where this is not possible the inshore survey vessel will cover the geophysical corridor.

1.2.2 Inshore Survey Vessel

The inshore survey operations will be undertaken by the MV Fugro Valkyrie (Figure 1.3) and the Fugro Xplorer. The vessel will be utilised for survey operations within 1 km from the coastline and in water depths of less than 20 m LAT.

Figure 1.2: MV Fugro Frontier

Figure 1.3: MV Fugro Valkyrie

1.3 Other Survey Operations

In addition to the dedicated vessels described in Sections 1.2.1 and 1.2.2 a Low-Logistics Autonomous Underwater Vehicle (LLAUV) will be utilised in areas where the offshore vessel is unable to operate either due to currents or there being insufficient room for vessel turns. The LLAUV would be used to acquire bathymetric and side scan sonar data.

Aerial LiDAR surveys will also be undertaken using Fugro's Rapid Airborne Multibeam Mapping System (RAMMS). The RAMMS, coupled with a Riegl 680i topographic Lidar, will be deployed from a fixed wing aircraft, a Pilatus PC-6 Porter or equivalent, over a period of approximately 3 days with a further five days contingency in case of unsuitable weather windows.

1.4 Survey Design and Equipment

The survey will use three types of noise emitting geophysical survey equipment. They are side scan sonar, multi-beam echosounder and sub-bottom profilers. Each is used to gain an aspect of geological information required for determination of seabed conditions. These data are then used in conjunction with geotechnical data collected from grab samples, boreholes and cone penetration tests to determine conditions with greater confidence.

Side scan sonar (SSS) is used to generate an accurate image of the seabed. An acoustic beam is used 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. The frequencies used by side-scan sonar are generally high and outside of the main hearing range of all marine species (JNCC, 2010). The higher frequency systems provide higher resolution, but shorter-range measurements.

Multi-beam echosounders (MBES) are used to obtain detailed maps of the seafloor which show water depths. They measure water depth by recording the two-way travel time of a high frequency pulse emitted by a transducer. The beams produce a fanned arc composed of individual beams (also known as a swathe). Multi-beam echo-sounders can, typically, carry out 200 or more simultaneous measurements.

Sub-bottom profilers (SBP), also known as shallow seismic systems, are used to identify and characterise layers of sediment or rock under the seafloor. A transducer emits a sound pulse vertically downwards towards the seafloor, and a receiver records the return of the pulse once it has been reflected off the seafloor.

Table 1.2 lists the proposed geophysical equipment for use on the vessels. Different vessels will be utilised for the inshore and offshore works. Therefore, there is more than one type of each equipment. Geophysical survey operations along the proposed survey routes within the Orkney Islands will take approximately 34 days to complete.

Table 1.2: Survey equipment list

Equipment	Type	Frequency [kHz]	Source Level [dB re 1μPa]
AA EasyTrak Nexus	Ultra-short baseline (USBL) acoustic positioning system	18-32 kHz	192
Kongsberg HiPAP 502+	Ultra-short baseline (USBL) acoustic positioning system	21-31 kHz	190-203
Sonardyne Mini Ranger2	Ultra-short baseline (USBL) acoustic positioning system	19-34 kHz	unknown
Kongsberg EM2040 Dual-Head	Multi-beam echosounder	200-400 kHz	248
Kongsberg EM2040 Dual-Head	Multi-beam echosounder	70-100 kHz	231
R2Sonic 2024^{+}	Multi-beam echosounder	170 – 450 kHz	221
Reson 7125*	Multi-beam echosounder	200 – 400 kHz	224
Edgetech 4200	Side scan sonar	100-900 kHz	196
Edgetech 4125	Side scan sonar	100-900 kHz	196
Innomar SES 2000 medium-100	Sub-bottom profiler	Primary Frequencies around 100 kHz; Secondary Frequencies at 4, 5, 6, 8, 10, 12, or 15 kHz	247-250
G-882	Magnetometer	n/a	n/a

$^{+}$ - Used on the FTV Xplorer only
* - Used on the Valkyrie only

1.5 Protected Areas

A number of protected sites have been designated around the Orkney islands Isles including Special Protection Areas (SPAs), Special Areas of Conservation (SACs), Nature Conservation

Marine Protected Areas (MPAs) and RAMSAR sites and the proposed cable survey routes pass through and close to a number of protected sites.

The Sanday to Fair Isle survey route passes through the Sanday SAC which is designated for intertidal mudflats and sandflats, reefs, subtidal sandbanks and Common seal. This cable survey segment also passes through the East Sanday Coast SPA and RAMSAR sites. These protected areas are designated for Bar-tailed godwit, Purple sandpiper and Turnstone.

The proposed survey route between Eday and Sandy will be 0.6 km, at the closest point, from the Calf of Eday SPA which protects a number of seabird species such as Cormorant, Fulmar, Great black-backed gull, Guillemot and Kittiwake.

The Westray to Eday survey would pass through or close to the Faray and Holm of Faray SAC which is designated for Grey seals.

The Rousay to Evie survey route will pass through the Rousay SPA which is designated for a number of seabird species including Arctic skua, Arctic tern, Fulmar, Guillemot and Kittiwake.

The location of these protected areas, and others outside of the cable survey area, are shown Figure 1.4.

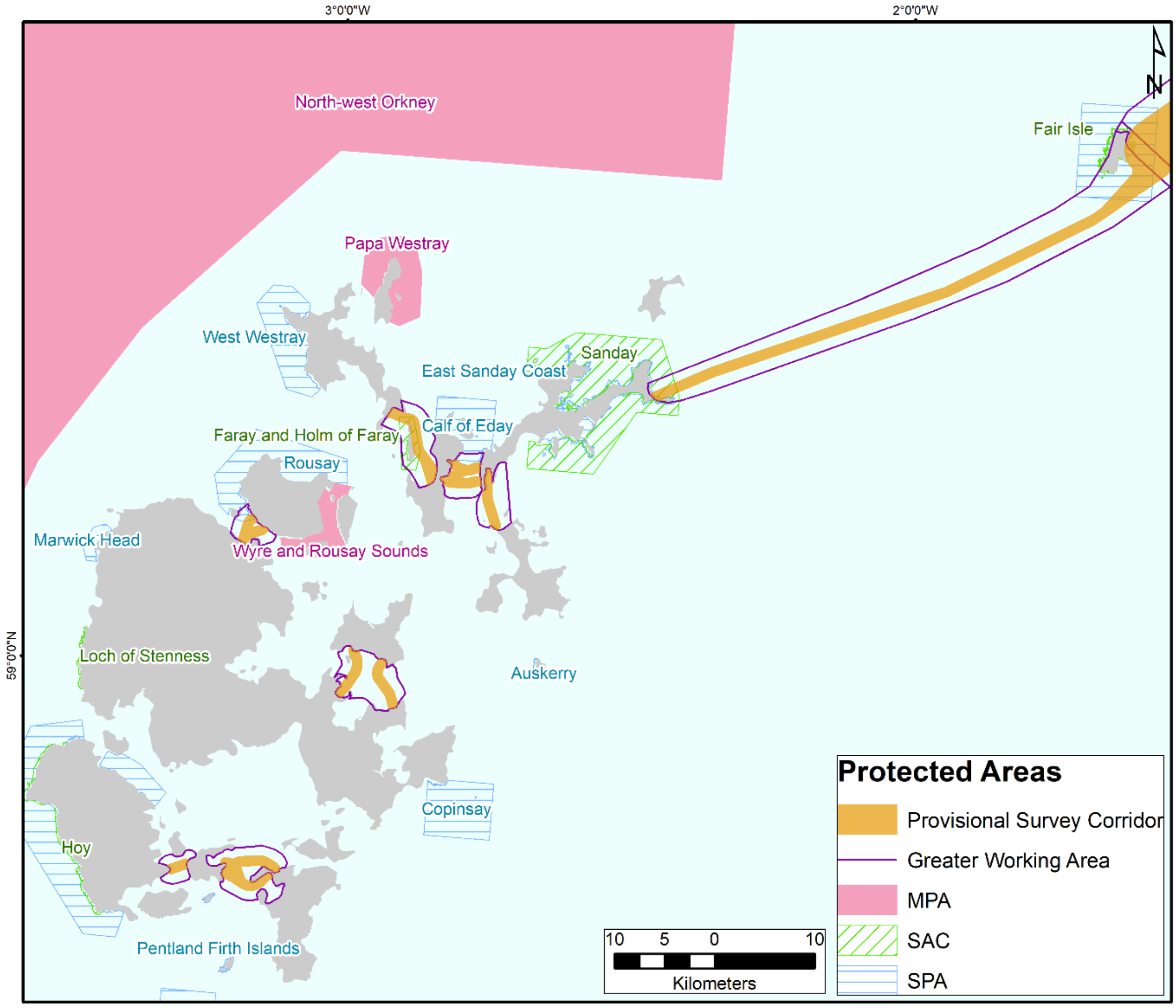

Figure 1.4: Proposed Orkney islands cable survey routes and designated sites

2. Legislation

2.1 The Wildlife and Countryside Act 1981

The Wildlife and Countryside Act 1981 was enacted in the United Kingdom to implement the Birds Directive and Bern Convention and applies to the terrestrial environment and inshore waters (up to 12 nm from land). Part 1 of the Act details a range of offences relating to the killing and taking of wild birds, animals and plants. Schedules to the Act set out in more detail the level of protection afforded to particular species.

Certain species of fish, vendace, powan and basking shark, are afforded protection under Schedule 5 of the Act which means that it is an offence to:

- intentionally or recklessly kill, injure or take fish;
- possess or sell fish; or
- intentionally or recklessly disturb or harass fish.

This protection was enhanced further by the Nature Conservation (Scotland) Act 2004. Under Schedule 6 of this legislation it is an offence to deliberately or recklessly capture, kill, or disturb basking sharks. Furthermore, the Wildlife and Natural Environment (Scotland) Act 2011 added a new licensing purpose to the 1981 Act, at section 16(3) (i)): '*for any other social, economic or environmental purpose*' for certain protected species including basking sharks.

Therefore, if an activity proposed to be undertaken within Scottish inshore waters is judged likely to cause to disturbance or injury to basking sharks a licence must be obtained from Marine Scotland to undertake the activity legally subject to licence conditions being complied with.

2.2 The Conservation (Natural Habitats, &c.) Regulations 1994

The Conservation (Natural Habitats, &c.) Regulations 1994 (as amended) implement certain requirements of the European Habitats Directive (92/43/EEC) in Scotland. Commonly referred to as the Habitat Regulations 1994, this legislation provides for the protection of animals and plants listed in Annex IV of the Habitats Directive whose natural range includes Great Britain. These regulations apply across the terrestrial environment and Scottish territorial waters up to 12 nm from the shore.

These regulations make it an offence for a person to deliberately capture, injure or kill any wild individual of an EPS or disturb any wild individuals of an EPS as listed under Annex IV of the Habitats Directive. Furthermore, the Habitats Regulations 1994 (as amended) make it an offence to deliberately or recklessly harass a wild animal or group of wild animals of an EPS including any such animals which may be migrating or hibernating. All species of cetaceans are listed as EPS and they are afforded additional protection through Regulation 39(1A) which states that "it is an offence to deliberately or recklessly, harass any wild animal of an EPS included in Schedule 2, such as a dolphin, porpoise or whale (cetacean)."

Any application for a licence that exempts a licence holder from the requirement to adhere to the protection afforded to EPS in the legislation referenced above must pass all three of the following tests (Marine Scotland, 2014):

- There is a licensable purpose to the activity;
- There are no satisfactory alternatives;
- The actions authorised will not be detrimental to the maintenance of the population of the species at favourable conservation status in their natural range.

If all three tests are not satisfied, then a licence application will fail.

3. Protected Marine Species Within the Survey Area

3.1 European Protected Species

All species of cetaceans are considered EPS. Twenty-eight species of cetaceans have been recorded in UK waters, of these, twenty-one are considered to be uncommon, rare or very rare in occurrence (JNCC, 2007). A number of species of cetaceans (whales, dolphins and porpoises), such as long-finned pilot whales, killer whales, minke whales and several species of dolphins are occasionally sighted in the offshore waters of the central North Sea (Reid et al., 2003; BODC, 1998).

The species most commonly observed in the area where the survey activity is proposed are Minke Whale (*Balaenoptera acutorostrata*), White-beaked dolphin (*Lagenorhynchus albirostris*), Bottlenose dolphin (*Tursiops truncates*) and harbour porpoise (*Phocoena phocoena*) (Reid et al., 2003; BODC, 1998). Of these species, harbour porpoise is the most abundant (Hammond et al., 2017).

Table 3.1 summarises the main characteristics of the cetacean species known to be present in the area as well as the density of animals/km^2 as recorded in the latest SCANS III report using Block S (Hammond et al., 2017).

Table 3.1: Cetacean species considered likely to be present in the survey area and estimated densities

Species	Cetacean Distribution and Abundance	Greatest Density of animals/km^2 SCANS III Data Block S
Killer whale	Killer whales are distributed over both the continental shelf and in deep offshore waters, with the main concentration of sightings over the slope to the north and northwest of Shetland. Although killer whales occur year-round, sightings increase during the early summer months. The majority of UK sightings have been of individuals or groups of less than eight animals.	No sightings recorded during SCANS III survey
Minke whale	Minke whales appear to move into the North Sea at the beginning of May, and are present until October. They occur throughout the northern and central North Sea, more frequently found in its western side. Minke whales are found mainly on coastal waters and on the continental shelf in water depths up to 200 m. These whales are generally seen singly or in pairs, but can form aggregations of up to fifteen individuals when feeding.	0.010
Long finned pilot whale	Pilot whales mostly occur in large pods and are frequently seen in association with other cetaceans. Typically found north of Scotland over the continental shelf in deep water habitats in pod sizes, typically, of between 3 and 12 individuals. Relatively few occurrences are noted in shallower waters around north Scotland and the northern North sea.	No sightings recorded during SCANS III survey

Species	Cetacean Distribution and Abundance	Greatest Density of animals/km^2 SCANS III Data Block S
Harbour porpoise	The harbour porpoise is common in shelf waters of the northern and central North Sea, with fewer records from deeper waters. However, it may be more abundant in deepwater than surveys suggest, as it is difficult to detect this species in rough conditions. This species occurs in very small groups of up to three individuals.	0.152
Common dolphin	Common dolphins are typically sighted on the west coast of Britain and Ireland in continental shelf waters notably in the Celtic Sea. In the summer it is frequently observed in the Sea of the Hebrides and occasionally in the North sea during the summer months,	No sightings recorded during SCANS III survey
Bottlenose dolphin	Bottlenose dolphins are common in the northeast coast of Scotland, particularly in the Moray Firth, with some animals present nearshore for the whole year. Bottlenose dolphins typically appear in groups of up to 25 individuals.	0.004
White beaked dolphin	White-beaked dolphins occur only in the North Atlantic and are widely distributed year-round on the UK continental shelf. Their distribution seems to be restricted by temperature, and they are seen particularly in the cooler waters of the western central and northern North Sea. They are most frequently observed between June and October. White-beaked dolphins are generally found in groups of less than ten individuals, although they have been observed in larger aggregations.	0.021
Atlantic white-sided dolphin	Atlantic white-sided dolphins are found only in the North Atlantic, sharing most of their range with the white-sided dolphin. They tend to occur more frequently in waters to the northwest of the UK and Ireland. This species is rare in the central and north-eastern North Sea. White-sided dolphins tend to form large groups of tens to hundreds of individuals.	No sightings recorded during SCANS III survey
Risso’s dolphin	Most sightings of Risso’s dolphins have been made in western Scotland, but occasionally it is sighted in the central and southern North Sea, particularly during the summer	No sightings recorded during SCANS III survey

3.2 Basking Sharks

Basking sharks (*Cetorhinus maximus*) are a wide ranging species ranging from the warm temperate waters of the European continental shelf as far north as the Arctic (Sims, 2008 and Evans et al. 2011). Whilst the sightings of most individuals are made in shallow, coastal waters records of basking sharks from offshore cetacean surveys and pelagic driftnet records, together with more recent telemetry studies, suggest that the species also utilises deeper, offshore waters (Booth et al. 2013).

In the UK, there are considered to be a number of “hotspots” for basking shark sightings where they can be regularly seen at the surface. These are, generally, the south west of

England (Devon and Cornwall), the Isle of Man and the western coast of Scotland (Booth et al. 2003 and Solandt and Chassin, 2013). Within the west coast of Scotland sightings are usually concentrated in the Clyde, north and west of Mull, Coll and Tiree and the Small Isles of the Inner Hebrides (Booth et al. 2003, Bloomfield & Solandt, 2006 and Solandt & Chassin, 2013). The waters around the Small Isles, specifically Hyskeir and Canna, are considered to support high numbers of basking sharks involved in courtship behaviour and frequent breaching activities have been recorded here (Hayes et al. 2018). Recent warming of European waters has led to an increase in the number of sightings being made further north in Scottish waters with occasional records around Orkney and Shetland (Evans et al. 2011). However, the occurrence and distribution of basking sharks in these areas are poorly understood and sightings are typically widely scattered with little to no concentration of sightings in an area (Evans et al. 2011 and Hayes et al. 2018).

Sightings of basking shark in Scotland follow a distinct pattern with an uptick in observations starting in May and rising gradually to a peak in August before rapidly diminishing to end in October or November (Bloomfield & Solandt, 2006, Evans et al. 2011 and Solandt & Chassin, 2013). The species is rarely sighted between November and April (Evans et al. 2011).

Basking sharks are known to feed where water masses meet such as interfaces between water bodies including tidal and oceanic fronts (Hayes et al. 2018). When feeding basking sharks are understood to be solitary however individuals will form loose aggregations where feeding on the same discrete patches of plankton (Bloomfield & Solandt, 2006). Basking sharks tend to feed near the surface principally on zooplankton with the calanoid copepod *Calnus* found to be the predominant pre group (Bloomfield & Solandt, 2006 and Sims, 2008) however recent studies have proposed that the species may spend more time near the seabed than previously recorded (Hawkes et al. 2020).

A record of basking shark sightings around the Orkney islands are provided in Bloomfield & Solandt, 2006 which highlights that most of the sightings in Scotland are around the Inner Hebrides and the Firth of Clyde. Sightings of basking sharks around Orkney were recorded in around the western and southern parts of the islands but were typically very low (1 to 5 Basking sharks per 5 km grid) suggesting the species is present only in very low numbers (Bloomfield & Solandt, 2006).

Data available from NatureScot (SNH, 2021) also shows that the number of sightings of basking sharks around the Orkney islands are low.

4. Risk Assessment

In recent years there has been growing awareness of the potential for manmade underwater noise to impact marine animals, particularly marine mammals and fish.

The dominant source of naturally occurring noise across the frequencies from 1 Hz to 100 kHz is associated with ocean surface waves generated by the wind (NRC, 2003). Other natural sounds in the sea include currents, rain, echo-location and communication noises generated by cetaceans and other natural sources such as tectonic activity.

In addition to naturally occurring sounds, there is anthropogenic noise generated by air traffic, shipping activity and the oil and gas industry. Of these, shipping is the dominant source of sound in the world's oceans, generally within a range from five to a few hundred Hertz (NRC, 2003). However, sound generated by geophysical survey equipment such as seismic surveys are also major contributors to low-frequency sound field in certain areas, such as the North Atlantic (Nieukirk et al, 2004; Tyack, 2008). These ambient noise levels in the oceans have increased significantly over the last few decades (e.g. Hatch & Wright, 2007; Andrew et al, 2002) giving marine animals little time to adapt to these changes in an evolutionary sense.

4.1 Sound Sources

The main sound source during this survey operation will be the intermittent sound pulses generated by the SBP. Whilst the survey will also utilise MBES, SSS and USBL systems, these types of equipment emit underwater sound levels that are well below the levels emitted by the SBP. Furthermore, these systems operate at high frequencies, which strongly affects the sound absorption, resulting in strong attenuation, thus limiting the distance that the sound travels through the water column. JNCC advises that MBES undertaken in shallower waters, those less than 200 m deep, are not typically considered to be of concern to cetacean species as it is thought the higher frequencies typically used in these operations fall outside the hearing frequencies of cetaceans and the sounds produced are likely to attenuate more quickly than the lower frequencies used in deeper waters (JNCC, 2017). Therefore, the underwater sound produced by the SBP is used as the worst-case underwater sound source in the remainder of this wildlife disturbance risk assessment.

4.1.1 Sub-bottom Profiler Parameters

The Innomar SES-2000 medium-100 Parametric Sub-bottom profiler uses the principle of "parametric" or "nonlinear" acoustics to generate short narrow-beam sound pulses. The SES-2000 medium-100 Parametric has a source level of 247-250 dB re: 1µPa @ 1m (0-peak), with an associated sound exposure level (SEL) of around 228 dB re: 1µPa^2-s (single pulse for maximum duty cycle of 1.4%).

A parametric SBP makes use of a physical effect, which generates low-frequency sound waves by transmitting two slightly different high frequencies (around 100 kHz) at high sound pressures simultaneously. The transmitted ‘primary’ high frequency (PHF) sound waves interact in the water and new frequencies are generated. These new frequency components, so called ‘secondary high frequencies’ (SHF) and ‘secondary low frequencies’ (SLF).

The SHF component comprises the sum of the primary frequencies and harmonics (integer multiples of the original frequencies) and is at least 6 dB below the PHF source level. The SHF components will attenuate over very short distances however, due to the high absorption coefficient of high frequency underwater sound in seawater.

The SES-2000 medium-100 sub-bottom profiler can be adjusted to generate SLF pulses at 4, 5, 6, 8, 10, 12, or 15 kHz, which are used as the source pulse for the sub-bottom profiling. The secondary SLF sound fields have much lower amplitudes (typically 30-40 dB lower than the primary waves).

Furthermore, it should be noted that the SES-2000 medium-100 SBP system is strongly directional, with the vast majority of the signal being emitted straight downward, as illustrated in Figure 4.1. This figure shows the modelled 196 dB isopleths for the individual elements (PHF, SLF and SHF) and all three parts combined (SUM) of the sound signature of the SES-2000 medium-100 SPB system, clearly illustrating the large asymmetry between the horizontal and vertical underwater sound attenuation.

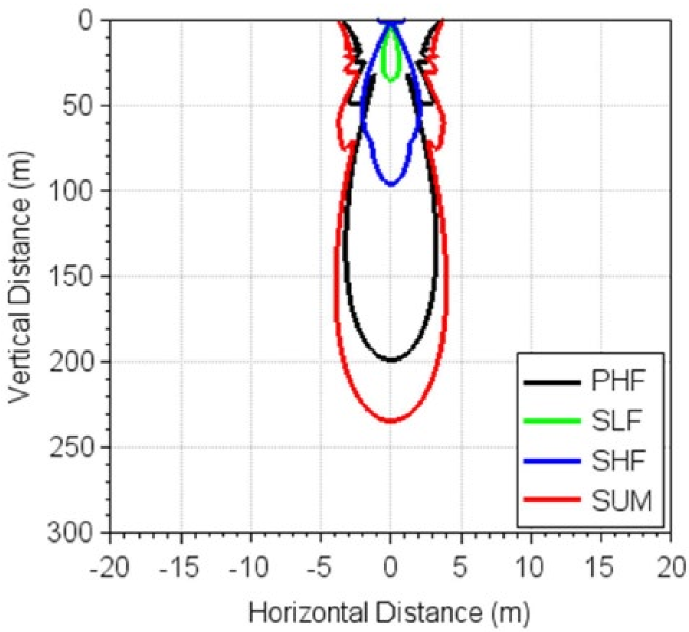

Figure 4.1: Modelling Example 196 dB Isopleth of SES-2000 medium-100 Parametric SBP (Wunderlich, 2021)

Table 4.1 shows the Vertical and Horizontal distances for a number of set cumulative SEL values over a 24 hour period, as well as for a single pulse SPL at 196 dB re: 1µPa @ 1m, for the SES-2000 medium-100 SBP system as modelled by Innomar (Wunderlich, 2021).

Figure 4.2 shows a graphical representation of the same SEL values at horizontal distances from the sound source.

Table 4.1: Vertical and Horizontal distance from Innomar SES-2000 medium-100 SBP transducer at certain set SPL and SEL values

	SEL <218 dB re: 1µPa²-s (24hrs)	SEL<168 dB re: 1µPa²-s (24hrs)	SEL<160 dB re: 1µPa²-s (24hrs)	SEL<140 dB re: 1µPa²-s (24hrs)	SPL <196 dB re: 1µPa @ 1m
Vertical Distance	300 m	3350 m	6500 m	20000 m	240 m
Horizontal Distance	10 m	550 m	800 m	1800 m	5 m
Source: Wunderlich, 2021					

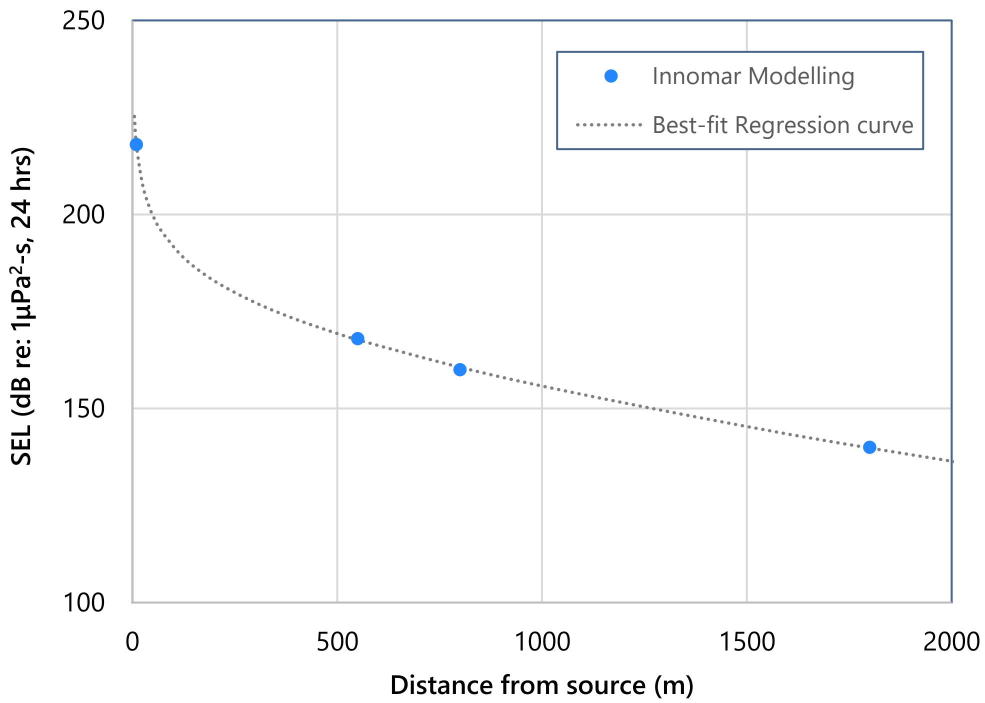

Figure 4.2: Horizontal Sound Attenuation Innomar SES-2000 medium-100 SBP

4.2 Impacts from Underwater Sound

This section assesses potential impacts from underwater sound focussing on marine mammals which are one of the groups believed to be most at risk from noise impacts. Sound is a particularly efficient way to propagate energy through the ocean, and many marine animals use hearing as their primary sense. Cetaceans are heavily dependent on sound for food-finding, communication, reproduction, detection of predators and navigation (Weilgart, 2007; Hildebrand, 2004).

The ocean is a naturally noisy environment and cetaceans have evolved ears that function well within this context. A review of anatomical and behavioural studies by Ketten (2004) indicated that whales and dolphins may be more resistant than many land mammals to temporary threshold shifts (loss of hearing sensitivity). However, these data also show that they are subject to disease and aging processes and are therefore not immune to hearing loss. Increasing ambient noise via human activities is a reasonable candidate for exacerbating or accelerating such losses (Ketten, 2004).

The introduction of additional noise into the marine environment could potentially result in an injury or cause a disturbance by interfering with the animals' ability to determine the presence of other individuals, predators, prey and underwater features and obstructions. This could therefore cause short-term behavioural changes and in more extreme cases, auditory damage. In addition to marine mammals, underwater sound may also cause behavioural changes in other animals such as fish and cephalopods.

Potential effects of anthropogenic sound sources on marine animals range from disturbance which may lead to (temporary) displacement from feeding or breeding areas, to auditory damage, tissue trauma and mortality (Carroll et al. 2017). Anthropogenic noise in the marine environment has been shown to affect foraging, vocalisation and movement of marine mammals whilst bony fish have been shown to display changes in movement patterns and feeding and antipredator behaviour (Chapuis et al. 2019). Conversely, some marine species may experience no effect from exposure to sound sources, particularly if the received frequency does not exceed their hearing thresholds (Carroll et al. 2017).

4.2.1 Impacts on Marine Mammals

Marine mammals use sound in various important contexts, such as in social interactions, foraging, and response to predators (Southall et al., 2007). Hearing is the primary sensory system for marine mammals, which is clearly shown by their level of ear and neural auditory centre development (Ketten, 2004). As the sea has never been a silent place, the ears of marine mammals, and those of whales and dolphins in particular, have evolved to function well within this context of ambient noise. However, little information exists to describe how marine mammals respond physically and behaviourally to intense sounds and to long-term increases in ambient noise levels (NRC, 2003).

4.2.1.1 Hearing Sensitivity

Marine mammals vary regarding to their hearing sensitivities and in order to assess the impacts of sound can be classed into functional hearing groups (Southall et al., 2007; NOAA, 2016; NOAA, 2018; and most recently Southall et al., 2019). The classification into functional hearing groups takes into account that not all marine mammal species have identical hearing or susceptibility to noise-induced hearing loss. Table 4.2 applies the most up to date classification by NOAA (2018) and Southall et al (2019) to the species that may be present in the wider area around the area of the proposed survey operations. Outside their generalized hearing ranges, the risk of auditory impacts from sounds is considered highly unlikely or very low.

Table 4.2: Function marine hearing groups for marine mammals potentially present in the greater survey area

Functional hearing group	Estimated auditory band width	Species potentially present in the survey area
Low-frequency cetaceans	7 Hz to 35 kHz	Minke whale.
High frequency cetaceans *(formerly referred to as Mid-frequency cetaceans)*	150 Hz to 160 kHz	Atlantic white-sided dolphin; white-beaked dolphin, common dolphin, bottlenose dolphin, killer whale, Risso's dolphin, Long finned pilot whale
Very high-frequency cetaceans *(formerly referred to High-frequency cetaceans)*	275 Hz to 160 kHz	Harbour porpoise
Pinnipeds in water	50 Hz to 86 KHz	Grey seal; common seal

Sources: BODC, 1998, Reid et al., 2003, NOAA, 2018 and Southall et al 2019.
Functional hearing groups in NOAA (2018) have been re-classified in Southall et al (2019) as low frequency, high frequency and very high frequency.

According to this classification, harbour porpoises are regarded as 'very high-frequency cetaceans', whereas dolphin species present around Orkney are classified as 'high-frequency cetaceans'. These classifications are based on the fact that odontocetes have highly advanced echolocation systems that use intermediate to very high frequencies. They also produce social sounds in a lower-frequency band, including generally low to intermediate frequencies (1 kHz to tens of kHz). Consequently, their functional hearing is expected to cover this whole range; however, their hearing sensitivity typically peaks at or near the frequency where echolocation signals are strongest (Southall et al., 2019).

The large baleen whales (mysticetes) are all categorised as low-frequency cetaceans. The most likely mysticete species present around Orkney is the minke whale. No direct measurements of hearing exist for these animals and theories regarding their sensory capabilities are consequently speculative. In these species, hearing sensitivity has been estimated from behavioural responses (or lack thereof) to sounds at various frequencies, most common vocalisation frequencies, body size, ambient noise levels at the frequencies they use most, and cochlear morphology. At present, the lower and upper frequencies for functional hearing in mysticetes, collectively, are estimated to be 7 Hz and 35 kHz (NOAA, 2018).

Research indicates that marine mammals can react differently to the introduction of additional noise into the marine environment. Reactions may vary depending on sound source level, propagation conditions and ambient noise, in addition to species, age, sex, habitat, individual variation, and previous habituation to noise (Richardson et al., 1995). It should also be noted that marine mammals react differently to stationary noise, compared to sudden bursts of noise and noises that appear to be coming towards them. Studies suggest that most cetaceans will alter their course or display avoidance reactions to a noise that appears to be moving directly towards them. Stationary noises, outwith an immediate zone of discomfort to the animal, seem to have a lesser effect in disturbing migration patterns and animal feeding, although data and observations on this matter are limited (Davis et al., 1990).

4.2.1.2 Potential Injury Impacts

The planned SBP operations will produce intermittent sound pulses, which are considerably more intense than the continuous noise emitted by most industrial noises in the ocean, such as shipping engine noise, for example. There are few direct data regarding the effects of intense sound on cetaceans, making it difficult to predict accurate safe exposure levels for these mammals (Finneran *et al*., 2000). Nonetheless, over the past two decades, various attempts have been made to create a set of injury criteria for individual marine mammals exposed to discrete noise events and several threshold criteria and methods for determining how sound levels are perceived by marine mammals are available (e.g. the dBht method and other hearing weighted and linear measures) and each has its own advantages and disadvantages.

JNCC guidance (JNCC, 2010) recommends using the injury criteria proposed by Southall et al. (2007) which are based on a combination of linear (i.e. un-weighted) peak pressure levels and mammal hearing weighted (M-weighted) sound exposure levels (SEL). The injury criteria proposed in Southall et al,. (2007) were updated by the US National Oceanic and Atmospheric Administration (NOAA) which introduced a new set of injury criteria in 2016 (NOAA, 2016), which were updated again in 2018 (NOAA, 2018) and these were subsequently maintained in Southall et al,. (2019). The NOAA (2018) and Southall et al,. (2019) thresholds are therefore regarded as the most up to date thresholds, and have been used in this assessment.

These injury criteria aim to set acoustic thresholds, at which individual marine mammals are predicted to experience temporary or permanent changes in their hearing sensitivity, as a result of acute, incidental exposure to underwater anthropogenic sound sources. These thresholds are referred to as 'Temporary Threshold Shift' (TTS) and Permanent Threshold Shift (PTS), respectively. The NOAA guidance makes a clear distinction between impulsive and non-impulsive sound sources, based on their physical characteristics at the source, with impulsive sound having physical characteristics making them more injurious (NOAA, 2018).

The acoustic thresholds for the type of underwater sound that will be generated by the proposed geophysical survey are based on dual metrics of peak sound level for a single pulse (SPL_R) and the cumulative sound exposure level (SEL_{cum}) over a 24 hr time period.

The SPL_R sound pressure level thresholds are based on the unweighted, or 'flat', threshold values for impulsive sounds, which are fixed for each hearing group. The SEL_{cum} thresholds however, are frequency dependent and therefore should be weighted accordingly. However, as explained in Section 4.1.1 the Innomar SES-2000 medium sub-bottom profiler produces a sound field covering a wide range of frequencies that overlap with the audible spectrum of all marine mammals groups (see Table 4.2). Therefore, no weighting adjustments have been used in the assessment to ensure the most conservative assessment method.

Table 4.3 presents the acoustic PTS thresholds for peak sound pressure level measured at distance R (SPL_R) and the cumulative sound exposure level (SEL_{cum}), for a recommended accumulation period of 24 hrs.

Table 4.3: PTS and TTS onset thresholds for marine mammals in the survey area

Marine Mammal Group	PTS onset, SPL_R, 0-pk, flat (dB re 1µPa)	PTS onset SEL_{cum}, 24hr (dB re 1µPa²-s)	TTS onset, SPL_R, 0-pk, flat (dB re 1µPa)	TTS onset SEL_{cum}, 24hr (dB re 1µPa²-s)
Low-frequency (LF) cetaceans Minke whale	219	183	213	168
Mid-frequency/High-frequency (HF) cetaceans Atlantic white-sided, White beaked dolphin, Common dolphin, Bottlenose dolphin, killer whale, Risso's dolphin, Long finned pilot whale	230	185	224	170
Very high-frequency (VHF) cetaceans Harbour Porpoise	202	155	196	140
Phocid carnivores in water (PCW) Grey and Common seals	218	185	212	170
Sources: NOAA, 2018 and Southall et al., 2019.				

The modelling results in Table 4.3 show that the lowest TTS onset SPL_R is 196 dB re 1µPa for 'Very High-frequency cetaceans' (harbour porpoises) and extends to 240 m straight underneath the SBP, but only extends 5 m in any direction horizontally around the SBP. Therefore, it seems extremely unlikely that the SPL_R criteria for either PTS or TTS exposure would be breached.

The second metric described in NOAA (2018) are the auditory thresholds for the cumulative SEL values over a 24 hour period. The modelling results summarised in Table 4.1 and Figure 4.2 show that the horizontal distance to the PTS threshold for the most sensitive species group, i.e. the harbour porpoises, is approximately 1 035 m, whereas the horizontal distance of the TTS threshold extends to 1 800 m.

However, it should be noted that this method assumes that any affected animal would remain in close proximity to, even following, the survey vessel for a period of 24 hours in order to exceed these thresholds, which is highly unlikely, as animals experiencing any discomfort caused by high sound levels are expected to (temporarily) move out of the area.

4.2.1.3 Potential EPS Disturbance Impacts

As explained in Section 2.2 above, it is an offence to deliberately disturb European Protected Species (EPS; species listed in Annex IV of the Habitats Directive) under Habitat Regulations 1994 and the Conservation of Offshore Marine Habitats and Species Regulations 2017, which implement the protection requirements of the Habitats and Birds Directives in the offshore marine area.

Therefore, an assessment has been undertaken to determine if any of the proposed survey operations taking place would potentially cause a 'disturbance offence' to any EPS, and subsequently would require a disturbance licence under these regulations. The potential disturbance caused by survey operations mainly refers to (underwater) noise.

EPS include all cetaceans, turtles and sturgeon. In UK waters, the latter two are at the limits of their global distributions (which are centred elsewhere in the west Atlantic or Europe) and only occur in low numbers around the UK. It is therefore extremely unlikely that a significant group of these animals would be present, or that their local abundance or distribution would be significantly affected by marine impacts (JNCC, 2010). Therefore, only cetaceans will be considered in this assessment from hereon.

As described above, it is unlikely that the proposed survey operations would cause any injury to cetaceans, however, a certain level of behavioural responses may be expected from individual cetaceans reacting to the produced underwater sound. Therefore, this assessment will be based on whether any of these behavioural responses could potentially significantly affect the local distribution or abundance of any of the cetacean species potentially present in the greater survey area.

No studies could be identified on the direct impacts of (parametric) sub-bottom profiling surveys. However, several studies are available on the behaviour of (small) odontocetes to seismic survey sound, which generally show some form of avoidance during survey operations, and these have been used as a proxy to estimate behavioural effects ranges for the proposed survey. Although, it should be noted that the vast majority of underwater sound energy produced by seismic surveys is typically at much lower frequencies than that produced by the proposed SBP operations. Hence, while the effects described below can be considered analogous they are not necessarily exactly equivalent to the proposed SBP operations.

A study by Goold (1996) reported general avoidance behaviour of common dolphins to airgun sound at up to 1 km during a 2D seismic survey off the coast of Pembrokeshire in the Irish Sea. Another study, looking at the effects of seismic surveys around the UK, showed that small cetaceans remained significantly further from the seismic vessel during periods of shooting (Stone & Tasker, 2006). Comparable behaviour was observed for Atlantic spotted dolphins by Weir (2008) during seismic exploration offshore Angola.

All three authors suggest that the avoidance behaviour appeared to be limited to within a few kilometres from the seismic airgun array. A similar effect was reported by Parente & de Araújo (2005) who reported a reduction in cetacean diversity, mainly among members of the family Delphinidae, during seismic surveying offshore Brazil.

Thompson et al (2013) found behavioural responses to 2D seismic survey noise in the Moray Firth in harbour porpoises within 5-10 km; although animals were typically detected again at affected sites within a few hours. Contrary to this, in their review of the effects of seismic surveys on marine mammals, Gordon et al (2004), quote a study which showed no change in the rate of detection of harbour porpoises during two seismic surveys, using an automated click detector.

Most studies on cetaceans report behavioural responses at received sound levels around 140 to 160 dB re 1 µPa, and sometimes even higher (e.g. Southall et al, 2007; Richardson et al, 1995). These responses typically consist of subtle effects on surfacing and respiration patterns. Sound levels of 150 to 180 dB will generally evoke behavioural avoidance reactions (Richardson et al, 1995). An underwater sound pressure level around 140 dB would be expected to occur around 2 km from the sound source. Hence, any behavioural effects are expected to be limited to within 2 km from the SBP sound source.

Table 4.4 shows cetacean species that may be present in the greater survey area, and which may therefore be affected by underwater noise generated by the proposed survey. It also presents an estimate of the number of individuals per species that may be expected to be present within the predicted zone of disturbance (i.e. up to 2 km distance from the SBP).

Table 4.4 shows that common dolphins (2.8) and harbour porpoises (1.9) are the most likely species to be present in the survey area. However, it should be noted that these numbers solely represent anticipated average numbers over a very large area. Furthermore, these numbers only make up very small fraction of the overall North Sea population and thus can be considered as not significant.

Table 4.4: Cetaceans Potentially Affected by Seismic Survey and their Estimated Population Size Based on SCANS III Data

Cetacean species	Density (animals / km^2)	Disturbance Zone (2 km)		Estimated Abundance over SCANS III Area
		No. of Animals Affected	% of Population Affected	
Harbour porpoise	0.152	1.9	0.0004 %	466 569
Minke whale	0.01	0.1	0.0009 %	14 759
White-beaked dolphin	0.021	0.3	0.0007 %	36 287
Atlantic white-sided dolphin	0.002	0.0	0.0002 %	15 510
Common dolphin	0.222	2.8	0.0006 %	467 673
Bottlenose dolphin	0.004	0.1	0.0002 %	27 697
Killer whale	No data	No data	No data	No data
Risso's dolphin	0.009	0.1	0.0008 %	13 584

Cetacean species	Density (animals / km²)	Disturbance Zone (2 km)		Estimated Abundance over SCANS III Area
		No. of Animals Affected	% of Population Affected	
Long finned pilot whale	0.004	0.1	0.0002 %	25 777
Source: Hammond et al, 2017. SCANS III data from survey Block S has been used to represent cetacean abundance in the vicinity of the survey area (Hammond et al, 2017). As no Atlantic white-sided dolphins, common dolphins, Risso's dolphins and long finned pilot whales were recorded in Block S during the SCANS III survey, the overall average density for the entire SCANS III area has been used for these species instead.				

No physical injuries are expected as a result of the underwater sound pulses generated by the parametric SBP during the seismic survey. However, any cetaceans in the immediate vicinity may exhibit avoidance responses and other subtler behavioural effects. It should be noted that the thresholds used to predict zones of effect around the SBP are precautionary, representing the lower limits of responsiveness from published studies, as reviewed by Southall et al. (2007), for example. As a consequence, not all marine mammals exposed to these levels of noise will respond as predicted, and some may show no measurable effects. In addition, the type and intensity of an animal's response is believed to vary depending on the ratio between the anthropogenic sound and ambient noise levels, the rate of change of the sound; and also the behavioural context and motivations at the time, the previous experience of exposed individuals and how the animal interprets the sound, i.e. as a predator or just an annoying stimulus (JNCC, 2010).

The Stage 1 Risk Assessment above shows that the risk of an injury or disturbance offence being committed is low but cannot be completely dismissed. Therefore, on this occasion, Fugro wishes to apply for an EPS disturbance licence for the survey operations.

4.2.2 Impact on Basking Sharks

Sharks, including basking sharks, only have an inner ear. Their ears comprise two small holes which are located on either side of their head, behind the eyes. They are made up of 3 cartilage tubes filled with fluid and lined with hair cells. Sound waves cause these tiny hairs to vibrate and the brain then interprets the sound (Shark Trust, 2021).

The paired inner ears, as in all fishes, detect the particle motion component of a sound. Unlike most bony fishes however, cartilaginous fishes (including sharks) do not possess a swim bladder, which responds to the pressure component of a sound, and therefore are thought to only be sensitive to particle motion (Chapuis et al., 2019). Consequently, the hearing sensitivity of sharks is limited to low frequency sounds only (between 20 Hz to 1 500 Hz) peaking between 200 and 600 Hz, depending on the species (Carroll et al., 2017 and Chapuis et al., 2019).

Little information exists on sound detection in basking sharks and there is no direct evidence of sound causing this species mortality or stress (Wilson et al., 2021). The aforementioned estimated hearing bandwidth of elasmobranchs is well below that of the geophysical survey equipment proposed for use in the survey operations (see Table 1.2). Furthermore, basking sharks are not known to vocalise and do not rely on hearing to forage. Hence, increased vessel noise is not considered likely have any impact on the species (Booth et al., 2013).

Therefore, it is very unlikely that basking sharks will be able to hear the underwater sound produced by any of the survey equipment, and thus no disturbance or injury from the effects of the additional underwater sound are anticipated.

However, basking sharks have been observed diving and moving away from areas when disturbed by boats, although some observations note that basking sharks remain relatively unaware of surface vessels (Bloomfield & Solandt, 2006 and Speedie & Johnson, 2008).

Therefore, they potentially may be susceptible to ship strikes, although there is a lack of information on the frequency of such events (Booth et al., 2013). Observations of basking sharks during seismic survey operations off Shetland noted that individuals and small groups continued to be observed even during firing of the air guns (Hayes et al., 2018).

Even though, basking sharks are considered to have a low sensitivity to noise, it is advised that any pressures associated with scientific acoustic surveys should be minimised through existing best practice, such as the JNCC 2017 Guidelines, to ensure basking sharks are not disrupted, particularly between the months of April and October (NatureScot, 2020).

To mitigate and reduce the risk of collision with survey vessels or towed equipment during the survey operations it is proposed that marine mammal observers (MMOs) undertake a pre-survey watch to detect basking sharks when at the surface in line with the JNCC guidance and any line turns are conducted in accordance with the mitigation measures detailed in the same guidance (JNCC, 2017) as discussed in Section 4.3. An ongoing watch for basking sharks will be maintained during the survey operations where conditions permit (i.e. during hours of daylight).

The species relative lack of awareness of vessel traffic and susceptibility to ship strikes conversely means that they are not likely to be susceptible to disturbance from the presence of additional vessels in an area (Speedie et al., 2009 in Booth et al., 2013). Thus, it is considered unlikely that the presence of the survey vessels will have a significant impact on basking sharks. However, to mitigate and reduce any potential risk of collision it is recommended that codes of conduct for vessel operators, such as the Scottish Marine Wildlife Watching Code (SMWWC), are adhered to and that the survey vessels have observers onboard to look out for basking sharks during transit and survey operations.

The survey operations for the proposed cable routes within the Orkney islands are planned for June and July which coincides with a general increase in basking shark sightings in Scotland however it is prior to the peak in recordings which typically occur in August (Bloomfield & Solandt, 2006). However, as discussed in Section 3.2, the majority of observations of basking sharks are reported from the west coast of Scotland particularly around northwest Mull, Coll, Tiree, west of Canna and the Northern Clyde Sea (Bloomfield & Solandt, 2006).

In addition, the proposed survey operations are of a short, temporary nature, lasting approximately 34 days in total. Due to the relatively low numbers of basking sharks within the Orkney islands (Bloomfield & Solandt, 2006 and SHN, 2021), it is not considered likely that the proposed survey operations will, for the reasons expanded on above, have a significant disturbance effect on basking sharks in the area.

Mitigation measures, as detailed in Section 4.3, will further reduce the potential for any disturbance or injury threat to basking sharks during survey operations.

The basking shark Risk Assessment above shows that the risk of an injury or disturbance offence being committed is low but cannot be completely dismissed. Therefore, on this occasion, Fugro wishes to apply for a basking shark licence for the survey operations.

4.2.3 Cumulative Impacts

Gordon *et al.* (1998) suggest that cumulative effects on feeding, migration and social behaviour in marine mammals may lead to wider population effects, particularly in areas of high interest where many seismic surveys occur at the same. However, to date there are no ready means of estimating the contribution of a specific activity to the cumulative effects of all human activities on a species or population (Moore *et al.*, 2012). This knowledge gap of cumulative impacts is widely acknowledged (e.g: NRC, 2003; Gordon *et al.*, 2004; Southall *et al.* 2007; Boyd *et al.* 2011).

As a result, at present, no causal links have been (or can be) made between cumulative impacts and seismic exploration. For example, various studies in northwestern Australia and along the Californian coast indicated that baleen whales continue to migrate into areas of consistently high survey activity (McCauley, 1994); Richardson *et al.*, (1987) found no evidence that bowhead whales were avoiding areas of seismic exploration in the Beaufort Sea during a long term study, and; the bottlenose dolphin population in the Moray Firth does not seem to be affected by the repeated seismic surveying activity in the area (Thompson *et al.*, 2013; Evans & Nice 1996; Turnpenny & Nedwell, 1994). Although currently unproven, Fugro does acknowledge that the potential for cumulative effects on marine mammals is plausible and will therefore adopt the following precautionary measures in the planning and execution of this seismic survey.

Bearing in mind the distances at which behavioural effects may occur in marine mammals and fish from a single geophysical survey, it is considered good industry practise to undertake such surveys consecutively through appropriate planning and co-operation, where possible. It is also worth noting that seismic surveys should not be undertaken in close proximity to each other for technical reasons as that would interfere with data collection. Therefore, if surveys are to be carried out simultaneously, Fugro will follow the International Association of Geophysical Contractors (IAGC) practice of time share between seismic marine crews, thereby minimising the potential for cumulative impacts.

Other producers of underwater sound that may interact with the seismic survey are shipping and fishing. In general, sound levels of shipping and fishing activities are typically attenuated to below levels expected to cause any effects on marine mammal or fish behaviour within a few km from the source. Fishing vessel activity in the area is not concentrated in any particular location, and commercial shipping traffic levels are typically low. Due to the transitory and temporary nature of noise inputs to the sea from other sea users (i.e. fishing and shipping), the interaction of these with underwater noise is unlikely to cause any significant cumulative impacts.

4.3 Mitigation Measures

One of the main mitigation measures in reducing environmental impacts from geophysical survey operations is to minimise the amount of anthropogenic noise entering the marine environment. Therefore, the proposed operations will use the lowest practicable power levels throughout the survey, and the SBP and other geophysical survey equipment will only be fired when necessary.

To minimise potential impacts on EPS and basking sharks in the area, the survey operations will adhere to the JNCC guidelines for 'minimising the risk of injury to marine mammals from geophysical surveys' (JNCC 2017) including the use of MMOs and soft starts, where practical (i.e. where the equipment is capable of undertaking a soft start).

A trained, non-dedicated MMO will be present on each vessel with a second trained, non-dedicated MMO, on the offshore vessel. The MMOs will survey the sea surface for the presence of cetaceans and basking sharks within 500 m of the survey site ensuring no individuals are present prior to the commencement of any survey operations. The use of Passive Acoustic Monitoring (PAM) on the offshore vessel is proposed as a complimentary mitigation measure for the survey works undertaken in the hours of darkness.

Not all geophysical survey equipment proposed for use in the survey operations are capable of undertaking "soft start" procedures, however, where the devices allow this it shall be used.

Personnel on the survey will ensure the operations are undertaken in compliance with the SMWWC.

By adhering to the mitigation measures detailed above, any disturbance effects on marine EPS or basking sharks in the area will be kept to a minimum and should not impact on the Favourable Conservation Status (FCS) of the species likely to be found within the survey area.

5. Conclusions

The likelihood of the proposed geophysical survey presenting an injury or disturbance risk to cetaceans or basking sharks in the vicinity of the survey areas is considered to be low. In order to mitigate any potential risk of injury to, or disturbance of, these species the 'JNCC 'minimising the risk of injury to marine mammals from geophysical surveys' guidelines will be followed (JNCC, 2017) and the survey crew will also adhere to the SMWWC.

However, the risk of an injury or disturbance offence being committed can never be completely dismissed and therefore Fugro wishes to apply for disturbance licences for EPS and basking sharks.

Nonetheless, it is considered that with the appropriate mitigation in place, the risk of injury and disturbance to EPS and basking sharks will be reduced to negligible levels and therefore maintain the FCS of the species likely to be present in the survey areas.

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