Contents

Appendix A: Marine Environmental Assessments

Overview

A.1. The content and structure of this appendix is based on the overarching approach noted in section 4 of the main report and sets out the data and evidence used for all of the different assessments. Based on the nature of the assessments, the main assessments are set out based on the impact pathways and receptors, which are then used to support the individual assessments, e.g. HRA. Based on CIEEM best practice, the following sections contain:

- Step 1 – Identification of the ecological features
  - This section contains information on all of the environmental features relevant to the area and activities to be undertaken as part of the survey, including the environmental baseline used for the assessments.
- Step 3 – Assess significance of the impact
  - This section contains the environmental assessments for each of the drivers. The results are set out based on its importance. The HRA assessments are noted separately, whilst drivers for other designated sites, e.g. EPS etc, are grouped under assessments based on the impact pathways and ecological receptors. This is with the exception of the WFD assessment, which was also undertaken separately due to its requirements.

A.2. Step 2 (determine potential impact pathways) and step 4 (identify appropriate mitigation) are included in the main report in sections 4.64-4.105 and 5.5-5.10, respectively.

Step 1 – Identification of ecological features

B.1. This section sets out the marine baseline with all the data and evidence gathered for the main ecological features that are relevant for the assessments. The evidence focuses on the ecological features of interest (e.g. cetaceans), as physical features (e.g. habitats) are not sensitive to the proposed activities of the survey and so are scoped out of the assessments.

Survey area

B.2. The survey area for the assessment was focussed on the inshore area off Copeland, Cumbria. In recognition of the potential propagation of underwater sound and highly mobile and transient nature of marine species (such as marine mammals and diadromous fish species), and the potential implications of local impacts on wider populations, a broader search was conducted (some of which extend to include the Celtic Sea, the west coast of Scotland, and the wider waters of the British Isles). This ensured that the initial screening in of marine receptors and designated sites was based on a precautionary approach. As part of this, sites beyond English territorial waters were identified in the initial data gathering and scoping stage to identify if any consultation of Statutory Nature Conservation Bodies beyond NE was required.

Cetaceans

B.3. Cetaceans are known to be sensitive to underwater sound, are designated as EPS, as well as being qualifying features in some designated areas around the UK coastline.

Key data sources

B.4. This study comprised a detailed desk-based review of publicly available information relevant to the survey area. This included publicly available information from the following sources:

- General:
  - Atlas of Cetacean Distribution in north-west European Waters (Reid et al., 2003);
  - UK Cetacean Status Review (Evans et al., 2003);
  - Sea Watch Foundation (2021; https://www.seawatchfoundation.org.uk/);
  - Sea Mammal Research Unit (SMRU) (2021; http://www.smru.st-andrews.ac.uk/);
  - UK Cetacean Stranding Investigation Programme (2021; http://ukstrandings.org/csip-publications/);
  - Inter-Agency Marine Mammal Working Group (IAMMWG) (2021);
  - Heinänen and Skov (2015) – which has developed distribution models for harbour porpoise within the UK Exclusive Economic Zone based on 18 years of survey data collected as part of the Joint Cetacean Protocol;
  - Waggit et al. (2019) – provides updated distribution models for 12 species of cetacean covering the north east Atlantic based on survey data collected between 1980 and 2018; and
  - References for cetacean swimming speeds (Blix and Folkow, 1995; Kasterlein et al., 2018; McGarry et al., 2017; Otani et al., 2000; and Van Beest et al., 2018).
- Specialist data sets (described in detail below):
  - Small Cetaceans in European Atlantic waters and the North Sea (SCANS) I, II and III data (Hammond et al., 2002; 2013 and 2017); and
  - Wildfowl and Wetlands Trust (WWT) data (WWT Consulting, 2009).

<u>SCANS data (I, II, and III)</u>

B.5. The Small Cetaceans in European Atlantic waters and the North Sea (SCANS) Project involved completing surveys to estimate the abundance of small cetaceans across the North Sea. The data from the SCANS-III surveys was first published in 2017, but has since been revised in 2021 following the ‘discovery of some analytical errors’.

B.6. SCANS surveys were conducted in the summer and therefore data is representative of summer distributions only. However, it is understood that the densities of cetaceans around the British Isles are likely to be highest during this season, and therefore the abundances presented are considered to represent the worst-case. Despite the fact the exact same area was not always sampled in each of the three SCANS monitoring years, some inference of temporal trends can be made from the data. This information can also be used to predict the potential evolution of baseline conditions for marine mammals within the survey area. As such, the SCANS data represents a key data source for cetaceans.

B.7. The SCANS-III survey was divided into blocks as shown in Figure A1; the survey area for the survey falls within Block F. Estimates of abundance for each species have been derived from this.

<u>WWT data (2001 – 2008)</u>

B.8. Between 2001 and 2008, WWT Consulting carried out aerial surveys for waterbirds. Opportunistic sightings of cetaceans, seals, turtles, sharks and ocean sunfish were also recorded and reported in WWT Consulting (2009). This data provides information about the distribution and abundance of these taxa around the British Isles and provides valuable supplement to the SCANS data.

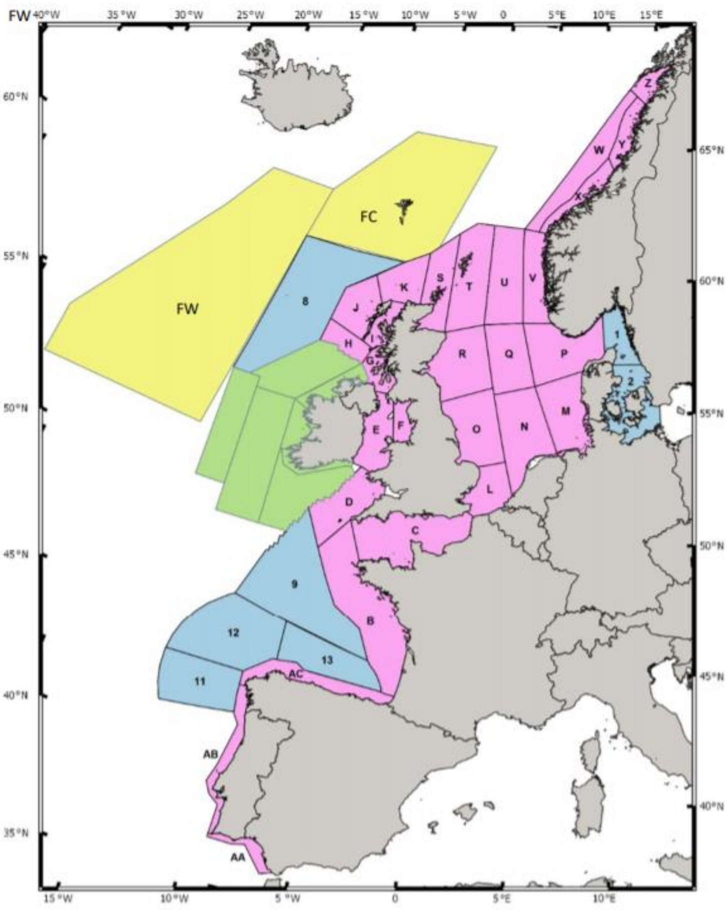

Figure A1. SCANS III survey blocks*

** Pink blocks were surveyed by air, blue numbered blocks were surveyed by ship. Blocks coloured green to the south, west and north of Ireland were surveyed by the Irish ObSERVE project. Blocks FC and FW coloured yellow were surveyed by the Faroe Islands as part of the North Atlantic Sightings Survey in 2015.*

Source: Hammond et al.*, 2021* (*reproduced with permission*)

Evidence baseline

B.9. Several marine mammal species are found in UK waters, including 28 recorded cetacean species and two seal species (JNCC, 2021). Twelve of these species are regularly seen, including harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), common dolphin (*Delphinus delphis*), Risso's dolphin (*Grampus griseus*), white beaked dolphin (*Lagenorhynchus albirostris*), minke whale (*Balaenoptera acutorostrata*), fin whale (*Balaenoptera physalus*), and sperm whale (*Physeter macrocephalus*). These species are all protected under national and international legislation (the protection afforded to the species of relevance to the survey area is presented in Table A1 with designated sites that contain a cetacean as a qualifying feature shown in **Appendix C: Figures - Figure C1**).

B.10. The waters off the northwest of England are considered to be less important for cetaceans due to the shallow water depths in this region (less than 50 m depth) and uniform nature of the bathymetry (Sea Watch Foundation, 2021). In the Irish Sea, the highest density and diversity of species can be found further to the west where the waters are deeper (up to 150 to 200 m in some places), such as in the North Channel, and around the Isle of Man, predominantly on the western coast. Cetacean species, which are frequently sighted in waters of the northwest England (and have therefore been considered in more detail within this baseline assessment), include (Sea Watch Foundation, 2021) although other species have been considered as well:

- Harbour porpoise:
- Bottlenose dolphin; and
- Common dolphin.

B.11. Estimates of abundance and density as part of the SCANS-III surveys (Hammond et al*.,* 2021) were only calculated where there was sufficient data for a particular species. In SCANS-III Block F, where the survey is planned (Table A1), calculations were only possible for harbour porpoise. Therefore, abundance estimates from the IAMMWG (2021), which defined Management Units (MUs) for the seven most common cetacean species found in UK waters (including the three species most commonly found in northwest England waters), have been used to supplement this data. However, these data do not include densities, and therefore SCANS-III remains the primary source for calculating the density of individuals within the survey area. The survey area falls within the Celtic and Irish Sea (CIS) MU for harbour porpoise, Irish Sea (IS) MU for bottlenose dolphin, and Celtic and Greater North Sea (CGNS) for common dolphin (and other species).

Table A1. Summary of protection measures in place for the key cetaceans known to be present in the survey area

Common name	Latin name	Wildlife and Countryside Act, 1981	EC Habitats Directive (Annex)	Bonn Convention (Appendix)	Bern Convention (Appendix)*	EU Council Regulation 338/97 (Annex)	ASCOBANS	ACCOBAMS
Harbour porpoise	Phocoena phocoena	Yes	II, IV	II	II	A	Yes	Yes
Bottlenose dolphin	Tursiops truncatus	Yes	II, IV	II	II	A	Yes	Yes
Common dolphin	Delphinus delphis	Yes	IV	II	II	A	Yes	Yes
*Only particular populations are protected by this Convention, but individuals of some of those populations may occur in the study area								

<u>Harbour porpoise</u>

B.12. The harbour porpoise is one of the most common marine mammal species recorded in north-western European shelf waters (Reid et al*.,* 2003) and is widely distributed and commonly recorded in the northern Irish Sea (Evans and Anderwald, 2005). Between 1980 and 2002, this species was the most frequently sighted marine mammal, representing 53% of all cetacean sightings recorded in UK waters and adjacent seas (Evans et al*.,* 2003). Harbour porpoise rarely occur in waters exceeding 200 m, with the highest densities observed in waters <100 m deep (Evans et al*.,* 2003; Booth et al., 2013). Individuals in coastal waters, are most frequently encountered close to islands and headlands with strong tidal currents (Evans et al*.,* 2003). Harbour porpoise are very active with high energy demands, and their small size means they need to feed regularly (Pierpoint, 2008). The diet of harbour porpoise in UK and Irish waters consists of small schooling fish, including herring and sprat (Clupeidae), sandeels (Ammodytidae), and members of the cod family (Gadidae). Harbour porpoise mating occurs in October, with births (typically a single calf) occurring in March to August, peaking in June and July (Evans et al*.,* 2003).

B.13. In the northern Irish Sea, clusters of sightings of harbour porpoise had previously been made around the Isle of Man, off the Mull of Galloway, the north coast of Anglesey and the Lleyn Peninsula in north Wales (Evans and Shephard, 2001). However, increased survey effort has indicated that this species is generally continuously distributed along the coasts of south west Scotland, north Wales, and north west England (Evans and Anderwald, 2005).

B.14. Sightings as part of the Sea Watch Foundation (2021) indicate that harbour porpoise are sighted in small numbers around the Isle of Man (predominantly in coastal waters on the south and west of the island), in Morecombe Bay, in Solway Firth (near Maryport), and around St Bee's Head in Cumbria. Based on the analysis of long-term effort related land-based observations in the UK, Evans et al. (2015) states that sightings rates in Lancashire and Cumbria are low (<0.5 individuals/hour), although slightly higher at St Bees Head (0.6 individuals/hour, with >40 hr effort). From 2019 to 2021, there were a total of 63 sightings records for the north west of England as part of the Sea Watch Foundation (2021), with a total of 120 individuals recorded (ranging between 1 and 11 individuals/sighting; mean = 1.9 individuals/sighting) (Sea Watch Foundation, 2021).

B.15. In Cumbria specifically, 28 individuals were recorded, across 15 sightings, of which one sighting of three individuals were recorded in the Solway Firth estuary (sighting in May 2021). Most sightings of harbour porpoise, as part of the Sea Watch Foundation, (2021) occurred between July to September. However, Evans et al. (2003) states that harbour porpoise in northwest of England waters are thought to be present year-round, with peak numbers of individuals in late winter and spring. The difference between these two sources is likely due to the methodologies used. Evans et al. (2003) analyses both sightings' data (of which 37,000 were opportunistic; 16,000 were effort based) and data from dedicated survey effort (approximately 50,000 hrs), whilst the Sea Watch Foundation (2021) have considered opportunistic public sightings only. Public sightings can often result in seasonal bias, as the number of sightings often increase significantly during the summer holiday period, suggesting a seasonal bias that may not exist.

B.16. Harbour porpoise are generally observed in small groups of up to three individuals. The mean group size observed from the SCANS-III data was 1.35, but only 1.00 for Block F (Hammond et al., 2021). Occasionally large aggregations are observed, but these probably result from many small groups and individuals concentrating in the same place at the same time to exploit feeding resources, as opposed to being coordinated gatherings (Hoek, 1992).

B.17. SCANS-III data indicated that within Block F an estimated abundance of 1,056 (95% Confidence Limits (CL) = 342 – 2,010) harbour porpoise were recorded with a density of 0.086 individuals/km^2 (see Figure A2). This is considered to be relatively small compared to abundance and densities recorded in the rest of the UK. For example, in the western Irish Sea (Block E) abundance was estimated to be 8,320 (95% CL = 4,643 – 14,354) with an average density of 0.282 animals/km^2.

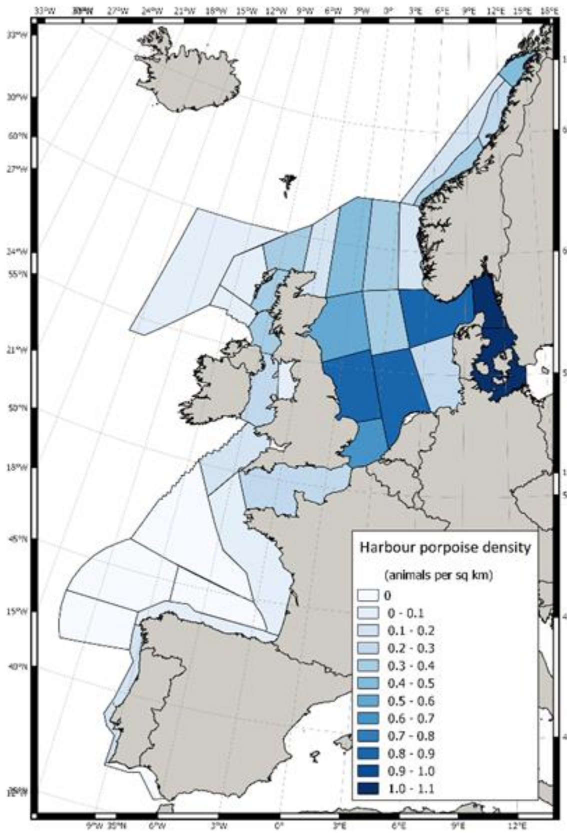

Figure A2. Estimated density of harbour porpoise for blocks surveyed during SCANS-III (July 2016)

Source: Hammond et al.*, 2021 (reproduced with permission)*

B.18. Within the UK portion of the IAMMWG (2021) CIS MU, the total abundance of harbour porpoise is estimated to be 62,517 (95% CL = 11,216 – 25,096). When compared to the SCANS-III data, the abundance of animals in Block F represents a small proportion of this total population and is therefore not considered to be a particularly important area for this species. Furthermore, the survey area was also not recorded as a high-density area for this species in summer and winter months (Heinänen and Skov, 2015). In contrast, more recent spatial and temporal distribution model predictions by Waggit et al. (2019), which collated data from a diversity of survey records, seems to disagree with both Heinänen and Skov (2015) and SCANS-III data. These data predict the density of harbour porpoise off the coast of north west England to be slightly higher than other areas of the Irish Sea (with the exception of areas around Wales). This is indicated in Figure A3, where the colour gradient consists predominantly of areas of yellow (<0.53 individuals/km^2), and patches of orange and red (up to 1.06 animals/km^2) for both winter and summer months in coastal areas.

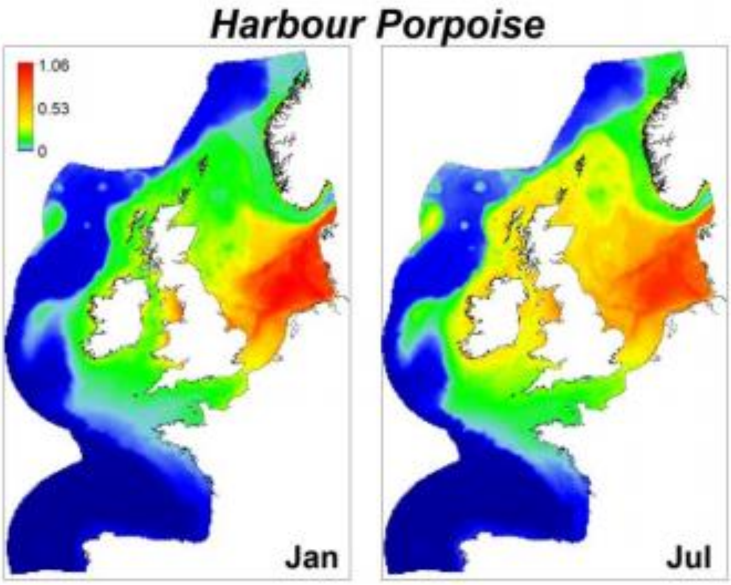

Figure A3. Harbour porpoise spatial variation in predicted densities (individuals/km2) in January and July

Source: Waggit et al.*, 2019 (reproduced with permission)*

B.19. There is very little evidence regarding harbour porpoise population trends in the Irish Sea. A southward shift in the distribution of this species was observed in the North Sea from 1994 to 2005 (between the SCANS and SCANS-II data), which was attributed to changes in prey distribution (Pinn et al., 2018). However, Evans and Anderwald (2005) state that there is no evidence that harbour porpoise in the northern Irish Sea has become less common or changed its distribution since 2001.

B.20. Harbour porpoise has the highest number of strandings in the UK, with a total of 1,677 individuals reported from 2011 to 2015 (the latest report by the UK Cetacean Strandings Investigation Programme) (CSIP, 2015). Strandings of harbour porpoise occurred across most of the English coastline, including the north west and Cumbrian coast (Figure A4). A recent stranding, in January 2021, was recorded on the Isle of Walney beach, in Cumbria (Fletcher, 2021).

B.21. In 2015, there were 273 strandings, 53 of which underwent post-mortem examination. Overall, individuals died due to by-catch (entanglement with fishing gear) (10 individuals), starvation (nine individuals), from bottlenose dolphin attacks (eight individuals), pneumonia due to parasitic infections (four individuals), from physical trauma of unknown cause (four individuals), as a consequence of live stranding (four individuals), from infections of the gastro-intestinal tracts (three individuals), as a result of potential attack by grey seal(s) (three individuals), from generalised bacterial infections (two individuals), as a consequence of dystocia (one individual), from severe hepatic parasitism (one individual), from starvation as a sequel to gastric impaction with bones (one individual), and from potential lymphoma (one individual).

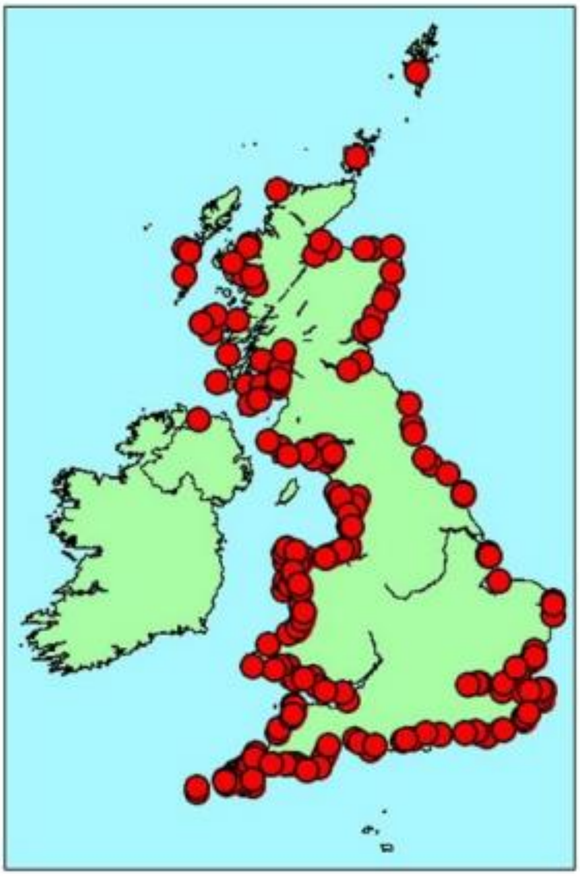

Figure A4. Distribution of harbour porpoise strandings in the UK in 2015

Source: CSIP, 2015 (reproduced with permission)

B.22. The most significant anthropogenic related threat to harbour porpoises in north western Europe is thought to be bycatch (IAMMWG, 2015). In the UK, the range and future prospect of the harbour porpoise is considered to be of 'favourable' conservation status, although the overall trend in the conservation status of this species is unknown (JNCC, 2019). In Europe, this species is considered 'vulnerable' by the International Union of Conservation of Nature (IUCN) (IUCN, 2019).

B.23. There are two designated sites in the Irish Sea for which harbour porpoise are a qualifying feature and that could be impacted by the geophysical survey:

- the North Channel Special Area of Conservation (SAC) (located 63 km west of the survey area); and
- the North Anglesey Marine / Gogledd Môn Forol SAC (located 63 km to the south west of the survey area).

B.24. The North Channel SAC is located in the northern Irish Sea (off the northern coast of Ireland), and represents an important winter habitat for harbour porpoise, providing suitable habitat for foraging and also breeding and calving (JNCC, 2021). During winter months this site has been identified as being in the top 10% of persistent high densities of harbour porpoise in UK waters (Heinänen and Skov, 2015). Within the Northern Channel SAC, land-based sightings in Northern Ireland, from Mew Island (near Donaghadee) to Island Magee (near Larne), from 1996 to 2014, have reported large groups of harbour porpoise ranging from 20 to 100 individuals (DAERA and JNCC, 2017).

B.25. The North Anglesey Marine SAC stretches into the Irish Sea from the coast of Anglesey and is estimated to support 2.4% of the UK Celtic and Irish Seas MU population (JNCC, 2021). This site has been designated for its importance in summer months as important foraging and breeding and calving habitat (April to September). This difference in seasonal use between the North Channel SAC and the North Anglesey Marine SAC reflects the changes in usage and distribution of this species with the seasons (JNCC, 2019).

B.26. Although the harbour porpoise is not a qualifying feature, the Solway Firth SAC has been identified as a Grade D location for this species (JNCC, 2021). Grade D locations are defined as having features of below SSSI quality occurring on SACs which are not a qualifying feature (i.e. a “non-significant presence”), indicated by a letter D (this is not a formal global grade). Harbour porpoises are the most commonly sighted species in the Solway Firth, often found throughout the north Solway and even in the upper reaches of the estuary (Solway Firth Partnership, 2011). Sightings of harbour porpoise in the Solway Firth are generally made from prominent headlands such as the Mull of Galloway, Castle Point, and Corsewall Point. The area between Southerness Point has been suggested to be a calving ground for the species, indicated by regular sightings in the area and a number of dead calves being found in this region (Hammond et al., 2002 cited in Canning et al., 2013).

B.27. Although both sites fall outside the impact ranges highlighted in JNCC guidance (e.g. 50 km for piling), the potential impacts from the survey still has the potential to impact on these sites and so are included for the environmental assessments.

Bottlenose dolphin

B.28. The bottlenose dolphin is a large species reaching 2.5 - 3.0 m in length and weighing up to 275 kg (Sea Watch Foundation, 2012). Between 1980 and 2002, bottlenose dolphin represented the second most frequently observed marine mammal species, accounting for 20% of all cetacean sightings recorded in UK waters and adjacent seas (Evans et al., 2003). This species is considered to be an inshore species, most frequently sighted 10 km off land, although they are also known to occur offshore (Evans and Shephard, 2001). In the Irish Sea, bottlenose dolphin occur in the largest numbers between July and October, peaking in August (Evans et al., 2003). Although bottlenose dolphin have a large range in the Irish Sea, with sightings occurring from the coast of Anglesey and off Morecombe Bay, animals are generally concentrated around Cardigan Bay (Evans and Anderwald, 2005; WDCS, 2012).

B.29. In the waters off the northwest coast of England, small numbers of bottlenose dolphin have been recorded as part of Sea Watch Foundation (2021). Sightings data are concentrated around the Isle of Man, off Heysham in the Solway Firth, and Morecombe Bay (with the majority of sightings occurring between July and September). In the Solway Firth and off the Dumfries and Galloway Coast, bottlenose dolphin are encountered (although much less frequently than harbour porpoise), and in July 2011 a large pod of 50 to 70 individuals were sighted (by a group of fisherman) off the mouth of Kirkcudbright Bay feeding on a school of mullet (Solway Firth Partnership, 2011).

B.30. As part of Sea Watch Foundation (2021) data, a total of 15 sightings were made between 2019 and 2021, where 85 individuals were recorded (ranging between 3 and 15 individuals/sighting; mean = 5.7 individuals/sighting). Of these sightings, the majority were made in Blackpool, Lancashire (a total of eight sightings), whilst five sightings were made in Cumbria, including from Walney Island.

B.31. As part the SCANS-III surveys, insufficient data was collected for bottlenose dolphin for abundance and density calculations to be made for Block F, indicative that this area is not particularly important for this species (Hammond et al., 2021) (see Figure A5). Calculations were made, however, for the western Irish Sea (Block E), where an estimated abundance of 288 (95% CL = 0 – 664) bottlenose dolphin were recorded, with a density of 0.008 animals/km^2. This is consistent with the analysis undertaken by Waggitt et al. (2019) (see Figure A6), which shows that the density of this species in the north west of England waters is approximately 0 individuals/km^2. Within the UK portion of the IAMMWG (2021) IS MU, the total abundance of bottlenose dolphin is estimated to be 186 (95% CL = 70 – 492).

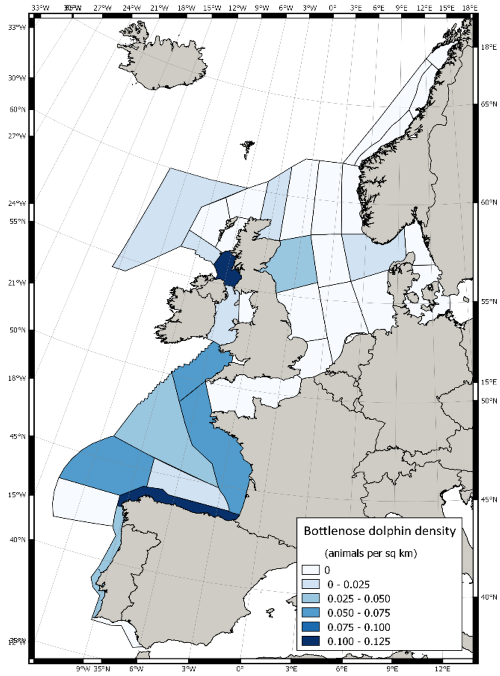

Figure A5. Estimated density of bottlenose dolphin for blocks surveyed during SCANS-III (July 2016)

Source: Hammond et al.*, 2021 (reproduced with permission)*

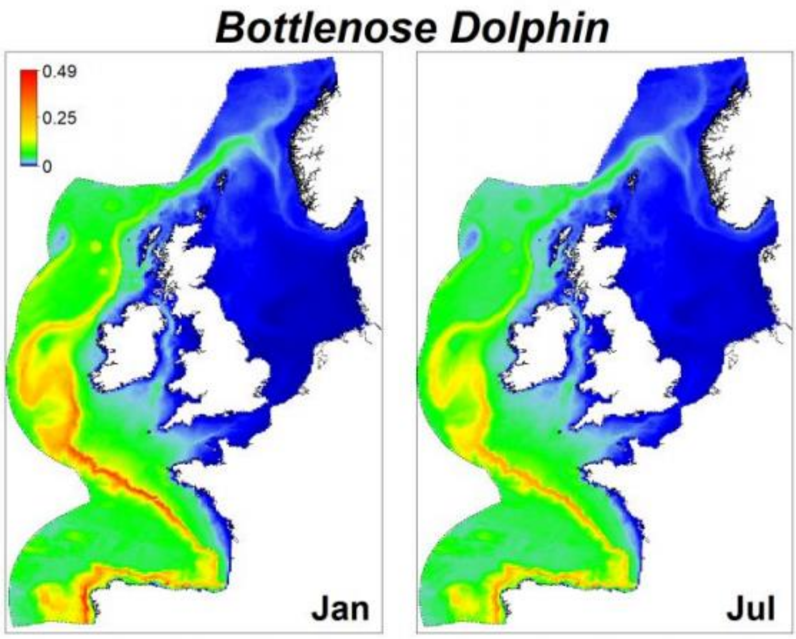

Figure A6. Bottlenose dolphin spatial variation in predicted densities (individuals/km2) in January and July

Source: Waggitt et al.*, 2019 (reproduced with permission)*

B.32. There have been few strandings of bottlenose dolphin in the UK, with a total of 51 individuals recorded from 2011 to 2015 in the latest report by the UK Cetacean

Strandings Investigation Programme (CSIP, 2015). In 2015, of the nine total strandings recorded in the UK, six were found in England, and two were found in Wales. A single individual was analysed at post-mortem, which was stranded in Wales, and was found to have died following entanglement with fishing gear (by-catch). A recent stranding of a bottlenose dolphin was reported in 2018 on Harrington beach, Cumbria (near to Whitehaven); the cause of death was not detailed (Cumberland News, 2018). In general, there has been a decline of bottlenose strandings reports in the north-west of Britain (Defra, 2005).

B.33. Evans and Anderwald (2005) state that in the northern Irish Sea, ‘there is no evidence for a change in status or a major distributional shift’ in bottlenose dolphin. However, there has been an overall decrease in the population of bottlenose dolphins in European waters over the last century, which is thought to have occurred in response to geophysical exploration, dredging, pollutant discharge, an increase in shipping activity and direct and indirect fisheries (Sini et al., 2005). Only small isolated pockets of this species now exist along the coasts of continental Europe and the UK and Ireland. Despite this, the range of bottlenose dolphin is considered to be at ‘favourable’ conservation status in UK waters (JNCC, 2019) and is of ‘least concern’ globally (IUCN, 2019).

B.34. The closest designated site for which bottlenose dolphin are a primary qualifying feature to the survey is the Cardigan Bay / Bae Ceredigion SAC (located 189 km south of the survey area). This site is located off the west coast of Wales and has been estimated to consist of around 125 individuals, which typically occur in the inshore waters of Cardigan Bay where they feed and reproduce. Bottlenose dolphin are also a secondary qualifying feature of the Pen Llŷn a'r Sarnau/ Lleyn Peninsula and the Sarnau SAC (located 124 km south of the study area). The bottlenose dolphin community at this site is part of the larger coastal population mainly associated with the Cardigan Bay SAC, showing a high degree of connectivity between these sites. Both sites are considered too far from the survey area for there to be an interaction with the survey, bottlenose dolphin ranges being shorter than those of harbour porpoise. Therefore, these sites have not been considered further within this assessment.

Common dolphin

B.35. The (short-beaked) common dolphin is a pelagic species typically found in offshore waters, but is regularly found in continental shelf waters, particularly in the Celtic Sea and southern Irish Sea (Waggit et al., 2019; Reid et al., 2003; Evans et al., 2003). This species is often sighted in central and western parts of the northern Irish Sea, including south-west of the Isle of Man, the North Channel, as well as occasional sightings into the Solway Firth (Sea Watch Foundation, 2021; Solway Firth Partnership, 2011). Around the Isle of Man (in Manx waters), this species is mainly recorded between May and September with fewer than five sightings a year, but in general is an occasional visitor to the area (Felce et al., 2013).

B.36. There are limited sightings data for common dolphin as provided by the Sea Watch Foundation (2021). However, in the period 2019 to 2021, there was one sighting of this species in August 2021, when two individuals were reported. This sighting was made in Cumbria at Coulderton, near St Bees Head. During 2001 to 2005, five live sightings were made of this species in the north-eastern Irish Sea, including from west of Blackpool (in Lancashire) (Evans and Anderwald, 2005).

B.37. There was insufficient data collected as part of the SCANS-III surveys for abundance and density calculations to be made for common dolphin in both Block F and E (eastern and western Irish Sea). Similarly, the modelled density, as per the work undertaken by Waggitt et al. (2019) (see Figure A7), is close to 0 individuals/km^2 in the north west of England water and the Irish Sea, with greater (but still low) densities found in the west of the Irish Sea. The IAMMWG management unit for common dolphin is the Celtic and Greater North Sea (CGNS) MU, which covers the entire UK EEZ waters. Within this MU (for UK EEZ waters), the abundance for this species is estimated to be 57,417 (95% CL = 30,850 – 106,863).

B.38. Common dolphin represents the second highest number of strandings in the UK after harbour porpoise, with 442 strandings reported in the period 2011 to 2015 (CSIP, 2015). In 2015, there were 110 strandings in the UK, although none of these occurred on the north west of England coast (Figure A8). The majority of strandings which were analysed at post-mortem were as a result of death from live stranding, by-catch (entanglement with fishing gear), infectious disease and starvation.

B.39. Evans and Anderwald (2005) state that in the northern Irish Sea, there is no clear indication that the status and distribution of common dolphin has changed over time. Common dolphin is considered to be at ‘favourable’ conservation status in UK waters (JNCC, 2018) and is of ‘least concern’ globally (IUCN, 2019).

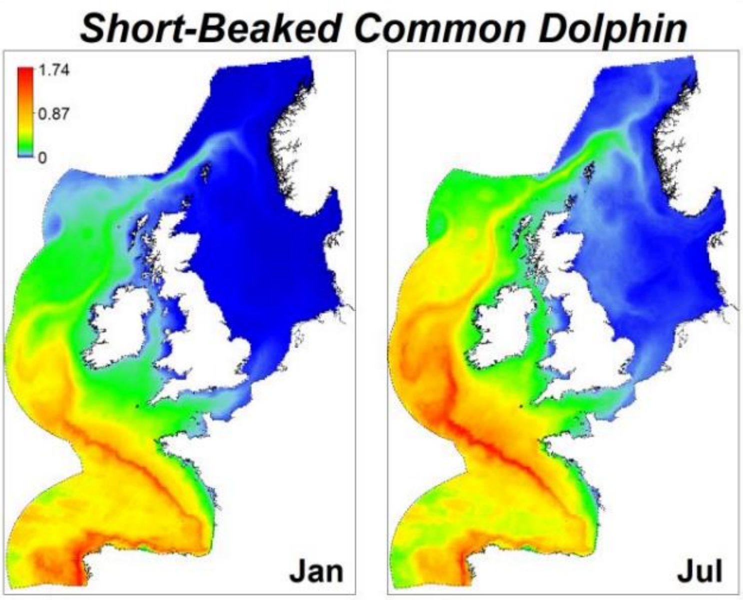

Figure A7. Common dolphin spatial variation in predicted densities (individuals/km2) in January and July

Source: Waggit et al.*, 2019 (reproduced with permission)*

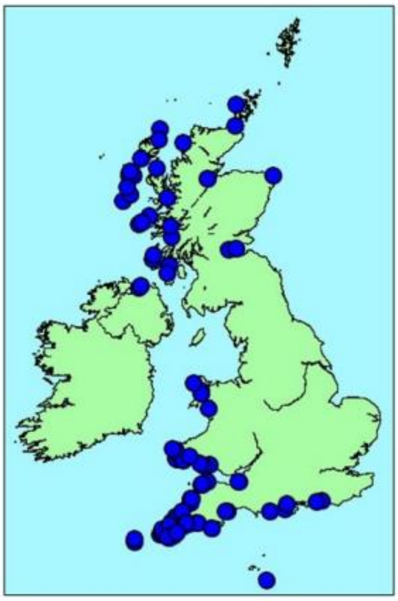

Figure A8. Distribution of common dolphin strandings in the UK in 2015

Source: CSIP, 2015 (reproduced with permission)

Other cetacean species

B.40. Other cetacean species which have been recorded in waters of the north west of England, as part of Sea Watch Foundation (2021) sightings data, include minke whale, fin whale, sei whale (Balaenoptera borealis), sperm whale, northern bottlenose whale (Hyperoodon ampullatus), white beaked dolphin, striped dolphin (Stenella coeruleoalba), Risso's dolphin, and the long-finned pilot whale (Globicephala melas). It is thought that of these species, minke whale, long-finned pilot whale, and Risso's dolphin are considered to be present in the northern Irish Sea at any time of the year or recorded as seasonal visitors annually (Evans and Anderwald, 2005). However, long-finned pilot whale is a deep-water species (>200 m), and is rarely sighted in the shallower waters, and therefore is unlikely to occur close to the survey area (Reid et al., 2003; Waggit et al., 2019).

B.41. Minke whales are a common species, representing 5% of all cetacean sightings recorded in UK waters and the adjacent seas between 1980 and 2002 (Evans et al., 2003). This species can often be seen close to land, where individuals sometimes enter estuaries, bays or inlets (Reid et al., 2003). Most sightings of this species in coastal waters occur between May and September, with peak numbers between July and September, depending on the region. However, they can be found in UK waters year-round (Evans et al., 2003). They are largely distributed around Scotland and in the northern and central portions of the North Sea (Anderwald and Evans, 2008). In the north east of the Irish Sea this species is very rare, and from 2001 to 2005 there are very few confirmed sightings (possible two individuals recorded around Anglesey in June and July 2005) (Evans and Anderwald, 2005). From 2019 to 2021, there were no sightings of minke whale as part of Sea Watch Foundation (2021) data in the north west of England. Generally, most sightings of this species occur on the western coast of Galloway, and even sightings here are rare (Solway Firth Partnership, 2011). However, a report of this species entangled in fishing gear was made in Luce Bay (by the Rhins of Galloway) in 2011, indicating very occasional presence.

B.42. Risso's dolphin is a continental shelf species. Most sightings in UK waters are in western Scotland, with the waters surrounding the Outer Hebrides forming a hotspot (Waggit et al., 2019). There are other clusters of sightings in the southern Irish Sea and off south-west Ireland. However, Risso's dolphin rarely come into the north-east part of the Irish Sea, with most observations concentrated around the Isle of Man (north and west coast) and Bardsey Island, and the Lleyn Peninsula of North Wales (Evans and Anderwald, 2005). There has been one sighting of an individual Risso's dolphin in November 2019 as part of Sea Watch Foundation (2021) data. This sighting was made in Blackpool, Lancashire.

B.43. There have been sporadic reports of strandings of rarer cetacean species in the north west of England, although these are uncommon, particularly when compared to harbour porpoise. For example, two of the latest three strandings of killer whale, as reported by Defra (2005), were recorded in Merseyside and Cumbria (in October 2001 and May 2003, respectively).

B.44. Based on the available data, although sightings are rare, Minke whales are the only other species of cetacean beyond harbour porpoise, common dolphin and bottlenose dolphin that have the potential to be present during the survey.

Summary of Cetacean Abundance and Density Estimates

B.45. Approximate abundances and densities in the area of the geophysical survey have been calculated for harbour porpoise, which is provided in Table A2. below. This data is based on the most recent SCANS-III surveys for survey Block F (Hammond et al., 2021). There was insufficient data to provide abundance and density data for other cetacean species due to the low presence of these species in the area. However, both bottlenose dolphin and common dolphin have been included in the table below to highlight the limited occurrence of these species. In general, the density of harbour porpoise within the survey area is low compared to other nearby areas (such as the western Irish Sea).

Table A2. Summary of abundance and density estimates based on SCANS-III survey block F

SCANS-III Survey Block	Species	Density (individuals/km2)	Total population size in Block
F (East Irish Sea)	Harbour porpoise	0.086	1,056
	Bottlenose dolphin	n/a	n/a
	Common dolphin	n/a	n/a
Source: Hammond et al. *(2021)*			

Pinnipeds

B.46. Pinnipeds, e.g. seals, can spend a large amount of their time at sea foraging and, as with cetaceans, can be impacted by underwater sound. Pinnipeds are designated as EPS, as well as being qualifying features in many designated areas around the UK coastline.

Key data sources

B.47. This study comprises a detailed desk-based review of publicly available information relevant to the survey area. This includes publicly available information from the following sources:

- Special Committee on Seals (SCOS) (2020) – SCOS provides scientific advice to the government annually on matters related to the management of seal populations. This includes information related to the abundance and distribution of seals;
- Carter et al. (2020) – this report by the Sea Mammal Research Unit provides habitat-based predictions of at-sea distributions for grey and harbour seals in the British Isles;
- Sea Watch Foundation (2021; https://www.seawatchfoundation.org.uk/);
- Sea Mammal Research Unit (SMRU) (2021; http://www.smru.st-andrews.ac.uk/);
- Cumbria Wildlife Trust (CWT) (2021); and
- Academic papers.

B.48. Designated areas that contain pinnipeds as a qualifying feature are shown in **Appendix C: Figures - Figure C2**.

Evidence baseline

Harbour seal

B.49. The harbour seal (Phoca vitulina) is widespread in the UK and approximately 32% of European harbour seals are found in the UK, although this has declined from approximately 40% in 2002 (SCOS, 2020). The population density of this species varies from place to place, with large areas of the UK exhibiting no to low counts of this species (see Figure A9) (JNCC, 2021). Harbour seals are found through the west coast of Scotland (including the Firth of Clyde), throughout the Hebrides and Northern Isles, as well as in Northern Ireland (JNCC, 2021; SCOS, 2020). Predicted harbour seal at-sea distribution for the British Isles shows that much of the Irish Sea, including the north west coast of England, is not a particularly important area for this species, with close to 0% of the at-sea population (per 25 km) occurring within this region (see Figure A10).

B.50. Harbour seal will haul-out throughout the year, often in patterns relating to tidal cycles (SCOS, 2020). They generally haul-out in sheltered waters, including sandbanks and rocky areas, typically in estuaries. This species will normally forage within 30 km of their haul-out site in water depths ranging from 10-50 m (Tollit et al., 1998). Harbour seals give birth to their pups in June and July and moult in August (SCOS, 2020).

B.51. The estimated total population of harbour seals for the UK from most recent (2016 – 2019) counts during the moulting season is 44,000 (95% CL = 36,000 – 58,700) (SCOS, 2020). The proposed survey area falls within the North West England Seal MU, where during August counts of harbour seals at haul-out sites in the period 1996 to 2019, 2 to 5 individuals were counted. However, these were only rough estimates. Overall, sightings of this species on the north west coast of England are rare, but have occurred in the Solway Firth and along the Cumbrian coastline (CBDC and CMG, 2017).

B.52. As an Annex II species of the EU Habitats Directive, a total of 16 SACs have been designated in the UK for the protection of harbour seal. In the Irish Sea, there are two SACs for which harbour porpoise are a feature of these designated sites, but not a primary reason for their selection. These are the Strangford Loch SAC and the Murlough SAC, which are located 103 km and 115 km away from the geophysical survey area, respectively. Harbour seals persist in discrete regional populations, usually staying within 50 km of the coast (Russell and McConnell, 2014; Russell et al., 2017). This is further attributed to their foraging behaviour, which generally occurs within 30 km of their haul-out site (Tollit et al., 1998). Thus, a 50 km screening threshold is considered to be appropriate for this species.

B.53. Across the UK, there have been declines in many harbour seal populations, such as around Scotland (SCOS, 2020). Whilst the range of harbour seal is considered to be at a 'favourable' conservation status, its overall conservation status is considered to be 'unfavourable – inadequate'. However, this is a positive change from 'unfavourable – bad' since the previous reporting round in 2013, and is due to an overall increase in the abundance of harbour seal in the UK (JNCC, 2019). The global conservation status of harbour seal is of 'least concern' (IUCN, 2019).

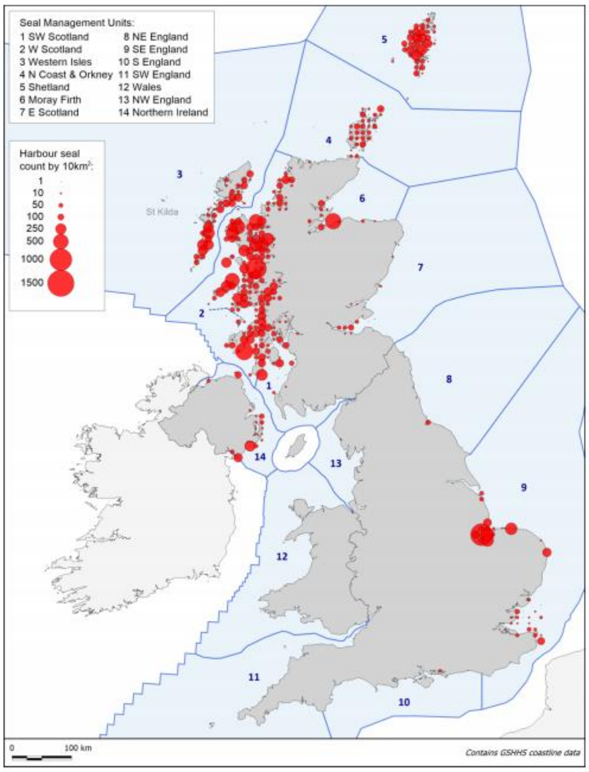

Figure A9. Distribution and abundance of harbour seal during August*.

**Estimates are made up of the most recent survey haul-out counts in each region collected up until 2019*
Source: SCOS, 2020 (*reproduced with permission*)

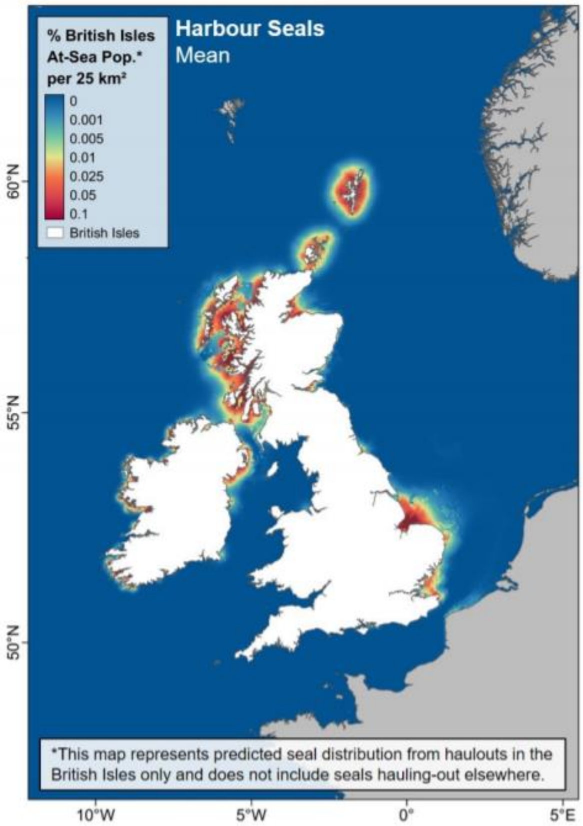

Figure A10. Harbour seal at-sea distribution maps for the British Isles.

Source: Carter et al.*, 2020 (reproduced with permission)*

Grey seal

B.54. Approximately 36% of the world's grey seal population breeds in the UK, with 81% of these breeding in Scotland (SCOS, 2020). The main concentrations are in the Inner and Outer Hebrides and Orkney, as well as on the east coast of the UK, particularly at the Firth of Forth (see Figure A11). There were no main breeding colonies identified in the north west of England as part of SCOS surveys, although a small breeding colony of approximately 50 pups was found on the south west coast of the Isle of Man, on the Calf of Man. In north west England, there are haul-out sites in the Solway Firth and Luce Bay, Walney Island and the Dee Estuary[1] (see **Appendix C: Figures, Figure C7**). Grey seals generally breed on coasts, uninhabited islands and caves, with the main breeding season occurring from August to November (which encompasses 95% of pup production) (SCOS, 2020; Langley et al., 2020). Predicted grey seal at-sea distribution for the British Isles shows that outside of the Dee Estuary and Liverpool Bay, the north west coast of England is not a particularly important area for this species (see Figure A12).

[1] The Dee Estuary noted in this study is located in North Wales.

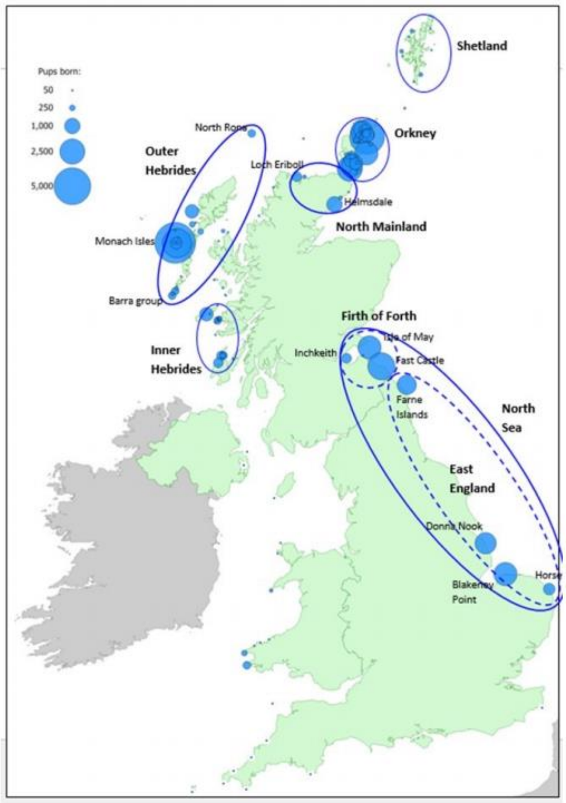

Figure A11. Distribution and size of the main grey seal breeding colonies in the UK*

**The blue circles show breeding colonies grouped by area for reporting*

Source: SCOS, 2020 (reproduced with permission)

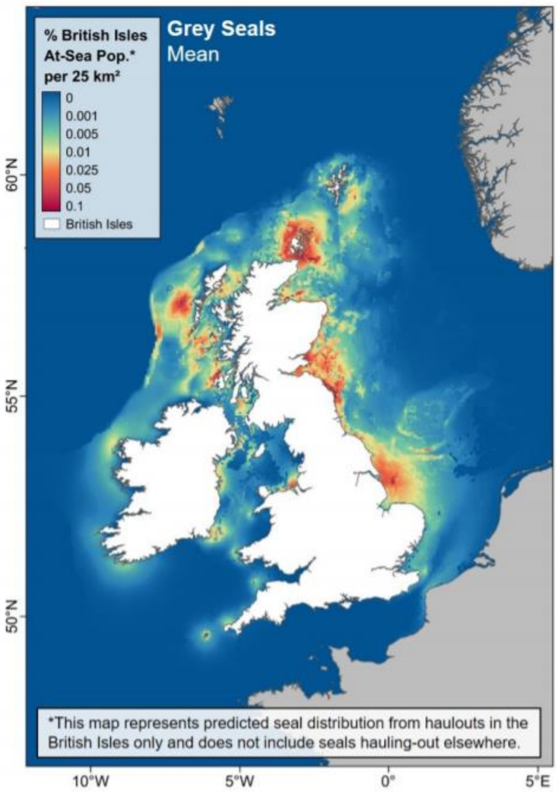

Figure A12. Grey seal at-sea distribution maps for the British Isles

Source: Carter et al.*, 2020 (reproduced with permission)*

B.55. The SCOS (2020) report estimated the England population size of grey seals to be 29,000 in 2019. On the north west coast of England, there have been a number of sightings of this species as part of Sea Watch Foundation (2021) data. There were two sightings (with an individual spotted each) in July 2020 in Blackpool, Lancashire. Cleveleys Beach in Blackpool is known to be regularly visited by grey seal, and in 2018 a pup was rescued from this beach (LWT, 2018). Along the Cumbrian coastline, there have been seven sightings reported in 2020 and 2021, occurring near Whitehaven, St Bees Head, Bootle Beach, and the South Walney Nature Reserve. Of these sightings, 518 individuals were observed at the South Walney Nature Reserve on Walney Island in February 2021, by the Cumbrian Wildlife Trust (CWT). This area represents one of the only haul-out sites in the northwest of England where large numbers of grey seals congregate (CWT, 2021). The seals located on the South Walney Nature Reserve have been identified as a Grade D feature (a feature of below SSSI quality occurring on SACs which are not a qualifying feature (i.e. a “non-significant presence”)) for the Mersey Bay SAC (JNCC, 2021). Grey seal pups are known to occur at this haul-out site, with reports highlighting from the CWT and the BBC, noting the presence of pups in Autumn 2015 and September 2019 (CWT, 2021; CWT, 2015; and BBC, 2019). An article by the BBC (2019) refers to this site as a breeding colony, where births usually occur from mid-October, although this site was not identified as a main breeding colony as part of the SCOS (2020) surveys. The numbers of pups recorded at this site, however, are low, ranging from 2 to 10 in the period 2015 to 2020. In 2021 only one pup, which died, was recorded.

B.56. The remaining Sea Watch Foundation (2021) sightings consisted of one individual per sighting. There are also two haul-out sites for this species in the Solway Firth which are recognised by the Scottish Government as designated haul-out sites for seals (Protection of Seals Orders) (2017) (Marine Scotland, 2017). These sites are located at Little Scares in Luce Bay and on the outer sandbanks of the Solway Firth (between Southerness Point and Dubmill Point).

B.57. Grey seals forage in open waters and then return to their haul-out site to rest, moult and breed (SCOS, 2020). Individuals can forage over large distances, and often travel over 100 km between haul-out sites (trips taking between 1 and 30 days). Grey seals (19 individuals tagged in Wales) were tracked in the Irish Sea by Hammond et al*.* (2005) in 2004. The tagged seals showed varying ranges between individuals, with some occurring in a limited area for the majority of the time and others travelling far distances. One individual was recorded along the northwest coast of England, the Isle of Man, the Solway Firth, and Liverpool Bay (Figure A13). More recently, Global System for Mobile communication (GSM) telemetry devices were tagged to 17 individuals of grey seal and deployed in the Celtic and Irish Sea (from the Bardsey, the Skerries, and Ramsey) in 2009 and 2010 (see Figure A14) (Carter et al., 2017). Individuals from the Skerries were recorded foraging in the eastern Irish Sea and travelling to the Isle of Man. Further GPS tags of 100 individuals of grey seal for habitat preference analysis were deployed by the SMRU from 2017 to 2019 (see Figure A15) (Carter et al*.,* 2020). Individuals tagged in the Dee Estuary were recorded predominantly in the Liverpool Bay area, with one or two grey seals making trips to the Isle of Man and within the eastern Irish Sea. It is assumed that the tracked path of one individual travelling to the south Walney Island was visiting the South Walney Nature Reserve haul-out location. Grey seals are known to show connectivity between sites, with individuals travelling to other haul-out sites from the main breeding colonies outside of the breeding season (Langley et al*.,* 2020). Studies of the movements of grey seals in northern England and southern Scotland showed that they spent 32% of their time travelling between haul-out sites (Langley et al*.,* 2020).

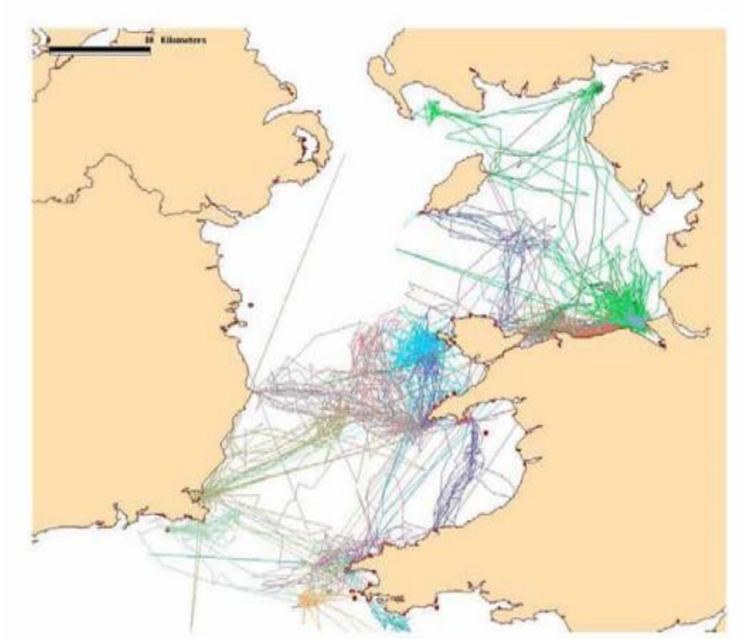

Figure A13. Satellite tracking of 19 grey seals tagged in Wales

Source: Hammond et al.*, 2005 (reproduced with permission)*

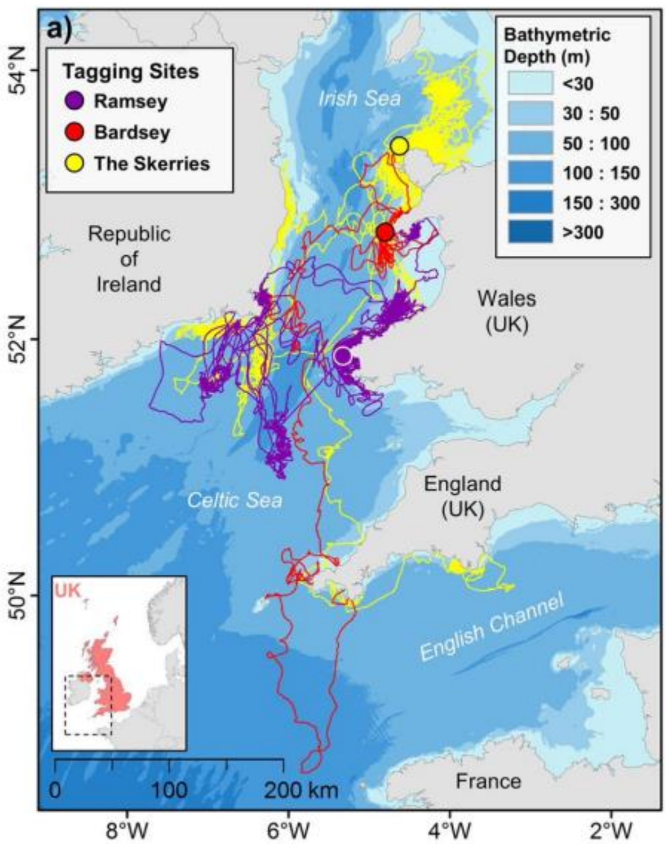

Figure A14. Tracking of 17 individuals of grey seals tagged in the Celtic and Irish Sea

Source: Carter et al.*, 2017 (reproduced with permission)*

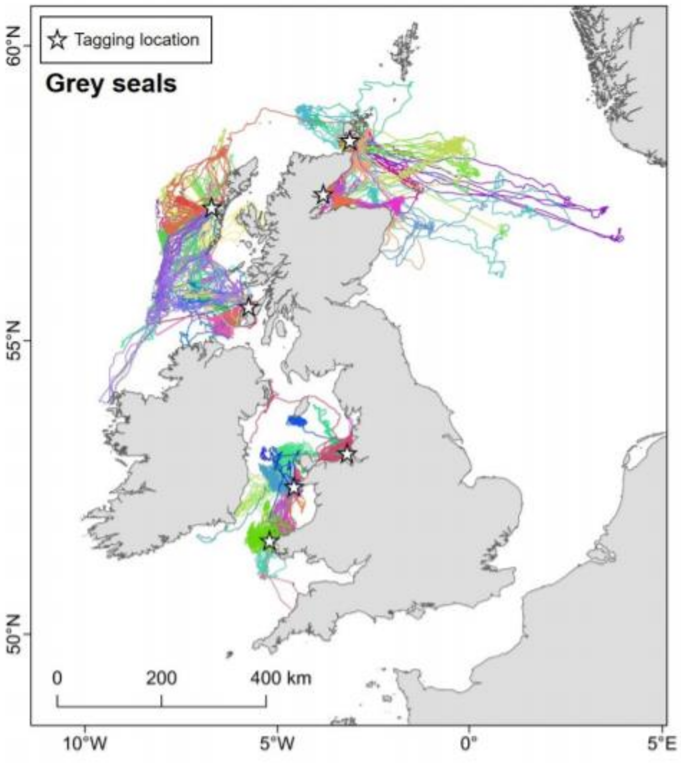

Figure A15. GPS tracking of 100 individuals of grey seals tagged across the British Isles

Source: Carter et al.*, 2020 (reproduced with permission)*

B.58. Being classified as an Annex II species of the EU Habitats Directive, a total of 13 SACs have been designated in the UK for the protection of grey seal. Of these, the Pembrokeshire Marine SAC is the closest designated site (for which grey seal is a primary reason for site selection) to the survey area, located 260 km away. However, based on the known foraging distances (over 100 km) of this species (and guidance from DAERA and NRW), a distance of 135 km has been used to identify SACs designated for the protection of grey seals. This means that the Pembrokeshire Marine SAC has not been identified as requiring an LSE review. However, the Pen Llŷn a'r Sarnau / Lleyn Peninsula and the Sarnau SAC, and the Maidens SAC, for which grey seal are a qualifying feature but not the primary reason for site selection, are located within the screening distance criteria of 135 km. These sites are located 124 km and 129 km from the survey area, respectively.

B.59. The Llŷn Peninsula and the Sarnau SAC consist of individuals of grey seals which are thought to comprise part of the west Wales breeding population, which is centred around the Pembrokeshire coast (protected as part of the Pembrokeshire Marine SAC, which is located 260 km from the survey area) (NRW, 2009). Most individuals are found hauled-out within the Llŷn Peninsula and the Sarnau SAC boundary, surrounding the Llŷn. The Maidens SAC represents a series of rock habitats which are suitable for grey seals and pups, as well as opportunities for feeding. However, in a study of grey seals around Northern Ireland in 2018 by the SMRU, the numbers at this site were low compared to other locations (Morris and Duck, 2018).

B.60. The UK grey seal population is considered to be stable and increasing (SCOS, 2020). Overall, this species is at 'favourable' conservation status in the UK (JNCC, 2019). Globally, populations are also considered to be increasing, and therefore the conservation status of this species is of 'least concern' (IUCN, 2019).

Sea turtles

B.61. Sea turtles are designated as EPS in the UK and can be impacted by marine and coastal projects.

Key data sources

B.62. This study comprises a detailed desk-based review of publicly available information relevant to the survey area. This includes publicly available information from the following sources:

- Academic papers.

B.63. No designated areas with sea turtles as a qualifying feature were identified.

Evidence baseline

B.64. The leatherback sea turtle Dermochelys coriacea is the largest species of marine turtle, and the only one to regularly visit higher latitude waters. Each summer, leatherbacks migrate to UK waters where they feed on jellyfish (Houghton et al., 2006). They are primarily found on the western coast of the UK and are regularly observed throughout the Irish Sea (Reeds, 2004; Houghton et al., 2006).

B.65. Jellyfish hotspots in the Irish Sea, including aggregations of Rhizostoma (medium to large jellyfish), have been identified as important foraging areas for this species (Houghton et al., 2006). The medusae of this taxa are known to persist from spring through to autumn (Glyn et al., 2015). Aerial surveys in 2003, 2004, and 2005 identified the western and eastern coast of Wales and Ireland, respectively, as having large aggregations of Rhizostoma (Houghton et al., 2006). In the same survey, significant numbers of aggregations were also recorded in the Solway Firth near St Bees Head (Cumbria), and further south along the Cumbrian coastline. This conformed with consistent sightings of this species from 1950 to 2005 along the north west coast of England and in the Solway Firth (see Figure). In this study, leatherback turtle abundances were seasonal, with peak sightings occurring between July and September. Additional aerial surveys in the Irish and Celtic Sea (2003 to 2006) observed 0.25 leatherbacks per 1,000 km of track flown (Doyle et al., 2008). The most recent record of a leatherback sea turtle in the Copeland inshore area was a sighting off St Bees Head in 2015 (BBC, 2015). There have been 11 reported strandings of this species in the UK from 2011 to 2015, three of which occurred in England in 2015 (see Figure A17) (CSIP, 2015).

B.66. In addition to the leatherback turtle, loggerhead Caretta caretta, green Chelonia mydas, hawksbill Eretmochelys imbricate and Kemp’s Ridley turtles Lepidochelys kempii are very occasionally observed in UK waters. However, sightings of these species are very rare, particularly on the north west coast of England (Harris, 2007; Rowley, 2005). However, the Lancashire and Cheshire Fauna Society (2004) noted three records of the species occurring in Lancashire, Merseyside and Cheshire since 2004, including a rescued individual off Knott End (Lancashire) in 2001. The same report also refers to a dead green turtle which washed up at Knott End in 2001.

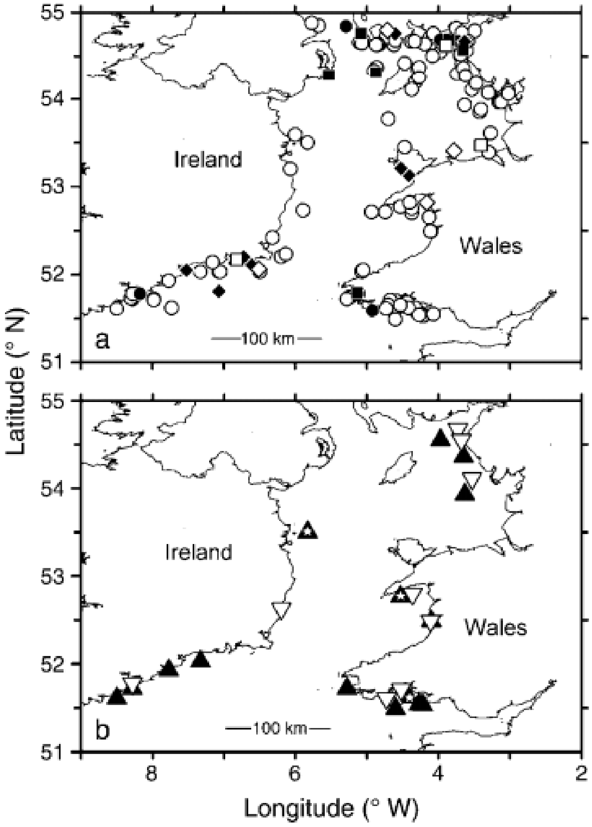

Figure A16. Leatherback turtle sightings in the Irish Sea from 1950 to 2005 (n = 143; circles = 1990 to 2005; squares = 1970 to 1990; diamonds = 1950 to 1970)*

**Figure b shows aggregations of jellyfish. Source: Houghton* et al.*, 2006 (reproduced with permission)*

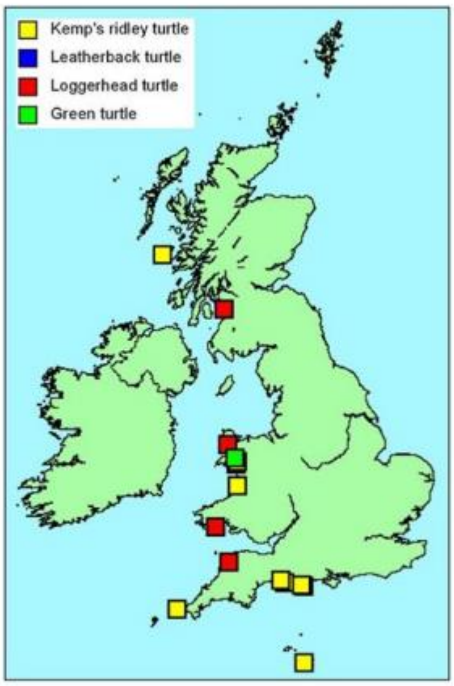

Figure A17. Distribution of marine turtle strandings in the UK in 2015 (Source: CSIP, 2015; reproduced with permission)

Fish

B.67. Fish are important to society for commercial reasons, as well as other marine life as prey items. Fish can be impacted by underwater sound at different stages of their lifecyles. Only Atlantic Sturgeon are noted as EPS, although other species such as smelt and lamprey are qualifying features in designated sites around the UK coast.

Key data sources

B.68. This study comprises a detailed desk-based review of publicly available information relevant to the survey area. This includes publicly available information from the following sources:

- JNCC 2018a & 2018b; and
- Academic papers.

Evidence baseline

Migratory fish

B.69. Diadromous (i.e. migratory) fish species migrate between bodies of freshwater and seawater during different life phases. Major physiological changes associated with these movements occur in order to adapt to altered salinity and, during such periods, sensitivity to environmental stressors increases (Shrimpton, 2012). Owing to their conservation importance and protection by a number of designated sites (including SACs and MCZs, **Appendix C: Figures, Figures C3 & C4**), it is necessary to understand the migration patterns of the diadromous species known, or likely, to be present within the survey area.

Sea and river lamprey

B.70. Sea lamprey (*Petromyzon marinus*) and river lamprey (*Lampetra fluviatilis*) are both anadromous[2] migratory species. Both species spawn in spring and early summer in freshwater. Following spawning, all adult individuals die (Maitland, 2003). The ammocoetes life stage (tadpole like larval phase) follows hatching, which is spent in the silt beds of streams and rivers (Laughton and Burns, 2003). In the ammocoetes phase, lamprey feed on organic detritus and can spend several years in freshwater, eventually transforming into the adult life stage in late summer and onwards (Laughton and Burns, 2003). Once an adult, both river and sea lamprey migrate out to sea where they become parasitic, using their suckers to attach onto host fish and feed on their blood (Maitland, 2003). The adults then return to freshwater once they have spent several years in the marine environment (Laughton and Burns, 2003).

B.71. Sea lamprey is widely dispersed in the open sea as they are solitary feeders, being rarely found in coastal and estuarine waters (Moore et al., 2003; Heessen et al., 2015). The distribution of sea lamprey is chiefly defined by their host (Waldman et al*.,* 2008), and they are often found at considerable depths in deeper offshore waters (Moore et al*.,* 2003). When returning to freshwater, sea lamprey generally choose larger rivers compared to river lamprey, although they can be found in tributaries of all sizes

[2] Migration from the sea into freshwater for spawning

(Heessen et al*.,* 2015). Sea lamprey typically feed on the blood of a range of marine mammals and fish, which include herring, cod, pollack (*Pollachius pollachius*), Atlantic salmon (*Salmo salar*), shad (*Alosa sapidissima*) and basking sharks (*Cetorhinus maximus*) (Kelly and King 2001, ter Hofstede et al., 2008).

B.72. In contrast, river lampreys are usually found in coastal waters, estuaries and accessible rivers, and young river lamprey are often found in large congregations (Maitland et al*.,* 2003). River lamprey feed on a variety of estuarine fish, predominantly herring, sprat and flounder (*Paralichthys dentatus*). River lamprey generally spend one to two years in estuaries and in the autumn, between October and December, when the water temperature reaches 10–11°C, they stop feeding and move upstream (Natural England, 2010; Zancolli, 2018).

B.73. Sea lamprey spawn when the water temperature reaches at least 15°C and they normally migrate into freshwater from April to June, and then spawn from late May to June (Maitland, 2003; Zancolli, 2018). The migration to sea can vary from river to river, although the metamorphosis of larvae into adults occurs in July to September (Maitland, 2003). There have been limited studies which have shown the migratory routes of these species from their spawning rivers into waters further offshore, particularly in the Irish Sea (Malcolm et al*.,* 2010). For the purpose of this assessment, it has been assumed that the migratory route of this species is diffuse.

B.74. While sea lamprey population sizes in Scotland do appear to be small, the trend for adult sea lamprey abundance in the UK does appear to show a general increase in spawning migrants, which may be as a result of ongoing water quality improvements and access to spawning habitat (Hume, 2017). In the UK, the population trends of both species are considered ‘stable’ (JNCC, 2018a; and 2018b).

B.75. The UK distribution of river lamprey and sea lamprey, presented in Figure A18, shows that both species are mainly found in Wales, Northern Ireland and southern Scotland. In the north west coast of England, the distribution of these species is limited and found to the south and north of the Cumbrian coastline. The following designated sites, for which river and sea lamprey are a qualifying feature (listed as Annex II species under the Habitats Directive (Council Directive 92/43/EEC)), occur along the coastline in the eastern Irish Sea, from the Solway Firth (including the Mull of Galloway), along the north west coast of England, to the river Dee on the north of Wales (distance to the survey area are noted in brackets):

- River Derwent and Bassenthwaite Lake SAC (12 km);
- River Eden SAC (41 km);
- Solway Firth SAC (42 km); and
- Dee Estuary SAC (64 km).

B.76. The River Derwent and Bassenthwaite Lake SAC and River Eden SAC, are both known to support good numbers of river and sea lamprey (JNCC, 2021). The extensive occurrence of gravels and silts within these rivers, as well as good water quality, all contribute to good spawning and nursery habitat for these species. The Solway Firth SAC provides a migratory passage for these species to a number of rivers, including the River Eden (and River Esk) (SNH and Natural England, 2010). It is thought that mature adults of sea lamprey migrate upstream in the Solway Firth in May, and begin their descent into the estuary between October and March. River lamprey are thought to begin their upstream migration into the Solway Firth in November, and spawn in May. Juvenile river lamprey then begin their descent into the estuary between October and March.

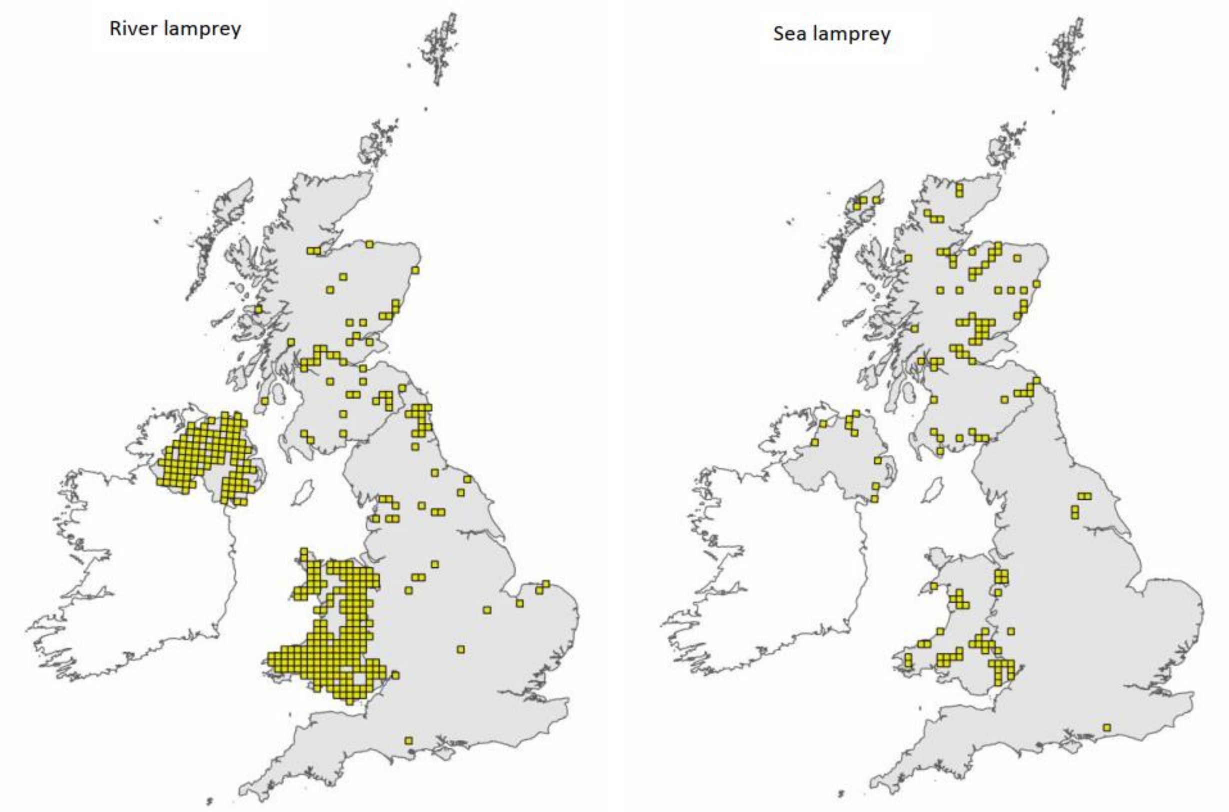

Figure A18. UK Distribution of River Lamprey (left) and Sea Lamprey (right)

Source: JNCC, 2018a; and 2018b (reproduced with permission)

B.77. The River Dee and its estuary (protected as the Dee estuary SAC), lead into the River Dee and Bala Lake SAC further upstream, which is also regarded as an important migratory route for sea and river lamprey (Natural England et al., 2010). Fish trap counts at Chester, between 1992 and 2002, recorded between 2 and 59 individuals per annum of sea lamprey and between 0 and 81 individuals per annum of river lamprey. The upstream migratory period for sea lamprey in the Dee Estuary occurs almost exclusively between May and June, whilst river lamprey have been identified as having two key periods of the year, early spring (March to April) and late summer and autumn (August to November).

Atlantic salmon

B.78. Salmon are an anadromous[3] migratory species, which during their lifetime utilise both marine and freshwater habitats. Spawning of salmon typically occurs in November or December, in the upper reaches of rivers where females deposit eggs into nests known as 'redds', which are cut into gravelly substrate (Heessen et al., 2015; Malcolm et al., 2012). Once the eggs hatch, the resultant larvae known as 'alevins' remain within the interstitial gravels, utilising nutrients from the yolk sac (Heessen et al., 2015). The larvae then develop into fry which prey on invertebrates, and then a 'parr', a young salmon distinguished by dark rounded patches evenly spaced along its sides. The length of time of the transition between life stages is geographically variable. Typically, the transition from larvae to parr occurs in the first summer in southern streams (Potter and Dare, 2003), or up to a year in upland systems. Following the parr life stage, salmon physically and morphologically change into the next life stage,

[3] Migration from the sea into freshwater for spawning

known as a ‘smolt’ (McCormick et al., 1998). This is preceding migration to the ocean following one to five years in freshwater. The migration of smolt down-river to the ocean usually occurs from spring to early summer, generally occurring earlier in the season for larger smolt (Thorstad et al., 2012; Heessen et al., 2015). Once salmon have spent another one to five years at sea, the adults then return to their spawning rivers, which in the UK usually peaks in June to August and October to December (Cowx and Fraser, 2003).

B.79. There have been limited studies which have shown the migratory routes of salmon from their spawning rivers into waters further offshore (Malcolm et al., 2010). Studies of post-smolt migrations of Atlantic salmon in a fjord in Norway have shown that individuals moved rapidly and actively towards the open sea when migrating (Malcolm et al., 2010). These individuals spent most time travelling out in the inner fjord and did not appear to use the immediate near-shore areas. Tracking of Atlantic salmon migrating from the east coast of Ireland showed that these individuals travelled out of the Irish Sea, through the North Channel, heading north along the coast (Barry et al., 2020).

B.80. In England and Wales, there are 80 rivers which regularly support salmon, 64 of which are designated ‘principal salmon rivers’, as shown in Figure A19. The performance of salmon stocks in these rivers is assessed against conservation limits (CL), which are identified by a target number of eggs deposited during spawning to ensure the status of the population remains favourable (Cefas et al., 2021). In the north west of England, there are 14 rivers which have ‘Salmon Action Plans’. The majority of these rivers are classified as ‘At Risk’ or ‘Probably at Risk’, whilst the River Duddon and River Esk are considered to be ‘Probably not at Risk’.

B.81. The following designated sites for which salmon is a qualifying feature (listed as Annex II species under the Habitats Directive (Council Directive 92/43/EEC)), occur along the coastline in the eastern Irish Sea, from the Solway Firth (including the Mull of Galloway), along the north west coast of England, to the river Dee on the north of Wales. Sites noted as being of particular importance were:

- River Derwent and Bassenthwaite Lake SAC (12 km);
- River Ehen SAC (21 km);
- River Eden SAC (41 km);
- River Dee and Bala Lake SAC (87 km); and
- River Bladnoch SAC (62 km).

B.82. The River Derwent and Bassenthwaite Lake SAC consists of good water quality and extensive gravel shoals, making it particularly suitable for salmon breeding, and supports a large population of this species (Natural England, 2019). Similarly, both the River Ehen and Eden are considered to hold a significant population of this species in the north west of England (Natural England, 2019; JNCC, 2021). The Eden in particular, consists of a large river system with distinct habitat types, which allows salmon to use most of the catchment area (JNCC, 2021). This has resulted in the Eden representing one of the largest populations of salmon in northern England. The key migratory period for the River Ehen has been identified as October through to the end of January (Natural England, 2019).

B.83. The River Bladnoch SAC is located in the south-west of Scotland and supports a high-quality salmon population, including a spring run of this species, which is considered unusual for rivers in this area (JNCC, 2021). However, the river’s headwaters are subject to acidification, which has the potential to affect this population of salmon. The River Dee and Bala Lake SAC, located south of the survey area in Cheshire/east Wales, is also known to support migratory salmon which spawn in the river (Hatcher and Garrett, 2008).

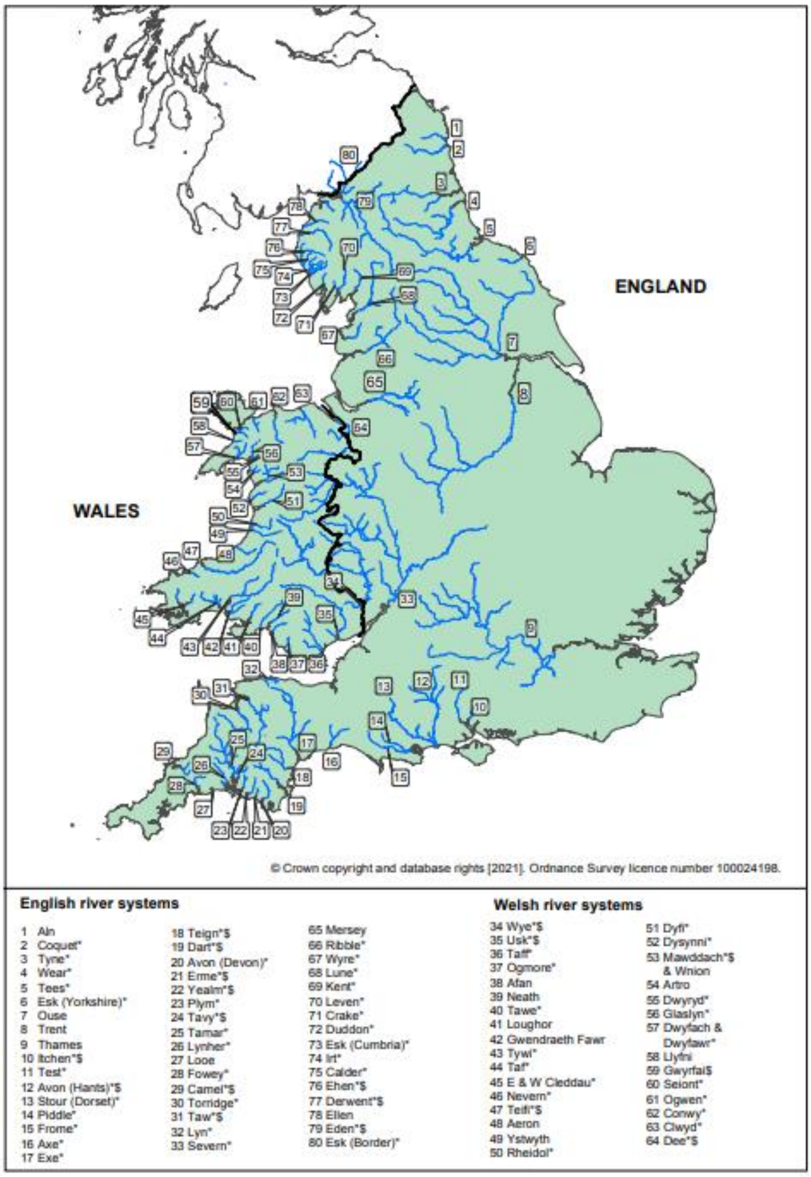

Figure A19. Main salmon rivers in England and Wales*

**Symbols denote those with Salmon Action Plans (*) and those designated as Special Areas of Conservation ($) in which salmon must be maintained or restored to favourable conservation status*
Source: Cefas et al.*, 2021 (reproduced with permission)*

<u>Smelt</u>

B.84. Smelt are a pelagic species, which are predominantly anadromous, although there are several landlocked populations known to occur in Finland, Sweden and Norway which are non-migratory and only found in freshwater (Heessen et al., 2015). The anadromous populations reside in estuaries, and to a lesser extent coastal shores, for most of their lives and migrate upstream into large clean rivers to spawn. They are a midwater species which are rarely found far from the shore (Maitland, 2003). This species is adapted to survive a range of aquatic habitats, helped in part by their tolerance of a wide range of salinity. It had previously been thought that smelt were unable to move through full strength seawater, although new research has shown that smelt can move between estuaries some distance apart (Graham et al., 2021). Individuals feed mostly on small crustaceans and small fish. Smelt are a shoaling species, especially during the spawning period when they aggregate in large numbers in estuaries before moving upstream to their spawning grounds, which can be up to 100 km upstream (Maitland, 2003; Heessen et al., 2015). Spawning takes place in the early spring for approximately a week, with fecundity ranging from 8,000 to 50,000 eggs (Maitland, 2003). The eggs are very adhesive, and hatch in about 3 to 4 weeks. Smelt utilise the incoming flow of the spring high tides, usually during the hours of darkness, to migrate to their spawning grounds (Graham et al., 2021).

B.85. There are three Marine Conservation Zones (MCZ) for which smelt are a qualifying feature, which are relevant to the survey:

- Wyre Lune MCZ (19 km);
- Ribble Estuary MCZ (38 km); and
- Solway Firth MCZ (55 km).

B.86. The Solway Firth has critical habitats for smelt, required to complete their lifecycle, including for feeding and post-larval development (Defra, 2019). Smelt were once abundant in the Solway Firth, but have declined considerably over the past 200 years, and therefore the MCZ designation aims to help focus further research to better understand the current use of the estuary by smelt. Previous surveys in the Solway Firth have found the abundance of smelt to be scarce in the estuary (Maitland, 2003). Smelt in the Solway Firth are thought to migrate into the River Eden, where they travel to spawn. In the upper Solway Firth and River Eden, it is 'quite likely, but not certain' that the smelt stock is now extinct in these areas (Maitland, 2003). However, other evidence suggests that smelt still occur in the inner Solway Firth, whilst a small population of smelt may also be present in the River Eden (where there are suitable spawning areas) (Graham et al., 2021). The River Cree in Scotland is the only remaining river in the Solway Firth where spawning is thought to occur (Graham et al., 2021). A Site Condition Monitoring (SCM) assessment of the river for the Scottish Natural Heritage (SNH) determined the river to be in favourable condition in 2010 and 2011. The River Cree smelt population typically spawns in the middle of February to the middle of March, influenced predominantly by river temperature, and to a lesser extent tidal height and river flow. Multiple spawning runs have previously occurred, which were linked to adverse conditions delaying the spawning.

B.87. Both the Wyre Lune MCZ and Ribble Estuary MCZ have been designated with aim of recovering smelt populations to a favourable condition (Graham et al., 2021). There are limited records of smelt for both of these designated sites and the area they protect, but it is thought that they do still occur (Maitland, 2003). The Environment Agency database has 21 smelt records of fish of various lengths from between 2004 and 2014 for the River Wyre and River Lune, and 28 smelt records from 2004 to 2015 for the Ribble estuary (Natural England, 2018). Smelt are also known to occur in Morecombe Bay, River Kent, River Leven, and River Duddon (although the population in this river appears to be extinct) (Maitland, 2003).

Fish spawning and nursery grounds

B.88. The presence and absence of spawning grounds and nursery grounds of selected fish species (i.e. those species for which data was provided by either Coull et al., 1998 or Ellis et al., 2012) located within the study area are presented in **Error! Reference source not found.** and **Error! Reference source not found.**, respectively. Of these species, cod (*Gadus morhua*), sandeels (Ammodytidae), plaice (*Pleuronectes platessa*) and Dover sole (*Solea solea*) were all found to have high intensity[4] spawning

[4] High intensity spawning grounds are considered to be areas for which the highest aggregation of fish for spawning are likely to occur, indicated by high catch rates of eggs and larvae (Ellis et al., 2012).

grounds within the survey area. The spawning and peak spawning periods for these species, including herring, are presented in **Error! Reference source not found.**.

B.89. High intensity nursery grounds were identified within the survey area for spurdog (Squalus acanthias), herring, cod, whiting (Merlangius merlangus) and Dover sole. Descriptions of the life histories of these species within the survey area, as well as for those species that have been identified as having high intensity, have been provided below. This information concentrates on spawning, larvae and juvenile life stages. Demersal flat fish and elasmobranchs are known to have a low sensitivity to underwater sound, and therefore plaice, Dover sole and spurdog have not been considered further below.

Table A3. Spawning grounds within or near the survey area (source: Ellis et al., 2012 and Coull et al., 1998)

Species	Ellis et al., 2012	Coull et al., 1998
Spurdog (*Squalus acanthias*)	Not well established	n/a
Tope shark (*Galeorhinus galeus*)	Not well established	n/a
Common skate (*Dipturus batis-complex*)	Insufficient data	n/a
Thornback ray (*Raja clavate*)	Insufficient data	n/a
Spotted ray (*Raja montagui*)	Insufficient data	n/a
Undulate ray (*Raja undulata*)	Insufficient data	n/a
Herring (*Clupea harengus*)	Present in Irish Sea (insufficient data)	Nearby (around Isle of Man)
Cod (*Gadus morhua*)	High intensity	Yes
Whiting (*Merlangius merlangus*)	Low intensity	Yes
Blue whiting (*Micromesistius poutassou*)	No	No
Blue ling (*Molva dypterygia*)	No	n/a
Ling (*Molva molva*)	Low intensity	n/a
European hake (*Merluccius merluccius*)	No	n/a
Anglerfish (*Lophius piscatorius*)	No	n/a

[4] High intensity nursery grounds are considered to be areas where the highest density of juveniles are likely to occur, indicated by high catch rates of juveniles (Ellis et al., 2012).

Species	Ellis et al., 2012	Coull et al., 1998
Horse mackerel (*Trachurus trachurus*)	No (low intensity nearby)	n/a
Sandeels (Ammodytidae)	High intensity (low intensity also found within survey area – representing most of area)	No
Mackerel (*Scomber scombrus*)	Low intensity	No
Plaice (*Pleuronectes platessa*)	High intensity	Yes
Dover Sole (*Solea solea*)	High intensity	Yes

Table A4. Nursery grounds within or near the survey area (source: Ellis et al., 2012; and Coull et al., 1998)

Species	Ellis et al., 2012	Coull et al., 1998
Spurdog (*Squalus acanthias*)	High intensity	n/a
Tope shark (*Galeorhinus galeus*)	Low intensity	n/a
Common skate (*Dipturus batis-complex*)	No	n/a
Thornback ray (*Raja clavate*)	Low intensity	n/a
Spotted ray (*Raja montagui*)	Low intensity	n/a
Undulate ray (*Raja undulata*)	No	n/a
Herring (*Clupea harengus*)	High intensity	Yes
Cod (*Gadus morhua*)	High intensity	No (some patches close)
Whiting (*Merlangius merlangus*)	High intensity	Yes
Blue whiting (*Micromesistius poutassou*)	No	No
Blue ling (*Molva dypterygia*)	Insufficient data	n/a
Ling (*Molva molva*)	No	n/a
European hake (*Merluccius merluccius*)	No	n/a
Anglerfish (*Lophius piscatorius*)	Low intensity	n/a

Species	Ellis et al., 2012	Coull et al., 1998
Horse mackerel (*Trachurus trachurus*)	No	n/a
Sandeels (Ammodytidae)	Low intensity	No
Mackerel (*Scomber scombrus*)	Low intensity	No
Plaice (*Pleuronectes platessa*)	Low intensity	Yes
Dover Sole (*Solea solea*)	High intensity (low intensity also found within survey area)	Yes (along coastline)

Table A5. Spawning times of species where high intensity spawning grounds occur in or near the survey area (source: Ellis et al., 2012)

Fish species	Hearing sensitivity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Herring (Clupea harengus)	H										*		
Cod (Gadus morhua)	M		*	*									
Sandeels (Ammodytidae)	L												
Plaice (Pleuronectes platessa)	L	*	*										
Sole (Solea solea)	L				*								

**peak spawning; blue cells denote known spawning and grey cells denote potential spawning*

Herring

B.90. Herring are demersal spawners, which means when spawning occurs large numbers of eggs are released (~50,000 per female) near the seafloor, which sink and attach to gravel, stones and shell, where they form a dense mat (Heessen et al., 2015). Herring are considered to be synchronous single-batch spawners and spawning can occur in episodes which are weeks apart (Heessen et al., 2015; Dempsey and Bamber, 1983). Following spawning, hatching of the eggs can take up to 3 weeks, depending on the temperature of the water (ICES, 2009).

B.91. Once developed into juvenile fish, herring aggregate into shoals which migrate into estuaries and shallow waters, where they remain for six months to a year (Dipper, 2001). After their first year, herring move offshore, joining the adult populations as they reach maturity (Heessen et al., 2015).

B.92. The earliest available spawning maps indicate the key herring spawning grounds in the Irish Sea are around the Isle of Man and the north east coast of Northern Ireland (Mourne) (Coull et al., 1998). A subsequent study found the Mourne grounds to be less important, which the authors suggested indicates spawning grounds vary year on year (Dickey-Collas et al., 2001). No larvae were detected on the Mourne ground in recent ICES surveys (ICES, 2020). Nevertheless, the Manx spawning ground was still considered as one of two sites which form the main component of the Irish Sea herring stock (Dickey-Collas et al., 2001) and the more recent report by Ellis et al. (2012) does not identify any other high intensity and low intensity spawning ground areas for this species. However, recent ICES surveys, as in previous years, found the vast majority of herring larvae were captured in the vicinity of the Douglas bank spawning ground and to the north of the Isle of Man (ICES, 2021). Thus, the key spawning ground for herring is around the northeast coast of the Isle of Man, with some proximity to the survey area (see **Figure C8** in **Appendix C: Figures**).

B.93. The timing of herring spawning is also uncertain. Data in Coull et al., (1998) is inconsistent, so it is not clear if the Manx stock is reported to spawn in August/September or October/November. However, Dickey-Collas et al., (2001) indicates peak spawning during their study was in late September, but continued into the new year. The most recent report from the ICES Working Group on Ichthyoplankton (ICES, 2020) states that in the Irish Sea the most intensive spawning period is at the beginning of November. Based on estimated hatching time (see below), this suggests spawning peaking in mid-October.

B.94. Based on this information, the survey area runs along the border of the identified Manx spawning ground for a short distance, and there is some potential for spawning to take place during the survey window, but it will not occur in the peak season, which has been assumed to be October. The spawning and peak spawning periods for herring are presented in **Error! Reference source not found.**.

B.95. Herring nursery grounds have been identified by Coull et al. (1998) and Ellis et al. (2012) in generally similar areas across a large area of the north eastern Irish Sea (see **Figure C11, Appendix C: Figures**).

Cod

B.96. From late winter to early spring, adult cod migrate to offshore spawning grounds. Spawning occurs in January in waters further to the south, and in April in waters further north (Dipper, 2001; Heessen et al*.,* 2015). Cod is classified as a determinate multiple spawner (McEvoy and McEvoy, 1992), with experiments reporting between 8 and 22 batches spawned per season (Kjesbu et al*.,* 1992). In a single spawning event, females produce between three million and six million eggs (Trippel, 1998), which rise to the surface and drift with ocean currents (Dipper, 2001). The key spawning grounds are shown in **Figure C9** in **Appendix C: Figures**.

B.97. The eggs and larvae of cod remain in the water column, developing into juvenile fish within six months. When individuals reach a size of approximately 7 cm, juveniles move to the seabed where they become demersal, often occurring between July and August (Heessen and Daan, 1994). Juvenile cod then move into coastal nursery areas once the spawning season is over, with young cod often found in estuaries and shallow waters. Juveniles prefer shallow waters where there are a range of habitats such as seagrass beds, gravel, rock and boulders, which provide protection from predators. The key nursery grounds are shown in **Figure C12** in **Appendix C: Figures**.

Sandeel

B.98. Sandbanks and other sandy areas are known to be important habitat for sandeel, which have a preference for habitats in water depths between 30 m and 70 m, but are known to occur at depths of 15 m and 120 m (Holland et al*.,* 2005). Sandeel are demersal spawners, with females releasing between 4,000 and 20,000 eggs, which they deposit within the sandy habitat of the adults (Tappin et al*.,* 2011; Winslade, 1971). Spawning periods vary depending on the species. Great sandeel spawn from late spring to summer, Raitt's sandeel from November to February, whilst the lesser sandeel may spawn both in spring and autumn (Heessen et al*.,* 2015). Once hatched, the larvae are pelagic, spending their time in the water column (undertaking vertical migrations that are influenced by light), until they develop into juveniles in the winter when they burrow into the sediment (Macer, 1966; Heessen et al*.,* 2015). The key spawning grounds are shown in **Figure C10** in **Appendix C: Figures**).

Whiting

B.99. Whiting do not make long-distance migrations from their spawning site (Heessen et al., 2015). Spawning of whiting is mainly triggered by temperature (5 – 10°C is optimal), and takes place from February to June (Coull et al., 1998), peaking in spring in shallow waters (Wheeler, 1978). Most whiting spawning occurs in water depths <100 m (Heessen et al., 2015). A female whiting of 30 cm will produce 400,000 eggs, which compared to other gadoids, demonstrates high relative fecundity (Hislop and Hall, 1974). Whiting release their eggs in many batches over a period which usually lasts up to 14 weeks (Hislop et al., 1991).

B.100. Once spawned, whiting grow relatively slowly during their first year of life, with large variations in growth rates between individuals (Hislop et al., 1991). Whiting typically reach maturity after two years and often spawn during this year.

B.101. The key nursery grounds are shown in **Figure C13** in **Appendix C: Figures**.

Basking shark

B.102. The basking shark is a large pelagic migratory species, with a circumglobal distribution (Dolton et al*.,* 2020), listed under Schedule 5 of the Wildlife and Countryside Act 1981. Witt et al*.* (2012) highlighted three regions in the UK where the density of basking shark surface sightings was highest in their dataset - the south west coast of England, west coast of Scotland and around the Isle of Man. The basking shark is also occasionally present in waters off the north west of England, although sightings are fewer than around the Isle of Man, despite their relative proximity (see Figure A20). In this study, a marked seasonality of basking shark sightings was recorded, which were at their greatest during the northeast Atlantic summer (June to August). The basking shark is an elasmobranch, a species that lacks any gas-filled cavities such as a swim bladder, and is regarded as having low sensitivity to underwater sound (Popper et al., 2014).

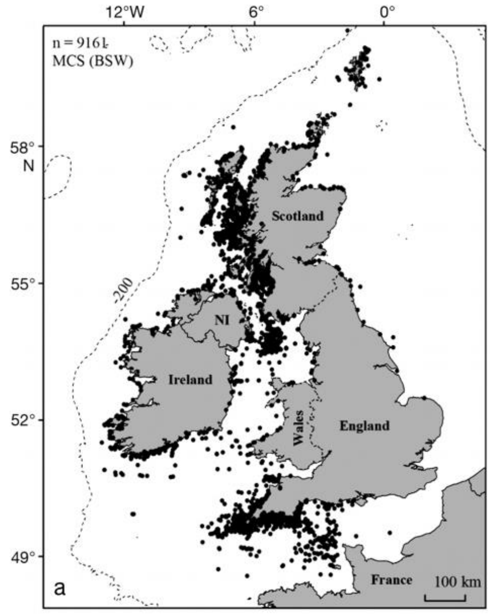

Figure A20. Spatial distribution of basking shark sighting records (1988 to 2008), showing the locations of all sightings records (Source: Witt et al., 2012; reproduced with permission)

B.103. The Isle of Man is a hotspot for this species during May to August, where some important behaviours thought to be associated with courtship have been observed in the IoM (Dolton et al*.,* 2020). There has also been one documented case of putative mating observed in IoM waters (Waller, 2000). Therefore, the waters of the IoM may potentially host breeding basking sharks.

B.104. Tracking of individuals around the Isle of Man (from 2013 to 2017) revealed that there was inter-annual site fidelity of this species to the Irish Sea and the Isle of Man, whilst summer movements of individuals to Scotland were also identified (Dolton et al*.,* 2020). However, in this study, basking shark were concentrated on the western coast of the Isle of Man (see Figure A21), whilst coastal movements in the Irish Sea were mostly in the western parts, with an avoidance of the north west of England. Austin et al*.* (2019) used an Ensemble Ecological Niche Model (EENM) modelling to determine habitat suitability for basking sharks around the British Isles, based on shark presence-absence data gathered by boat-based surveys (see Figure A22). This identified the waters around the Isle of Man to have suitable habitat for this species, with an absence of suitable habitat along the north west coast of England. This conforms with recent sightings data from the Manx Basking Shark Watch (MBSW, 2021), which were predominantly made on the south west coast of the Isle of Man around Peel, Glenmaye, Port Erin and the Calf of Man. Sightings of basking shark in the Solway Firth are occasional, and occur when they follow the plankton blooms on the western coast in the UK (Solway Firth Partnership, 2011). In the north west of England, there has been one sighting recorded as part of Sea Watch Foundation (2021) sightings programme. This sighting was made in Beckermet, Cumbria in July 2019 and consisted of two individuals.

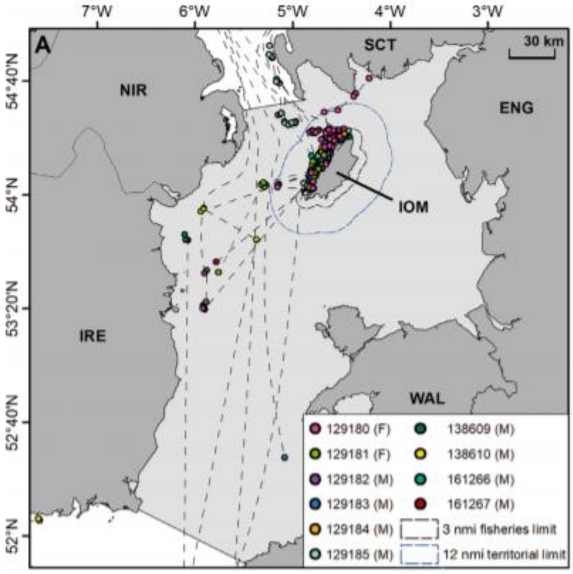

Figure A21. Coastal movements of 10 satellite tracked basking sharks within the Irish Sea (Source: Dolton et al., 2020; reproduced with permission)

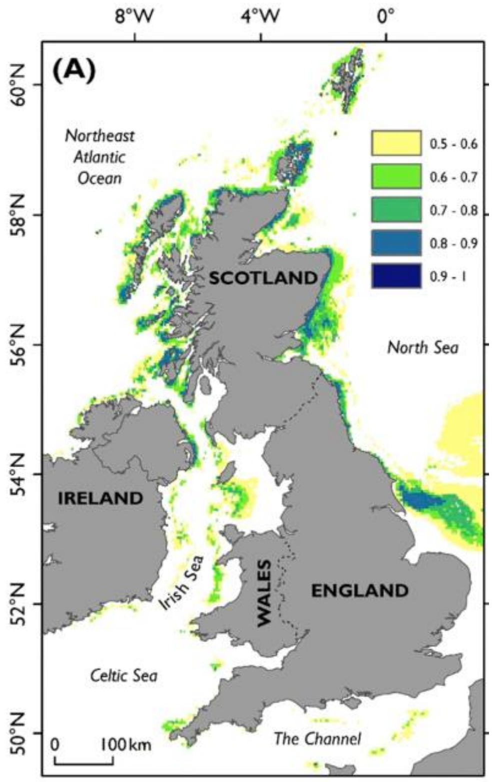

Figure A22. Habitat suitability for basking sharks, based on presence-absence data (Source: Austin et al., 2019; reproduced with permission)

B.105. From 2011 to 2015, there have been 18 reported strandings of basking shark in the UK, of which two, in 2015, occurred in England (CSIP, 2015). However, these were both in Cornwall, a significant distance from the survey area (see Figure A23). Witt et al. (2012) report that sightings of this species have changed over time, with a decreasing number of small sharks being sighted and an increase in medium sized sharks. Globally, populations are considered to be decreasing and the International Union for Conservation of Nature (IUCN) states that the 'conservation status of this species is ‘endangered’ (IUCN, 2019).

Figure A23. Distribution of basking shark strandings in the UK in 2015 (Source: CSIP, 2015; reproduced with permission)

Ornithology

Key data sources

B.106. The ornithological baseline relevant to the survey area has been determined from the following sources of data and information:

- The Joint Nature Conservation Committee (JNCC) website for details of Special Protection Areas (SPAs), including site information and designation details;
- The British Trust for Ornithology (BTO) website for site specific data from the Wetland Bird Survey (WeBS), a partnership between the BTO, the Royal Society for the Protection of Birds (RSPB) and JNCC (the last on behalf of Natural England (NE), Natural Resources Wales (NRW), Scottish Natural Heritage (SNH) and the Department of the Environment Northern Ireland (DENI)), in association with the Wildfowl and Wetlands Trust (WWT);
- The Joint Nature Conservation Committee (JNCC) atlas of seabird distribution in north west European waters (Stone et al., 1995);
- Relevant Environmental Statements and associated appendices detailing the results of project specific ornithological surveys, such as Robin Rigg offshore wind farm, Ormonde offshore wind farm, Barrow offshore wind farm and Walney and Walney Extension offshore wind farms (various phases);
- Seabird foraging ranges (Thaxter et al., 2012; Woodward et. al, 2019); and
- FAME (Future of the Atlantic Marine Environment) and STAR (Seabird Tracking and Research) seabird tracking projects.

Evidence baseline

Sites designated for birds

B.107. The survey area is located nearby or overlaps with the following designated sites, for which there is potential for effects as a result of the survey to arise:

- Morecambe Bay and Duddon Estuary SPA;
- Liverpool Bay SPA; and
- Solway Firth Special Protection Area (SPA).

B.108. The citations for these designated sites are provided in Table A6. The potential for species cited within these designations to occur within or near the survey area is also considered.

Table A6. Sites Designated for Ornithology within or near the survey area

Designated Site	Reason for Designation	Relationship to the survey area and potential for cited species to occur within the survey area
Morecambe Bay and Duddon Estuary SPA	Over winter – Whooper Swan *Cygnus Cygnus* Little Egret *Egretta garzetta* Golden Plover *Pluvialis apricaria* Ruff *Calidris pugnax* Bar-tailed Godwit *Limosa lapponica* Mediterranean Gull *Larus melancephalus* Breeding season – Common Tern *Sterna hirundo* Sandwich Tern *Sterna sandvicensis* Little Tern *Sternula albifrons* Lesser black-backed Gull *Larus fuscus* Herring Gull *Larus argentatus* On passage – Pink-footed Goose *Anser brachyrhynchus* Shelduck *Tadorna tadorna* Oystercatcher *Haematopus ostralegus* Ringed Plover *Charadrius hiaticula* Grey Plover *Pluvialis squatarola* Knot *Calidris canutus* Sanderling *Calidris alba* Dunlin *Calidris alpina* Black-tailed Godwit *Limosa limosa* Curlew *Numenius arquata* Pintail *Anas acuta* Turnstone *Arenaria interpres* Redshank *Tringa totanus* Lesser Black-backed Gull *Larus fuscus* Waterbird assemblage including all qualifying features listed above, as well as the following species: Great White Egret *Ardea alba*, Spoonbill *Platalea leucorodia*, Brent Goose *Branta bernicla*, Wigeon *Anas penelope*, Teal *Anas crecca*, Green-winged Teal *Anas carolinensis*, Shoveler *Anas platyrhynchos*, Ring-necked Duck *Aythya collaris*, Eider *Somateria mollissima*, Goldeneye *Bucephala clangula*, Red-breasted Merganser *Mergus serrator*, Cormorant *Phalacrocorax carbo*, Lapwing *Vanellus vanellus*, Little Stint *Calidris minuta*, Spotted Redshank *Tringa*	The survey area overlaps with this SPA and includes approximately 49.3 km^2 of the western offshore area of the site, from Ravenglass to Walney Island. Given the survey area occurs in inshore waters species associated with tidal mudflats and grazing marshes are unlikely to be present. The following species have the potential to be present in the inshore waters of the SPA during the non-breeding season and are considered further: • Mediterranean Gull • Goldeneye • Red-breasted merganser • Cormorant • Eider • Common Gull The following species have the potential to be present in the inshore waters of the SPA during the breeding season and are considered further: • Common Tern • Sandwich Tern • Little Tern • Lesser black-backed Gull • Herring Gull

Designated Site	Reason for Designation	Relationship to the survey area and potential for cited species to occur within the survey area
	erythropus, Greenshank *Tringa nebularia*, Black-headed Gull *Chroicocephalus ridibundus*, Common Gull *Larus canus* and Herring Gull *Larus argentatus*.	
Liverpool Bay SPA	Over winter – red-throated diver *Gavia stellata* Little Gull *Hydrocoloeus minutus* Common Scoter *Melanitta nigra* Breeding Season - Little Tern *Sternula albifrons* Common Tern *Sterna hirundo* Waterbird assemblage including all qualifying features listed above, as well as the following species (over winter): Cormorant *Phalacrocorax carbo,* Red-breasted Merganser *Mergus serrator,* Black-headed Gull *Chroicocephalus ridibundus,* Common Gull *Larus canus,* Eider *Somateria mollissima,* Fulmar *Fulmarus glacialis,* Great Black-backed Gull *Larus marinus,* Great Crested Grebe *Podiceps cristatus,* Guillemot *Uria aalge,* Gannet *Morus bassanus,* Puffin *Fratercula arctica,* Herring Gull *Larus argentatus,* Kittiwake *Rissa tridactyla,* Lesser Black-backed Gull *Larus fuscus,* Great Northern Diver *Gavia immer,* Shag *Phalacrocorax aristotelis,* Razorbill *Alca torda,*	The survey area is located approximately 600 m north of the SPA, just offshore from Walney Island. Given the survey area occurs in offshore waters species associated with tidal mudflats and grazing marshes are unlikely to be present. The following species have the potential to be present in the inshore waters of the SPA during the non-breeding season and are considered further: • Black-headed Gull • Common Gull • Common Scoter • Cormorant • Eider • Fulmar • Gannet • Great Black-backed Gull • Great Crested Grebe • Great Northern Diver • Guillemot • Herring Gull • Kittiwake • Lesser Black-backed Gull • Little Gull • Puffin • Razorbill • Red-breasted Merganser • Red-throated Diver • Shag The following species have the potential to be present in the inshore waters of the SPA during the breeding season and are considered further: • Little Tern • Common Tern
Solway Firth SPA	Over winter - red-throated diver *Gavia stellata* Whooper Swan *Cygnus cygnus* Barnacle Goose *Branta leucopsis* Golden Plover *Pluvialis apricaria* Bar-tailed Godwit *Limosa lapponica* Pink-footed Goose *Answer brachyrhynchus* Pintail *Anas acuta* Knot *Calidris canutus* Curlew *Numenius arquata* Redshank *Tringa totanus*	The survey area is located approximately 12 km to the southwest of the SPA. Given the survey area occurs in inshore waters species associated with tidal mudflats and grazing marshes are unlikely to be present. The following species have the potential to be present in the inshore waters of the SPA during the non-breeding season and are considered further:

Designated Site	Reason for Designation	Relationship to the survey area and potential for cited species to occur within the survey area
	Scaup *Aythya marila* Oystercatcher *Haematopus ostralegus* On passage - Ringed plover *Charadrius hiaticula* Waterbird Assemblage including: Shelduck (*Tadorna tadorna*), Teal (*Anas crecca*), Shoveler (*Anas clypeata*), Common scoter (*Melanitta nigra*), Goldeneye (*Bucephala clangula*), Goosander (*Mergus merganser*), Grey plover (*Pluvialis squatarola*), Lapwing (*Vanellus vanellus*), Dunlin (*Calidris alpina*), Sanderling (*Calidris alba*), Turnstone (*Arenaria interpres*), Cormorant (*Phalacrocorax carbo*), Black –headed Gull (*Chroicocephalus ridibundus*), Common gull (*Larus canus*), Herring gull (*Larus argentatus*).	• Red-throated Diver, • Scaup, • Common Scoter, • Goldeneye, • Goosander, • Cormorant, • Black-headed Gull, • Common Gull • Herring Gull

B.109. The following designated sites are also in proximity to the proposed survey area and were also considered for the assessments based on the cited species associated with these designated sites occurring within the survey area. These are:

- Cumbria Coast MCZ (is near to the survey away, approx. 3 km away)
  - It is, in part, designated to protect razorbill (Alca torda) resting and loafing immediately offshore from their breeding colonies along St. Bees Head.
- Duddon Estuary Ramsar and SSSI (approximately 3 km to the east of the survey area)
  - Forms part of the Morecombe Bay and Duddon Estuary SPA. There are no further species to those identified in the sites presented in Table A6 that are likely to occur in the inshore waters of the survey area.
- Morecombe Bay Ramsar (approximately 5 km to the east of the survey area)
  - Forms part of the Morecombe Bay and Duddon Estuary SPA. There are no further species to those identified in the sites presented in Table A6 that are likely to occur in the inshore waters of the survey area.
- South Walney and Piel Channel Flats SSSI (approximately 5 km to the east of the survey area)
  - Forms part of the Morecombe Bay and Duddon Estuary SPA/Ramsar site.
- St. Bees Site of Special Scientific Interest (SSSI) (approximately 7 km to the east of the survey area)
  - It is, in part, designated for its breeding seabird colony, including guillemot, fulmar, kittiwake, razorbill, cormorant, puffin, shag, herring gull and black guillemot (*Cepphus grylle*). Given the survey area occurs in inshore waters, it is likely to be used by foraging seabirds associated with the SSSI.
- Ribble and Alt Estuaries SPA and Ramsar (approximately 31 km southeast of the survey area)
  - Designated for waterbird species that utilise the intertidal mudflats and coastal grazing marshes. There are no further species to those identified in the sites presented in Table A6 that are likely to occur in the inshore waters of the survey area.

B.110. All other designated sites were considered to be sufficiently distant from the survey area that associated seabird species are either unlikely to occur within the survey area or, if individuals do occur, then numbers do not represent a significant proportion of the cited populations, and the survey area is not considered an important resource for these species. This includes sites such as the Anglesey Terns SPA in northwest Wales. The distance of the survey area, at over 80km from this designated site, is beyond the typical foraging distances of the tern species present. This is supported by the tracking studies of marked individuals to inform the boundaries of the extension to marine area of the SPA (NRW, 2016).

Breeding seabirds

B.111. For this study, breeding seabirds are those that have been identified as qualifying features for designated sites because they use them for nesting as well as other purposes.

B.112. The survey area occurs in inshore waters which may be used by foraging seabirds from designated sites listed in **Section: 'Ornithological designated sites'**. The mean maximum foraging ranges of seabirds present in the designated sites are presented in Table A7 (Woodward et al*.,* 2019; Owen, 2015). These foraging ranges would potentially place breeding seabirds from St Bees SSSI foraging within the survey area, as well as terns and gulls from breeding colonies within the Morecambe Bay and Duddon Estuary SPA/Ramsar site/SSSI complex.

Table A7. Indicative breeding season foraging ranges

Column heading	Mean maximum Foraging Range (km)
Guillemot	73.2 ± 80.5
Fulmar	542.3 ± 657.9
Kittiwake	156.1 ±144.5
Razorbill	88.7 ± 75.9
Cormorant	25.6 ± 8.3
Puffin	137.1 ± 128.3
Shag	13.2 ± 10.5
Herring Gull	61.1 ± 44
Black Guillemot	7.45
Sandwich Tern	34.3 ± 23.2
Common Tern	18.0 ± 8.9
Little Tern	5
Herring Gull	58.8 ± 26.8
Lesser Black-backed Gull	127 ± 109

Source: Woodward et al., 2019; and Owen, 2015

B.113. It is also recognised that seabirds from other SPA colonies may also occur in the survey area, particularly those with extensive foraging ranges, e.g. gannet and manx shearwater, or outwith the breeding period. However, it is not possible to determine which designated sites these birds may originate from, and evidence from surveys for wind farm developments off the Cumbria coast do not indicate concentrations of these long ranging species in this area of the Irish Sea.

B.114. The breeding season for seabirds varies between species, but broadly extends between April and August, with the core breeding period between May and July, during which time their distribution in the inshore area is constrained by the requirement to return to their breeding sites. Following breeding, seabirds disperse away from their colonies to their wintering areas, with colonies on the west coast of Britain heading west into the Atlantic. Guillemots and razorbills disperse from the colonies during July and August. Adults become flightless during their post-breeding moult and the males are accompanied by flightless chicks. The highest numbers of flightless birds initially occur near the breeding colonies during July and early August. From September onwards, the number of Auks in inshore waters decreases.

B.115. Common, sandwich and little tern breeding colonies are present in the Morecambe Bay and Duddon Estuary SPA/Ramsar site/ SSSI complex and Liverpool Bay SPA, with these populations potentially foraging in the survey area.

B.116. Within the Morecambe Bay and Duddon Estuary SPA/Ramsar site/ SSSI complex, the main sandwich tern breeding colony is at Hodbarrow Lagoon, on the Duddon Estuary. Foraging areas for this breeding colony were modelled to inform the extension of the SPA boundary in marine areas to protect key foraging areas. The predicted usage was greatest in the vicinity of the colony, with usage predicted to decrease with distance offshore (Figure A24). However, the survey area does overlap with the outer limits of the predicted foraging areas.

B.117. Whilst common tern is retained on the citation for the Morecambe Bay and Duddon Estuary SPA, the current breeding numbers are considered to be below the relevant qualifying threshold, so modelling of foraging ranges for the species from the Morecambe Bay and Duddon Estuary SPA has not been undertaken. The extension of the marine area of the SPA, based on sandwich tern predicted foraging areas, was considered sufficient to cover that used by Common Tern (Natural England, 2016). Therefore, the survey area potentially overlaps the outer extents of the foraging range of common tern. The Liverpool Bay SPA supports foraging common tern from breeding colonies in the Mersey Narrows and North Wirral Foreshore SPA.

B.118. Modelling of the predicted foraging ranges of these breeding common tern predicted highest usage around colonies, decreasing westwards into Liverpool Bay. This means that for common tern nesting within the Mersey Narrows and North Wirral Foreshore SPA, the predicted foraging area extends north approximately to Formby, west along most of the Wirral foreshore, and into the mouth of the Mersey Estuary, approximately to Rock Ferry. Therefore, the area of the survey area within the Liverpool Bay SPA is not an important foraging area for common tern associated with Liverpool Bay SPA population (NE, NRW, JNCC, 2016).

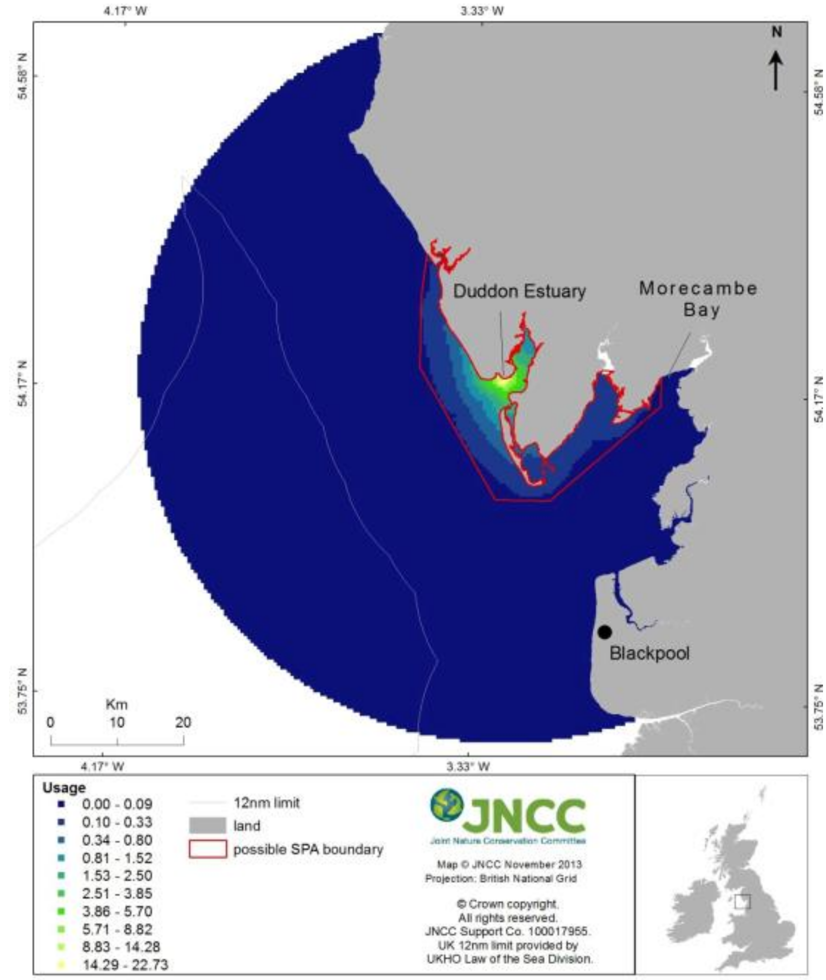

Figure A24. Predicted habitat usage by Sandwich Terns foraging at the Hodbarrow colony within the Duddon Estuary SPA (Source: Win et al. 2013)

B.119. Little tern are the smallest commonly breeding tern in Britain and have the most limited foraging range (see Table A7). Shore-based surveys of colonies within the Morecambe Bay and Duddon Estuary SPA were undertaken to inform the extension of the Morecambe Bay and Duddon Estuary SPA to protect tern foraging areas. The alongshore foraging extents are shown in Figure A25, along with the generic seaward value[5]. These foraging areas do not extend into the survey area.

[5] No boat-based surveys were undertaken at Morecambe Bay SPA. Therefore, the seaward foraging extent was set to the generic seaward extent value derived from all of the surveys at all of the colonies, i.e. 2,176 m.

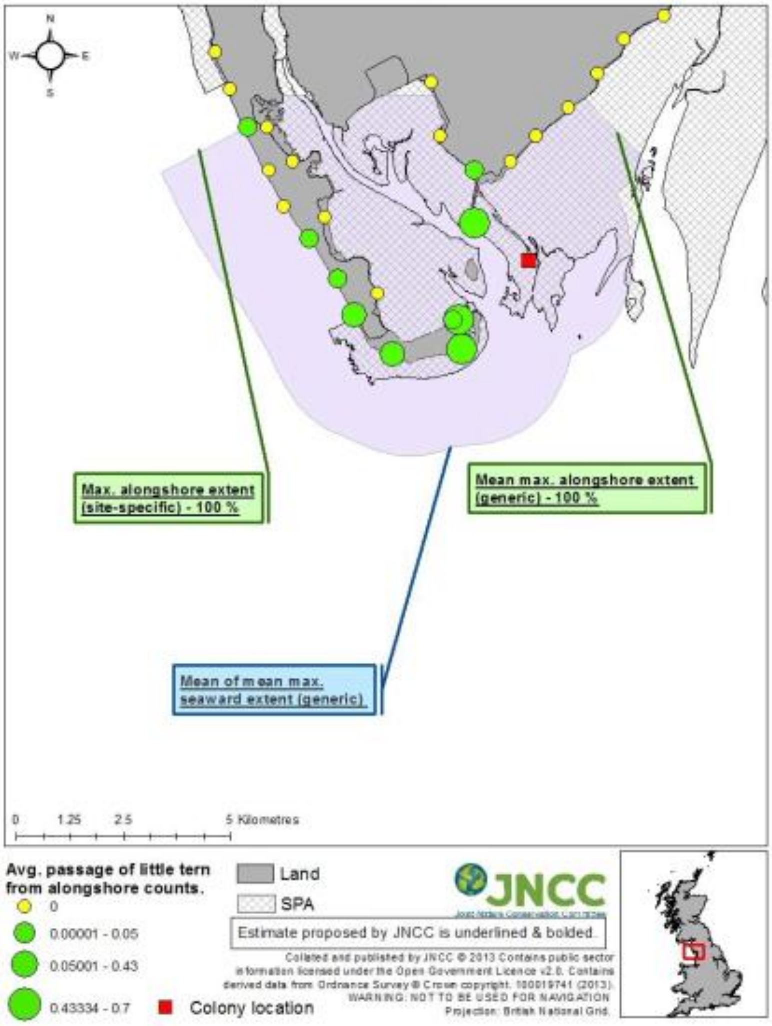

Figure A25. Alongshore and generic seaward extents to define boundaries to Little Tern foraging areas at Morecambe Bay SPA (Source: NE, 2016)

B.120. The little tern breeding population associated with the Liverpool Bay SPA is concentrated at the coastal colony at Gronant, on the Dee Estuary. Survey work to determine foraging ranges from this colony indicated a maximum seaward foraging extent of 1.8 km (Parsons et al. 2015). There is no foraging area for little terns associated with the Liverpool Bay SPA.

B.121. A summary of other foraging seabirds identified from the data sources set out in **Section: 'Key data sources'**, as likely to be present within the survey area during the breeding season, is provided in

B.123. Table A8.

Table A8. Presence and Seasonal Distribution of selected Seabirds within the survey area during the Breeding Season

Species	Summary of Data relevant to the study area	Presence in the survey area
Manx Shearwater	The nearest breeding colonies are on Sanda, Argyll and the Calf of Man, Isle of Man. They feed at the sea-surface, either making plunge dives from a height of 1-2m, or making shallow, wing-propelled dives to catch prey items. Prey species include herring, sardine and sprat plus sometimes squid. Only recorded as present within the summer months off the Cumbria coast, with no/few birds present after the end of August.	Low numbers likely to be present in the survey area between July and August.
Gannet	The nearest Gannet colony is Ailsa Craig, over 100km to the north of the study area. However, the species has extensive foraging ranges and the survey area is well within these. They are a pelagic feeder, foraging primarily on lipid-rich pelagic fish up to 30 cm in length such as mackerel, herring and sandeel. The majority of Gannet recorded were during the summer, with only sporadic sightings between October and March.	Low numbers likely to be present in the survey area between April and September and only sporadic presence between October and March.
Cormorant	Primarily associated with rocky coasts and estuaries, with prey species including plaice, flounder, cod and spat. Recorded throughout the year, predominantly in inshore and estuarine areas.	Present all year round, but only where the survey area approaches the shoreline.
Kittiwake	Qualifying feature of St. Bees SSSI where they nest on tall seas cliffs. Leave their breeding colonies in July/August and spend the winter at sea, often beyond the Continental Shelf. Prey species capelin, herring, sprat and sand eel and have been known to take crustaceans such as shrimps. Highest numbers recorded in the spring and summer.	Widely distributed in the survey area between July and August, at unknown abundance.
Herring Gull	Qualifying feature of St. Bees SSSI. Breeding begins in March or April with eggs laid between April and late June. Opportunistic feeder, taking fish, crustaceans, young birds and even garbage. Recorded throughout the year.	Present all year round, but likely to be present in higher numbers within the survey area where it approaches the shoreline.
Lesser Black-backed Gull	Breeding begins in March or April with eggs laid between April and late June. Opportunistic feeder, taking fish, crustaceans, young birds and even garbage. Recorded throughout the year.	Predominantly present between March and September, although recorded throughout the year, but likely to be present in higher numbers within the survey area where it approaches inshore areas.
Guillemot	Qualifying feature of St. Bees SSSI where they nest on tall seas cliffs. Leave their breeding colonies from	Highest numbers present close to nesting

Species	Summary of Data relevant to the study area	Presence in the survey area
	July and spend the winter at sea. Prey species predominantly consists of sandeel and clupeids. Highest numbers recorded in the spring and early summer.	colonies, but likely to be widely distributed throughout the survey area, with numbers declining from July onwards as nest sites are abandoned.
Razorbill	Qualifying feature of St. Bees SSSI and Cumbria Coast MCZ where they nest on small ledges or in cracks of rocky cliffs and in associated screes. Breeding begins in late April with a peak in mid-May. Prey species predominantly consists of sandeel. Highest numbers recorded in the spring and early summer.	Highest numbers present close to nesting colonies, but likely to be widely distributed throughout the survey area, with numbers declining from July onwards as nest sites are abandoned.

<u>Non-breeding seabirds</u>

B.124. For this study, breeding seabirds are those that have been identified as qualifying features for designated sites because they use them for purposes other than nesting.

B.125. Red-throated diver and other waterbirds, such as goosander, goldeneye, scaup and common scoter move to coastal areas in winter from their breeding sites. Red-throated diver and goosander feed on a wide variety of fish, which they catch by diving from the surface and pursuing their prey underwater. The fish species taken will be influenced by what is locally most readily available, but the diet of these species can include haddock (*Melanogrammus aeglefinus)*, cod (*Gadus morhua)*, herring (*Clupea harengus)*, sprats (*Sprattus sprattus)* and gurnard (*Eutrigla gurnardus)*, along with smaller species such as sandeels (*Ammodytidae),* pipefish (*Syngathidae)*, gobies (Gobiidae), flatfish (*Pleuronectidae)* and butterfish (*Pholis gunnellus)*.

B.126. Common scoter, scaup and goldeneye feed almost exclusively on molluscs and small crustaceans, diving from the surface to pluck their prey from the seabed. Diving activity varies among species, but average foraging dive depths are shallower than 15 m.

B.127. Red-throated diver arrive in UK coastal waters in September and decline in numbers in February, although the main period of occurrence in coastal offshore waters is from October to March (Natural England, 2012; Lawson et al*.,* 2016). Red-throated diver, along with common scoter, scaup, goosander and goldeneye, are associated with inshore waters, occurring in sandy bays, firths, and sea lochs, as well as open coastline and shallow offshore areas, i.e. sandbanks. Red-throated diver is less abundant on western coasts of the UK, with a patchy abundance (Natural England, 2016). Aerial surveys used to assess populations of waterbirds in association with the Liverpool Bay SPA, showed that the highest densities of Red-throated diver were concentrated around the Ribble estuary and the Liverpool Bay area, whilst a small area in the inshore waters surrounding the Barrow-in-Furness also had higher densities of this species (Lawson et al*.,* 2016). The remaining Cumbrian coast and waters further offshore had very low densities of red-throated diver, close to or equal to 0 individuals/km^2. Common scoter densities were also very low along the Cumbrian coast and within the survey area. Aerial surveys undertaken as part of the designation process for the Solway Firth SPA reported the highest densities of Red-throated diver from Southerness to Maryport, with some concentrations of this species around Whitehaven (densities of 0.15 to 0.6 individuals/km^2) (Natural England and SNH, 2016). Densities of this species (and common scoter) are thought to be much lower outside of the Solway Firth SPA site boundary. Given the habitat preferences of goosander, scaup and goldeneye, a similar pattern of occurrence is likely.

Step 3 - Assess significance of any impacts

Overview

C.1. This section includes the overarching evidence of the assessments looking for the likely impacts and potential effects of the survey on the designated sites and their qualifying features, as well as wider marine wildlife (e.g. EPS). This includes both scoping (i.e. is there an impact pathway that needs an assessment?) and screening (e.g. is there a potential LSE under HRA?) stages of assessments for each designated site etc.

C.2. Although the assessment followed best practice, due to the targeted nature and pressures from survey, the baseline was compiled as a receptor led process. This was done to allow technical reviews of each sensitive receptor, although the relevant designated sites have been clearly stated within the baseline text for each receptor, as appropriate, to show the links to assessments such as HRA.

C.3. The likely impacts and effects (impact pathways) of the survey on marine ecological receptors that have been scoped in for consideration within this impact assessment are:

- Impact pathway 1: Underwater Sound Disturbance;
- Impact pathway 2: Airborne Sound and Visual Disturbance; and
- Impact pathway 3: Collision risk.

C.4. Broad assessments based on these three pathways are noted below, followed by specific assessments for HRA, WFD etc, which draw on the evidence from the broad assessments.

Pathway 1: Underwater Sound Disturbance

Marine mammals

C.5. Sound from anthropogenic activities can negatively impact marine mammals as it influences their ability to echolocate and communicate, and some sound sources can cause physical harm, including impairment of auditory apparatus. Sound can also cause certain species to change their behaviour, such as increased alertness, modification of vocalisations, interruption or cessation of feeding or social interactions, alteration of movement or diving behaviour, and temporary or permanent habitat abandonment. Sound associated with animal responses, such as panic, flight, stampede, or disorientation which could lead to stranding, which could sometimes result in indirect injury or death, have only been observed in relation to sound from explosions or some military type sonar. For sound generated by geophysical activities, the effects of concern relate to auditory and behavioural changes.

C.6. Cetaceans produce and receive sound over a great range of frequencies for use in communication, orientation, predator avoidance and foraging (Tyack, 1998). As sound production in marine mammals is integral to a range of important behaviours, any interference with these communicative functions has the potential for adverse effects. Seals also produce a diversity of sounds, though generally over a lower and more restricted bandwidth than cetaceans. Their sounds are used primarily for social and reproductive interaction, both in water and air (Southall et al., 2007).

C.7. Man-made sound sources have the potential to affect cetaceans where the frequency of the sound generated is within a species auditory range. To reflect the different hearing sensitivities of cetacean species, Southall et al. (2007) classified marine mammals into functional hearing groups. These groupings have been used widely since publication, including in the most recent NMFS guidance for underwater sound criteria for marine mammals (NMFS, 2018), which provides the most up-to-date auditory threshold criteria (PTS and TTS) for cetaceans and seals. Although Southall et al., 2019 revised these groupings slightly[6] to maintain consistency with the majority of the literature, the 2007 terms are maintained. These groups are shown in Table A9. below, together with the species in each category that could be present in the survey area.

Table A9. Hearing sensitivity of marine mammals in survey area

Marine Mammal Hearing Group	Relevant Key Species	Estimated auditory bandwidth
Low Frequency Cetacean (LF)	Baleen whales including minke whale	7 Hz to 35 kHz
Mid Frequency Cetacean (MF)	The toothed whales and dolphins including bottlenose dolphin and common dolphin	150 Hz to 160 kHz
High Frequency Cetacean (HF)	Harbour porpoise	275 Hz to 160 kHz
Phocid Seal in Water (PW)	Harbour and grey seal	75 Hz to 75 kHz

C.8. The impact of underwater sound in marine mammals is generally split into the following categories:

- Effects on hearing
  - a consequence of damage to the inner ear of marine mammals, the organ system most directly sensitive to sound exposure and, thus, the most susceptible to sound-derived damage (Southall et al., 2007). Hearing loss or a shift in hearing thresholds can be permanent or temporary.
- Permanent Threshold Shift (PTS)
  - is a permanent elevation in hearing threshold (i.e., an unrecoverable reduction in hearing sensitivity). PTS can occur from a variety of causes, but it is most often the result of intense and/or repeated noise exposures.
- Temporary Threshold Shift (TTS)
  - is a recoverable elevation in hearing threshold (i.e., a non-permanent reduction in hearing sensitivity), most commonly resulting from long-term noise exposure not high enough to cause PTS.

6

- Behavioural responses
  - are highly variable and context-specific, ranging from increased alertness, altering vocal behaviour, interruption to feeding or social interaction, alteration of movement or diving behaviour, and temporary or permanent habitat abandonment. In some circumstances, sound from explosions or military sonar have been associated with animal responses such as panic, flight, stampede or stranding, sometimes resulting in indirect injury, or death could occur. Minor or temporary behavioural responses are often simply evidence that an animal has heard a sound.
- Masking
  - anthropogenic underwater sound may partially or entirely reduce the audibility of signals of interest, such as those used for communication and prey detection.
- Detection
  - the limit of hearing. Marine mammals generally have high sensitivity to sound pressure (low detection thresholds) and can hear across a broad range of bandwidths.

Threshold criteria

C.9. The most up to date sound exposure criteria for auditory injury in marine mammals have been published by the US National Marine Fisheries Service (NMFS), often referred to as the NOAA criteria (NMFS, 2018), and in a relatively recent peer-reviewed academic paper (Southall et al., 2019). These values are an update to the commonly applied Southall et al., 2007 guidelines and have been widely accepted for use in impact assessments by UK regulators.

C.10. The NMFS thresholds are for PTS and TTS only and, as in previous criteria, are based on dual criteria of unweighted, instantaneous peak sound pressure levels (SPLp) and M-weighted7 Sound Exposure Levels (SEL) (Table A10).

Table A10. PTS and TTS thresholds for impulsive sound sources for marine mammals

Cetacean hearing group	Permanent Threshold Shift (PTS)		Temporary Threshold Shift (TTS)	
	SPLp	SEL	SPLp	SEL
Low Frequency	219	183	213	168
Mid Frequency	230	185	224	170
High Frequency	202	155	196	140
Phocids in Water	218	185	212	170
Source: NFMS (2018) and Southall et al. (2019).				

[7] Frequency weighting applied to the SEL allowing functional hearing bandwidths of different marine mammal groups and taking a relevant or derived species audiogram into account in the sound propagation.

C.11. There are no quantitative thresholds for behavioural disturbance in the latest guidance (NMFS, 2018 and Southall et al., 2019), reflecting both a lack of empirical evidence and a high level of variability in behavioural responses, which have been shown to be often unrelated to the sound level received (e.g. see Gomez et al., 2016).

C.12. However, thresholds used in the US for the application of an “Incidental Take Authorization” under the Marine Mammal Protection Act, and the Endangered Species Act, provide a threshold for ‘Level B harassment’, a definition which equates to behavioural disturbance (NOAA, 2021). The published value for impulsive sound, such as that produced by a geophysical array, is an SPL_{rms} of 160 dB re 1µPa @1m. The onset of TTS has also been proposed as the point at which a significant behavioural response to impulsive sound can be expected to occur (Southall et al., 2007). These criteria, in conjunction with the ecological context of the particular receptor, are considered in the assessment.

Cetaceans

C.13. Based on the information noted earlier, only two designated sites were identified for cetaceans, and both were over 50 km away from the survey area. As such, the focus of the assessments was on the receptor’s designation as EPS.

C.14. The harbour porpoise is the cetacean species most likely to be found in the vicinity of the study area. This species is categorised as having high frequency hearing (Southall et al., 2007; NMFS, 2018; Southall et al., 2019), with a very acute sense of hearing underwater (Kastelein et al., 2002). Harbour porpoise have been shown to use echolocation to find their prey, as well as for spatial orientation and navigation (Lucke et al., 2009 and references therein). Thus, this acoustic sense is likely key to survival, and any significant impairment or damage to their auditory system may have long-term harmful consequences for the affected individual.

C.15. The most recent threshold for TTS in harbour porpoise is based on a number of studies involving a small number of captive harbour porpoise. For example, in an experiment by Kastelein et al. (2017), a harbour porpoise was exposed to either 10 or 20 consecutive shots from two air guns firing simultaneously. A mean threshold shift of 4.4 dB occurred after exposure to a weighted cumulative sound exposure level (SEL) of 140.3 dB, which is consistent with other studies supporting the 140 dB SEL_{cum} threshold for high frequency cetaceans for impulsive sources (NMFS, 2019). The authors conclude the threshold provides a reasonably robust measure of low levels of TTS occurring over a range of spectra of impulsive sound sources. No direct measurement of permanent threshold shift (PTS) in marine mammals has been published, and the thresholds have been extrapolated from marine mammal TTS measurements (i.e. using growth rates from terrestrial and marine mammal data) (NMFS, 2018).

C.16. Based on the project-specific underwater sound propagation modelling, PTS and TTS from exposure to a single acoustic pulse (as measured by Sound Pressure Level) is largely restricted to an area in relatively close proximity to the sound source. On the basis of this metric, the potential PTS effect zone ranges from 375 to 528 m, depending on the time of year (i.e. the sound speed profile). It should be noted that JNCC guidance is aimed at minimising the chance of any marine mammal being within 500 m of the sound source, and allow sound to increase gradually during the soft-start PTS. Therefore, making it highly unlikely to occur in any cetacean when the survey begins or restarts after a break.

C.17. However, the survey operations are made up of multiple pulses over a period of time, and the cumulative energy produced also has the potential to result in auditory effects. The modelling of SEL_{cum} for a fleeing animal has been determined on the basis of the ability of a harbour porpoise to maintain a swimming speed of ~7 m/s when moving away from pile driving sounds (Kastelein et al., 2018, Otani et al, 2000). Such avoidance behaviour is common in harbour porpoise, as described in the assessment of behavioural responses below. Assuming the animal moves away at 90o to the vessel (not directly opposite which is much quicker), the decreasing sound intensity with distance means that the PTS threshold is not reached at any point, allowing for all directions of travel the two sound speed profiles modelled. For a comprehensive assessment, exposure was also determined allowing for the required JNCC mitigation measures of a 500 m exclusion zone and a soft-start, and the potential for PTS is even further reduced. Thus, the potential for PTS in harbour porpoise is considered to be negligible, with or without the JNCC mitigation measures in place (JNCC, 2017). It is also worth considering that an exposure causing 40 dB of TTS is considered equivalent to PTS onset, and yet no studies measuring this in any cetacean have been made (NMFS, 2018).

C.18. Adopting the same initial fleeing animal scenario estimates that TTS would be reached very quickly, within 15 seconds. However, accounting for a soft-start and 500 m exclusion zone, the TTS threshold would only be exceeded after a period of 42 minutes, by which time a harbour porpoise would have travelled a distance of 4.9 km. On the basis of this scenario, the TTS would only be above the threshold by a minimal amount, a maximum SEL of 141.8 dB compared to the threshold of 140 dB, which does not increase thereafter as exposure falls with increasing distance from the vessel. The time for recovery from TTS is still poorly understood, but is related to the sound level and duration and the degree of TTS (NMFS, 2018). Any TTS that did occur is expected to be minor and recovery fairly rapid once the short-term sound source stops, and with the potential, based on the low density of animals in the survey area, to affect very few individuals. Studies show harbour porpoise actively avoid areas where impulsive sounds are occurring, and so the expectation is that the risk of TTS is low.

C.19. Clearly there are uncertainties around the fleeing animal estimates, but they indicate the likely level of auditory effect, allowing for the expected avoidance behaviour, of harbour porpoise is small. Such responses in harbour porpoise have been well documented in response to offshore wind pile driving, with avoidance behaviour observed up to 25 km away from operations (Dahne, 2013).

C.20. Avoidance behaviour in cetaceans is often assumed to occur, though it is in fact highly variable, with responses influenced by factors such as site fidelity, motivation to remain in a particular location, life-cycle stage, such as breeding and nursing young, as well as habituation to anthropogenic underwater sound (Southall et al., 2007). Thus, assumptions of a fleeing animal in the estimation of effect zones can be controversial. This can be of particular relevance to harbour porpoise which have high metabolic rates and have limited ability to cope with prolonged starvation (Pirotta et al., 2014), where good feeding opportunities may override avoidance behaviour.

C.21. Data indicates that survey area has a low density of harbour porpoise, particularly in comparison to the north western Irish Sea, which is known to be important for foraging and breeding. There are nursery grounds of fish species such as herring, which are known prey items for harbour porpoise, in the north eastern Irish Sea, but the low density of this cetacean indicates they are not key foraging grounds. Therefore, with good foraging opportunities over a wide area elsewhere, there is no indication there will be a strong motivation to remain for any animals in the vicinity of the survey vessel. Therefore, for this area estimation of the effect of avoidance behaviour on sound exposure is considered appropriate.

C.22. There is also evidence of avoidance and other behaviours in harbour porpoise in the case of geophysical sound sources. For example, observations undertaken during 201 geophysical surveys in UK and adjacent waters were analysed to examine effects on cetaceans (Stone and Tasker, 2006). Of these, 110 used large airgun arrays with a peak source level of around 250 dB re. 1µPa @ 1 m in the dominant bandwidth. Sighting rates of small odontocetes, which includes harbour porpoise, were significantly reduced during periods of shooting on surveys with large volume airgun arrays. The median closest distance of approach of harbour porpoise to the vessel, observed during periods of good weather, was around 0.5 km when the geophysical source was not active, and increased to around 1.5 km during surveys. There was also a demonstrable effect on the orientation of animals during survey operations, with more animals moving away. Although precise data on other aspects of behaviour were not collected, observers' records suggested that fewer cetaceans were foraging, and observers also gained the impression that small odontocetes tended to swim faster when the sound source was active.

C.23. Similarly, a study of harbour porpoise vocalisations during a commercial geophysical survey, with a sound intensity estimated at an SPL_{peak} of 242-247 dB, showed that the relative density of porpoises decreased within 10 km of the survey vessel and increased at greater distances (Thompson et al., 2013), indicating avoidance behaviour. The passive acoustic techniques used were unable to detect individual animal movements, but the data on group responses showed that the number of animals in the impacted area returned within a day, indicating no long-term disturbance effect. A sister study during the same survey used an array of passive acoustic loggers, coupled with calibrated sound measurements, to test whether the survey influenced the activity patterns of porpoises that remained in the area (Pirotta et al., 2014). During geophysical operations, harbour porpoise made fewer 'buzz', vocalisations thought to be associated with foraging and communication. A harbour porpoise subject to geophysical pulses in an aquarium also demonstrated clear avoidance behaviour when the source was active (Lucke et al., 2009).

C.24. The density of harbour porpoise in the survey area is low, and so the number of individuals cetaceans with the potential to be affected by the underwater sound is expected to be small. Evidence shows any harbour porpoise present in the region of the survey vessel are highly likely to move away before any significant auditory impacts occur. The duration of the survey is short and impacts likely to be limited to behavioural disturbance, particularly with the adoption of the required JNCC mitigation and the natural avoidance behaviour of harbour porpoise. Any reduction in density in the area will be temporary, as animals are known to return to an area once the sound source ceases. The wider area is considered to offer ample suitable alternative habitat for feeding and other activities and, being highly mobile and free-ranging animals, cetaceans would be able to temporarily relocate to areas outside of the zone of disturbance. Also, as outlined in other sections of the impact assessment, there is predicted to be no significant impact to fish and benthic species from the survey activities, and therefore no indirect effects to cetaceans from a loss or change in prey resource is expected to occur.

C.25. Thus, the energetic cost of avoidance behaviour is not anticipated to have a significant effect, and the impact of the survey on harbour porpoise is considered to be not significant. Based on the relatively large distance of the survey from the designated sites, the low importance of the survey area for foraging (indicated by the low densities of harbour porpoise in this area), as well as the implementation of the survey design, it is considered that the conservation objectives of these sites will not be undermined as a result of the survey. Therefore, there will be no Likely Significant Effects on the integrity of these SACs.

C.26. In terms of wider considerations as an EPS, behaviour disturbance as a result of the survey is anticipated, and could result in an avoidance or fleeing reaction if an individual is close to the acoustic sound source. Individuals which utilise the North Channel SAC or North Anglesey Marine SAC could travel away from these sites if foraging for food and may be found within an area close to the survey area. In this instance, behavioural disturbance could occur in these individuals. However, the survey area and wider eastern Irish Sea has low densities of harbour porpoise, indicating that this area is not particularly important for foraging. Any behavioural disturbance would be minimal, and in a worst-case scenario would only affect a small number of harbour porpoise and not have wider population effects. Given the distance of the survey area from these designated sites, any disturbance would not lead to the exclusion of individuals from entering either of these sites, and therefore is not considered significant in the context of the SACs conservation objectives.

C.27. There is also evidence to indicate that survey may influence the behaviour of other cetaceans in a number of ways, potentially leading to reduced sighting rates ((Gordon et al., 2003; Nowacek et al., 2015; Kavanagh et al., 2018) e.g. Stone et al., 2006). It is suggested that different taxonomic groups of cetaceans may adopt different strategies for responding to acoustic disturbance from geophysical surveys. Whilst small odontocetes, like the harbour porpoise, move out of the immediate area, slower moving baleen whales orient away from the vessel and increase their distance from the source, but do not move away from the area completely (Stone et al., 2006). Some species, such as long-finned pilot whales, showed only a change in orientation, and sperm whales showed no statistically significant effects.

C.28. Bottlenose and common dolphin have also been observed in the region, but only as relatively occasional visitors. Both are mid-frequency hearing species, which makes them much less sensitive to the impact of geophysical surveys compared to harbour porpoise. Although avoidance behaviours by Atlantic spotted dolphin (*Stenella frontalis*) in response to geophysical sound have been observed (Weir, 2008). The maximum distances for PTS and TTS, based on a 24-hour exposure period, are 499 m and 9,092 m, respectively, with maximum sound propagation in the direction of deeper water. With the marine mammal mitigation measures in place, the risk of impact from the survey of short duration, over a smaller area for a less acoustically sensitive species, is low.

C.29. Low frequency cetaceans, predominantly the baleen whales such as the minke whale, which can be present in the survey area, are considered to be the most sensitive to the dominant low frequency spectra of underwater sound, though similar behavioural responses have also been seen in mysticetes (Kavanagh et al., 2018). However, modelling indicates very extensive potential exposure zones, depending upon the length of time, (**Appendix D: Underwater sound supporting information, Tables A.1 to A.24**), which means underwater sound may be detected from significant distances away. For example, long and short- term displacement and changes in vocal, diving and movement behaviour of baleen whales have all been recorded in response to geophysical surveys (see details in Kavangh et al., 2018). However, there is a low likelihood of the presence of baleen whales, and thus a small likelihood of an effect, particularly as the survey is of very short duration and will adopt the required mitigation to minimise risk (JNCC, 2017). Thus, the impact for low frequency cetaceans is also considered to be not significant.

<u>Pinnipeds</u>

C.30. As noted earlier, there are grey seal haul-out sites at the South Walney Nature Reserve, the Dee Estuary, and two sites close to the Solway Firth. Grey seals haul-out in autumn and winter to give birth, and the pupping season is reported to be September to October in Wales and November to December in Scotland. There is, therefore, the potential for seals to be pupping towards the end of the survey window of July to August, particularly at South Walney Nature Reserve and the Dee Estuary site, if pups are born early. However, female grey seals endure a fast while lactating, remaining on land for about 3-4 weeks before weaning their pups and returning to sea (Langley et al*.,* 2020). Following the mother's departure, grey seal pups have been reported to remain on land for 10–40 days before they themselves are seaworthy.

Thus, the presence of any mothers or pups in the water during the survey window is unlikely and impacts to this group of seals can be scoped out.

C.31. The nearest designated site for grey seal is 260 km away, but grey seals are known to undertake wide ranging movements within and between SACs and non-designated sites (Langley et al., 2020). There is evidence of individuals travelling along the Cumbria coast during the survey window, though tracking data indicates only small numbers in this area compared to further west. Thus, there may be grey seals present in the vicinity of the inshore area during the survey, albeit in low numbers. The presence of the harbour seal in the vicinity of the survey area is very low as the nearest hotspots are two SACs on the Irish Coast, ~ 100 km away, and there are no known haul-out sites in close proximity to the survey area. Nevertheless, there have been sightings of harbour seals in the Solway Firth and along the Cumbrian coast, so there is potential for occasional presence.

C.32. Geophysical survey activity has been shown to result in avoidance behaviour in several seal species (Harris et al., 2001) and, during controlled exposure experiments with small airguns, grey seals showed short-term avoidance behaviour (Thompson et al 1998). On exposure to geophysical survey sounds, seals interrupted feeding and often showed avoidance until the airgun pulses ceased. However, in the Harris et al., (2001) study some ringed seals (a phocid seal) remained within 100-200 m of the geophysical sound source operating at a level of 211 dB SPL_{peak} (reported as SPL_{rms} of 198 dB). However, some early studies showed that pinnipeds can be quite tolerant of exposure to strong underwater sounds, especially in areas where they are attracted to a concentrated source of food, and in situations where habituation has occurred (Richardson, 2004). Also, seal scarers deployed to deter seals from fish farms, have sometimes been found to be ineffective due to seals' natural curiosity (Coram et al., 2014).

C.33. On the basis that avoidance behaviour is expected, a fleeing animal scenario has been combined with the sound propagation modelling (**Appendix D: Underwater sound supporting information, paragraphs 5.4 - 5.11**)., which indicates that PTS is not reached, but that there is potential for a risk of a small degree of TTS, up to 6 dB for any seals that were very close the vessel. A potential TTS of up to 12.1 dB is estimated for any animals that travels in a westerly direction into deeper water where sound propagation is more extensive, but as seals are thought to travel along the coast near the survey area, avoidance behaviour is not anticipated to be in this direction

C.34. The exceedance of the TTS threshold reflects the generally better hearing of seals at low frequencies, although Reichmuth et al. (2016) exposed two spotted seals (Phoca largha), and two ringed seals (Pusa hispida), to single impulses from a 10 in 3 sleeve air gun with no measurable TTS, though at maximum peak SPL of ~ 203 dB re 1 μPa this was lower than the sound source modelled for the survey. However, TTS in seals has been observed in other sound exposure experiments. A TTS of 4.6 to 4.9 dB was recorded in harbour seals, elephant seals and California sea lions exposed to 20-25 minutes of mid frequencies, ranging from 100 Hz to 2 kHz, at octave band sound levels of 60-75 dB above the threshold level at the central frequency (Kastak et al., 1999). All animals showed full recovery after 24 hours. There are, however, no data that can be used to extrapolate from small TTS at low level, short-duration noise exposures to TTS resulting from louder, longer exposures typical of a geophysical survey (Kastak et al, 2005).

C.35. However, considering avoidance behaviour, which will minimise sound exposure, the relatively short duration of the survey, and the JNCC mitigation measures adopted (JNCC, 2010), the potential for PTS is thought unlikely and a negligible risk of some low level TTS in very few animals, if any. The most likely effect of the survey is disturbance, but since there is no evidence to indicate the survey area is of particular importance for foraging, and that nearby nursing mothers and pups will be land bound during the survey, any disturbance is considered to be short-term, likely to affect a very small number of animals, but not during a key life stage, and therefore is assessed as not significant to the long-term survival of individuals or populations of seals.

C.36. Although some individuals will be disturbed, resulting in localised avoidance of the area during the survey, only a small proportion of the local population is likely to be affected, and for a relatively short period of time. In addition, harbour porpoise are known to return to an area once the sound source has stopped. Thus, the potential impact of the survey activities on seals is considered to be low.

C.37. Disturbance from the survey can be considered to be negligible and unlikely to be detrimental to the maintenance of grey seal populations at a Favourable Conservation Status (FCS) in their natural range.

<u>Sea turtles</u>

C.38. There are few data available on the impacts of sound source effects on sea turtles. It is possible that sound source exposure could mortally injure sea turtles that are very close to the source, though other studies suggest sea turtles may be highly resistant to high intensity sounds, such as that from explosives (Ketten et al. 2005).

C.39. Morphological examinations of sea turtles (e.g. Lenhardt et al. 1985) support the proposal that fish hearing is the most appropriate model to use for sea turtles until more data becomes available. The most recent thresholds for turtles (Popper et al., 2014) provide numerical threshold criteria for mortality and mortal injury only (**Error! Reference source not found.**). For other effects, including hearing impairment and behavioural responses, relative risk criteria (high, moderate, low risk) are given for turtles at three distances from the sound source, also defined in relative terms as near (N), intermediate (I), and far (F). The authors of the guidelines recommend that while it is not appropriate to ascribe specific distances to effects because of the many variables in making such decisions, “near” might be considered to be in the tens of metres from the source, “intermediate” in the hundreds of metres, and “far” in the thousands of metres (Popper et al., 2014).

C.40. The only available behavioural threshold for marine turtles, given as an SPL of 175 dB re 1 μPa @1 m, is published in US Navy guidance (Finneran and Jenkins, 2012). This value is based on experiments with caged turtles, which showed that above a received SPL of 166 dB re 1 μPa @1 m animals noticeably increased their swimming activity compared to non-airgun operation periods (McCauley et al., 2000). Above 175 dB re 1 μPa @1 m behaviour became more erratic, possibly indicating the turtles were in an agitated state. The authors noted that the point at which the turtles showed the more erratic behaviour would be expected to approximately equal the point at which avoidance would occur for unrestrained turtles (McCauley et al., 2000).

C.41. The potential effect zone for the onset of injury in turtles, for the modelled sound source, is estimated to occur at a maximum distance of 284 m from the sound source. Since the embedded JNCC mitigation for geophysical operations (JNCC, 2017) requires the monitoring of a 500 m exclusion zone for 30 minutes prior to any sound source starting, it is likely that no marine receptors, including sea turtles, will be within the exclusion zone, and thus outside the distance at which the SPL threshold criteria would be exceeded.

Table A11. Threshold Criteria for Underwater Sound Effects in Sea Turtles

Threshold Source	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Popper et al., 2014	210 dB SELcum	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low
Finneran and Jenkins, 2012	-	-	-	-	175 dB_{rms}

C.42. Sea turtles are generally not fast swimmers, but avoidance behaviour is expected to occur in any animals in the vicinity of the sound source. Turtles usually cruise at around speeds of between 1.4 and 9.3 km/h, but have been found to swim up to 35 km/hr when frightened (https://ocean.si.edu/ocean-life/reptiles/sea-turtles). Taking a swimming speed of 7 km/hr as a precautionary value, the fleeing animal scenario indicates the threshold for mortality or mortal injury would not be exceeded.

C.43. As turtles are mobile, they can avoid areas of disturbance if given enough time to do so. With the adoption of the JNCC guidelines (JNCC, 2017) for the survey, any turtle in the vicinity of the survey vessel is expected to be at least 500 m away, because of the observation procedures, before sound activation occurs. Also, because a soft-start will always occur when the sound source is first activated, or after a break, sound intensity starts low and builds up before reaching full strength, enabling any turtles in the vicinity of the vessel to move away. Whilst any turtles present are likely to be foraging on jellyfish, the distribution of these prey items is anticipated to be diffused, and so low levels of site fidelity expected such that any turtles can move away.

C.44. Avoidance behaviour, based on an SPL threshold, suggests there is a risk of behaviour disturbance up to and around a kilometre from the sound source. However, the extent of a behavioural response in any marine animal, including turtles, depends on the distance from source and, on the basis of a 500 m exclusion zone and a soft-start before any operations begin, any kind of panic or fleeing reaction is not expected to occur.

C.45. There have been reports of blooms of jellyfish in Cumbrian waters, including in the summer months, and there may therefore be turtles foraging. However, current data indicate the number of animals observed is very low, and blooms are likely to be observed along the whole coastline. These animals are not undertaking well known migration and, because prey availability is relatively widespread, probably occurring along the whole coastline when numbers are high, there is no specific area of particular importance for foraging turtles. Blooms of jellyfish also tend to congregate in the shallows around beaches (see Cumbria Wildlife Trust reports).

C.46. To conclude, whilst all turtle species are EPS species and therefore of high conservation importance, the risk of injury is exceedingly small, particularly considering the standard JNCC mitigation measures which should be extended to include turtles in the observation measures, and that any behavioural disturbance would be very local in extent, of short duration (a matter of several weeks to a few months), and not likely to result in any detrimental effect on normal behaviour, including foraging, because prey will be widely available. Thus, the magnitude of the effect to individual turtles is considered to be negligible and not thought to have the potential for an effect on populations. Thus, the effect of underwater sound from a single, short-duration survey on turtles is not significant.

Fish

C.47. Sound plays a major role in the lives of fish (Fay and Popper, 2000), being important for communication, locating prey and avoiding predators, as well as for developing a general understanding of its surroundings. Research has also shown the sound signatures of different habitats are important for settlement of larvae and juvenile fish (Popper and Hastings, 2009).

C.48. The impact of sound on fish is, to a large extent, determined by the physiology of fish, particularly the presence or absence of a swim bladder, and the potential for that swim bladder to improve the hearing sensitivity and range of hearing (Popper et al., 2014). Underwater sound is detected as the swim bladder gas vibrates, and links between the swim bladder and the ear allow the sound wave energy to be re-directed to the ear. These morphological features have been used to define hearing categories of fish, depending on how they might be affected by sounds, and these are used when assessing impacts (Popper et al., 2014).

C.49. The fish hearing categories are:

- Fish species with no swim bladder or other gas filled chamber, such as elasmobranchs (sharks and rays), lamprey and flatfish. These species generally only detect particle motion and are less sensitive to sound pressure. However, some physiological injury/barotrauma could result from exposure to intensive sound pressure.
- Fish species with swim bladders in which hearing is separate from the swim bladder or any other gas filled chamber, such as Atlantic salmon. While hearing only involves particle motion, not sound pressure, these species are sensitive to physiological effects.
- Fish species in which hearing involves a swim bladder or other gas filled chamber: e.g. herring and cod. These species are sensitive to physiological effects being able to detect sound pressure and particle velocity.
- Fish eggs and larvae: The limited available data (e.g. larvae displaying similar startle thresholds) suggests larvae have similar hearing frequency ranges to those of adults. It is thought swim bladders may develop at a larval stage, meaning there may be a susceptibility to pressure related trauma (Popper et al. 2014).

C.50. Popper and Hastings (2009) found that exposure of fish to very high sound levels, such as that caused by underwater explosions, could cause possible rupture of blood vessels leading to superficial or internal bleeding, but only in very close proximity to the sound source. Geophysical surveys, which have a lower sound source level than explosives, have not been reported to result in physical injury in fish, though threshold criteria for geophysical survey sound sources are provided by Popper et al., (2014) (Table A12). They have, however, been reported to cause some damage to the sensory hair cells of the ear of the pink snapper, in cages subjected to sound from geophysical surveys of 216 dB SPL_{peak}, though it was not established if this resulted in any hearing loss and no mortality was seen as a result (McCauley et al., 2003).

C.51. The threshold criteria provided by Popper et al., 2014 are shown in Table A12 below.

Table A12. Threshold Criteria for Underwater Sound Effects in Fish

Type of Animal	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable injury	TTS	Masking	
Fish: no swim bladder (particle motion detection	>219 dB SEL$_{cum}$ or >213 dB$_{peak}$	>216 dB SEL$_{cum}$ or >213 dB$_{peak}$	>186 dB SEL$_{cum}$	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder is not involved in hearing (particle motion detection)	210 dB SEL$_{cum}$ or >207 dB$_{peak}$	203 dB SEL$_{cum}$ or >207 dB$_{peak}$		(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: swim bladder involved in hearing (primarily pressure detection)	207 dB SEL$_{cum}$ or >207 dB$_{peak}$	203 dB SEL$_{cum}$ or >207 dB$_{peak}$		(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate
Eggs and larvae	>210 dB SEL$_{cum}$ or >207 dB$_{peak}$	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low
All Fish: behavioural 'may affect threshold'	-				> 150 dB rms

Notes: peak and rms sound pressure levels (SPL) dB re 1 µPa; sound pressure level (SEL) dB re 1 µPa 2 ·s. All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist. Relative risk (high, moderate, low) is given for animals at three distances from the source defi ned in relative terms as near (N), intermediate (I), and far (F).

C.52. Popper et al. (2014) does not provide a quantitative threshold for behavioural responses to underwater sound, as behavioural responses are highly variable and difficult to measure. Other studies also show that responses do not scale with received level, making the use of quantitative thresholds problematic (e.g. Gomez, 2016; Merchant et al., 2017). Instead, Popper et al. (2014) use a risk rating for behavioural responses for relative distance from a sound source.

C.53. Threshold levels may be assigned to the onset of behavioural responses in fish species. Hawkins et al. (2014) observed the behaviour of shoals of wild, pelagic species of fish were subjected to playback of geophysical survey airgun sound. When insonified, the shoals were seen to temporarily break up, or change swim direction or depth before reforming. The ensuing statistical analysis determined received sound levels at which 50% of the shoals exhibited the defined response. It was found that the corresponding single strike sound exposure levels were 135.0 dB re 1 mPa2 s for sprat and 142.0 dB re 1 mPa2 s for mackerel. Sprat are members of the herring family and, given their audiological physiology (Popper and Fay. 1993), are known to be sensitive to underwater sound. As such, they are likely to be classified as Group 3 or

Group 4. Mackerel lack a connection between the inner ear and swim bladder and are thus less sensitive to underwater sound. They are likely to be classified as Group 2.

C.54. Underwater sound modelling has been undertaken to determine effect risk zones for all fish groups, based on dual criteria of SPL and SEL, incorporating a moving vessel, and a fleeing animal scenario where appropriate, as described in the following sections (**Appendix D: Underwater sound supporting information, paragraphs 5.7 – 5.11**).

C.55. The fish species of concern, and scoped into the assessment are:

- Basking shark – identified as a species of interest and seen in the Irish sea in proximity to the survey area;
- Migratory fish that are qualifying features of designated (e.g. SACs) and protected sites (e.g. MCZ's) in the vicinity of the survey area;
- Fish eggs and larvae - it is a requirement of the MMO to identify risks to spawning and nursery grounds in the vicinity of the survey area; and
- Adult fish, including herring, to determine potential impacts on the key prey items of a number of wintering and nesting bird species that feed in coastal waters, and are qualifying features of protected sites (e.g. SPAs and SSSIs), as well as important for local fisheries.

Migratory fish

C.56. There are four species of migratory fish, specifically protected by designated sites in the vicinity of the survey area, that are considered in this section as part of the HRA. They are:

- Sea and river lamprey;
- Atlantic salmon; and
- Smelt.

C.57. The designated sites that were included in this assessment were the:

- Dee estuary (lamprey);
- River Eden (salmon and lamprey):
- River Ehen (salmon);
- River Bladnoch (salmon);
- Solway Firth (lamprey); and
- River Derwent and Bassenthwaite Lake (salmon and lamprey).
-

C.58. The Wyre-Lune MCZ, Ribble estuary MCZ and the Solway Firth MCZ were also assessed due to the presence of smelt as qualifying features.

Sea and river lamprey

C.59. There is limited information available on hearing in lamprey and no reported audiograms exist for these species. However, they lack any specialist hearing structures, have an ear that is relatively simple, and have no swim bladder or anatomical structure tuned to amplify sound signal. This means lamprey are generally considered to be sensitive only to sound particle motion within a narrow band of frequencies (Popper and Hawkins, 2019)). Therefore, it is usually considered that behavioural or physiological effects from underwater sound on lamprey are not likely to occur, unless animals are very close to a powerful sound source (Popper, 2005; Popper and Hastings, 2009).

C.60. Underwater sound propagation modelling indicates the SPL_{peak} threshold for mortal or recoverable injury is exceeded to a distance of 71 to 126 m. Assuming a stationary receptor and vessel, sound exposure over a full 24-hour period would result in thresholds exceeded up to 1.4-1.8 km for mortality and 1.9-2.6 km for recoverable injury. Taking account of the movement of the vessel, and a conservative estimate of the swim speed of an individual fish, for a 24-hour exposure, even for an animal start position close to the vessel, the injury thresholds are not exceeded. As a comparison, on the basis of sound exposure from a single strike (at full power), as recommended for sound thresholds by Popper et al. (2014), the distances are <1 m for both injury thresholds. The greatest risk of injury occurs from the first sound pulse at full power.

C.61. There is also potential for auditory effects in fish, and this is reflected in the quantitative threshold for TTS provided by Popper et al. (2014). Modelling sound propagation against thresholds indicates that for exposure to a single strike (i.e. SEL_{ss}), the TTS threshold is exceeded for between 175 and 240 m (depending on direction from the sound source). At the other extreme, considering a 24-hour exposure period results in the TTS threshold being exceeded up to 99.2 km from the sound source. For a 30-minute exposure, the distances are between 5 and 15 km depending on direction and the nature of the water column (i.e. the sound speed profile). Accounting for a slow-moving fish and vessel movement, the TTS threshold is met in the immediate vicinity of the source, but exposure declines thereafter. For fish some distance from the source, the TTS risk declines with distance. As discussed, in relation to basking shark the TTS threshold does not account for the low sensitivity of fish without a swim bladder, so calculated threshold distances are considered to be significantly overestimated for these species.

C.62. Some behavioural reactions have been observed in response to underwater sound. For example, some experiments carried out on sea lamprey by Lenhardt and Sismour (1995) detected a startle reaction when sound at frequencies between 20 and 100 Hz was played to captive fish. However, startle reactions while swimming were rare, suggesting that direct contact with the vibrating surface was needed to trigger the reaction. In another study, river lamprey were subject to sound from a playback system, with sound at frequencies between 20 and 600 Hz, to study the potential as a deterrent for reducing estuarine fish intake rates at a power plant cooling water inlet (Maes et al. 1999, 2004). No significant reductions in river lamprey catches were observed in this study. The absence of a significant response of lamprey during the above investigations confirms a low hearing ability for these species.

C.63. Considering the sound intensity, some behavioural responses are assumed possible, but significant responses are only expected in close proximity to the sound source. The Popper et al., 2014 thresholds indicate a moderate risk of a significant behavioural response to a distance in the order of hundreds of metres. Beyond that the risk is low. The survey is in open water and there is, therefore, no barrier to moving away from the potential effect risk zones. There is also no indication the study area is particularly important for foraging or other behaviours, and thus the energetic cost of any necessary avoidance is expected to be minimal and have little potential to affect the long-term survival of lamprey individuals or populations.

C.64. Lamprey migration in the rivers in this region of the UK is reported to occur in late spring and early summer for upstream migration, and October to March for the downstream return of juveniles to the estuary. The mouth of the nearest river where lamprey will congregate for migration, the River Derwent, is 12 km away. There is therefore no spatial or temporal interaction between migration periods and the study survey. There was no information found on the distribution of sea lamprey outside these migratory periods, but they attach to a host animal (often another fish), and so are expected to be found in open marine water in low numbers only (the numbers reported in migratory areas, where densities are highest, are low).

C.65. For these designated sites, there was no information found on the distribution of the sea lamprey outside these migratory periods, but it is assumed they may be found in open marine water, albeit in low numbers (the numbers reported in migratory areas, where densities are highest, are low) and with a diffuse distribution.

C.66. The survey will be short-term, meaning so will any disturbance effects to lamprey. The location of the survey area in relation to the SACs, the period in which the survey will take place (i.e. avoiding the key migratory periods of these species), and the survey execution and design controls to be implemented (JNCC guidelines for geophysical operations (JNCC, 2017)) also mean it is considered there will be no Likely Significant Effects on the integrity of these SACs.

Atlantic salmon and smelt

C.67. Atlantic salmon and smelt are both migratory species considered to have medium hearing sensitivity. They have a swim bladder, but hearing is separate from it or any other gas filled chamber, indicating hearing is by particle motion, not sound pressure. However, physical injury effects from underwater sound are most pronounced in fish with a swim bladder because the organ is unable to adapt quickly enough to the high intensity geophysical pressure waves. For example, impulsive sounds from pile driving can cause mild to lethal injuries, such as swim bladder rupture, hematoma and haemorrhaging (Paxton et al., 2017 and references therein).

C.68. There were no data found indicating physical damage in fish from geophysical sound source, but acute auditory impacts to individual fish, such as damage to sensory ear hair cells in the ear of the pink snapper (Pagrus auratus), have been shown to occur with close-range exposure to low-frequency, high-intensity sounds in laboratory settings (McCauley et al., 2003). In a similar study with caged fish, also of medium hearing sensitivity, exposed to a short period of sound pulses, TTS was observed in two of the three species (Popper et al. 2005), but no damage to inner ears was observed (Song et al., 2008).

C.69. Studies also show that exposure to moderately loud sounds can result in temporary hearing loss (TTS) in fish (Popper et al., 2014). These studies have been undertaken for a few species, including goldfish (Carassius auratus) and fishes with specialised hearing, though not specifically in relation to geophysical survey sound sources. Most investigations into the effect of underwater sound on Atlantic salmon relate to impact piling, due to the concentration of infrastructure development in estuarine environments. There were no specific data found for smelt, but as with species in the same hearing sensitivity grouping, the assessment for salmon and smelt are undertaken as one.

C.70. The lack of data on geophysical survey effects mean the latest quantitative thresholds for injury and auditory effects (TTS) are based on data taken from piling studies (Popper et al., 2014). These sound sources are similar, being impulsive in nature with a rapid rise time and regular pulses, but do have some different distinguishing features. One major difference between pile driving and geophysical survey sound sources is that it is harder to determine SEL_{cum} for geophysical surveys. This is because the received SEL_{ss} changes from shot to shot, since the survey vessel is moving and at different distances from the fish. Thus, a guideline ultimately based on the closest peak level or the closest SEL_{ss} may actually be more useful than one based on the SEL_{cum} (Popper et al., 2014).

C.71. Underwater sound propagation modelling indicates the SPL_{peak} threshold for mortal or recoverable injury is exceeded up to a distance of between 198 and 284 m, depending on the transect. The lowest sound propagation loss is for the western transects which go to deeper water. Assuming a stationary receptor and vessel, sound exposure over a full 24-hour period would result in thresholds exceeded up to 7.7 km for mortality and 14.1 km for recoverable injury. However, taking account of the movement of the vessel, and assuming a stationary receptor, the mortal injury threshold is not exceeded, and a fish would need to remain close to the vessel for over 5 hours for the recoverable injury threshold to be exceeded. Most fish do exhibit some movement and so reaching this threshold seems highly unlikely. The TTS threshold is exceeded up to 99.2 km for a 24-hour exposure period. Accounting for a stationary fish and vessel movement, the TTS threshold is met in the immediate vicinity of the source, but exposure declines thereafter. Behavioural responses of fish to impulsive sounds are more difficult to quantify, but may include changes in abundance in particular habitats, changes in swimming patterns or feeding, as well as physiological stress, which could even lead to mortality for chronic exposure. There is conflicting evidence on the behavioural effects of geophysical surveys on fish. Some studies have reported no significant effect on the behaviour of various fish species, even in very close proximity to the sound source. For example, Wardle et al. (2001) used videos to examine the behaviours of fish on a reef in Scotland in response to a sound source with a peak SPL of 210 dB re 1 µPa at 16 m from the source and found no permanent changes in behaviour. There was no indication of any observed damage to fish, although possible long-term damage was not monitored.

C.72. In contrast, other studies have concluded that fish leave the immediate area around the survey vessel for the period when the acoustic source is active (Lokkeborg and Soldal, 1993). In some investigations, reductions in fish catches were observed for up to five days after survey activity stopped (Slotte et al., 2004; Lookeborg et al., 2012). In the experimental trials conducted by McCauley et al (2000), a return to normal behaviour was observed 14-30 minutes after fish were exposed to sound energy.

C.73. The Popper qualitative thresholds suggest that the risk of behavioural responses in mid hearing sensitivity fish, like salmon and smelt, is high only when in proximity to the sound source, and moderate at intermediate distances. These thresholds for effects on behaviour refer to substantial changes in behaviour for a large proportion of the animals exposed to a sound. This may include long-term changes in behaviour and distribution, including moving from preferred sites for feeding and reproduction, or alteration of migration patterns. This criterion does not include effects on single animals or small changes in behaviour, such as a startle response or minor movements. Thus, based on the Popper thresholds, there is a moderate risk of substantial changes in behaviour at distances, but only in the order of hundreds of metres from the vessel.

C.74. The survey will take place when the density of salmon in open water will be low, meaning that any behavioural disturbance, in the form of avoidance reaction, will be negligible. Furthermore, the survey is short-term and temporary and outside of the key migratory period for this species. Overall, it is considered that there will be no Likely Significant Effects on the integrity of the SACs considered within this assessment.

C.75. The impact of behavioural responses, largely avoidance reactions, are only likely to have a significant ecological effect if the timing of the survey and impact area interact during key life stages, such as migration and spawning. Salmon and smelt migrate from the marine environment into the upper reaches of rivers to spawn in freshwater, and thus will be at the greatest density of individuals as they congregate in estuaries at the start of the migration period. At this point of their life cycle, avoidance behaviour may be overridden by the desire to migrate increasing sound exposure and the risk of auditory effects. In the case of a physically constrained water body such as a river, intense sounds could present an acoustic barrier to migration, which could reduce spawning success, and this isn’t expected in the open waters of the inshore area.

C.76. There are a number of salmon rivers in Cumbria, but those of greatest importance are the River Derwent (12 km), River Ehen (21 km), River Eden (41 km), River Bladnoch

(62 km) and the River Dee and Bala Lake (87 km), all of which are protected by an SAC designation. Salmon spawning times are reported to be November/December, and thus a higher number of fish could be in the inshore and estuarine areas around the key migratory rivers in October for salmon and late winter for smelt. With a survey window of July to August, the survey will not be taking place at the key stages described above and, whilst the sound from the survey may disturb any individuals in open water, the risk is very low because of the very low density of fish present. Thus, there is no pathway for a significant impact on salmon.

C.77. Smelt are protected by three MCZ's in the region – the Solway Firth MCZ (approximately 55 km), the Ribble Estuary MCZ (38 km) and the Wyre Lune MCZ (19 km). These sites are a distance beyond the point at which any injury or significant behavioural response is expected to occur as a result of sound from the survey.

C.78. The spawning period for smelt is reported to be in early spring, and thus there is not anticipated to be any overlap with the survey window of July to August. However, smelt are reported to remain in shallow inshore waters outside the spawning period (pers. comm. NE), but even allowing for a higher density of animals in inshore waters around Wyre Lune MCZ, the distance to the survey area is beyond the point at which significant behavioural response would occur. Thus, it is predicted that no significant impact on individual smelt or the population, as the designating feature of the MCZ, will occur. On the basis of the distance and timing, the confidence in this assessment is high.

Spawning and nursery grounds & adult fish

C.79. The north eastern region of the Irish Sea has been identified as having high intensity spawning grounds for herring, cod, sandeel, plaice and sole. On the basis of a survey window, the survey has the potential to overlap with the spawning period for herring, but not the other species (main report, Table A7). The key herring spawning grounds in proximity to the survey area are the Manx grounds, although there is minimal direct overlap. The exact timing of the herring spawning season is also not fully understood, but most evidence points to peak spawning around October to early November, though it may start as early as August, and can run through to the New Year. Thus, on the basis of a potential temporal overlap between the survey and the beginning of the spawning season, for a species that is not only of commercial importance, but also one with high hearing sensitivity (Popper et al., 2014), the potential effect of underwater sound from the survey was considered.

C.80. Fish eggs and larvae are considered separately from adult fish in the threshold tables because of their vulnerability, reduced mobility and small size. There are, however, very few peer-reviewed papers that discuss the responses of eggs and larvae to man-made sound (Popper et al., 2014). Nevertheless, the species that have been studied appeared to have hearing frequency ranges similar to those of adults and similar acoustic startle thresholds (see Popper et al., 2014 and references therein). The development of a swim bladder, or other gas bubbles, during the larval stage may render larvae susceptible to pressure-related injuries.

C.81. Many studies suggest that eggs and larvae only in very close proximity (< 5 m) to sounds sources used for geophysical surveys are likely to suffer mortality and tissue damage (Booman et al. 1996). For example, studies examining effects of sound from geophysical sources on ichthyoplankton indicated that injury and mortality is only likely to occur at sound levels in excess of 230 dB re 1µPa @ 1 m (Turnpenny and Nedwell, 1994), with egg injury rates recorded at 7.8 percent (for anchovy). Popper (2012) also concluded that damage caused to fish eggs and larvae from geophysical surveys is assumed to be limited to the proximity of a sound source. Sætre and Ona (1996) report that mortality rates caused by exposure to sound sources are so low compared to natural mortality that the impact from geophysical surveys should be regarded as insignificant.

C.82. A large project undertaken in Norway investigated the effects of a geophysical survey array on fish eggs, larvae and juveniles (fry) of a wide range of species, including cod, saithe (Pollachius virens), turbot (Scophthalmus maximus), plaice (Pleuronectes platessa) and herring (Clupea harengus) (Booman et al., 1996). The latter species is known to have particularly high hearing sensitivity. There were some differences between the species observed, but results showed significantly increased rates of mortality, but only very close to the sound source. The most substantial effects were within 1.4 m for peak sound pressure levels of 220 to 242 dB re 1 μPa @ 1 m, and the estimated mortality was less than 1% of the total fish larvae population.

C.83. For the survey, a sound source of 252 dB re 1 μPa @ 1 m is planned, somewhat higher than that observed in the Booman et al study (1996), therefore a greater proportion of eggs and larvae, at a greater distance than 1.4 m, may be affected. The mortality and recoverable injury guidelines for fishes, including eggs and larvae, are based on predictions derived from effects of impulsive sounds, such as are produced by impact piling, since there are no quantified data for geophysical sound sources (Popper et al., 2014).

C.84. The quantitative thresholds specifically for mortality in fish eggs and larvae are predictions based on a study by Bolle et al. (2012), that indicated no damage was caused by simulated pile driving signals of 210 dB re 1 μPa2·s SEL_{cum}. The underwater sound modelling predicts potential effect zones for mortality and mortal injury in fish eggs and larvae up to a distance of between 188 and 284 m from the sound source (depending on direction and sound speed profile), based on the SPL metric and <1 m for the SEL_{ss} metric (**Appendix D: Underwater Sound Propagation Modelling Report**). Using cumulative SEL exposure, assuming a moving vessel but stationary eggs and larvae, the threshold would be exceeded only after 3.9 hours exposure. Thus, some mortality of herring eggs and larvae may occur, but only at very close range to the sound source. However, the potential is for only local effects, over very short duration of the survey with minor interaction with the peak spawning region. As such the overall effect is predicted to be minor particularly in relation to natural mortality. This is further supported, for example, by the depth of the Irish sea that the study area covers, where the sound source is expected to always be at least 20 metres away from any potential eggs and larvae in the herring spawning grounds. In Norway, research into the effect of geophysical surveys demonstrated that the risk that such mortality negatively affects recruitment to the fishable stock is close to non-existent (Sivle et al., 2021).

C.85. Assuming spawning starts in August, there is some potential for the survey to impact adult herring during this key life stage. Sound exposure modelling indicates that the threshold for mortal or recoverable injury in adult herring, based on SPL_{peak} and SEL_{ss} metrics, would be exceeded at up to 245 m from the sound source (**Appendix D: Underwater sound supporting information, Annex A**) and that the distance for TTS is 214 m. Thus, injury in spawning fish is possible in a small area around the sound source, but the risk of this is considered to be unlikely on the basis of a slowly approaching vessel, so no rapid rise in sound pressure is experienced, and the ability of fish to move away from an uncomfortable sound source.

C.86. There has been a small number of studies using sonar to investigate the behaviour of some fish species directly exposed to a geophysical survey. For example, Slotte et al. (2004) observed that Atlantic herring and blue whiting (Micromesistius poutassou) moved out of the area, or to deeper waters (10–50 m deeper), in an area where geophysical survey occurred. Decreases in herring abundance were observed to occur up to 37 km from geophysical surveys (Slotte et al. 2004). In Norway, Sivle et al., 2021 report that if similar avoidance occurs when fish are at spawning grounds, they may move too far away from these optimal geographical and oceanographical conditions, or if they delay or even stop their spawning, the spawning may be less successful with regards to time and physical conditions. However, such avoidance behaviour is not always observed. For example, Peña et al. (2013) described the real-time behaviour of herring schools exposed to a full-scale geophysical survey. No changes were observed in swimming speed, swimming direction or school size that could be attributed to a transmitting seismic vessel as it approached from a distance of 27 km to 2 km, over a 6 h period. The unexpected lack of a response to the geophysical survey was interpreted as a combination of a strong motivation for feeding by the fish, a lack of suddenness of the airgun stimulus, and an increased level of tolerance to seismic shooting. On the basis of the single strike SEL threshold of Hawkins et al. (2014), behavioural responses in 50% of individuals is predicted up to 20 km (an average across all transects), but at these distances the responses are relatively low level behavioural changes in swimming direction and similar.

C.87. Thus, on the basis that the survey is very short, will not take place in either peak season or peak location, and that suitable spawning grounds are widespread, there will be some behavioural disturbance, but not at a level that is anticipated to have a significant impact on spawning herring.

C.88. The survey area is within high intensity nursery grounds for herring, cod and whiting (see **Appendix C: Figures**, **Figures C8-C13**). The juveniles of these species are thought to be present year round, but the grounds are extensive, and on the basis of the threshold distances for adults, discussed above, the potential for injury is limited. Avoidance behaviour is likely, but the nursery grounds are extensive, and avoidance behaviour in response to a survey of very short duration is not expected to have a significant impact on individual fish or local populations, including those that are important prey items for diving birds.

Basking shark

C.89. There has been little research on the hearing ability of elasmobranchs, and therefore the overall effect of anthropogenic sound on these animals remains largely unknown (de Vincenzi, 2021). Elasmobranchs do not possess a swim bladder, a gas filled sac which responds to the pressure component of a sound, and so this group of fish is thought to be more sensitive to particle motion (Chapuis et al., 2019). Nevertheless, some studies have shown that elasmobranchs have an acoustic sensitivity threshold between 20 and 1500 Hz (peaking between 200 and 600 Hz, depending on the species) (Myrberg, 2001). Some elasmobranch species have been seen to be attracted by low intermittent frequencies, whilst others exhibit avoidance behaviour (Myrberg et al., 1976; Myberg et al.,1978).

C.90. It is not known if elasmobranchs are susceptible to some forms of barotrauma (e.g. to the liver, kidney and intestines), such as that observed in bony fish exposed to pile driving (Casper et al., 2012). The lack of studies on elasmobranchs makes it difficult to evaluate potential physical effects that could be associated with their exposure to underwater sound from geophysical surveys. Based on the Popper threshold criteria for fish without a swim bladder, the potential zone of risk for mortality or mortal injury is a maximum of 126 m for the SPL metric and 1.8 km for the SEL threshold, assuming a 24-hour exposure period (**Appendix D: Underwater sound supporting information, Annex A**). For recoverable injury, the potential risk zones are 126 m for SPL and 2.3 km for the 24-hr SEL exposure period.

C.91. Thus, there is a potential risk of injury for any basking shark in very close proximity to the first pulse of the sound source at full power, or for any individual that remains within a relatively short distance of the vessel for a period of 24 hours. However, the likelihood of this is considered to be low, on the basis of the anticipated behaviour of the animals, and the implementation of the required JNCC mitigation (JNCC, 2017) for the protection of marine mammals. These measures will ensure there is no sound source operating at full-power until after an observation period and a soft-start. The soft-start allows the underwater sound to build up only gradually, enabling any basking shark to move away from the sound source. Once the survey is in operation, the vessel is constantly moving, such that any sound level heard by basking shark will increase slowly as the vessel slowly changes position. Basking shark are highly mobile fish, following feeding fronts whilst foraging, so the presence of an individual remaining in close proximity to the vessel for a 24-hour period is considered unlikely.

C.92. A temporary shift in hearing (TTS) is a short duration decrease in hearing sensitivity, which has been found only after multiple exposures to intense sounds (e.g. > 203 dB re 1 μPa SPL0-peak), or as a result of long-term exposure (e.g. tens of minutes or hours) to somewhat less intense sounds. Following exposure, normal hearing ability returns over a period that may range from minutes to days, depending on many factors, including the intensity and duration of exposure (see Popper and Hawkins, 2019 and references therein).

C.93. There is only a single threshold for TTS in fish, which covers the full range of hearing sensitivity. The sound modelling for TTS indicates potential risk zones up to tens of kilometres from the sound source, assuming a 24-hour exposure period for a stationary vessel and a stationary receptor. However, studies show the development of TTS varies significantly between fish species, but also between individuals of the same species, and in some it does not occur at all. Where it does occur, normal hearing sensitivity returns within a few hours to several days (Popper and Hawkins, 2019). There is also evidence that, given the same type and duration of sound exposure, a much more intense sound will be required to produce TTS in fishes that do not hear well, such as fish without a swim bladder, compared with those that do (Popper et al., 2007; Smith et al., 2004). This indicates TTS is much less likely to occur in elasmobranchs, and the TTS risk zone determined by modelling is likely to be much smaller for basking sharks.

C.94. Popper and Hawkins (2019) report that TTS is of far greater concern when there is long-term noise exposure, such as in harbours and other areas where there is a long-term increase in sound level. The survey is very short-term and will not remain in the same location for the duration of the acoustic activities. Thus, whilst there is a small risk of potential TTS, it is considered to have the potential to affect only a very small number of individuals, if any, because although the survey may take place in the breeding season, the data on distribution shows most individuals are observed to the west of the Isle of Man, far beyond the potential zone of influence.

C.95. Behavioural responses could occur though there are no reliable quantitative thresholds for any fish, and particularly not for basking shark or other elasmobranchs. For fish with no swim bladder the Popper et. al., (2014) thresholds are qualitative, indicating there is a moderate risk of behavioural responses in the region of hundreds of metres, rather than kilometres, from the sound source. The 150 dB_{rms} threshold, which also does not distinguish between different hearing sensitivity groups, is met up to a distance of 23 km away. Behavioural responses are expected to decrease in occurrence and significance with distance from the sound source though there is much evidence to show there is not a clear scaling relationship between behaviour and the sound intensity.

C.96. Research on the specific behavioural response of elasmobranchs to the low-frequency sounds is lacking, though observations of basking sharks during geophysical survey operations off Shetland noted that individuals and small groups did not move away during the operation of the sound source (Hayes et al., 2018). This also supports the evidence above that behavioural responses will be local to the sound source, but there is some uncertainty regarding the attraction of basking shark to the low frequency sounds of geophysical survey.

C.97. The survey window of July to August means there is potential for an overlap with peak presence in the Irish Sea of May to August. However, the majority of observations are reported from the west coast of the Isle of Man and outside the potential zone of influence. The potential for significant numbers of basking shark in close proximity to the survey area will be low, but minimal presence cannot be ruled out.

C.98. The survey will be of very short duration (15-20 days) and temporary in nature, and so does not result in a chronic increase in underwater sound levels. Elasmobranchs are not considered to have particularly high sensitivity to underwater, and thus the risk of both auditory injury and significant behavioural disturbance is low. Effects are expected to be limited to some relatively local behavioural disturbance, with any effect disappearing once the survey stops or the vessel moves away. Thus, the magnitude of the effect is small, and the potential effect of underwater sound to basking sharks is assessed as not significant.

<u>Seabirds</u>

C.99. All potential impacts on seabirds were assessed in terms of the designated areas they are qualifying features for, and therefore in line with HRA requirements. Direct effects from sounds created by the survey on diving birds could potentially occur through physical damage, or through disturbance of normal behaviour, although evidence for such effects is very limited. Deeper-diving species, which spend longer periods of time underwater (e.g. auks), may be most at risk of exposure to high-intensity sound from the survey and consequent injury or disturbance, but all species which routinely submerge in pursuit of pelagic or benthic prey (i.e. excluding shallow plunge feeders, such as terns) may be exposed to anthropogenic sound.

C.100. The following species relevant to the survey area that are potentially vulnerable to underwater sound effects, and weren't scoped out in the initial data gathering stage, are:

- Divers: including great northern diver and red-throated diver;
- Gannet, cormorant and shag;
- Auks: including guillemot, razorbill and puffin; and
- Seaduck: including scaup, eider, common scoter, velvet scoter, goldeneye, red-breasted merganser and goosander.

C.101. At sea, seabirds forage either predominantly by surface feeding, e.g. gulls and petrels; surface diving, e.g. auks, or plunge diving, e.g. terns and gannets. Surface feeders and plunge diving species are largely aerial and spend relatively short periods of time, if any, below the sea surface, e.g. plunge diving gannets spend on average 4.7 (±2.8) seconds below the sea surface, although individual dives may last longer, with occasional dives recorded lasting up to 39 seconds (Garthe et al. 2000, Ropert-Coudert. 2009, Cox et al. 2016). Surface feeders spend relatively longer periods of time below the sea surface. In shallow waters, Guillemot have been reported to spend on average 46.4 (±27.4) seconds below the sea surface and shag 61 seconds (Thaxter et al. 2009, Wanless et al. 1993). Consequently, surface diving seabirds (e.g. guillemot, razorbill, puffin) are at more risk of impacts from underwater sound than other species of seabird predicted to be present in the survey area.

C.102. Very high amplitude low frequency underwater sound may result in acute trauma to diving seabirds, with several studies reporting mortality of diving birds in close proximity (i.e. tens of metres) to underwater explosions (Yelverton et al. 1973; Cooper 1982; Stemp 1985, Danil and St Leger 2011). However, mortality of seabirds has not been observed during extensive geophysical operations in the North Sea and elsewhere. While seabird responses to approaching vessels are highly variable, flushing disturbance would be expected to displace most diving seabirds from close proximity to geophysical survey sound sources, particularly among species more sensitive to visual disturbance, such as scoter, divers and cormorant (Garthe and Hüppop 2004). Therefore, the potential for acute trauma to diving birds from geophysical survey is considered to be very low.

C.103. Data relating to the potential behavioural disturbance of diving birds due to underwater sound are very limited. The reported in-air hearing sensitivity for a range of diving duck species, Red-throated diver and gannet, has been tested for tone bursts between frequencies of 0.5-5.7kHz, with the region of greatest sensitivity from 1-3kHz, with a sharp reduction in sensitivity >4 kHz (Crowell et al. 2015). Testing on the Long-tailed Duck underwater showed reliable responses to high intensity stimuli (> 117 dB re 1μPa) from 0.5-2.9 kHz (Crowell 2014). An underwater hearing threshold for cormorant of 70-75 dB re 1μPa rms for tones at tested frequencies of 1-4kHz has been suggested (Hansen et al. 2017). The authors argue that this underwater hearing sensitivity, which is broadly comparable to that of seals and small odontocetes at 1-4 kHz, is suggestive of the use of auditory cues for foraging and/or orientation, and that cormorant, and possibly other species which perform long dives, are sensitive to underwater sound.

C.104. McCauley (1994) inferred from vocalisation ranges that the threshold of perception for low frequency geophysical sound in some species (e.g. penguins, a possible proxy for auk species) would be high, hence individuals might be adversely affected only in close proximity to the source. Pichegru et al. (2017) used telemetry data from breeding African penguins to document a shift in foraging distribution during a geophysical survey off South Africa. Pre/post shooting, areas of highest use (indicated by the 50% kernel density distribution), bordered the closest boundary of the survey; during shooting, their distribution shifted away from the survey area, with areas of higher use at least 15 km from the closest survey line. However, insufficient information was provided on the spatio-temporal distribution of geophysical sound source activation, or penguin distribution, to determine an accurate displacement distance. The penguins quickly reverted to normal foraging behaviour after cessation of survey activities, suggesting a relatively short-term influence on these birds' behaviour and/or that of their prey (Pichegru et al. 2017).

C.105. The data are limited, but the observed regions of greatest hearing sensitivity for cormorants in water, and other diving birds in air, are above the low frequencies (i.e. <500Hz) which dominate and propagate most widely from geophysical surveys. While there is some evidence of sound-induced changes in the distribution and behaviour of diving birds in response to impulsive underwater sound, these have been temporary and may be a direct disturbance, or reflect a change in prey distribution, during that period. A lack of reported injury or disturbance effects to diving birds, combined with the likely avoidance of the physical presence of survey vessel(s), suggests that the risk of significant mortality, injury or disturbance is very low.

C.106. Therefore, the potential impact of underwater sound to diving seabirds is considered to be not significant.

<u>Plankton and Invertebrates</u>

C.107. There is very limited research concerning sound effects on phytoplankton or zooplankton (the fish eggs and larvae component of the plankton are assessed in Section: 'Fish'). There are a few, mostly laboratory-based, studies of the effect of underwater sound on the larval or early life stages of invertebrates. For example, experiments conducted on the early life stages of the Dungeness crab observed damage to be limited to the immediate vicinity of a sound source, and a reduction in survival of less than 10% for the larvae was reported (McCauley et al., 1994). However, a recent study of zooplankton populations in the vicinity of a geophysical survey found mortality in larval krill up to 1,200 m from the geophysical source (McCauley et al., 2017).

C.108. Most plankton have no, or very limited, mobility and therefore unable to move away from a potentially harmful sound source. Thus, some mortality or injury of plankton could occur within tens to hundreds of metres from the sound source. However, phytoplankton and zooplankton are widely distributed through the water column, and so only a fraction of any population may be involved. Any effect will also be short-term, as many of these organisms are quickly replaced due to rapid generational turnover times, and so any observable effect at the population level is unlikely (Sommer, 2012).

C.109. The survey is planned to occur outside the main Irish Sea spring bloom season, the timing of which is variable, but generally peaks between March and May (Gowen and Stewart, 2005), with an expected peak in secondary production (i.e. zooplankton) some weeks later. Therefore, the survey will not interact with the main productive season, and is highly unlikely to have any effect on overall plankton population dynamics compared to natural mortality rates from predation for example, or events such as storms, cyclones or natural shifts in oceanographic patterns (Swan et al., 1994).

C.110. The sensitivity of marine invertebrates to underwater sound has not been well studied, probably because most lack specialised auditory organs. However, many species do have tactile hairs or mechano-sensory systems that are thought to respond to the particle displacement components of sound, rather than the pressure component (Popper et al. 2001). Crustaceans, for example, are thought to detect the particle motion component of sound (Lovell, 2005), and there is evidence that the balance organs of selected cephalopod species can be injured from controlled exposure to low frequency (50 to 400 Hz) sound (André et al., 2011). Payne et al. (2007) reported that exposure of lobster to very high, as well as low, sound levels had no effects on delayed mortality or damage to mechano-sensory systems associated with animal equilibrium and posture. Solan et al. (2016) observed that burrowing and other behavioural responses were observed in many invertebrate species, but results were highly variable and non-linear with respect to sound level.

C.111. Thus, whilst there are a small number of studies indicating there is some potential for injury in adult or developmental stages of individual invertebrates, they are generally considered to be unaffected by underwater sound, except in the immediate vicinity of the sound source (Spiga et al., 2012).

C.112. Therefore, the impact on plankton and benthic invertebrates is considered to be of low intensity, with fast recovery of localised impacts and no long-term effect on populations. Therefore, no significant impacts are predicted, and these receptor groups are not considered further. In particular, any effect on the benthic invertebrate component of seabed habitats, which may be the designating feature of a protected site, such as an SAC or MCZ, can be screened out for any likely significant effect.

Pathway 2: Airborne Sound and Visual Disturbance

Pinnipeds

C.113. The movement of the survey vessel could result in changes in visual stimuli (including artificial light), and an increase in airborne sound leading to avoidance behaviour in pinnipeds and disturbance effects which could affect breeding, moulting and foraging activities, with potential for wider implications for populations.

C.114. It can often be very difficult to separate out the relative contribution of different stimuli causing disturbance to marine organisms. However, for larger taxa which occur in shallow or surface waters, or that migrate onto land (e.g. seals hauled-out), changes in visual cues (particularly light) are known to strongly influence behaviour.

C.115. Seals which have surfaced or hauled-out could be affected by changes to visual stimuli and an increase in ambient airborne sound, causing individuals to stop resting, feeding, travelling and/or socialising, with possible long-term effects of repeated disturbance, resulting in permanent displacement and/or a decline in fitness and productivity. In general, shipping traffic more than 1,500 m away from a haul-out site is not thought to evoke any reaction. However, between 900 m and 1,500 m, grey seals could be expected to detect the presence of vessels; and at closer than 900 m, a flight reaction may occur (Scottish Executive, 2007). Studies of harbour seals have shown a flight response to boats occurs at a distance of around 500 m (Anderson et al., 2012).

C.116. During the survey, when the survey vessel is in open water away from the coastline, there is a low probability that the vessel will come into close proximity of individuals of pinnipeds who are surfaced (likely to be foraging or moving between haul-out sites), and therefore result in disturbance effects. Although haul-out sites for grey seals have been identified in the eastern Irish Sea, the number of individuals recorded away from these sites is occasional and low in number. Furthermore, seals are highly mobile and so individuals would be expected to move away from any visual or airborne sound disturbance if they came close to the vessel. When survey equipment is operating, an increase in UWS close to the vessel will likely result in disturbance effects (in the form of avoidance), prior to any individuals coming close enough for visual and airborne sound disturbance.

C.117. The closest grey seal haul-out site is located on the South Walney Nature Reserve and is approximately 9 km away from the survey area. However, the location from which the vessel will mobilise is currently unknown, meaning there is potential for the vessel to pass in close proximity to this site. Despite this, it is unlikely that the vessel will pass within 1,500 m of the site, given that the vessel will operate in water depths greater than 10 m, meaning disturbance effects are not probable. If the vessel does pass closer to this site and a reaction is invoked, this will only be for a very short period of time (until the vessel has moved away) and temporarily allowing individuals to return to their haul-out site shortly after disturbance. Given the proximity of this haul-out site to the Heysham and Isle of Man ferry crossing route, some habituation to anthropogenic sources of visual stimuli and vessel airborne sound is expected.

C.118. In light of this, there is considered to be limited potential for detectable changes in the behaviour, abundance, distribution and conservation status of pinnipeds as a consequence of visual stimuli, and an increase in airborne sounds as a result of the survey vessel, and any effects would be not significant.

Seabirds

C.119. The movement of the survey vessel could result in changes in visual stimuli (including artificial light) and an increase in airborne sound, which may result in disturbance and displacement of ornithological receptors in the subtidal zone. Disturbance can lead to a number of physiological and behavioural responses which can affect demographic characters of the bird population. Responses to disturbance can result in loss of energy, impaired breeding, unrest through increased vigilance, disruption to incubation, and increased nest failures due to predation and nest abandonment (Valente et al. 2011).

C.120. The extent to which marine birds respond to disturbance is dependent upon a number of factors, including: period of breeding cycle during which disturbance occurs; duration, type and intensity of the disturbance (e.g. onshore works are likely to be more disruptive to seabirds than the inshore works, due to the generation of loud sounds and use of machinery); presence of opportunistic predators; and the degree of habituation with the disturbance (Showler et al., 2010). Some seabirds are more resilient to disturbance than others. Furness and Wade (2012) have assessed the vulnerability of seabird populations to offshore wind farms and, as part of this study, ranked species of concern in the context of disturbance or displacement from habitat (incorporating disturbance by ship and helicopter traffic, habitat flexibility and conservation importance). This assessment indicated that red-throated diver (Gavia stellata) and common scoter (Melanitta nigra) were amongst the highest scoring birds in terms of sensitivity to disturbance and conservation importance. Red-throated diver is highly sensitive to disturbance, and vessel activity through areas where red-throated diver are present on the surface may result in temporary displacement from optimal areas for feeding/loafing.

C.121. The MMO (2018) have provided an overview on the current knowledge of potential disturbance effects on seabirds from anthropogenic marine activities in English territorial waters, to inform Marine Licence consenting and the management of National Site Network sites. Within this report, sensitivity indices are provided for key seabird species groups recorded in England, summarising a combination of defined displacement[8] and habituation[9] indices. Of the ornithological species recorded within the study area, red-throated diver, common scoter, and cormorants (*e.g.* cormorant and shag) were determined to have a 'Very High' displacement to traffic and transport (*i.e*. shipping) marine activities, in which airborne sound and visual disturbance to ornithological receptors is likely to occur. Great crested grebe were found to show 'Moderate' displacement, whilst the remaining species groups were found to have a 'Very Low' to 'Moderate' displacement to traffic and transport marine activities. There was little data available on the habituation of seabirds to vessel activities, and therefore the level of displacement was the determining factor in defining sensitivity for these species. For example, terns (including common tern, sandwich tern, and little tern) displayed 'Low' displacement impacts, and therefore have a 'Low' sensitivity to this activity overall. Although cormorant, shag and great crested grebe are known to occur within the study area, *i.e.* cormorant and shag are present at breeding colonies along St. Bees Head, greater numbers are present during the non-breeding period (as indicated by their inclusion on the Solway Firth SPA as over-wintering features). As such, these species are not considered to be present within the study area in significant numbers during the operational period of the geophysical survey, and have not been considered further within this assessment.

C.122. The Joint Natural England and JNCC and NE Interim Advice Note: *Presenting information to inform assessment of the potential magnitude and consequences of displacement of seabirds in relation of Offshore Windfarm Developments* (JNCC and Natural England, 2017) has applied the Furness and Wade (2012) sensitivity scores to an assessment of displacement buffers for seabirds. They recommend a 2 km displacement buffer for most seabirds and 4 km for divers and seaducks. Wind farm projects, such as East Anglia Three, have used a 2 km buffer for construction activities across the wind farm and the export cable corridor. Given that there will only be one vessel used for the survey, the potential disturbance is likely to be less than from offshore wind farm disturbance, and therefore a 2 km buffer ZoI has been applied for all bird species.

C.123. The Liverpool Bay SPA and Solway Firth SPA are both classified for the protection of wintering populations of red-throated diver and common scoter in the UK. These designated sites are located approximately 0.6 km and 12 km away from the study area, respectively. An assessment of the density of these species in association with

[8] A reduced number of birds occurring within or immediately adjacent to an area in which an anthropogenic activity is occurring or has occurred
[9] A reduction (or cessation) of response by birds to disturbance inducing activities; specifically (for the purpose of this review) a reduction in displacement / avoidance response

each designated site indicates that these species are concentrated within the Liverpool Bay SPA and Solway Firth SPA site boundaries (Lawson et al., 2016; Natural England and SNH, 2016). The red-throated diver and common scoter density maps indicate that within the study area there are low densities of these species, with the main concentrations of birds avoiding busy shipping areas. However, a small area in the inshore waters surrounding the Barrow-in-Furness (which overlaps with the proposed survey area) had higher densities of red-throated diver compared to the surrounding waters (Lawson et al., 2016).

C.124. Red-throated diver are known to start arriving at their wintering around the UK coast from September, although peak occurrence is typically October to March (Lawson et al., 2016; Natural England, 2012). Thus, the survey would occur outside the peak season for these species, when densities will be significantly reduced (in an area already identified as having low densities of these species). Furthermore, the survey vessel will be slow moving (travelling at ~8.1 km/hr (4.5 knots) during geophysical data acquisition) and will not represent a significant increase in vessel traffic. Any potential disturbance will take place in the context of existing sources of disturbance, such as commercial shipping, recreational boating and wind farm service vehicles. Given the wider area available, if birds are present, they are likely to be able to find alternative feeding/loafing grounds in the short-term. Therefore, should any works overlap with the winter months, disturbance to red-throated diver is likely to be minimal.

C.125. The survey area comes into close proximity to the Cumbria Coast MCZ (approx. 2 km from the site), but the survey vessel will remain away from the St Bees Head SSSI (10 km from the site). This area is particularly important for breeding razorbill, for which the Cumbria Coast MCZ protects the key loafing and foraging areas for this species, whilst the St Bees Head SSSI provides protection for the nesting areas of this species. The breeding season for seabirds varies between species, but broadly extends between April and August, with the core breeding period between May and July. From September onwards, the number of auks (*e.g.* razorbill) in nearshore waters decreases. Therefore, there is the potential for temporal cross-over of the geophysical survey and the presence and breeding period of this species. Furthermore, the survey vessel will be well beyond the 2 km ZoI distance from the key nesting areas of this species and is unlikely to result in disturbance effects.

C.126. Although individuals may be found loafing and foraging within the waters defined by the Cumbria Coast MCZ, the highest density of this species is assumed to be along the cliffs where the nesting areas for this seabird are located. This means the vessel will be beyond the 2 km ZoI distance where disturbance may occur. In addition, the presence of the survey vessel will be very short in duration. Any razorbill present within this area that are loafing or foraging can move to an alternative area of the MCZ boundary and return once the vessel has moved away. Razorbill have been determined to demonstrate ‘Moderate’ displacement to traffic and transport activity (MMO, 2018). Taking this into consideration, and the short duration in which the vessel will be present within this area, any displacement to razorbill is thought to be minimal and will not result in population effects to this breeding colony.

C.127. The potential effect on marine birds has been assessed as not significant based on low numbers of marine birds likely to be present within the survey area, the survey area being considered beyond the ZoI, the temporary nature of the survey, and that the vessel will not represent a significant increase in vessel traffic.

Pathway 3: Collision Risk

C.128. Direct strikes from moving vessels, including sharp objects such as propellers, have the potential to cause injury to marine mammals (cetaceans and pinnipeds), sea birds, turtles and basking sharks, and in some cases mortality (Bexton et al., 2012; Speedie et al., 2009). The vessel to be used as part of the survey has been assumed to be (based on similar surveys) a medium sized vessel (50 – 100 m) with 2-3 km long streamers; this will be the only vessel used. The vessel will be travelling at around 8.1 km/hr (4.5 knots) during the survey, and at between 18 and 27 km/hr (10 to 15 knots) whilst in transit to the survey area.

C.129. Marine vessels which collide with marine megafauna, result in the most serious injuries if they are large ships, typically 80 m and longer, as well as by vessels travelling faster than 25 km/hr (14 knots) (Laist et al., 2001). There has been growing concern of high-speed ferry traffic travelling at similar speeds, which have been proven to be particularly lethal (Carrillo and Ritter, 2010). Injuries from such collisions can be divided into two broad categories: blunt trauma from impact and lacerations from propellers. Marine mammals, and to a lesser extent basking sharks, possess a thick subdermal layer of blubber or fat deposits which provides a level of protection to their vital organs, meaning they are reasonably resilient to minor strikes and collisions (Wilson et al., 2007). Turtles are small in size and possess a hard carapace that can reduce the likelihood and severity of impacts from collisions with marine vessels. However, injuries may result in individuals becoming vulnerable to secondary infections or predation.

C.130. Marine mammals are considered to be fast swimming, agile species, with fast reflexes and good sensory capabilities (Hoelzel, 2002). Avoidance behaviour by cetaceans is often associated with fast, unpredictable boats, such as speedboats and jet-skis (Bristow and Reeves, 2001; Gregory and Rowden, 2001), while neutral or positive reactions, particularly in dolphins, have been observed with larger, slower moving vessels, such as cargo ships (Leung Ng and Leung, 2003; Sini et al., 2005). Although there have been reports of vessel strikes to marine mammals, including several cases of seal injuries caused by propellers and thrusters (for dynamic positioning of vessels), evidence of risk is limited (Bexton et al., 2012; Deaville, 2015). Mortality and injury of cetaceans resulting from vessel strikes have been mostly reported in large baleen whales which are slow swimming (JNCC, 2015). There are few reports of vessel strikes with harbour porpoise and other small cetacean, likely due to the avoidance behaviour of these species (particularly porpoises).

C.131. Sea turtles are not fast or agile species and cannot be relied upon to avoid vessels travelling faster than approximately 3.6 km/hr (2 knots). Individuals are most vulnerable when foraging or swimming in water depths which are insufficient to allow the draft of the vessel and propellers to pass over (e.g. in nearshore areas) (Shimada et al., 2017). Individuals that bask, mate or breathe close to the sea surface are also vulnerable to vessel collisions, or being struck by propellers.

C.132. Under normal conditions, there is no risk of collisions with seabirds. However, given the birds noted in earlier sections, there is the potential for diving birds (e.g. razorbills) to get caught under water as the survey vessel passes overhead, or for species that are moulting (e.g. red-throated divers) to lack the ability to fly away as a vessel approaches.

C.133. Basking sharks are considered to exhibit a general lack of awareness of vessel traffic, making them more susceptible to vessel strikes, particularly during the summer months when individuals spend a large proportion of time at the surface feeding (Booth et al., 2013). 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 and Solandt, 2006).

C.134. The likelihood of the survey vessel colliding with marine megafauna (such as cetaceans, pinnipeds, sea turtles and basking sharks) is low, given that the survey area is not seen as a particularly important area for these receptors. Most marine mammal species, such as bottlenose and common dolphin, are only occasionally observed in the eastern Irish Sea. Larger cetacean species, such as baleen whales, which are more susceptible to vessel strike, are very rare and there are only one or two records of these species having occurred in this area. This is also true of turtles, and although there are increasing numbers of basking shark around the Isle of Man during May to August, these individuals are often concentrated on the western coast of the Isle of Man, and are infrequently present in the north west waters of England. The cetacean species found in the highest numbers in the survey area is harbour porpoise, although the density of the species in the eastern Irish Sea is still low compared to other areas in the UK (Block F: 0.086 individuals/km^2, Hammond et al., 2021). However, there have been few reports of harbour porpoise vessel strikes. Post-mortem investigations of stranded harbour porpoise have revealed some deaths caused by trauma (potentially linked with vessel strikes). However, current advice on operations in relation to the North Channel SAC (the closest designated site to the survey area for which harbour porpoise are a primary feature, located 63 km away), indicates that collision with vessels is not currently considered a significant risk (JNCC, 2019). Furthermore, in UK waters the issue of EPS injury through vessel collision is not currently thought to be of major concern, and so there are no specific mitigation measures recommended by JNCC (JNCC, 2010).

C.135. The survey will consist of one vessel which does not represent a significant increase in vessel traffic in the area as the inshore waters are subject to regular vessel activity, particularly around Liverpool Bay and between the Isle of Man and Lancaster. In addition, the vessels will be slow moving during survey operations, at approximately 8.1 km/hr, meaning that individuals (particularly marine mammals) can easily avoid the vessel, greatly reducing the risk of collision. When the survey equipment is operating, an increase in underwater sound close to the vessel will likely result in disturbance effects (in the form of avoidance) prior to any individuals coming close enough for any risk of vessel strike.

C.136. When the vessel is transiting to the survey area, it will travel at faster speeds of between 18 and 27 km/hr, at which lethal injury is considered more likely. However, the period in which the vessel will be travelling at these speeds is very short considering the overall survey vessel operating time. The location from which the vessel will mobilise is currently unknown. Therefore, there is potential that the vessel will pass in close proximity (<10 km) to the grey seal haul-out site located on the South Walney Nature Reserve. Grey seals are effectively central place foragers, returning regularly to land between foraging trips, and thus their distribution at sea is likely to be higher near any haul-out sites (Russell, 2016).

C.137. Taking this into consideration, the greatest concentration of grey seals is expected to be within 5 km of the haul-out site outside of the survey area. Taking into consideration the project design controls, the increase in potential for collision with vessels associated with survey work is considered to be not significant.

Habitats Regulation Assessment

D.1. This section presents the results of the assessments for designated areas noted in the sections above.

Evidence and scoping

Zones of influence

D.2. The activities and potential impacts from geophysical surveys can go significantly beyond the operational boundaries of the surveys themselves. As such in order to ensure the most appropriate designated sites were included for the test of LSE, an initial scoping exercise was undertaken to identify if at least one of the impact pathways could potentially impact on conservation objectives for potential sites. Where there was a potential, the site was reviewed appropriately for LSE from the survey.

Pathway 1: underwater sound disturbance

D.3. Underwater sound as a result of the survey has the potential to result in effects to marine mammals (cetaceans and pinnipeds) including: lethal effect and physical injury; auditory injury; behavioural responses; and masking (Southall et al*.,* 2007). For geophysical surveys, the JNCC (through consultation) have advised that LSE to harbour porpoise SACs would occur within 15 km, which can also be considered as applicable to bottlenose dolphin given that they are a Mid frequency Cetacean (MF) and therefore are less sensitive to higher frequency sound. The ZoI is also considered appropriate for pinnipeds, based on the NMFS threshold values (NMFS, 2018). Based on these distances, the ZoI for this impact pathway is considered to be 15 km.

D.4. Underwater sound as a result of the survey has the potential to impact migratory fish, ranging from auditory injury to behavioural responses. The fish species which are a qualifying feature of the European Sites included within this assessment (see **Appendix B: Designated Sites Scoping Matrix** for information on European Sites included for assessment of LSE) are Atlantic salmon, river lamprey, and sea lamprey. Atlantic salmon is considered to be a medium hearing sensitivity fish. There is little information on the hearing sensitivity of river and sea lamprey, but given that they lack a swim bladder, these species would be categorised as low hearing sensitivity fish. Despite this, behavioural responses to sound in lamprey species, such as increased swimming, is still expected at frequencies of 50 to 300 Hz (Mickle et al., 2018). The most up to date acoustic sensitivity thresholds are provided by Popper et al*.* (2014) with quantitative criteria for mortality or mortal injury. Based on these thresholds, there is a moderate risk of significant behavioural disturbance in a medium sensitivity fish (i.e. Atlantic salmon) within hundreds of metres of the sound source, and a low risk to distances in the order of thousands of metres of the geophysical sound source. The zone of influence for behavioural disturbance for medium (and low) sensitivity fish has been defined as an arbitrary, but precautionary, distance of 5 km.

D.5. The data pertaining to underwater sound impacts for ornithological receptors are limited, but the observed regions of greatest hearing sensitivity for cormorants in water and other diving birds in air are above the low frequencies (i.e. <500 Hz) which dominate and propagate most widely from geophysical survey sound source. While there is some evidence of sound-induced changes in the distribution and behaviour of diving birds in response to impulsive underwater sound, these were temporary and may be a direct disturbance or reflect a change in prey distribution during that period.

A lack of reported injury or disturbance effects to diving birds, combined with the likely avoidance of the physical presence of survey vessel(s) suggests that the risk of significant mortality, injury or disturbance from underwater sound is very low or negligible and for ornithological receptors is not considered further.

D.6. There were no European sites for which pinnipeds are a qualifying feature, within the defined screening criteria distance and therefore this impact pathway has not been assessed for this receptor.

Pathway 2: airborne sound and visual disturbance

D.7. Airborne sound and changes in visual stimuli as a consequence of vessel movements during the proposed, may result in disturbance and displacement of protected seabirds. The Joint Natural England and JNCC Interim Advice Note: Presenting information to inform assessment of the potential magnitude and consequences of displacement of seabirds in relation of Offshore Windfarm Developments (Natural England and JNCC, 2012; 2017) has applied the Furness and Wade (2012) sensitivity scores to an assessment of displacement buffers for seabirds. They recommend a 2 km displacement buffer for most seabirds and 4 km for divers and seaducks. Given that the survey will only be undertaken from one survey vessel the potential disturbance is likely to be less than from offshore wind farm disturbance (which consists of displacement from the footprint of an Offshore Wind Farm, and associated boat and helicopter traffic), and therefore a 2 km buffer ZoI has been applied for all bird species.

Pathway 3: collision risk

D.8. Table A13 shows the distances used to assess if a site should be included in the test for LSE or not.

D.9. The Zone of Influence for collision risk is considered to be 0 km, where a vessel comes into contact with a marine mammal. Within a screening criteria distance of 15 km (as advised by the JNCC for geophysical surveys), there were no European sites for which cetaceans and pinnipeds are a qualifying feature, within this defined distance and therefore the impact pathway ‘collision risk’ has not been assessed for these receptors.

Table A13. Summary of potential impacts and effects that may occur during project phases and associated Zones of Influence (ZoI)

Impact pathway and effect	Receptor	Zone of influence
Underwater Sound Disturbance	Marine Mammals (cetaceans)	15 km
	Migratory Fish	5 km
Airborne Sound and Visual Disturbance	Seabirds	2 km

Scoping of designated sites and qualifying features

D.10. The ZoI for each of the impact pathways was used as the scoping criteria to identify European sites, based on each marine receptor noted in the baseline.

Cetaceans

D.11. Cetaceans which are designated as Annex II species under the Habitats Directive (Council Directive 92/43/EEC) include harbour porpoise and bottlenose dolphin. The site selection for SACs designated for harbour porpoise has been based on broad selection criteria, focussing on distribution analysis to determine key areas for this species, for which six sites have been selected (where harbour porpoise are a primary feature) (JNCC, 2021). For bottlenose dolphin, only two SACs have been selected for the protection of this species, which are seen as having a substantial semi-resident population of bottlenose dolphin, as well as providing biological and physical factors essential to the reproduction of this species (JNCC, 2021).

D.12. Both harbour porpoise and bottlenose dolphin can range over a number of kilometres and will move to different habitats depending on the season (Heinänen and Skov, 2015). For the purpose of this assessment, the Management Units (MUs) defined by the IAMMWG (2021) for each of these species have been used to screen in the necessary SACs (i.e. those occurring within each MU). For harbour porpoise, the MU applicable to the survey area is the Celtic and Irish Seas MU (the UK EEZ proportion only), whilst for bottlenose dolphin the Irish Sea MU (the UK EEZ proportion only) is of consideration. These MUs have been defined by the IAMMWG based on their understanding of the biological population structure of these species, and the ecological differentiation of these populations (taking into account political boundaries and the management of human activities). However, as part of consultation for an MMO (2019) HRA screening report (prepared by AECOM), the JNCC advises that a buffer of 15 km around harbour porpoise SACs should be used for geophysical surveys, beyond which likely significant effects would not occur. For pile driving, the JNCC recommend a 50 km buffer distance. The survey equipment is likely to represent a loud underwater sound source with disturbance effects which could extend beyond 15 km. On this basis, the larger buffer distance of 50 km has been applied for this screening exercise in the context of the underwater sound disturbance impact pathway, only. Given that harbour porpoise is a High frequency Cetacean (HF), effects from underwater sound for bottlenose dolphin are expected to occur over shorter distances and therefore a buffer distance of 50 km can also be applied to this species. For all other impact pathways (i.e. the impact pathway ‘collision risk’), a 15 km buffer distance has been used for cetaceans.

D.13. These buffer distances have been used to screen out those designated sites which occur within the respective IAMMWG MUs but are too far away to be impacted. For example, the Bristol Channel Approaches SAC, West Wales Marine SAC, Cardigan Bay SAC, and Lleyn Peninsula and the Sarnau SAC, all of which are either designated for the protection of harbour porpoise or bottlenose dolphin (and occur within their respective MUs), occur over 200 km from the study area and have therefore been screened out.

D.14. There are no SACs designated for cetaceans which fall within 15 km of the survey area, and therefore the impact pathway ‘collision risk’ was not relevant for the assessment of LSE. Additionally, no sites were within 50 km of the survey area for the other impact pathways. However, taking a precautionary approach, the following European sites (i.e. those which fall just beyond the recommended distance) were include in for assessment of LSE:

- North Channel SAC (63 km – harbour porpoise); and
- North Anglesey Marine SAC (63 km – harbour porpoise).

D.15. No SACs for other cetaceans were identified within relevant proximity of the survey area and therefore other cetaceans were not reviewed in the HRA for the survey.

Pinnipeds

D.16. Both grey seal and harbour seal are Annex II species under the Habitats Directive (Council Directive 92/43/EEC), protected by a series of Special Areas of Conservation (SACs) around the UK. The site selection of SACs, for which grey seal are a protected feature, has been based on those areas which are considered the largest breeding colonies for this species, based on pup production (JNCC, 2021). For SACs designated for harbour seals, sites have been selected based on their importance as both general haul-out sites and those important for moulting and pupping (JNCC, 2021).

D.17. Grey seals are known to forage over large distances between and away from haul-out sites (where they return to rest, moult, and breed), often travelling over 100 km on trips which can last between 1 and 30 days (SCOS, 2020). In contrast, harbour seals are known to forage much closer to their haul-out sites, typically within 30 km in water depths ranging from 10 - 50 m (Tollit et al., 1998). To account for these foraging distances, a distance of 135 km has been used to screen in SACs designated for the protection of grey seals, whilst 50 km has been used to screen in harbour seal SACs.

D.18. There are no European sites for which pinnipeds are a primary qualifying feature, which occur within the proposed screening criteria distances and therefore any impact pathways relating to this receptor were not included in the assessment of LSE. However, the Pen Llŷn a'r Sarnau / Lleyn Peninsula and the Sarnau SAC and the Maidens SAC, for which grey seal are a qualifying feature but not the primary reason for site selection, are located within the screening distance criteria of 135 km. These sites are located 124 km and 129 km from the survey area, respectively.

D.19. The Llŷn Peninsula and the Sarnau SAC consists of individuals of grey seals which are thought to comprise part of the west Wales breeding population which is centred around the Pembrokeshire coast (protected as part of the Pembrokeshire Marine SAC which is located 260 km from the survey area) (NRW, 2009). Most individuals are found hauled-out within the Llŷn Peninsula and the Sarnau SAC boundary, surrounding the Llŷn. Taking this into consideration and given the distance of the site from the survey, and the connectivity of this site with the Pembrokeshire Marine SAC (i.e. these individuals represent the upper extent of this population), this designated site is not considered further within this assessment.

D.20. The Maidens SAC represents a series of rock habitats which are suitable for grey seals and pups as well as opportunities for feeding. However, in a study of grey seals around Northern Ireland in 2018 by the SMRU, the numbers at this site were low compared to other locations (Morris and Duck, 2018). Given the distance of this site from the survey and the low numbers of individuals recorded, this designated site has not been considered further within this assessment.

Migratory fish

D.21. The migratory species of relevance to the survey area are river lamprey (*Lampetra fluviatilis),* sea lamprey (Petromyzon marinus), and Atlantic salmon (*Salmo salar*). These species are listed as Annex II species under the Habitats Directive (Council Directive 92/43/EEC) and are a designating feature of a number of nearby SACs.

River lamprey, sea lamprey, and Atlantic salmon spawn in rivers and in later life stages will migrate downstream into the sea, where they are susceptible to potential disturbance from the survey. River lamprey that have migrated downstream will generally spend one to two years in estuaries and in some instances coastal areas surrounding their spawning ground rivers (Maitland, 2003). Atlantic salmon (in their post-smolt life stage) and sea lamprey migrate into open ocean, and in the case of sea lamprey can be found at considerable depths in open ocean (Moore et al., 2003). However, there have been limited studies which have shown the migratory routes of these species from their spawning rivers into waters further offshore (Malcolm et al., 2010).

D.22. For the purpose of this screening exercise, it has been assumed that the migratory route of sea lamprey is diffuse. Studies of post-smolt migrations of Atlantic salmon in a fjord in Norway have shown that individuals moved rapidly and actively towards the open sea when migrating (Malcolm et al*.,* 2010). These individuals spent most time travelling out in the inner fjord, and did not appear to use the immediate near-shore areas. Tracking of Atlantic salmon migrating from the east coast of Ireland showed that these individuals travelled out of the Irish Sea through the North Channel, heading north along the coast (Barry et al*.,* 2020). Based on this information and given the isolated nature of the north west of England coastline, disturbance is likely to occur where the survey area falls in front of a migratory route into a river. Therefore, SACs designated for migratory fish species have been screened in if they occur in the eastern Irish Sea, from the Solway Firth (including the Mull of Galloway), along the north west coast of England, to the river Dee on the north of Wales.

D.23. Based on the criteria outlined above, the following European sites for which migratory fish are a qualifying feature and therefore, have been included in the assessment of LSE are:

- River Derwent and Bassenthwaite Lake SAC (12 km – sea and river lamprey, and Atlantic salmon);
- River Ehen SAC (21 km – Atlantic salmon);
- River Eden SAC (41 km – sea and river lamprey, and Atlantic salmon);
- Solway Firth SAC (42 km – sea and river lamprey);
- River Bladnoch SAC (62 km – Atlantic salmon);
- Dee Estuary SAC (64 km – sea and river lamprey); and
- River Dee and Bala Lake SAC (87 km - sea and river lamprey, and Atlantic salmon).

Seabirds

D.24. The survey is being undertaken in waters within or adjacent to several European sites designated for their ornithological importance and it is recognised that potential impacts that could cause a likely significant effect could occur to a number of qualifying species both within and out with these designated sites.

D.25. The criteria applied for identifying which European sites designated for birds should be included, considered the typical foraging ranges for breeding seabirds (Woodward et al*.,* 2019) and the displacement sensitivities for seabirds and waterbirds set out in guidance by Natural England and JNCC (JNCC and NE, 2017).

D.26. Based on these criteria the following European sites (see **Figures C5 & C6**, **Appendix C: Figures**) have been included in the LSE Screening:

- Morecambe Bay and Duddon Estuary SPA/Ramsar sites;
- Liverpool Bay SPA;

- Solway Firth SPA/Upper Solway Flats and Marshes Ramsar site; and
- Ribble and Alt Estuaries SPA/Ramsar sites.

D.27. The survey could take place in inshore waters during the seabird breeding season, during which time birds within the area of the proposed survey may originate from SPAs designated for breeding seabirds. It is recognised that seabirds from other SPA colonies may also occur in the survey area, particularly those with extensive foraging ranges, *e.g.* gannet, or outwith the breeding period. However, it is not possible to determine which designated sites these birds may originate from and consequently the sites cannot be considered within this assessment.

Scoping summary

D.28. The sites which have been scoped in for inclusion in the LSE test are summarised below in Table A14. All designated sites considered within this assessment, have been provided alongside relevant qualifying features and the distances for each from the survey area (full details on ornithological qualifying features are included in Table A14 for sites that were scoped into assessments for LSE). The impact pathways noted are those that are viable for each designated site and qualifying feature.

Table A14. European sites scoped in for assessment of LSE along with relevant impact pathways

European Site	Examples of qualifying features	Distance from survey area	Impact Pathway Assessed
North Channel SAC	**Annex II Species (primary reason for selection):** • Harbour porpoise (*Phocoena phocoena*)	63 km	Underwater Sound Disturbance
North Anglesey Marine SAC	**Annex II Species (primary reason for selection):** • Harbour porpoise (*Phocoena phocoena*)	63 km	Underwater Sound Disturbance
River Derwent and Bassenthwaite Lake SAC	**Annex I Habitat (primary reason for selection):** • Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea* **Annex I Habitat (secondary reason for selection):** • Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation **Annex II Species (primary reason for selection):** • Marsh fritillary butterfly (*Euphydryas (Eurodryas, Hypodryas) aurinia*) • Sea lamprey (*Petromyzon marinus*) • Brook lamprey (*Lampetra planeri*) • River lamprey (*Lampetra fluviatilis*) • Atlantic salmon (*Salmo salar*) • Otter (*Lutra lutra*) • Floating water-plantain (*Luronium natans*)	12 km	Underwater Sound Disturbance

European Site	Examples of qualifying features	Distance from survey area	Impact Pathway Assessed
River Ehen SAC	**Annex II Species (primary reason for selection):** • Freshwater pearl mussel (*Margaritifera margaritifera*) **Annex II Species (secondary reason for selection):** • Atlantic salmon (*Salmo salar*)	21 km	Underwater Sound Disturbance
River Eden SAC	**Annex I Habitat (primary reason for selection):** • Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea* • Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation • Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*) **Annex II Species (primary reason for selection):** • White-clawed (or Atlantic stream) crayfish (*Austropotamobius pallipes*) • Sea lamprey (*Petromyzon marinus*) • Brook lamprey (*Lampetra planeri*) • River lamprey (*Lampetra fluviatilis*) • Atlantic salmon (*Salmo salar*) • Bullhead (*Cottus gobio*) • Otter (*Lutra lutra*)	41 km	Underwater Sound Disturbance
Solway Firth SAC	**Annex I Habitat (primary reason for selection):** • Sandbanks which are slightly covered by sea water all the time • Estuaries • Mudflats and sandflats not covered by seawater at low tide • Salicornia and other annuals colonizing mud and sand • Atlantic salt meadows (*Glauco-Puccinellietalia maritimae)* **Annex I Habitat (secondary reason for selection):** • Reefs	42 km	Underwater Sound Disturbance

European Site	Examples of qualifying features	Distance from survey area	Impact Pathway Assessed
	• Perennial vegetation of stony banks • "Fixed coastal dunes with herbaceous vegetation (""grey dunes"")" **Annex II Species (primary reason for selection):** • Sea lamprey (*Petromyzon marinus*) • River lamprey (Lampetra fluviatilis)		
River Bladnoch SAC	**Annex II Species (primary reason for selection):** • Atlantic salmon (*Salmo salar*)	62 km	Underwater Sound Disturbance
Dee Estuary SAC	**Annex I Habitat (primary reason for selection):** • Mudflats and sandflats not covered by seawater at low tide • Salicornia and other annuals colonizing mud and sand • Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*) **Annex I Habitat (secondary reason for selection):** • Estuaries • Annual vegetation of drift lines • Vegetated sea cliffs of the Atlantic and Baltic Coasts • Embryonic shifting dunes • "Shifting dunes along the shoreline with *Ammophila arenaria* (""white dunes"")" • "Fixed coastal dunes with herbaceous vegetation (""grey dunes"")" • Humid dune slacks **Annex II Species (primary reason for selection):** • Sea lamprey (*Petromyzon marinus*) • River lamprey (*Lampetra fluviatilis*) • Petalwort (*Petalophyllum ralfsii*)	64 km	Underwater Sound Disturbance
River Dee and Bala Lake SAC	**Annex I Habitat (primary reason for selection):**	87 km	Underwater Sound Disturbance

European Site	Examples of qualifying features	Distance from survey area	Impact Pathway Assessed
	• Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation **Annex II Species (primary reason for selection):** • Atlantic salmon (*Salmo salar*) • Floating water-plantain (*Luronium natans*) **Annex II Species (secondary reason for selection):** • Sea lamprey (*Petromyzon marinus*) • Brook lamprey (*Lampetra planeri*) • River lamprey (*Lampetra fluviatilis*) • Bullhead (*Cottus gobio*) Otter (*Lutra lutra*)		
Morecambe Bay and Duddon Estuary SPA	**Annex I bird species (non-breeding):** • Whooper swan (*Cygnus Cygnus*) • Little egret (*Egretta garzetta*) • European golden plover (*Pluvialis apricaria*) • Bar-tailed Godwit (*Limosa lapponica*) • Ruff (*Calidris pugnax*) • Mediterranean gull (*Larus melancephalus*) **Annex I bird species (breeding season):** • Little tern (*Sternula albifrons*) • Sandwich tern (*Sterna sandvicensis*) • Common tern (*Sterna hirundo*)	0 km	Airborne Sound and Visual Disturbance
Liverpool Bay SPA	**Annex I bird species (non-breeding season):** • Red-throated diver (*Gavia stellata*) • Common scoter (*Melanitta nigra*) • Little gull (*Hydrocoloeus minutus*) **Annex I bird species (breeding season):** • Little tern (*Sternula albifrons*) • Common tern (*Sterna hirundo*)	0.6 km	Airborne Sound and Visual Disturbance

European Site	Examples of qualifying features	Distance from survey area	Impact Pathway Assessed
Solway Firth SPA	**Annex I Bird Species:** • Red-throated diver (*Gavia stellata*) • Whooper swan (*Cygnus cygnus*) • Barnacle goose (*Branta leucopsis*) • Golden plover (*Pluvialis apricaria*) • Bar-tailed godwit (*Limosa lapponica*) **Supports Migratory Populations of European Importance:** • Pink footed goose (*Anser brachyrhynchus*) • Shelduck (*Tadorna tadorna*) • Teal (*Anas crecca*) • Pintail (*Anas acuta*) • Shoveler (*Anas clypeata*) • Scaup (*Aythya marila*) • Common scoter (*Melanitta nigra*) • Goldeneye (*Bucephala clangula*) • Goosander (*Mergus merganser*) • Oystercatcher (*Haematopus ostralegus*) • Knot (*Calidris canutus*) • Ringed plover (*Charadrius hiaticula*) • Grey plover (*Pluvialis squatarola*) • Lapwing (*Vanellus vanellus*) • Dunlin (*Calidris alpina*) • Sanderling (*Calidris alba*) • Redshank (*Tringa totanus*) • Turnstone (*Arenaria interpres*) • Curlew (*Numenius arquata*) • Cormorant (*Phalacrocorax carbo*) • Black –headed gull (*Larus ridibundus*) • Common gull (*Larus canus*) Herring gull (*Larus argentatus*)	12 km	Airborne Sound and Visual Disturbance

European Site	Examples of qualifying features	Distance from survey area	Impact Pathway Assessed
Ribble and Alt Estuaries SPA	**Annex I bird species (non-breeding):** • Bewick's Swan (*Cygnus columbianus bewickii*) • Whooper Swan (*Cygnus cygnus*) • Golden Plover (*Pluvialis apricaria*) • Bar-tailed Godwit (*Limosa lapponica*) **Annex I bird species (breeding season):** • Ruff (*Philomachus pugnax*) • Common Tern (*Sterna hirundo*)	31 km	Airborne Sound and Visual Disturbance
Duddon Estuary Ramsar	**Qualifying Species (peak counts in winter):** • Northern pintail (*Anas acuta*) • Red knot (*Calidris canutus islandica*) • Common redshank (*Tringa totanus totanus*)	3 km	Airborne Sound and Visual Disturbance
Morecambe Bay Estuary Ramsar	**Qualifying Species (breeding season):** • Lesser black-backed gull (*Larus fuscus graellsii*) • Herring gull (*Larus argentatus argentatus*) • Sandwich tern (*Sterna (Thalasseus) sandvicensis sandvicensis*) **Qualifying Species (peak counts in spring/autumn):** • Great cormorant (*Phalacrocorax carbo carbo*) • Common shelduck (*Tadorna tadorna*) • Northern pintail (*Anas acuta*) • Common eider (*Somateria mollissima mollissima*) • Eurasian oystercatcher (*Haematopus ostralegus ostralegus*) • Ringed plover (*Charadrius hiaticula*) • Grey plover (*Pluvialis squatarola*) • Sanderling (*Calidris alba*) • Eurasian curlew (*Numenius arquata arquata*) • Common redshank (*Tringa totanus totanus*) • Ruddy turnstone (*Arenaria interpres interpres*) • Lesser black-backed gull (*Larus fuscus graellsii*)	5 km	Airborne Sound and Visual Disturbance

European Site	Examples of qualifying features	Distance from survey area	Impact Pathway Assessed
	Qualifying Species (peak counts in winter): • Great crested grebe (*Podiceps cristatus cristatus*) • Pink-footed goose (*Anser brachyrhynchus*) • Eurasian wigeon (*Anas Penelope*) • Common goldeneye (*Bucephala clangula clangula*) • Red-breasted merganser (*Mergus serrator*) • European golden plover (*Pluvialis apricaria apricaria*) • Northern lapwing (*Vanellus vanellus*) • Red knot (*Calidris canutus islandica*) • Dunlin (*Calidris alpina alpine*) • Bar-tailed godwit (*Limosa lapponica lapponica*)		
Ribble and Alt Estuaries Ramsar	**Qualifying Species (breeding season):** • Lesser black-backed gull (*Larus fuscus graellsii*) **Qualifying Species (peak counts in spring/autumn):** • Ringed plover (*Charadrius hiaticula*) • Grey plover (*Pluvialis squatarola*) • Red knot (*Calidris canutus islandica*) • Sanderling (*Calidris alba*) • Dunlin (*Calidris alpina alpine*) • Black-tailed godwit (*Limosa limosa islandica*) • Common redshank (*Tringa totanus totanus*) • Lesser black-backed gull (*Larus fuscus graellsii*) **Qualifying Species (peak counts in winter):** • Tundra swan (*Cygnus columbianus bewickii*) • Whooper swan (*Cygnus cygnus*) • Pink-footed goose (*Anser brachyrhynchus*) • Common shelduck (*Tadorna tadorna*) • Eurasian wigeon (*Anas penelope*) • Eurasian teal (*Anas crecca*) • Northern pintail (*Anas acuta*) • Eurasian oystercatcher (*Haematopus ostralegus ostralegus*)	31 km	Airborne Sound and Visual Disturbance

European Site	Examples of qualifying features	Distance from survey area	Impact Pathway Assessed
	• Bar-tailed godwit (*Limosa lapponica lapponica*)		
Upper Solway Flats and Marshes Ramsar	**Qualifying Species (peak counts in spring/autumn):** • Eurasian oystercatcher (*Haematopus ostralegus ostralegus*) **Qualifying Species (peak counts in winter):** • Whooper swan (*Cygnus cygnus*) • Pink-footed goose (*Anser brachyrhynchus*) • Barnacle goose (*Branta leucopsis*) • Northern pintail (*Anas acuta*) • Greater scaup (*Aythya marila marila*) • Red knot (*Calidris canutus islandica*) • Bar-tailed godwit (*Limosa lapponica lapponica*) • Eurasian curlew (*Numenius arquata arquata*) • Common redshank (*Tringa totanus totanus*)	42 km	Airborne Sound and Visual Disturbance

Task 1 – screening

D.29. The screening task was undertaken against the identified impact pathways for each of the designated sites and features taken forward from scoping.

Pathway 1: Underwater sound disturbance

D.30. Ambient underwater sound is the background sound level made up of a broad range of individual sound sources present in the ocean of both natural and anthropogenic origin (Hildebrand, 2004). Many marine organisms, including marine mammals and fish, use sound for communication, to locate mates, to search for prey, to avoid predators and hazards, and in the case of cetaceans, for short- and long-range navigation (OSPAR, 2009).

D.31. Anthropogenic underwater sound sources arise from activities in and near the sea such as dredging, construction, hydrocarbon exploration and production, geophysical and geophysical surveys and sonars, among others (Richardson et al., 1995). These have the potential to result in short-term behavioural changes and, in more extreme cases, cause auditory and physiological damage and in extreme cases mortality in both marine mammal and fish receptors.

D.32. The proposed geophysical survey will generate sound energy which represents a potential risk to a number of marine receptors, given its mostly low frequency range which is thought to be audible to a wide range of marine receptors. A number of survey execution and design controls will be implemented in order to minimise the risk of underwater sound as a result of the survey. These follow the JNCC guidelines for geophysical operations (JNCC, 2017). These measures include a 20-minute soft start employed for the geophysical sound source, the presence of a marine mammal observer (to identify any marine mammals prior to the start of any sound generating activities), and the use of Passive Acoustic Monitoring (PAM) equipment. In addition, the lowest practicable sound source level will be used to meet data collection requirements.

<u>European sites designated for harbour porpoise</u>

D.33. As previously noted, the following SACs are designated due to their importance for the Annex II species harbour porpoise (*Phocoena phocoena*):

- North Channel SAC (63 km – harbour porpoise); and
- North Anglesey Marine SAC (63 km – harbour porpoise).

D.34. Both sites represent significant foraging, breeding, and calving habitat for harbour porpoise. The North Channel SAC has been identified as consisting of important habitat in the winter, whilst the North Anglesey Marine SAC consists of important habitat for this species in summer months. This difference in seasonal use between the North Channel SAC and the North Anglesey Marine SAC reflects the changes in usage and distribution of this species with the seasons (JNCC, 2019). With a survey window of July to August, it is anticipated that there will be higher densities of harbour porpoise in the North Anglesey Marine SAC during these months.

D.35. The conservation objectives of both sites is to ‘make the best possible contribution to maintaining Favourable Conservation Status (FCS) for harbour porpoise in UK waters’ (JNCC, 2019). The designations for these sites, state that these objectives will be achieved by ensuring that:

- ‘harbour porpoise is a viable component of the site’ - by minimising the risk of injury and killing or other factors that could restrict survivability and reproductive potential of harbour porpoise using these sites;
- ‘there is no significant disturbance of the species’ – disturbance is considered significant if it leads to the exclusion of harbour porpoise from a significant proportion of these sites; and
- ‘the condition of supporting habitats and processes, and the availability of prey is maintained’ – the densities of harbour porpoise at these sites is likely to be as a result of the availability and density of prey within the site (including gobies, sandeel, whiting, herring, and sprat).

D.36. Harbour porpoise are categorised as having high frequency hearing and therefore there is the potential for the survey to result in significant impairment or damage to their auditory system may have long-term harmful consequences for the affected individual (Southall et al*.,* 2007). However, the assessment for underwater sound, provided in **Appendix D: Underwater Sound Propagation Modelling**, states that PTS and TTS in harbour porpoise is highly unlikely. The density of harbour porpoise within the survey area is known to be low. If TTS did occur, it is expected to be minor and recovery fairly rapid once the short-term sound source stops and with the potential, based on the low density of animals in the survey area, to affect very few individuals. In addition, although not accounted for in the initial HRA assessment, it is known that the implementation of JNCC mitigation as part of the survey design, will minimise the chance of any marine mammal being within 500 m of the sound source, and allow sound to increase gradually during the soft-start.

D.37. Behaviour disturbance as a result of the survey is anticipated, and could result in an avoidance or fleeing reaction if an induvial is close to the acoustic sound source. Individuals which utilise the North Channel SAC or North Anglesey Marine SAC could travel away from these sites if foraging for food and may be found within an area close to the seismic survey. In this instance, behavioural disturbance could occur in these individuals. However, the survey area and wider eastern Irish Sea has low densities of harbour porpoise, indicating that this area is not particularly important for foraging. Any behavioural disturbance would be minimal and in a worst-case scenario would only affect a small number of harbour porpoise and not have wider population effects. Given the distance of the survey area from these designated sites, any disturbance would not lead to the exclusion of individuals from entering either of these sites, and therefore is not considered significant in the context of the SACs conservation objectives.

D.38. Based on the relatively large distance of the survey from the designated sites screened in for assessment of LSE, the low importance of the survey area for foraging (indicated by the low densities of harbour porpoise in this area), as well as the implementation of the survey design, prior to any potential mitigation considerations, it is considered that the conservation objectives of these sites will not undermined as a result of the survey. Therefore, there will be **no potential for Likely Significant Effects (LSE)** on the integrity of these SACs.

European sites designated for sea and river lamprey

D.39. The SACs noted below are designated due to their importance for the Annex II species sea lamprey and river lamprey and have been assessed based on their relative proximity to the survey area and the potential for the migration route of the species to coincide with the survey area considered within this assessment. The conservation objectives of these sites are to ensure that the integrity of these sites is maintained and restored (as appropriate) and ensure that the site contributes to achieving the Favourable Conservation Status of its qualifying features.

- River Derwent and Bassenthwaite Lake SAC (12 km);
- River Eden SAC (41 km);
- Solway Firth SAC (42 km);
- Dee Estuary SAC (64 km); and
- River Dee and Bala Lake SAC (87km)

D.40. There is little information on the hearing sensitivity of river and sea lamprey, but given that they lack a swim bladder (or an anatomical structure tuned to amplify sound) and possess a relatively simple ear, these species are considered as low hearing sensitivity fish. Lamprey are generally considered to be sensitive only to sound particle motion within a narrow band of frequencies, although behavioural reactions have been observed in response to underwater sound (Popper and Hawkins, 2019). Based on the survey design to be implemented and the behaviour of these species (which will allow these species to move away from the geophysical sound source), physical injury and TTS is considered unlikely. Although behavioural responses are assumed as a result of the survey, these will occur in open water and in an area not considered to be particularly important for foraging and other behaviours. The energetic cost of any avoidance behaviour will be minimal and won't affect the long-term survival of lamprey.

D.41. The closest SACs to the survey, are the River Derwent and Bassenthwaite Lake SAC, the River Eden SAC, and the Solway Firth SAC (which is used as a migratory route to the River Eden SAC). Lamprey migration in the rivers in this region of the UK is reported to occur in late spring and early summer for upstream migration and October to March for the downstream return of juveniles to the estuary. In the Solway Firth SAC, sea lamprey are reported to migrate upstream into freshwater in November (spawning occurring in May), and begin their descent back into the estuary between October and March. Therefore, there is considered to be no spatial or temporal interaction between migration periods and the survey. For the Dee Estuary SAC (which leads into the River Dee and Bala Lake SAC further upstream), river lamprey migration upstream occurs over two key periods: early spring (March to April) and late summer and autumn (August to November). Although the latter period may coincide with the survey, river lamprey are found in estuaries (and to a lesser extent coastal waters) which are connected to their spawning grounds. The Dee Estuary is located 64 km from the geophysical survey (the River Dee and Bala Lake SAC is located 87 km from the survey) and therefore there is considered to be no interaction between these individuals and the survey.

D.42. For these designated sites, there was no information found on the distribution of the sea lamprey outside these migratory periods but it is assumed they may be found in open marine water albeit in low numbers (the numbers reported in migratory areas, where densities are highest, are low) and with a diffuse distribution.

D.43. The survey will be short term meaning so will any disturbance effects to lamprey. The location of the survey in relation to the SACs screened in, the period in which the survey will take place (i.e. avoiding the key migratory periods of these species), and the survey design to be implemented (JNCC guidelines for survey operations (JNCC, 2017)) also mean it is considered there will be **no potential for Likely Significant Effects (LSE)** on the integrity of these SACs.

European sites designated for Atlantic salmon

D.44. The SACs, for which the Annex II species Atlantic salmon is a qualifying feature, have been grouped together and are shown below. The conservation objectives of these sites are to ensure that the integrity of these sites is maintained and restored (as appropriate), and ensure that the site contributes to achieving the Favourable Conservation Status of its qualifying features.

- River Derwent and Bassenthwaite Lake SAC (12 km);
- River Ehen SAC (21 km);
- River Eden SAC (41 km);
- River Bladnoch SAC (62 km); and
- River Dee and Bala Lake SAC (87 km).

D.45. Atlantic salmon are considered to be a medium hearing sensitivity fish, possessing a swim bladder in which hearing does not involve the swim bladder or other gas volume (Popper et al*.,* 2014). This means that salmon hearing only involves particle motion rather than sound pressure. Despite this, a swim bladder is unable to adapt quickly enough to high intensity geophysical pressure waves, meaning that salmon are susceptible to barotrauma and in some cases lethal injury. There is little information to suggest that physical damage has resulted in fish as a result of geophysical sound, although acute auditory injury and TTS is thought to occur if fish are in close proximity to moderately loud sound, such as from the survey.

D.46. Behavioural responses in fish to impulsive sounds are more difficult to quantify but may include changes in abundance in particular habitats, changes in swimming patterns or feeding, as well as physiological stress which could even lead to mortality for chronic exposure. It is expected that behavioural responses in Atlantic salmon as a result of the survey will consist largely of avoidance reactions. Salmon in the survey area are pelagic in nature whilst the survey takes place in open inshore waters so fish can easily move away and are not expected to remain within close proximity of the vessel during the survey. The risk of injury to salmon is therefore considered to be very low.

D.47. There is the potential for the survey to interact with the key life stages of salmon migrating to and from the designated sites screened in for assessment, which are known to be key spawning rivers for this species. If the sound from the survey is intense enough, this could present an acoustic barrier preventing migration of salmon to their suitable spawning ground habitat in the upper reaches of these rivers. The River Derwent and Bassenthwaite Lake and the River Ehen are the closest SACs (for which Atlantic salmon are a qualifying feature) to the proposed geophysical survey, located 12 km and 21 km away, respectively. The key migratory period for the River Ehen has been identified as November to December for adults and the smolt run period generally occurs from March – May (Natural England, pers comm). With a survey window of July to August the survey activity will not be taking place at the key stages described above.

D.48. The survey will take place when the density of salmon in open water will be low meaning that any behavioural disturbance, in the form of avoidance reaction, will be negligible. Furthermore, the survey is short-term and temporary and outside of the key migratory period for this species. Overall, it is considered that there will be **no potential for Likely Significant Effects (LSE)** on the integrity of the SACs considered within this assessment.

Pathway 2: Airborne sound and visual disturbance

Seabirds

D.49. European sites which are designated for the protection of ornithological features (e.g. SPAs), and are included in the assessment of LSE, include:

- Solway Firth SPA;
- Liverpool Bay SPA;

- Morecombe Bay and Duddon Estuary SPA;
- Ribble and Alt Estuaries SPA;
- Duddon Estuary Ramsar;
- Morecombe Bay Estuary Ramsar;
- Ribble and Alt Estuaries Ramsar; and
- Upper Solway Flats and Marshes Ramsar.

D.50. In recognition of the extensive list of species included within the citations for the above sites, each site has been reviewed in the context of to the ZoI established earlier, to determine which species may be subject to potential effects from airborne sound and visual disturbance (Table A15). Further to this those species present within the ZoI have been screened for their likelihood to be present within the operation window of the survey.

D.51. Based on feedback from Natural England, although designated sites were assessed in the normal way for HRA, further attention was paid to red-throated divers, terns, gulls and razorbills due to their presence and sensitivity to disturbance.

Table A15. Sites Designated for Ornithology and species noted for screening of LSE

Designated Site	Reason for Designation	Potential for cited species to occur within the ZoI	Species likely to occur within the ZoI and present during the operational survey period
Solway Firth SPA	Over winter - red-throated diver *Gavia stellata* Whooper Swan *Cygnus cygnus* Barnacle Goose *Branta leucopsis* Golden Plover *Pluvialis apricaria* Bar-tailed Godwit *Limosa lapponica* Pink-footed Goose *Answer brachyrhynchus* Pintail *Anas acuta* Knot *Calidris canutus* Curlew *Numenius arquata* Redshank *Tringa totanus* Scaup *Aythya marila* Oystercatcher *Haematopus ostralegus* On passage - Ringed plover *Charadrius hiaticula* Waterbird Assemblage including: Shelduck (*Tadorna tadorna*), Teal (*Anas crecca*), Shoveler (*Anas clypeata*), Common scoter (*Melanitta nigra*), Goldeneye (*Bucephala clangula*), Goosander (*Mergus merganser*), Grey plover (*Pluvialis squatarola*), Lapwing (*Vanellus vanellus*), Dunlin (*Calidris alpina*), Sanderling (*Calidris alba*), Turnstone (*Arenaria interpres*), Cormorant (*Phalacrocorax carbo*), Black –headed Gull (*Chroicocephalus ridibundus*), Common gull (*Larus canus*), Herring gull (*Larus argentatus*).	Given the survey area occurs in inshore waters species associated with tidal mudflats and grazing marshes are beyond 2km and outside the ZoI. The following species have the potential to be present in the inshore waters of the SPA and ZoI during the non-breeding season and are considered further: • Red-throated diver, • Scaup, • Common Scoter, • Goldeneye, • Goosander, • Cormorant, • Black-headed Gull, • Common Gull • Herring Gull	The Solway Firth is designated for its over-wintering waterbirds. Therefore, the significant populations of waterbirds for which the site is designated are not present during the operational period of July to August. It has been noted that red-throated diver may be present in late August (NE pers comm), with birds arriving from breeding grounds to undertake their post-breeding moult. As a precautionary approach **red-throated diver** is therefore, considered to potentially be present during the end of the operational period.
Morecambe Bay and Duddon Estuary SPA	Over winter – Whooper Swan *Cygnus Cygnus* Little Egret *Egretta garzetta*	Given the survey area occurs in inshore waters species associated with tidal mudflats and grazing marshes are beyond	Species potentially present in the ZoI during the operational period are:

	Golden Plover *Pluvialis apricaria* Ruff *Calidris pugnax* Bar-tailed Godwit *Limosa lapponica* Mediterranean Gull *Larus melancephalus* Breeding season – Common Tern *Sterna hirundo* Sandwich Tern *Sterna sandvicensis* Little Tern *Sternula albifrons* Lesser black-backed Gull *Larus fuscus* Herring Gull *Larus argentatus* On passage – Pink-footed Goose *Anser brachyrhynchus* Shelduck *Tadorna tadorna* Oystercatcher *Haematopus ostralegus* Ringed Plover *Charadrius hiaticula* Grey Plover *Pluvialis squatarola* Knot *Calidris canutus* Sanderling *Calidris alba* Dunlin *Calidris alpina* Black-tailed Godwit *Limosa limosa* Curlew *Numenius arquata* Pintail *Anas acuta* Turnstone *Arenaria interpres* Redshank *Tringa totanus* Lesser Black-backed Gull *Larus fuscus* Waterbird assemblage including all qualifying features listed above, as well as the following species: Great White Egret *Ardea alba*, Spoonbill Platalea leucorodia, Brent Goose *Branta bernicla*, *Wigeon Anas penelope*, Teal *Anas crecca*, Green-winged Teal *Anas carolinensis*, Shoveler *Anas platyrhynchos*, Ring-necked Duck *Aythya collaris*, Eider *Somateria mollissima*, Goldeneye *Bucephala clangula*, Red-breasted Merganser *Mergus serrator*, Cormorant	2km and outside the ZoI. The following species have the potential to be present in the inshore waters of the SPA and ZoI during the non-breeding season and are considered further: • Mediterranean Gull • Goldeneye • Red-breasted merganser • Cormorant • Eider • Common Gull The following species have the potential to be present in the inshore waters of the SPA and ZoI during the breeding season and are considered further: • Common Tern • Sandwich Tern • Little Tern • Lesser black-backed Gull • Herring Gull	• **Common Tern** • **Sandwich Tern** • **Little Tern** • **Lesser black-backed Gull** • **Herring Gull** The remaining species potentially present within the ZoI are present during the winter (non-breeding) period and therefore, significant populations of these species are not present during the operational period of July to August.

	Phalacrocorax carbo, Lapwing *Vanellus vanellus*, Little Stint *Calidris minuta*, Spotted Redshank *Tringa erythropus*, Greenshank *Tringa nebularia*, Black-headed Gull *Chroicocephalus ridibundus*, Common Gull *Larus canus* and Herring Gull *Larus argentatus*.		
Liverpool Bay SPA	Over winter – Red-throated Diver *Gavia stellata* Little Gull *Hydrocoloeus minutus* Common Scoter *Melanitta nigra* Breeding Season - Little Tern *Sternula albifrons* Common Tern *Sterna hirundo* Waterbird assemblage including all qualifying features listed above, as well as the following species: Cormorant *Phalacrocorax carbo,* Red-breasted Merganser *Mergus serrator,* Black-headed Gull *Chroicocephalus ridibundus,* Common Gull *Larus canus,* Eider *Somateria mollissima,* Fulmar *Fulmarus glacialis,* Great Black-backed Gull *Larus marinus,* Great Crested Grebe *Podiceps cristatus,* Guillemot *Uria aalge,* Gannet *Morus bassanus,* Puffin *Fratercula arctica,* Herring Gull *Larus argentatus,* Kittiwake *Rissa tridactyla,* Lesser Black-backed Gull *Larus fuscus,* Great Northern Diver *Gavia immer,* Shag *Phalacrocorax* *aristotelis,* Razorbill *Alca torda,*	Given the survey area occurs in inshore waters species associated with tidal mudflats and grazing marshes are beyond 2km and outside the ZoI. The following species have the potential to be present in the inshore waters of the SPA and ZoI during the non-breeding season and are considered further: • Black headed gull • Common gull • Common scoter • Cormorant • Eider • Fulmar • Gannet • Great black backed gull • Great crested grebe • Great northern diver • Guillemot • Herring gull • Kittiwake • Lesser black backed gull • Little gull • Puffin • Razorbill • Red breasted merganser	Species potentially present in the ZoI during the operational period are: • **Common Tern** • **Little Tern** It has been noted that Red-throated Diver may be present in late summer, with birds arriving from breeding grounds to undertake their post-breeding moult. As a precautionary approach **red-throated diver** is therefore, considered to potentially be present during the end of the operational period. The remaining species potentially present within the ZoI are present during the winter (non-breeding) period and therefore, significant populations of these species are not present during the operational period of July to August.

		• Red-throated diver • Shag The following species have the potential to be present in the inshore waters of the SPA and ZoI during the breeding season and are considered further: • Little Tern • Common Tern	
Ribble and Alt Estuaries SPA	Over winter- Bewick's Swan (*Cygnus columbianus bewickii*) Whooper Swan (*Cygnus cygnus*) Golden Plover (*Pluvialis apricaria*) Bar-tailed Godwit (*Limosa lapponica*) Breeding Season - Ruff (*Philomachus pugnax*) Common Tern (*Sterna hirundo*)	Given the survey area occurs in inshore waters species associated with tidal mudflats and grazing marshes are beyond 2km and outside the ZoI. Therefore, no over-wintering species cited on the SPA have the potential to be present in the inshore waters of the SPA and ZoI during the non-breeding season and these species are not considered further. Given the distance (31 km) from the survey area there are no species which have a foraging range in the breeding season which means they are likely to occur in the survey area.	No cited species for the Ribble and Alt Estuaries SPA are likely to be present in the survey area or ZoI and as such, there are no likely significant effects arising from airborne sound and visual disturbance
Duddon Estuary Ramsar	Over winter - Northern pintail (*Anas acuta*) Knot (*Calidris canutus*) Common redshank (*Tringa totanus*)	Given the survey area occurs in inshore waters species associated with tidal mudflats and grazing marshes are beyond 2 km and outside the ZoI. Therefore, no over-wintering species cited on the SPA have the potential to be present in the inshore waters of the SPA and ZoI during the non-breeding season and these species are not considered further	No cited species for the Duddon Estuary Ramsar site are likely to be present in the survey area or ZoI and as such, there are no likely significant effects arising from airborne sound and visual disturbance and no adverse effect on the integrity of the Duddon Estuary Ramsar site.

Morecambe Bay Estuary Ramsar	Over winter/passage – Great crested grebe (*Podiceps cristatus cristatus*) Pink-footed goose (*Anser brachyrhynchus*) Wigeon (*Anas penelope*) Common goldeneye (*Bucephala clangula clangula*) Red-breasted merganser (*Mergus serrator*) Golden plover (*Pluvialis apricaria*) Lapwing (*Vanellus vanellus*) Knot (*Calidris canutus*) Dunlin (*Calidris alpina*) Cormorant (*Phalacrocorax carbo*) Shelduck (*Tadorna tadorna*) Pintail (*Anas acuta*) Eider (*Somateria mollissima*) Oystercatcher (*Haematopus ostralegus*) Ringed plover (*Charadrius hiaticula*) Grey plover (*Pluvialis squatarola*) Sanderling (*Calidris alba*) Curlew (*Numenius arquata)* Redshank (*Tringa totanus*) Turnstone (*Arenaria interpres*) Lesser black-backed gull (*Larus fuscus graellsii*) Bar-tailed godwit (*Limosa lapponica*) Breeding Season – Lesser black-backed gull (*Larus fuscus graellsii*) Herring gull (*Larus argentatus*) Sandwich tern (*Sterna (Thalasseus) sandvicensis*)	Given the survey area occurs in inshore waters species associated with tidal mudflats and grazing marshes are beyond 2 km and outside the ZoI. The following species have the potential to be present in the inshore waters of the SPA and ZoI during the non-breeding season and are considered further: • Great Crested Grebe • Goldeneye • Red-breasted merganser • Cormorant • Eider The following species have the potential to be present in the inshore waters of the SPA and ZoI during the breeding season and are considered further: • Sandwich Tern • Lesser black-backed Gull • Herring Gull	Species potentially present in the ZoI during the operational period are: • **Sandwich Tern** • **Lesser black-backed Gull** • **Herring Gull** The remaining species potentially present within the ZoI are present during the winter (non-breeding) period and therefore, significant populations of these species are not present during the operational period of July to August.
Ribble and Alt Estuaries Ramsar	Over winter/passage – Bewick's swan (*Cygnus columbianus*) Whooper swan (*Cygnus cygnus*) Pink-footed goose (*Anser brachyrhynchus*)	The following species have the potential to be present in the inshore waters of the SPA and ZoI during the breeding season and are considered further:	Species potentially present in the ZoI during the operational period are: • **Lesser black-backed Gull**

	Shelduck (*Tadorna tadorna*) Wigeon (*Anas penelope*) Teal (*Anas crecca*) Pintail (*Anas acuta*) Eurasian oystercatcher (*Haematopus ostralegus*) Bar-tailed godwit (*Limosa lapponica*) Ringed plover (*Charadrius hiaticula*) Grey plover (*Pluvialis squatarola*) Red knot (*Calidris canutus islandica*) Sanderling (*Calidris alba*) Dunlin (*Calidris alpina alpine*) Black-tailed godwit (*Limosa limosa islandica*) Common redshank (*Tringa totanus totanus*) Lesser black-backed gull (*Larus fuscus graellsii*) Breeding Season – Lesser black-backed gull (*Larus fuscus graellsii*)	• Lesser black-backed Gull	The remaining species potentially present within the ZoI are present during the winter (non-breeding) period and therefore, significant populations of these species are not present during the operational period of July to August.
Upper Solway Flats and Marshes Ramsar	Over winter/passage – Whooper swan (*Cygnus cygnus*) Pink-footed goose (*Anser brachyrhynchus*) Barnacle goose (*Branta leucopsis*) Northern pintail (*Anas acuta*) Scaup (*Aythya marila marila*) Red knot (*Calidris canutus islandica*) Bar-tailed godwit (*Limosa lapponica*) Eurasian curlew (*Numenius arquata arquata*) Eurasian oystercatcher (*Haematopus ostralegus*)	Given the survey area occurs in inshore waters species associated with tidal mudflats and grazing marshes are beyond 2 km and outside the ZoI. The following species have the potential to be present in the inshore waters of the SPA and ZoI during the non-breeding season and are considered further: • Scaup	No cited species for the Upper Solway Flats and Marshes Ramsar site are likely to be present in the survey area or ZoI in significant numbers during the operational period of Scheme. As such, there are no likely significant effects arising from airborne sound and visual disturbance and no adverse effect on the integrity of the Upper Solway Flats and Marshes Ramsar site.

Red-throated diver

D.52. Based on the assessments noted above red-throated divers were reviewed in more detail. The Liverpool Bay SPA and Solway Firth SPA are both designated for the protection of wintering populations of red-throated diver and are located 0.6 km and 12 km away from the survey area, respectively. Both these designated sites are included in for assessment for LSE. The conservation objectives of these sites include maintaining and restoring: the population of each of the qualifying features; and the distribution of the qualifying features within the site.

D.53. The Solway Firth SPA also supports a large wintering population of red-throated diver, consisting of a mean peak abundance of 527 individuals (3.1% of the Great Britain population). Aerial surveys undertaken as part of the Solway Firth SPA designation process, reported the highest densities of red-throated diver from Southerness to Maryport, with some concentrations of this species around Whitehaven (densities of 0.15 to 0.6 individuals/km2) (Natural England and SNH, 2016). The survey area is well beyond (12 km) the 2 km ZoI (within which displacement and disturbance may occur) from the SPA.

D.54. The Liverpool Bay SPA supports numbers of red-throated diver which are well above the 1% Great Britain population threshold, consisting of 1,409 individuals (5 year mean peak from 2004/2005 to 2010/2011). Aerial surveys used to assess populations of waterbirds in association with the Liverpool Bay SPA, showed that the highest densities of red-throated diver were located along the coastline close inshore. Within the site boundary, the highest aggregations of this species were recorded near to the Ribble Estuary and within the Liverpool Bay and Dee Estuary area. Despite the survey area occurring within close proximity with the Liverpool Bay SPA, the survey area is located well beyond the 2 km ZoI (within which displacement and disturbance may occur) from any large aggregations of red-throated diver identified within the designated site boundary.

D.55. The aerial surveys undertaken to assess the density of red-throated diver within the Liverpool Bay SPA and Solway Firth SPA took place during the main non-breeding period, from October to March. Although there are reports of red-throated diver arriving in the UK in September, the densities of this species outside of the main wintering period are assumed to be significantly reduced compared to the assessment made for each of the SPAs considered. If the vessel does pass in close proximity to the Liverpool Bay SPA (0.6 km), the chance of red-throated diver being present is greatly reduced. If an individual is found in close proximity to the vessel (i.e. within the 2 km ZoI), then displacement may occur. However, given the wider area available, if birds are present, they are likely to be able to find alternative habitat in the short term. Overall, any disturbance as a result of survey activities, including the presence of the vessel, will not result in population effects which would compromise the conservation objectives of the Liverpool Bay SPA and Solway Firth SPA. Therefore, there will be **no potential for Likely Significant Effects (LSE)** on the integrity of these SPAs.

Terns

D.56. The SPAs of interest which are designated for the protection of terns (including sandwich tern, common tern, and little tern), are shown below:

- Morecambe Bay and Duddon Estuary SPA (sandwich tern, common tern, and little tern);
- Liverpool Bay SPA (common tern, and little tern); and
- Morecambe Bay Ramsar (sandwich tern).
-

D.57. The Morecambe Bay and Duddon Estuary SPA/Ramsar Site complex comprises areas for foraging breeding sandwich terns. The main breeding colony for this species is located at Hodbarrow Lagoon, with the majority of individuals foraging in the vicinity of the colony. Predicted usage was found to decline with distance from the colony. Although the survey area does overlap with the predicted foraging areas for sandwich tern, the density of seabirds in this area is thought be low, consisting of usage between 0.00 to 0.33 (compared with usage of 14.29 to 22.73 in the peak foraging area).

D.58. Included on the Morecambe Bay and Duddon Estuary SPA citation are common tern. However, the current breeding numbers of this species are considered to be below the relevant qualifying threshold, so modelling of foraging ranges for the species for this site has not been undertaken. The foraging areas for sandwich tern are also thought to include the areas used by common tern and therefore, the study area could potentially coincide with foraging common tern. Despite this, given the low number of breeding individuals recorded at this site, it is considered that the numbers of common tern within the ZoI of airborne sound and visual disturbance from the vessel would also be small and potential displacement would be negligible.

D.59. The Liverpool Bay SPA also supports foraging common tern from breeding colonies in the Mersey Narrows and North Wirral Foreshore SPA. Modelling of the predicted foraging ranges of these breeding common tern determined the highest usage to be around these colonies. Based on this information, the foraging areas for common tern associated with Liverpool Bay SPA are considered to fall outside the ZoI of the survey area.

D.60. Little tern have limited foraging ranges, with a mean maximum foraging distance of 5 km (Woodward et al., 2019). Shore-based surveys of colonies within the Morecambe Bay and Duddon Estuary SPA were undertaken to inform the extension of the Morecambe Bay and Duddon Estuary SPA and show that the foraging areas for this species do not extend into the survey area and associated ZoI. Little tern breeding populations associated with the Liverpool Bay SPA are concentrated at the coastal colony at Gronant, on the Dee Estuary where they have a maximum seaward foraging extent of 1.8 km (Parsons et al., 2015). This is considered well beyond the ZoI of the survey.

D.61. Overall, there is potential for the geophysical survey to coincide with the foraging areas of sandwich tern and common tern within the Morecambe Bay and Duddon Estuary SPA/Ramsar site complex. However, if present, the number of individuals will be small compared to areas of peak foraging close to the key breeding colonies of these species. The survey vessel will be slow moving (travelling at ~8.1 km/hr (4.5 knots) during geophysical data acquisition) and will not represent a significant increase in vessel traffic and any time that the vessel spends within these foraging areas will be short and temporary. Furthermore, terns (including common tern, sandwich tern, and little tern) are considered to display ‘Low’ levels of displacement to vessel activities (MMO, 2018). Therefore, it is considered that there will be **no potential for Likely Significant Effects (LSE)** on the integrity of the SPAs and Ramsar sites considered within this assessment.

Gulls

D.62. The SPAs of interest, which are designated for the protection of gulls (lesser black-backed gull, and herring gull), are shown below:

- Morecambe Bay and Duddon Estuary SPA (lesser black-backed gull, and herring gull);
- Morecambe Bay Ramsar (lesser black-backed gull, and herring gull); and
- Ribble and Alt Estuaries Ramsar (lesser black-backed gull).

D.63. Breeding populations of lesser black-backed gull and herring gull are found within the Morecambe Bay and Duddon Estuary SPA/Ramsar site complex, with colonies located as part of the South Walney and Piel Channel Flats SSSI. These colonies are located over 4 km away from the survey area and therefore fall outside the ZoI from disturbance as a result of survey vessel related activities. However, there is potential that individuals from these colonies could be foraging within the survey area.

D.64. Lesser black-backed gull are known to forage over large distances, and can travel over 150 km in a single foraging trip (Ross-Smith et al., 2014). This species will routinely fly 40 to 80 km from their breeding colonies to find food. As such, there is potential for individuals of this species from the Ribble and Alt Estuaries Ramsar to be present within the survey area. However, given the broad foraging range of this species, and the range of available food sources, it is unlikely that individuals will be present during the survey. If they are present and are displaced, they can move to alternative feeding grounds and return once the vessel has moved on after a short time without significant effect.

D.65. Herring gull are also known to have wide ranging foraging distances, particularly after breeding where they can travel up to 60 km (Woodward et al*.,* 2019). However, the breeding colony located on Walney Island, has been shown to have clear foraging hotspots, which consists of mussel bed areas south of Barrow-in-Furness (Thaxter et al*.,* 2017). This area falls outside of the proposed survey area and therefore, vessel activities are not considered to disturb foraging individuals of this species.

D.66. The MMO (2018) consider gulls to display ‘Low’ levels of displacement to vessel activities. Taking this into consideration, and given the large available area for foraging for lesser black-backed gull and herring gull, as well as the short and temporary period within which the survey vessel will be operating, the survey is not considered to result in significant displacement of gulls. Therefore, there will be **no potential for Likely Significant Effects (LSE)** on the integrity of these SPAs and Ramsar sites.

Marine Conservation Zone Assessment

Stage 1

D.67. Based on the survey area, and the three impact pathways, initially four MCZs were deemed relevant for this assessment from the long list of sites screened in for consideration (**Appendix B: Designated Sites Scoping Matrix**). These were the:

- West of Walney (0 km)
  - Site designated based on seabed habitats: subtidal sand and subtidal mud and sea-pen and burrowing megafauna communities;
- Wyre-Lune (19 km)
  - Site designated due to its community of migratory smelt (*Osmerus eperlanus*);
- Cumbria coast (2 km)
  - Site designated based on habitats and birds, such as razorbills and guillemots; and
- Solway Firth[10] (9 km)
  - Site designated with its community of migratory smelt (*Osmerus eperlanus*).

D.68. The designated features for the West of Walney MCZ are not sensitive to underwater sound and, as there would be no interaction between the survey apparatus and the seabed, there is predicted to be, with a high level of confidence, no likely significant effects to the site or its designating features.

D.69. Smelt are a migratory species considered to have medium hearing sensitivity. The spawning period for smelt is reported to be in early spring and thus, there is not anticipated to be any significant overlap with the survey window. However, smelt are reported to remain in shallow inshore waters outside the spawning period (pers. comm. NE). But even allowing for a higher density of animals in nearshore waters around Wyre Lune MCZ, the distance from the inshore area to the geophysical survey area is beyond the point at which significant behavioural response would occur. Thus, it is predicted that no significant impact at the individual or population level within the MCZ is likely. Based on the distance and timing, the confidence in this assessment is high.

D.70. The Cumbria coast MCZ and Solway Firth MCZs were identified as part of the baseline, however both were scoped out due to distance and no clear impact pathways. The Cumbria coast MCZ is designated for birds such as Razorbills and the Solway Firth, with smelt as qualifying features. Both sites were screened out of the final assessment, as the geophysical survey area is beyond the potential zone of influence for disturbance and there were no potential impact pathways with a high level of confidence.

[10] This also covers the small populations in the River Eden and River Cree

Stage 2

D.71. As no significant impacts were identified in the Stage 1 assessment, no site was put forward for a Stage 2 assessment.

Other Habitats and Species of Conservation Importance

Sites of Special Scientific Interest

D.72. The survey falling within the Impact Risk Zones of these sites, as provided by Natural England (2021). The SSSIs identified included:

- Morecambe Bay SSSI (forms part of the Morecambe Bay and Duddon estuary SAC and SPA);
- Duddon Estuary SSSI (forms part of the Morecambe Bay and Duddon estuary SAC and SPA);
- Drigg Coast SSSI (forms part of the Drigg coast SAC) ; and
- South Walney and Piel Channel Flats SSSI (forms part of the Morecambe Bay and Duddon estuary SPA).

D.73. As all four sites are part of SACs and SPAs and covered in the HRA section, no separate assessment was deemed necessary.

Water Framework Directive Assessment

E.1. In accordance with the EA guidance for completing WFD assessments for coastal and transitional waters (EA, 2017a) and the Planning Inspectorate's Advice Note Eighteen (Planning Inspectorate, 2017), a three-stage approach was adopted:

- Stage 1: WFD Screening - Identification of the proposed work activities that are to be assessed and determination of which WFD water bodies could potentially be affected through identification of a zone of influence (ZoI). This step also provides a rationale for any water bodies screened out of the assessment.
- Stage 2: WFD Scoping - For each water body identified in Stage 1, an assessment is carried out to identify the effects and potential risks to quality elements from all activities. The assessment is made taking into consideration embedded mitigation (measures that can reasonably be incorporated into the design of the proposed works) and good practice mitigation (measures that would occur with or without input from the WFD assessment process).
- Stage 3: WFD Impact Assessment - A detailed assessment of the water bodies and activities carried forward from the WFD screening and scoping stages. It involves:
  - A review of the baseline conditions of the concerned water bodies;
  - An assessment of the risk of deterioration (either in isolation or cumulatively);
  - A description of any additional mitigation that is required (if applicable) and how it will be implemented; and

- An explanation of any positive contributions to the River Basin Management Plan (RBMP) objectives proposed, and how they will be delivered.

E.2. This assessment covers all three stages of the WFD compliance assessment process.

Project Activities relevant for the assessment

E.3. Based on the survey description noted in Section 3 of the report the primary activities associated with the Project that are relevant to the WFD assessment include:

- The survey – physical presence of survey vessel and underwater sound generated by data acquisition from operations planned for July\August 2022
- Changes to marine water quality from accidental leaks and spills from vessels, including loss of fuel oils

E.4. See Section 3 of the main report for further details on the survey.

E.5. Additional measures that are built into the survey design include:

- There will be no anchoring during marine operations to minimise physical disturbance of the seabed;
- The latest guidance from the GB non-native species secretariat (2015)11 will be followed and a Biosecurity Plan produced;
- All project vessels shall adhere to the International Convention for the Control and Management of Ships' Ballast Water and Sediments with the aim of preventing the spread of Invasive Non-native Species (INNS);
- Project vessels shall comply with all relevant health, safety and environmental legislation. This includes compliance with the International Regulations for Preventing Collisions at Sea (1972) and regulations relating to International Convention for the Prevention of Pollution from Ships (the MARPOL Convention 73/78) with the aim of preventing and minimising pollution from ships; and
- All vessels shall have a contingency plan for marine oil pollution (Shipboard Oil Pollution Emergency Plan). Pollution prevention strategies would also be expected to be developed and implemented in accordance with the relevant Guidance for Pollution Prevention to reduce the potential for, and the scale of any environmental impacts. This includes development and implementation of an Emergency Spill Response Plan and a Waste Management Plan.

Stage 1 - Screening Assessment

Zones of Influence

E.6. WFD water bodies were screened into this assessment using a ZoI approach and on the basis of whether they are:

- A designated WFD water body within the ZoI; or

[11] http://www.nonnativespecies.org/home/index.cfm

- A designated WFD water body indirectly affected by the ZoI (principally related to migratory fish species).

E.7. Two sets of criteria were used which identified six water bodies (Table A16).

E.8. Unplanned events, such as an accidental spill, could occur during the survey operations. Therefore, under the precautionary principal, such events are considered throughout this assessment. To avoid the accidental release of fuel and chemicals (e.g. oil) from operational vessels, best practise measures will be adopted during the survey. However, a 5 km zone of influence has been defined for the purpose of this assessment, to account for a worst-case scenario, since the volume of any spill is likely to be relatively small given its restriction to onboard fuel supplies.

E.9. Underwater sound as a result of the survey has the potential to impact migratory fish, ranging from auditory injury to behavioural responses. The fish species which are a qualifying feature of the European Sites included within this assessment are Atlantic salmon, river lamprey, and sea lamprey. Based on the thresholds set by Popper et al 2014., there is a moderate risk of significant behavioural disturbance in a medium sensitivity fish (i.e. Atlantic salmon) within hundreds of metres of the sound source, and a low risk to distances in the order of thousands of metres of the seismic sound source. The zone of influence for behavioural disturbance for medium (and low) sensitivity fish has been defined as an arbitrary, but precautionary, distance of 50 km. The waterbodies considered relevant, are only those with associated special areas of conservation (SACs), with migratory fish as a designating feature.

Table A16 Zones of Influence

Potential pathway	ZoI and basis for determination	Relevant water bodies
Changes to marine water quality from accidental leaks and spills from vessels, including loss of fuel oils	Footprint of the seismic survey area plus 5 km buffer; based on professional judgement and consideration of worst-case	Esk (W) (GB531207408400) Cumbria (GB641211630002) Duddon Sands (GB641211172000)
Underwater sound generated by seismic survey operations	Footprint of the seismic survey area plus 50 km buffer; based on professional judgement and consideration of worst-case. These waterbodies are associated with rivers that have SAC designations, where	Cumbria (GB641211630002)[12] Solway Outer South (GB641211630003)[13] Solway (GB530207614700)[14] Mersey Mouth (GB641211630001)[15]

[12] River Ehen SAC designated for the protection of Atlantic Salmon

[13] River Derwent & Brassenthwaite Lake SAC designated for the protection of Sea and River Lamprey, and Atlantic Salmon; Solway Firth SAC designated for the protection of Sea and River Lamprey; River Eden SAC designated for the protection of Sea and River Lamprey, and Atlantic Salmon.

[14] Solway Firth SAC designated for the protection of Sea and River Lamprey; River Eden SAC designated for the protection of Sea and River Lamprey, and Atlantic Salmon.

[15] Dee Estuary SAC designated for the protection of Sea and River Lamprey.

Potential pathway	ZoI and basis for determination	Relevant water bodies
	migratory fish species are listed as designating features	

E.10. Further details on the water bodies on noted in the tables below.

Esk (W)

Water body	Description, notes or more information
WFD water body name	Esk (W)
Water body ID	GB531207408400
River basin district name	North West
Water body type (estuarine or coastal)	Estuarine
Water body total area (km^2)	3.5939
Overall water body status (2016)	Good
Ecological status	Good
Chemical status	Good
Target water body status and deadline	Good, 2015
Hydromorphology status of water body	Supports Good
Heavily modified water body and for what use	No
Phytoplankton status	-

Cumbria

Water body	Description, notes or more information
WFD water body name	Cumbria
Water body ID	GB641211630002
River basin district name	North West
Water body type (estuarine or coastal)	Coastal

Water body	Description, notes or more information
Water body total area (km^2)	243.6463
Overall water body status (2016)	Good
Ecological status	Good
Chemical status	Good
Target water body status and deadline	Good, 2015
Hydromorphology status of water body	Supports Good
Heavily modified water body and for what use	No
Phytoplankton status	Good

Solway Outer South

Water body	Description, notes or more information
WFD water body name	Solway Outer South
Water body ID	GB641211630003
River basin district name	North West
Water body type (estuarine or coastal)	Coastal
Water body total area (km^2)	455.3129
Overall water body status (2016)	Moderate
Ecological status	Moderate
Chemical status	Good
Target water body status and deadline	Moderate, 2015
Hydromorphology status of water body	Supports Good
Heavily modified water body and for what use	No
Phytoplankton status	Good

Duddon Sands

Water body	Description, notes or more information
WFD water body name	Duddon Sands
Water body ID	GB641211172000
River basin district name	North West
Water body type (estuarine or coastal)	Coastal
Water body total area (km^2)	27.8614
Overall water body status (2016)	Good
Ecological status	Good
Chemical status	Good
Target water body status and deadline	Good, 2015
Hydromorphology status of water body	Not assessed
Heavily modified water body and for what use	Yes
Phytoplankton status	-

Solway

Water body	Description, notes or more information
WFD water body name	Solway
Water body ID	GB530207614700
River basin district name	Solway Tweed
Water body type (estuarine or coastal)	Estuarine
Water body total area (km^2)	305.6043
Overall water body status (2016)	Moderate
Ecological status	Moderate
Chemical status	Good

Water body	Description, notes or more information
Target water body status and deadline	Good, 2027
Hydromorphology status of water body	Supports Good
Heavily modified water body and for what use	No
Phytoplankton status	Moderate

Mersey Mouth

Water body	Description, notes or more information
WFD water body name	Mersey Mouth
Water body ID	GB641211630001
River basin district name	North West
Water body type (estuarine or coastal)	Coastal
Water body total area (km^2)	420.5156
Overall water body status (2016)	Moderate
Ecological status	Moderate
Chemical status	Good
Target water body status and deadline	Good, 2027
Hydromorphology status of water body	Not assessed
Heavily modified water body and for what use	Yes – Navigation, ports, and harbours
Phytoplankton status	Moderate

Stage 2 - Scoping Assessment

Overview

E.11. A scoping assessment is required to determine which receptors may be at risk from the survey, and therefore need to be assessed in the WFD impact assessment (Stage 3). These receptors are defined in accordance with the EA guidance (EA, 2017a) and are based on the water body’s quality elements but also includes invasive non-native species (INNS).

E.12. This section of the WFD Compliance Assessment Report is based on the approach set out by the EA (available here: https://www.gov.uk/guidance/water-framework-directive-assessment-estuarine-and-coastal-waters).

Hydromorphology

E.13. There will be no interaction between the seabed and the vessel or the seismic equipment. There is, therefore, no pathway that could result in the alteration of the physical characteristics of any waterbody.

Biology: Habitats

E.14. There will be no interaction between the seabed and the vessel or the seismic equipment. Thus, there is no pathway that could result in physical harm to benthic habitats.

Biology: Fish

E.15. Diadromous (i.e. migratory) fish species migrate between bodies of freshwater and seawater during different life phases. There are four species of migratory fish, specifically protected by designated sites in the vicinity of the survey area that are considered in this section of the impact assessment. These species are:

- Sea and river lamprey;
- Atlantic salmon; and
- Smelt.

E.16. Underwater sound has the potential to impact fish. The significance of such impact will vary dependant on distance to the sound source, pressure of the sound and the resilience and sensitivity of each species. Impacts may vary from behavioural disturbances, to physiological impacts (temporary loss of hearing, permanent loss of hearing or, in extreme cases, mortal injury or death).

Scoping result

E.17. Fish have been included in this scoping assessment because the survey is planned for inshore waters outside of Morecambe Bay, extending north to the Solway Firth. The sound generated from the survey could impact normal fish behaviour like movement, migration or spawning.

E.18. Table shows the risks to WFD status for fish that require further assessment for the water bodies noted above, based on the proposed geophysical survey.

Table A17 Characterisation of risks to fish

Risk	Requires Impact Assessment	Impact Assessment Not Required	Biology: Fish risk issue(s)
Is in an estuary and could affect fish in the estuary, outside the estuary but could delay or prevent fish entering it or could affect fish migrating through the estuary	✓		Yes - The survey area is located in nearshore waters outside of an estuary
Could impact on normal fish behaviour like movement, migration or spawning (for example creating a physical barrier, sound, chemical change or a change in depth or flow)	✓		Yes – The survey will generate underwater sound
Could cause entrainment or impingement of fish		✓	No – there is no risk of entrainment or impingement of fish as a result of the survey operations

Water quality (physico-chemical and chemical)

E.19. Impacts to ecological water quality relates to effects on any of the following: water clarity, temperature, salinity, oxygen levels, nutrients, microbial patterns for longer than a spring neap tidal cycle (approximately 14 days). In addition to the above, if the water body has a history of harmful algae or a phytoplankton status of moderate, poor or bad this will need to be considered.

E.20. The following physico-chemical quality elements are scoped out as being at risk from the Project for all waterbodies:

- Water clarity;
- Thermal conditions;
- Salinity;
- Oxygenated conditions;
- Nutrient concentrations; and
- Microbial patterns.

E.21. The above physico-chemical quality elements are not considered to be at risk of deterioration due the survey activities because the air gun array and streamers are solid objects deployed into the water column temporarily only. On this basis and in accordance the EA guidance on WFDs for estuarine and coastal waters (Environment

Agency, 2017a), the physico-chemical quality elements listed above have been scoped out from requiring consideration within the WFD impact assessment.

E.22. The following chemical quality elements are scoped out as being at risk from the project for all waterbodies within the 5 km ZOI:

- Specific pollutants;
- Priority substances; and
- Priority hazardous substances.

E.23. Oil could enter the marine environment during seismic operations as a result of accidental streamer rupture or collision with another vessel.

E.24. In the unlikely event of accidental streamer rupture, it will result in a small spill, i.e., several hundred litres of non-hydrocarbon fluids entering the environment from a streamer parting whilst deployed. In this case, the quantity of fluid spilled into the marine environment would be relatively low and because the project has committed to using streamers containing non-hydrocarbon fluid, pollution effects are minimised.

E.25. Accidental collision with another vessel and complete loss of vessel fuel would be the worst-case scenario. However, the risk of interaction or collision with another vessel in the area is considered to be low since the vessel will be moving very slowly and a Notice to Mariners will be required for the survey activities. If the spilled oil contains a high percentage of light hydrocarbon fractions, such as diesel, a large part of the spilled oil will evaporate relatively quickly. Oil spill response resources would be mobilised immediately to control the extent of the resulting slick.

<u>Scoping Result</u>

E.26. Considering the potential effects to water quality (physico-chemical and chemical) and the very low likelihood of occurrence, this receptor has been scoped out for further consideration in the WFD impact assessment (Table and

E.27. Table).

Table A18 Characterisation of risks to ecological water quality

Risk	Requires Impact Assessment	Impact Assessment Not Required	Water quality risk issue(s)
Could affect water clarity, temperature, salinity, oxygen levels, nutrients or microbial patterns continuously for longer than a spring neap tidal cycle (about 14 days)		✓	No – the survey isk not considered to affect water clarity, temperature, salinity, oxygen levels, nutrients or microbial patterns continuously for longer than a spring neap tidal cycle

Is in a water body with a phytoplankton status of moderate, poor or bad		✓	No – although Morecambe Bay has a phytoplankton status of 'poor', the seismic survey area is located 4.9 km from the waterbody. There is considered to be no realistic pathway for impact to ecological water quality due to the seismic survey operations.
Is in a water body with a history of harmful algae		✓	No – although the water body summary table indicates there is a history of harmful algae within Morecambe Bay, the survey area is located 4.9 km from the waterbody. There is considered to be no realistic pathway for impact to ecological water quality due to the survey operations.

Table A19 Characterisation of risks to chemical water quality by chemical use, release or disturbance of chemicals

If your activity uses or releases chemicals (for example through sediment disturbance or building works) consider if:	Requires Impact Assessment	Impact Assessment Not Required	Water quality risk issue(s)
The chemicals are on the Environmental Quality Standards Directive (EQSD) list		✓	Not applicable – vessel fuel (diesel) is not listed under the EQSD.
It disturbs sediment with contaminants above Cefas Action Level 1		✓	Not applicable – Project activities will not disturb the seabed

The chemicals released are on the EQSD list		✓	Not applicable – Project activities will not intentionally release any chemicals.

Protected Areas

WFD protected areas include:

- Special areas of conservation (SAC)
- Special protection areas (SPA)
- Shellfish waters
- Bathing waters
- Nutrient sensitive areas

E.28. A protected area is only scoped in for further assessment if it is located within 2 km of the survey area (as per WFD guidance online). As such only the Morecambe Bay and Duddon Estuary SPA is scoped in for assessment.

Scoping Result

E.29. Considering the potential effects to Protected Areas, this receptor has been scoped in for further consideration in the WFD impact assessment.

Table A20 Characterisation of risk

Consider if your activity is:	Requires Impact Assessment	Impact Assessment Not Required	Protected areas risk issue(s)
Within 2 km of any WFD protected area	✓		Yes - airborne sound and changes in visual stimuli because of vessel movements during the survey, may result in disturbance and displacement of protected seabirds at Solway Firth SPA, Liverpool Bay SPA and Morecambe Bay and Duddon Estuary SPA.

Invasive non-native species (INNS)

E.30. This section considers whether the survey poses any risk to the marine environment from introduction or spread of INNS.

- Risks of introducing or spreading INNS include:
- materials or equipment that have come from, had use in or travelled through other water bodies; and

- activities that help spread existing INNS, either within the immediate water body or other water bodies

E.31. Given that this is a moving survey, with no interaction with the seabed, there will be no permanent introductions (materials, installations, or equipment) to the marine environment. Furthermore, the Project has adopted appropriate avoidance measures to embed in the survey design to minimise risk when travelling through waterbodies.

Scoping Result

E.32. Considering the potential effects of INNS, this receptor has been scoped out for further consideration in the WFD impact assessment.

Table A21 Characterisation of INNS risk

Consider if your activity could:	Requires impact assessment	Impact assessment not required	INNS risk issue(s)
Introduce or spread INNS		✓	No – appropriate measures to avoid the introduction or spread of INNS have been embedded into the survey design.

Stage 3 - Impact Assessment

Biology: Fish

E.33. There are four species of migratory fish, specifically protected by designated sites in the vicinity of the survey area that are considered in this impact assessment. Sea and river lamprey, Atlantic salmon, and smelt were scoped in for further assessment in relation to potential impacts from underwater sound which will be generated during the survey.

Sea and river lamprey

E.34. There is limited information available on hearing in lamprey and no reported audiograms exist for these species. However, they lack any specialist hearing structures, have an ear that is relatively simple and have no swim bladder or anatomical structure tuned to amplify sound signal. This means lamprey are generally considered to be sensitive only to sound particle motion within a narrow band of frequencies (Popper & Hawkins, 2019). Therefore, it is usually considered that behavioural or physiological effects from underwater sound on lamprey are not likely to occur, unless animals are very close to a powerful noise source (Popper, 2005); (Popper & Hastings, 2009).

E.35. Underwater sound propagation modelling has been undertaken specifically for the Project, the results of which have been presented in the HRA (**Appendix A: Detailed Marine Environmental Risk Assessment**).

E.36. The project is adopting the JNCC measures for the protection of marine mammals, and as the vessel is constantly moving, sound intensity experienced by individual fish will only ever build gradually, significantly minimising the risk of harm. Thus, it is considered that mortal or recoverable physical injury is highly unlikely to occur.

E.37. Considering the sound intensity some behavioural responses are assumed possible but significant responses are only expected in close proximity to the sound source. The survey is in open water and there is therefore, no barrier to moving away from the potential effect risk zones. There is also no indication the survey area is particularly important for foraging or other behaviours and thus the energetic cost of any necessary avoidance is expected to be minimal and have little potential to affect the long-term survival of lamprey individuals or populations.

E.38. Lamprey migration in the rivers in this region of the UK is reported to occur in late spring and early summer for upstream migration and October to March for the downstream return of juveniles to the estuary. The mouth of the nearest river where lamprey will congregate for migration, the River Derwent, is over 9 km away. There is therefore no spatial or temporal interaction between migration periods and the Copeland in

E.39. shore survey. There was no information found on the distribution of sea lamprey outside these migratory periods, but they attach to a host animal (often another fish) and so are expected to be found in open marine water in low numbers only (the numbers reported in migratory areas, where densities are highest, are low).

E.40. The survey is short-term and thus any disturbance will be short-term and due to the timing and location of the survey, and with the protective features of the standard JNCC mitigation, there is no real route to affect sensitive migratory stages and behaviour in lamprey species. Therefore, it is considered that there are no grounds to anticipate an adverse effect on lamprey species as fish quality features, resulting from the survey. The impact is assessed as **not significant.**

Atlantic Salmon and Smelt

E.41. Atlantic salmon and smelt are both migratory species considered to have medium hearing sensitivity. They have a swim bladder, but hearing is separate from it or any other gas filled chamber indicating hearing is by particle motion, not sound pressure. However, physical injury effects from underwater sound are most pronounced in fish with a swim bladder because the organ is unable to adapt quickly enough to the high intensity seismic pressure waves. For example, impulsive sounds from pile driving can cause mild to lethal injuries such as swim bladder rupture, hematoma and haemorrhaging (Paxton et al., (2017) and references therein).

E.42. Underwater sound propagation modelling for the project, which took account of the movement of the vessel, and a conservative estimate of the movement of an individual fish (even for an individual close to the vessel), indicates that injury thresholds are not exceeded.

E.43. Considering the soft-start procedures adopted for the survey and the fact that migratory fish in the survey area are pelagic in nature and that the survey takes place in open nearshore waters so fish can easily move away. Thus, fish are not expected to remain within close proximity of the vessel during the survey such that behavioural responses reduce the potential for injurious levels of sound to be experienced, and therefore the injury risk is considered to be very low.

E.44. There are a number of salmon rivers in Cumbria but those of greatest importance are the River Derwent (9 km), River Ehen (5 km), and River Eden (41 km), all of which are protected by an SAC designation. Salmon spawning times are reported to be November/December and thus, a higher number of fish could be in the nearshore and estuarine areas around the key migratory rivers in October for salmon and late winter for smelt. With a survey window of July to August the survey will not be taking place at the key stages described above and whilst the sound from the survey may disturb any individuals in open water the risk is very low because of the very low density of fish present. Thus, there is **no pathway for significant impact** on salmon as a fish quality feature.

E.45. Smelt are protected by three MCZ's in the region – the Solway Firth MCZ (35 km), the Ribble Estuary MCZ (33 km) and the Wyre Lune MCZ (13 km). These sites are a distance beyond the point at which any injury or significant behavioural response is expected to occur because of seismic sound.

E.46. The spawning period for smelt is reported to be in early spring and thus, there is not anticipated to be any overlap with the survey window. However, smelt are reported to remain in shallow nearshore waters outside the spawning period (pers. comm. NE) but even allowing for a higher density of animals in nearshore waters around Wyre Lune MCZ, the distance from the nearshore area to the survey area is beyond the point at which significant behavioural response would occur. Thus, it is predicted that **no significant impact** on individual smelt or the population as the WFD fish quality feature or designating feature of the MCZ, will occur. Based on the distance and timing, the confidence in this assessment is high.

Protected Areas

E.47. Three SPAs were scoped in for assessment due to their proximity to the seismic survey area:

- Solway Firth SPA
- Liverpool Bay SPA
- Morecambe Bay and Duddon Estuary SPA
-

E.48. The HRA assessment concluded that there will be no LSE on the designated sites or their qualifying features. As such there will be no impact on compliance with WFD requirements either.

WFD assessment conclusions

E.49. The WFD assessment indicates that, based on the evidence and other assessments in this report, the survey will not result in significant effects to any identified WFD receptor (i.e. hydromorphology, water quality, habitats, invertebrates and fish). As a result of this, it is also considered that the survey does not present a risk to any of the qualifying features for which the SPAs that fall within 2 km of the of the survey area, are designated.

Appendix B: Designated Sites Scoping Matrix

Table B1. Designated Sites Identified for consideration of impact pathway interactions (dark green = major impact pathway, light green = potential minor pathway)

Site name	Designation	Designating features	Distance to survey area (km)	Airborne sound and visual disturbance	Underwater sound disturbance	Collison risk	Scoping Outcome
Solway Firth	SPA	Wintering birds including divers, sea ducks and seabirds	11.6			x	SCOPED IN
Upper Solway Flats and Marshes	SSSI	Birds and intertidal habitats. All features covered by Solway Firth SAC and Solway Firth SPA	42.4			x	SCOPED IN
Liverpool Bay	SPA	Wintering birds including divers, sea ducks, seabirds and breeding terns	0.6			x	SCOPED IN
Morecambe Bay and Duddon Estuary	SPA	Wintering/passage birds and breeding terns and gulls	0				SCOPED IN
Morecambe Bay	SAC	Intertidal habitats including dunes	3.2	x	x	x	SCOPED OUT
Morecambe Bay	SSSI	Birds and intertidal habitats. All features covered by Morecambe Bay and Duddon Estuary SPA and Morecambe Bay SAC	10.0			x	SCOPED IN
Duddon Estuary	SSSI	All features covered by Morecambe Bay and Duddon Estuary SPA and Morecambe Bay SAC	3.2			x	SCOPED IN
Solway Firth	SAC	Lamprey and intertidal habitats, Estuaries	42.2	x		x	SCOPED IN
Drigg Coast	SAC/ SSSI	Intertidal habitats including dunes and saltmarsh habitats	2.3	x	x	x	SCOPED OUT
South Walney and Piel Channel Flats	SSSI	Intertidal habitats and supporting habitats for birds covered by Morecambe Bay and Duddon Estuary SPA	5.0			x	SCOPED IN
Dee Estuary	SAC	Intertidal habitats and lamprey (not primary feature)	64.4	x		x	SCOPED IN
River Eden	SAC	Atlantic salmon, sea and river lamprey	41.3	x		x	SCOPED IN
River Ehen	SAC	Atlantic salmon	20.7	x		x	SCOPED IN
St Bees Head	SSSI	Breeding razorbill	7.3			x	SCOPED IN
River Derwent and Bassenthwaite Lake	SAC	Atlantic salmon, sea and river lamprey	11.7	x		x	SCOPED IN
Solway Firth	MCZ		55.1				SCOPED IN
Cumbria Coast (Zones 1 and 2)	MCZ	Razorbill on sea surface during breeding period	1.9				SCOPED IN
West of Walney	MCZ	Subtidal sand and subtidal mud and sea-pen and burrowing megafauna communities	0	x	x	x	SCOPED OUT
West of Copeland	MCZ	Subtidal habitats (sand, coarse and mixed sediments)	1.1	x	x	x	SCOPED OUT

Allonby Bay	MCZ	Intertidal and subtidal habitats including mussel beds and intertidal biogenic reefs	35.4	x	x	x	SCOPED OUT
Wyre-Lune	MCZ	Smelt (Osmerus eperlanus)	18.8	x		x	SCOPED IN
Upper Solway Flats and Marshes	SSSI	All features covered by Solway Firth SAC and SPA	42.4			x	SCOPED IN
South Walney and Piel Channel Flats	SSSI	All features covered by Morecambe Bay SPA/Ramsar	5.0			x	SCOPED IN
North Channel	SAC	Harbour porpoise	62.5	x			SCOPED IN
North Anglesey Marine	SAC	Harbour porpoise	63.4	x			SCOPED IN
Fylde	MCZ	Subtidal habitats	16.2	x	x	x	SCOPED OUT
Ribble Estuary	MCZ	Smelt	38.1	x		x	SCOPED IN
South Rigg	MCZ	Subtidal seabed habitats	62.4	x	x	x	SCOPED OUT
Queenie Corner	MCZ	Subtidal mud and Sea-pen and burrowing megafauna communities.	90.8	x	x	x	SCOPED OUT
Luce Bay & Sands	SAC	Intertidal mudflats, dunes	45.6	x	x	x	SCOPED OUT
Shell Flat and Lune Deep	SAC	Intertidal sand banks subtidal	12.2	x	x	x	SCOPED OUT
Ribble and Alt Estuaries	SPA	Breeding terns	30.8	x	x	x	SCOPED OUT

Appendix C: Figures

Designated Sites

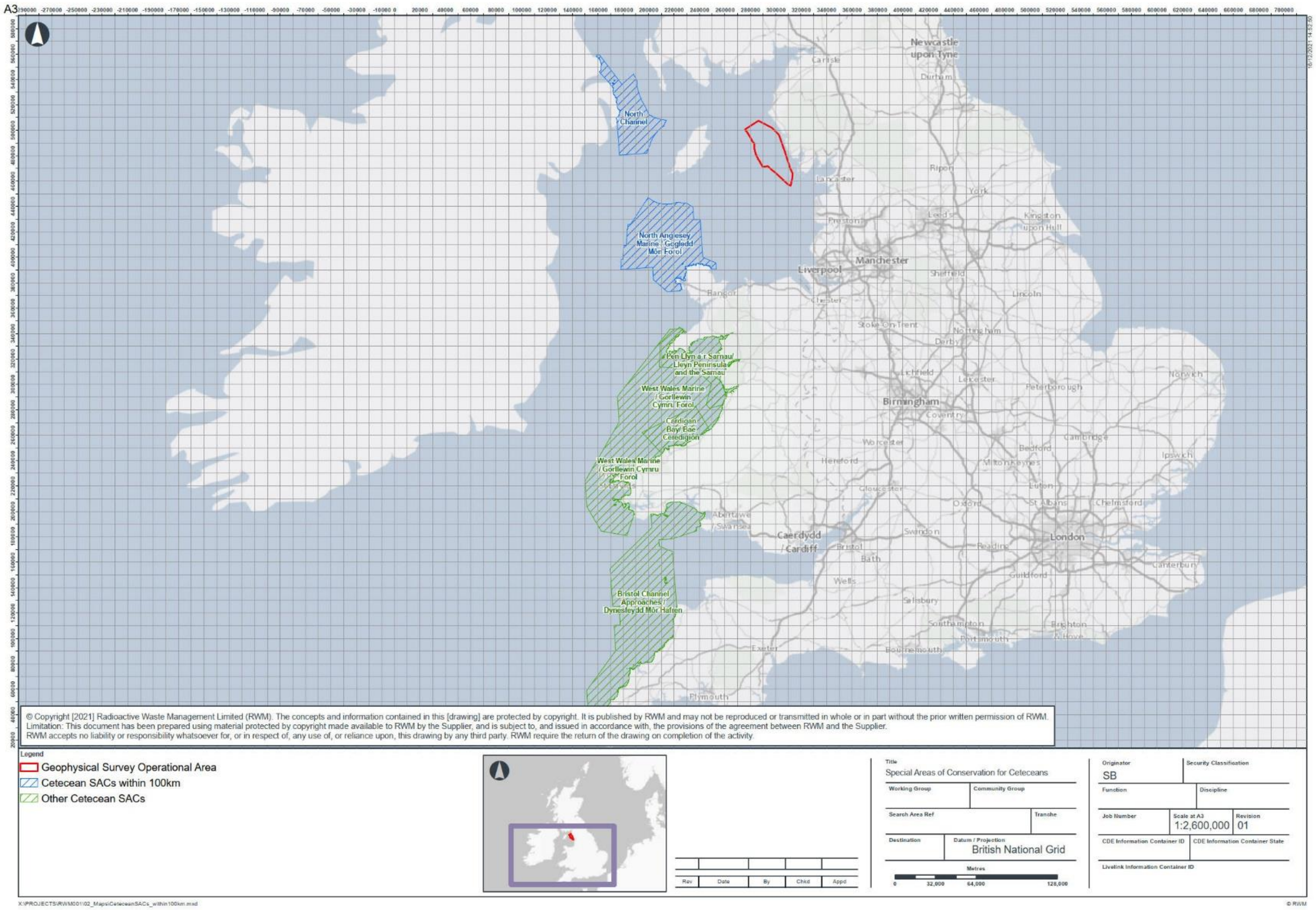

Figure C26. Special Areas of Conservation (SACs) for which cetaceans are a qualifying feature

The sites highlighted blue are those that have been scoped in/screened in for further assessment

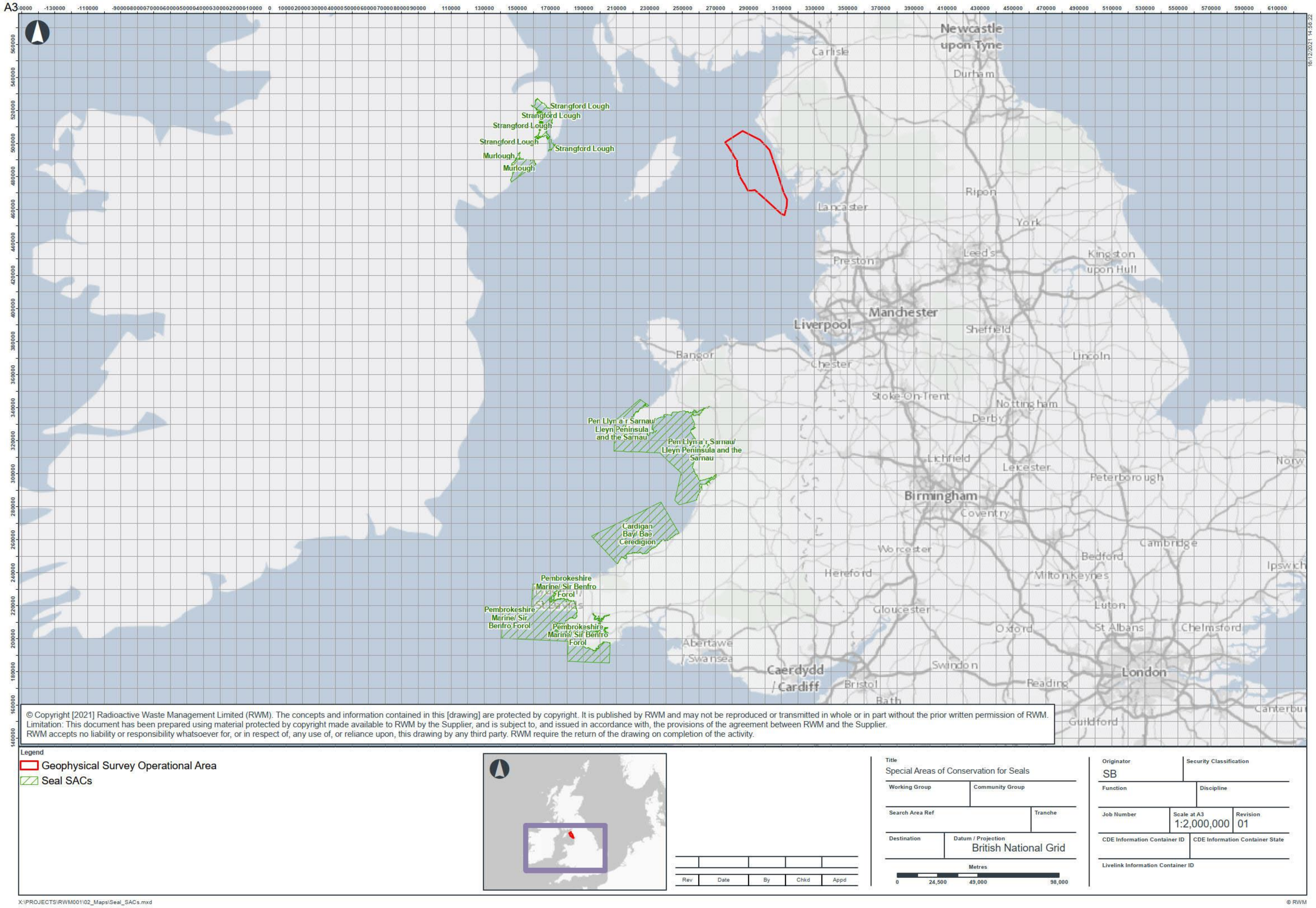

Figure C27. Special Areas of Conservation (SACs) for which pinnipeds are a qualifying feature

The sites highlighted blue are those that have been scoped in/screened in for further assessment

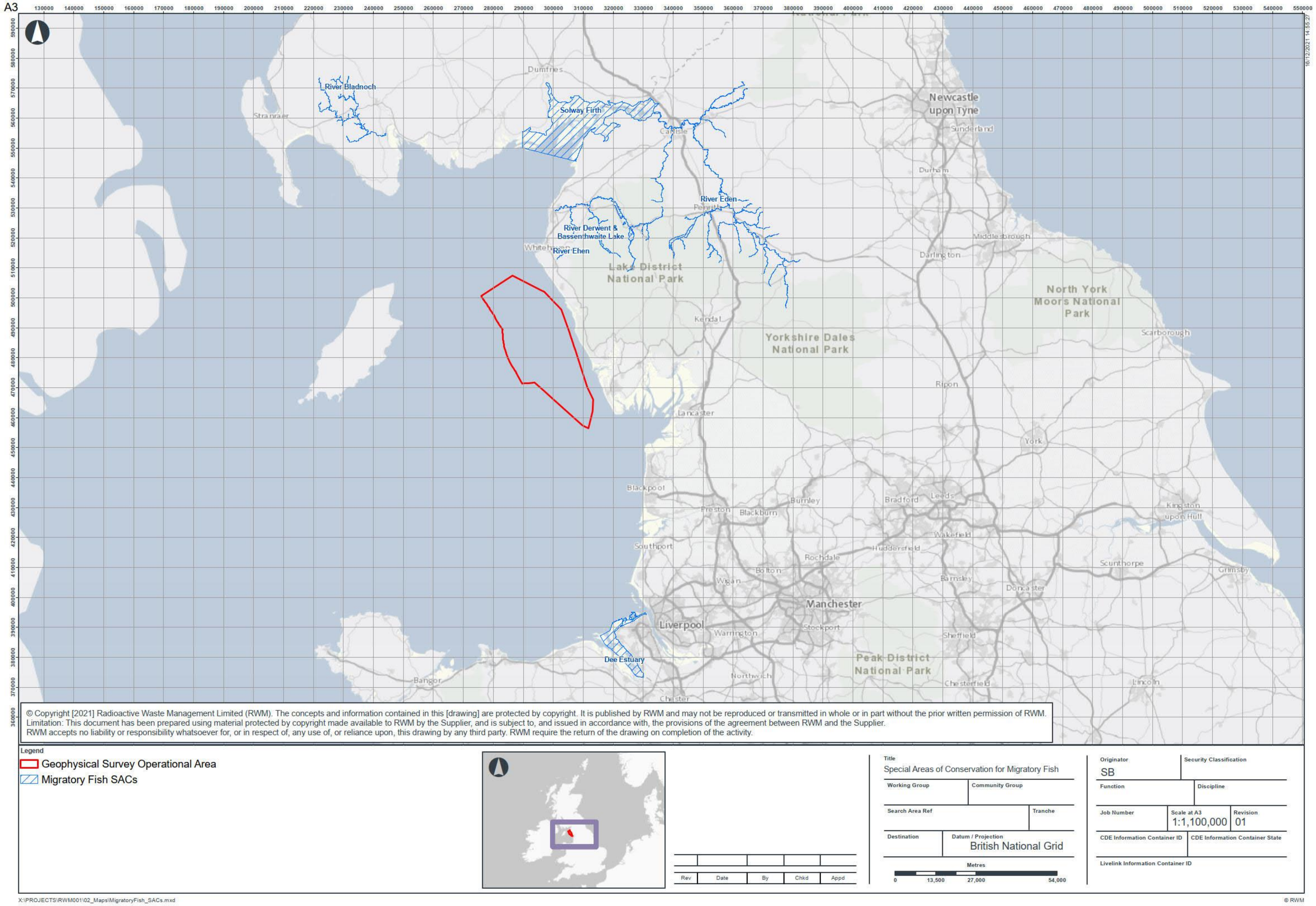

Figure C28. Special Areas of Conservation (SACs) for which migratory fish are a qualifying feature

The sites highlighted blue are those that have been scoped in/screened in for further assessment

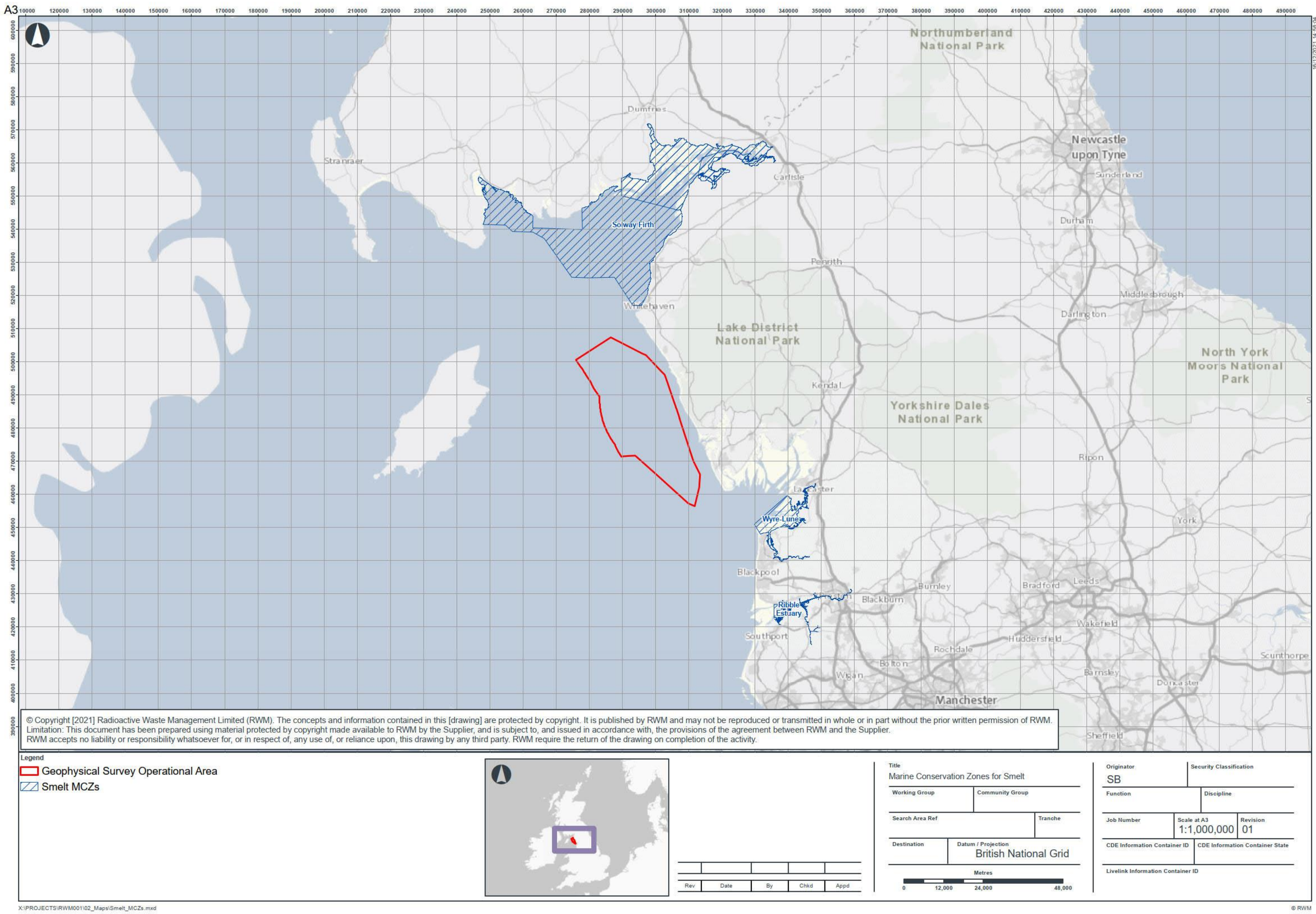

Figure C29. Marine Conservation Zones (MCZs) which are designated for the protection of smelt (Osmerus eperlanus)

The sites highlighted blue are those that have been scoped in/screened in for further assessment

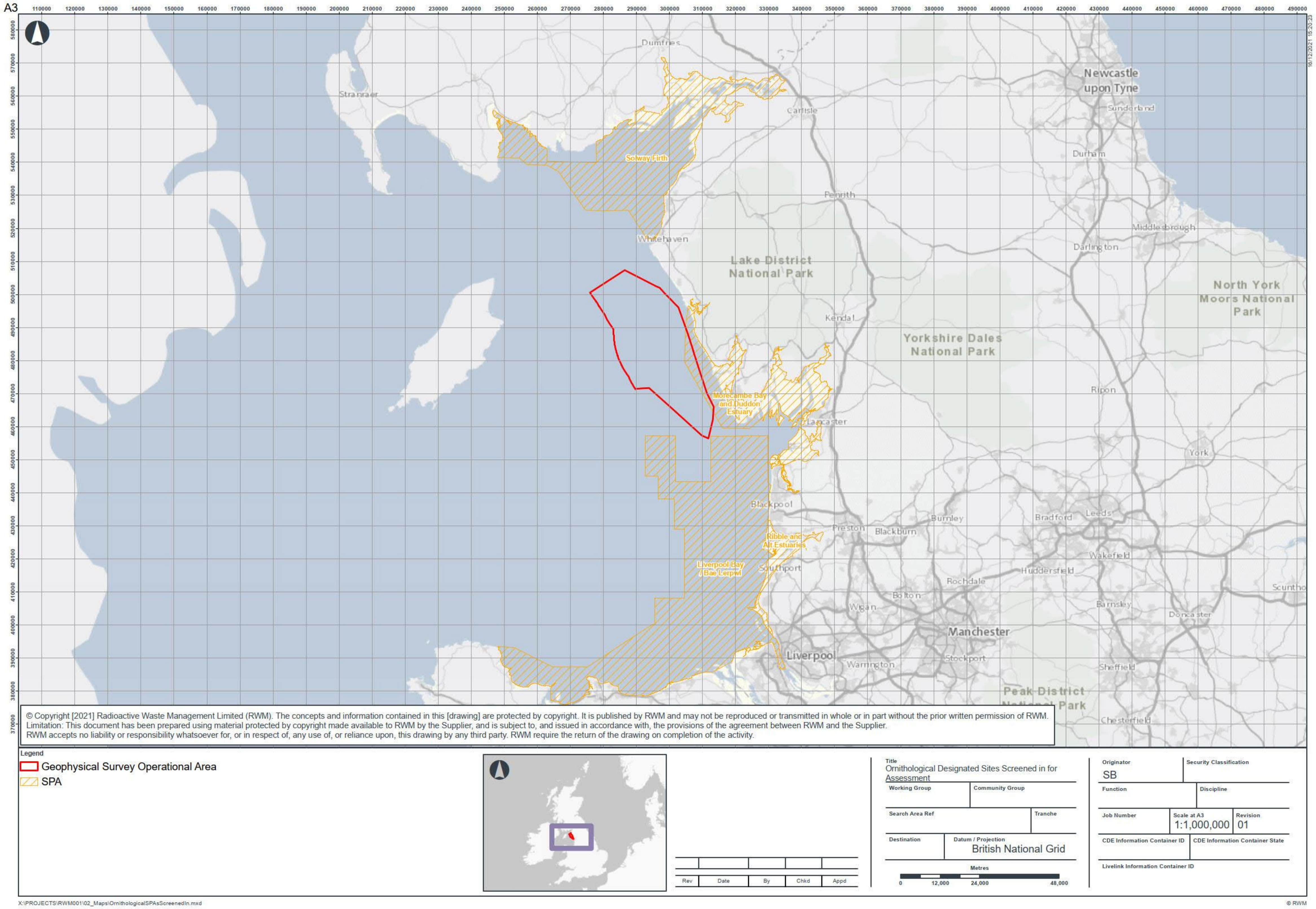

Figure C30. Special Protected Areas (SPAs) scoped in/screened in for further assessment

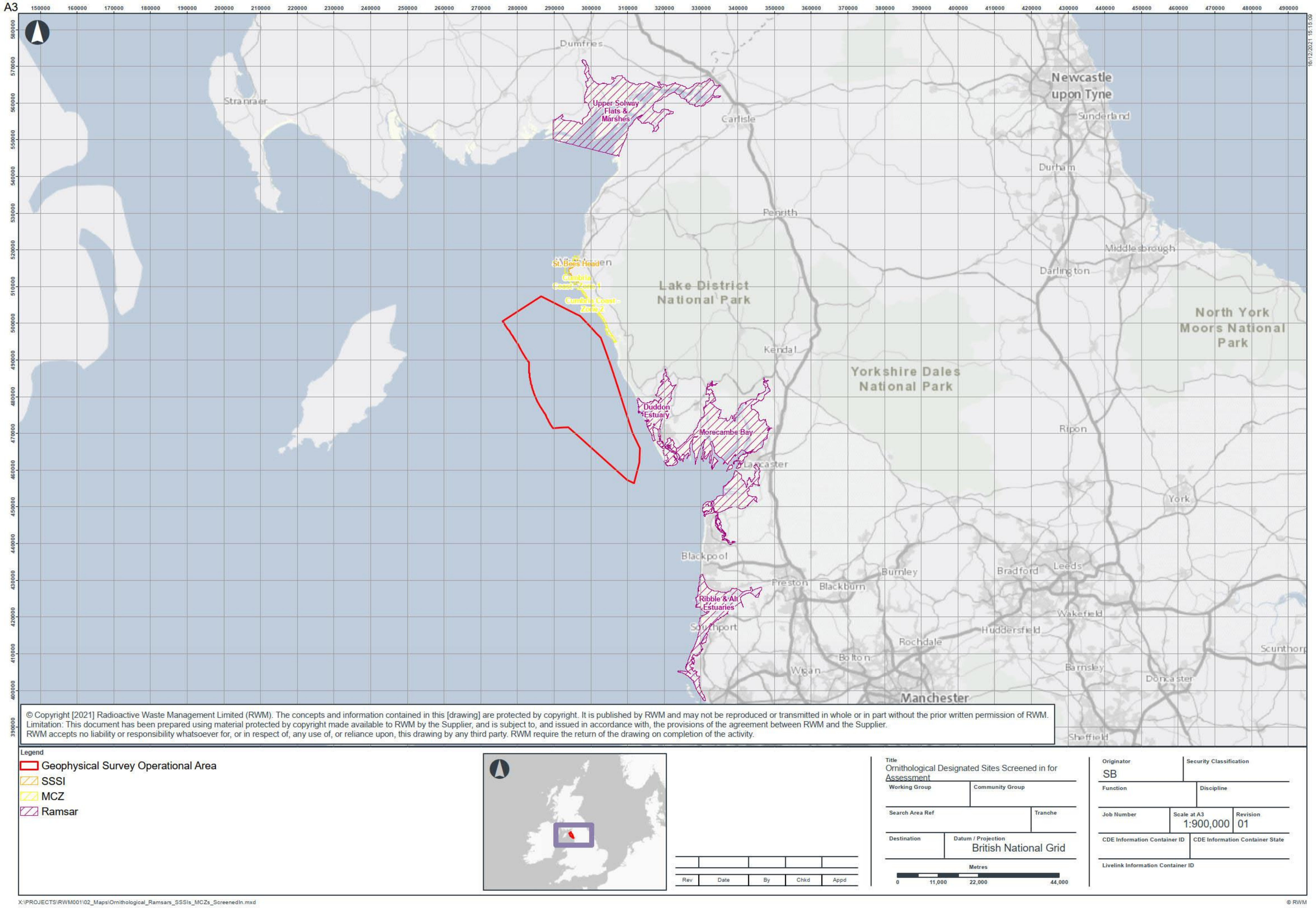

Figure C31. Ornithological Ramsar sites, SSSIs, and MCZs scoped in/screened in for further assessment

Grey Seal Haul-Out Sites

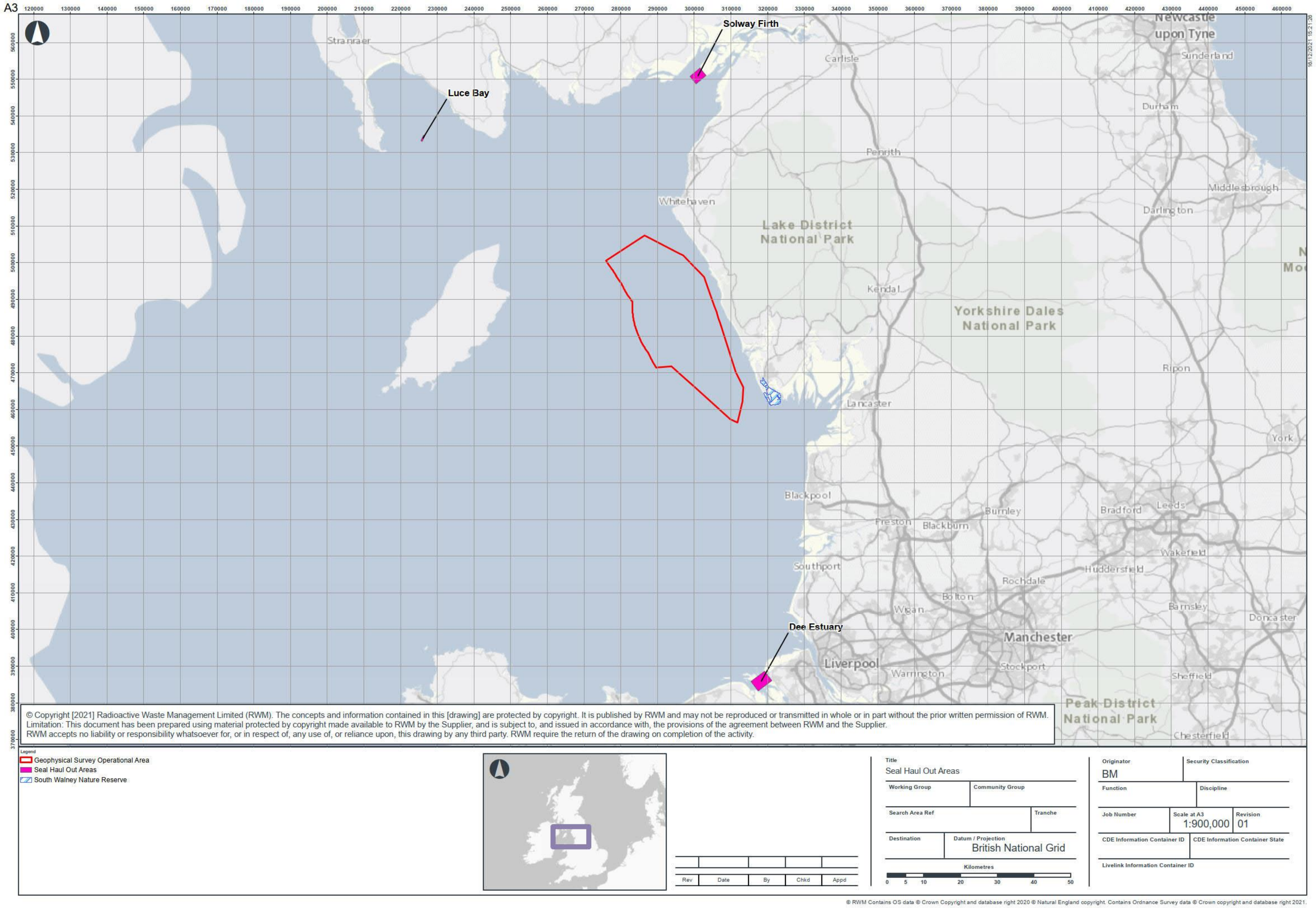

Figure C32. Grey seal (Halichoerus grypus) haul-out sites in proximity to the seismic survey

Fish Nursery and Spawning Grounds

The data from the below figures came from the following sources: Ellis et al. (2012) and Coull et al. (1998). The data from these sources is ‘public data – no limitations to reuse’.

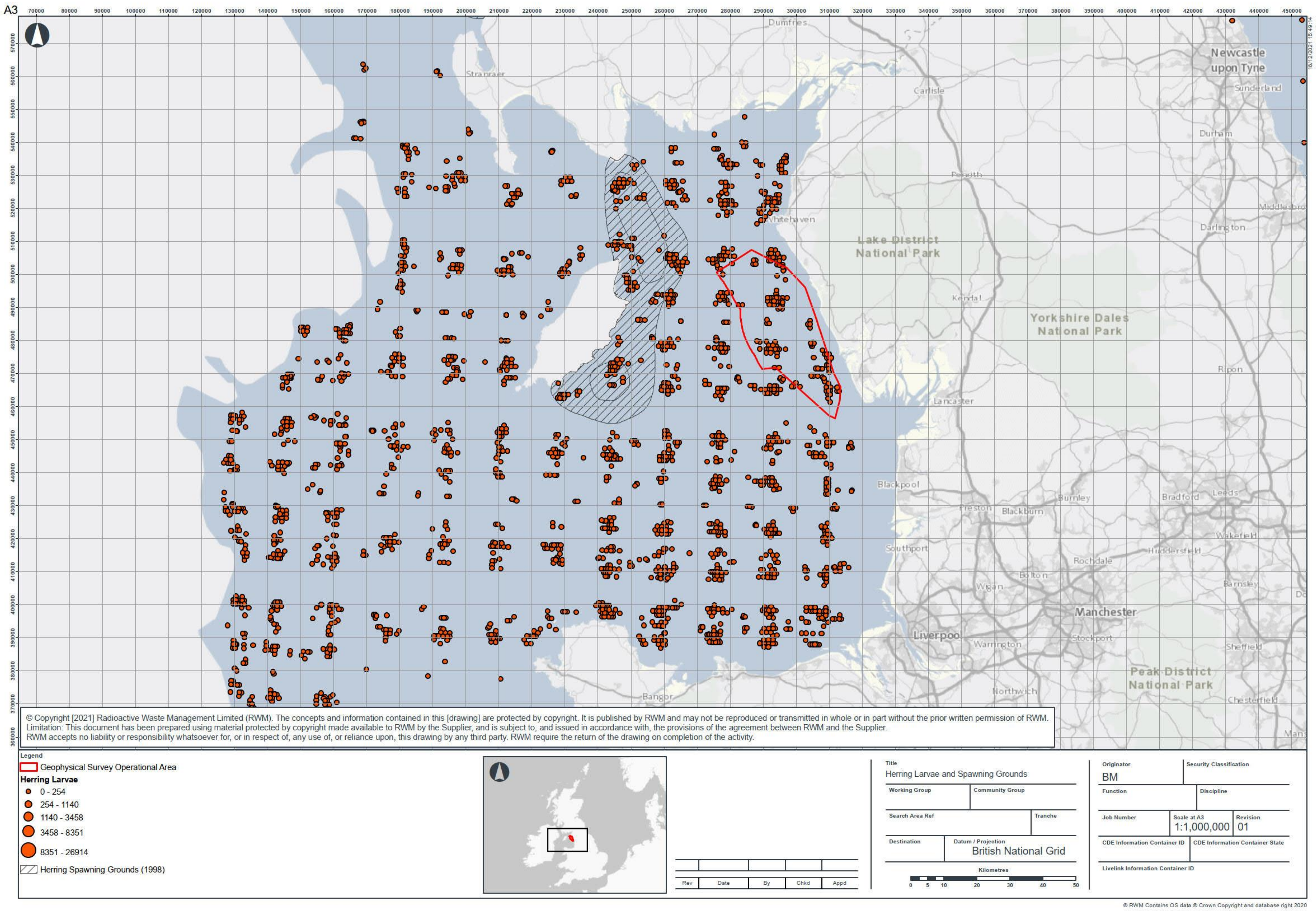

Figure C33. Herring (Clupea harengus) spawning grounds

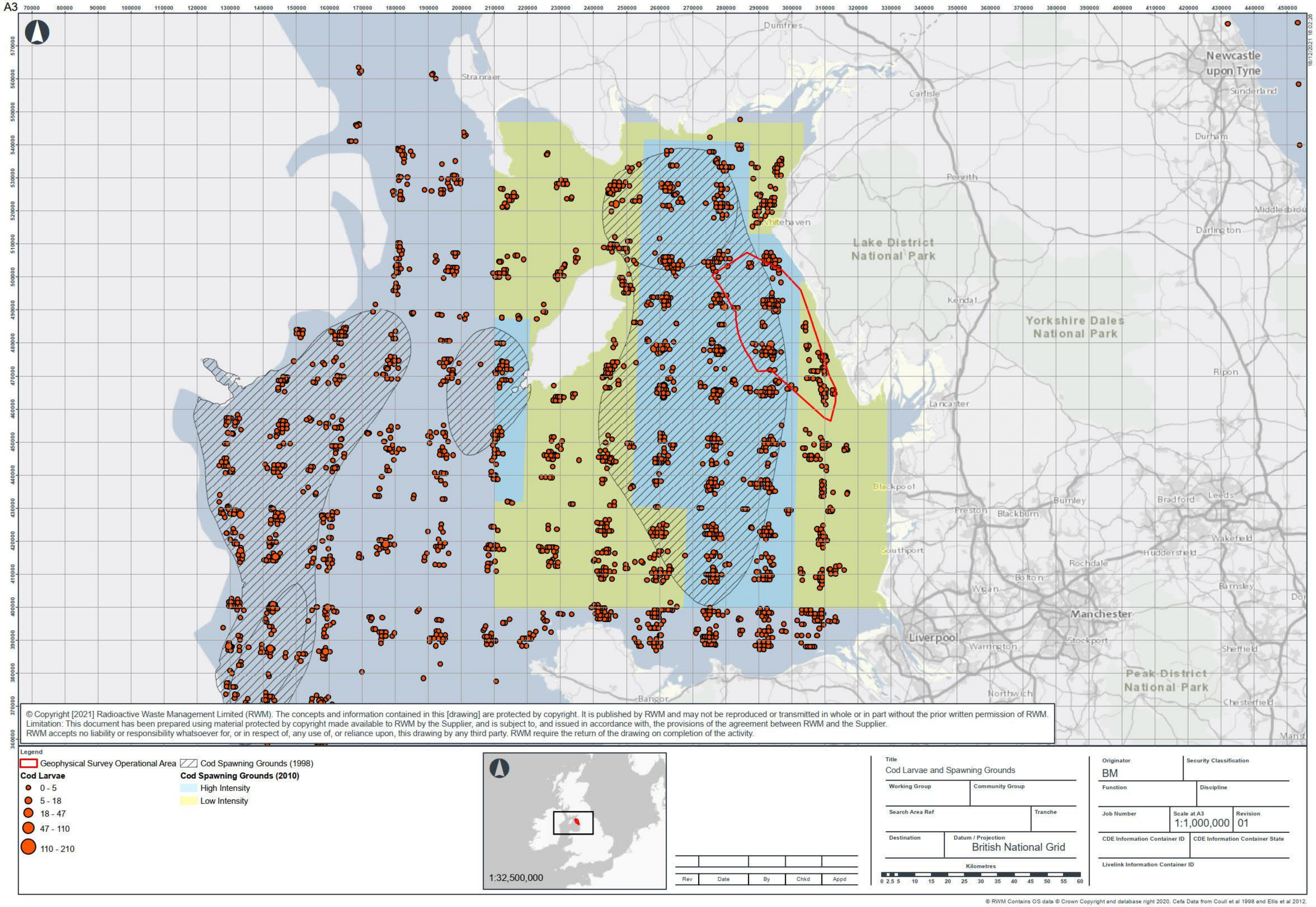

Figure C34. Cod (Gadus morhua) spawning grounds

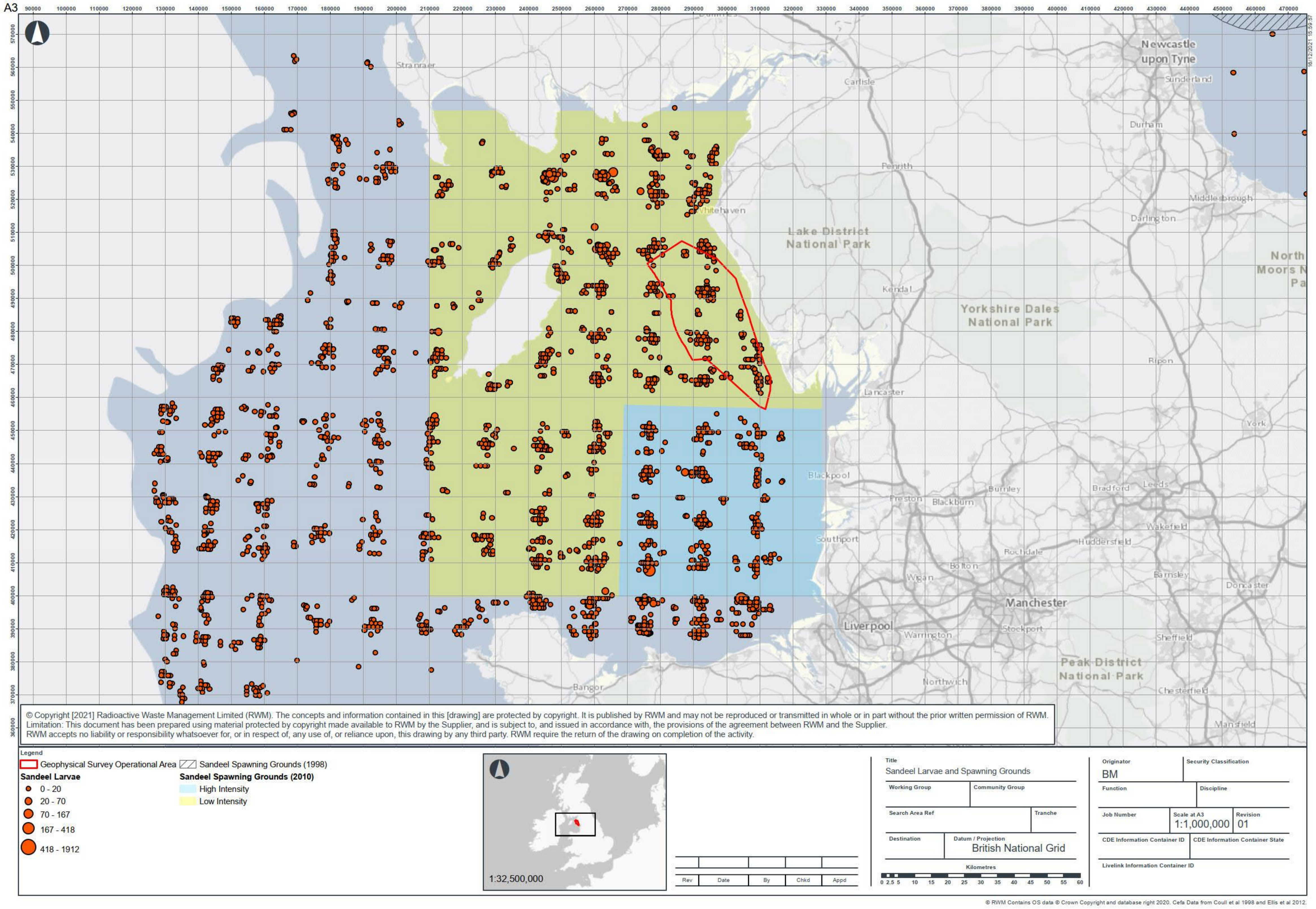

Figure C35. Sandeel (Ammodytidae) spawning grounds

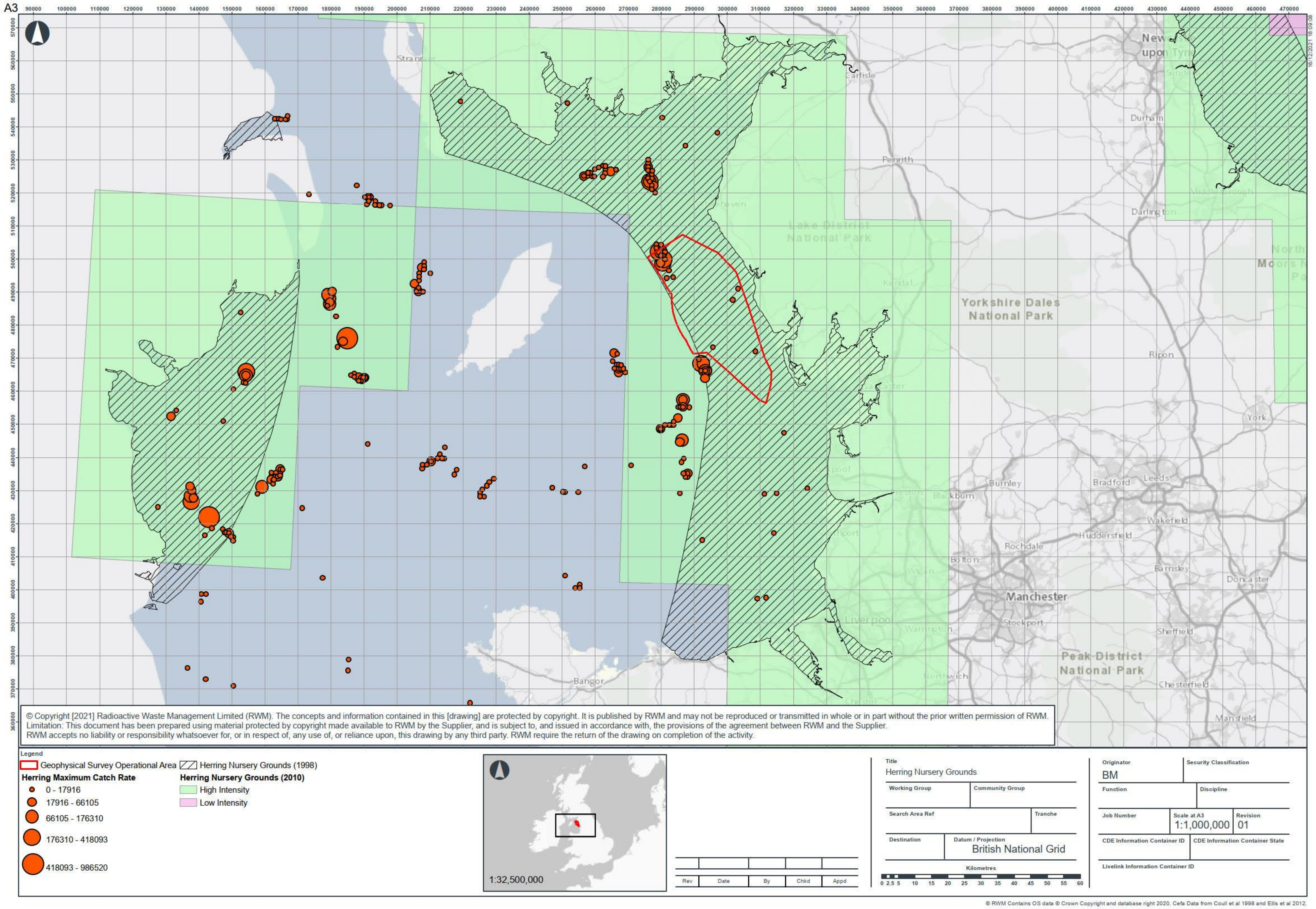

Figure C36. Herring (Clupea harengus) nursery grounds

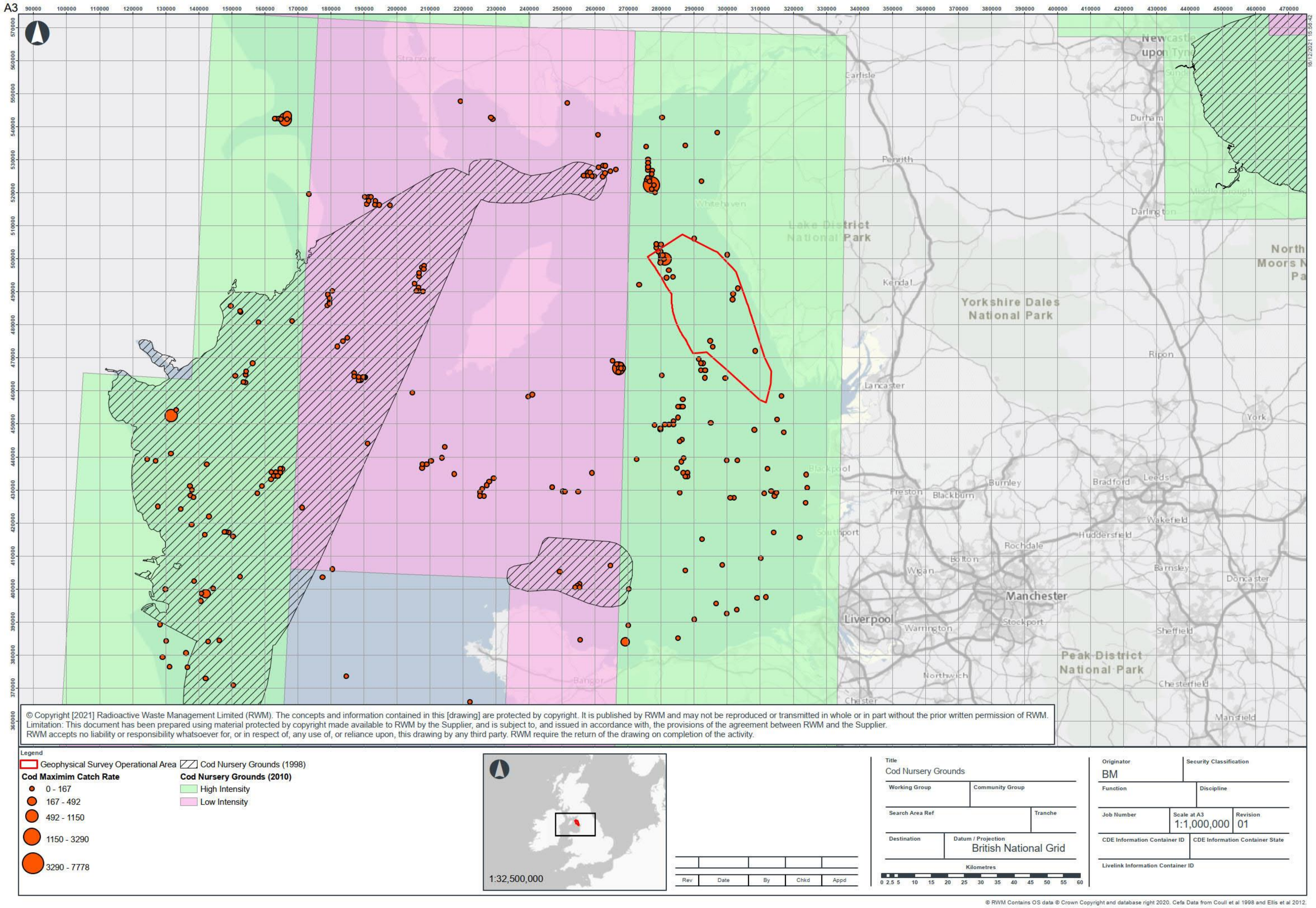

Figure C37. Cod (Gadus morhua) nursery grounds

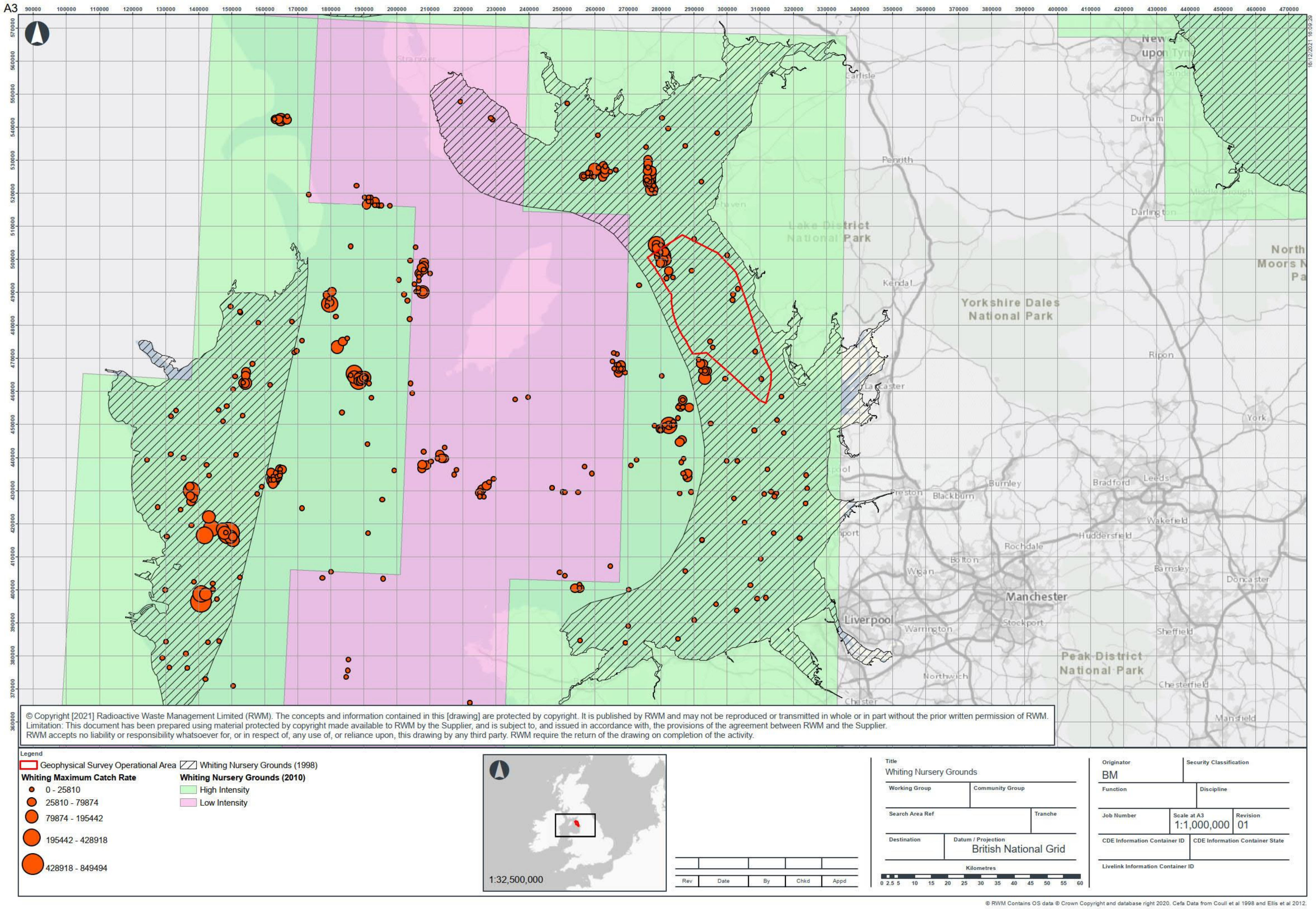

Figure C38. Whiting (Merlangius merlangus) nursery grounds

Vessel Density Grids

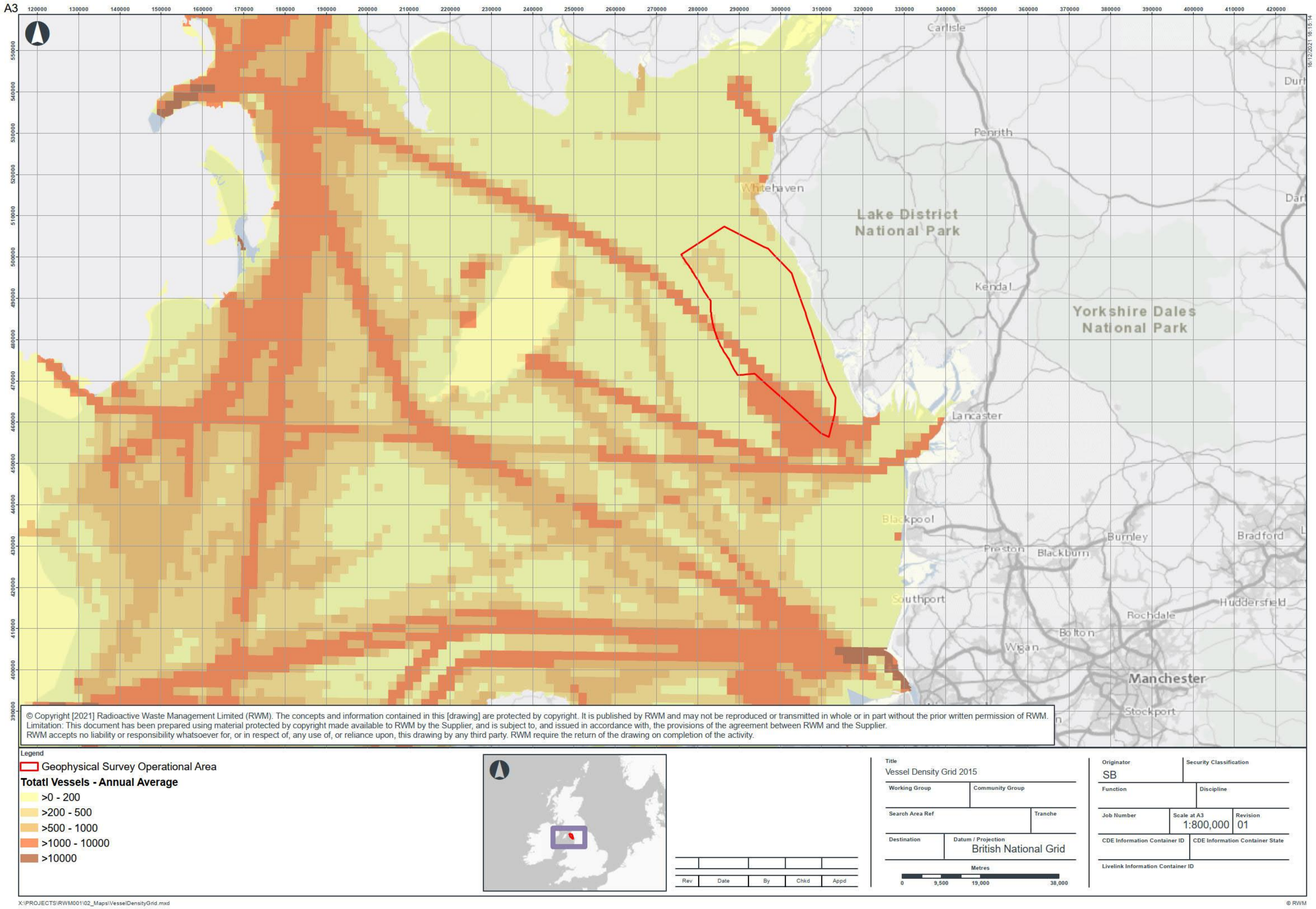

Figure C39. Vessel Density Grids from 2015 (Source: MMO, 2017)16

[16] The data reproduced in this figure is publicly available data under an Open Government Licence: https://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/

Seabed Characteristics

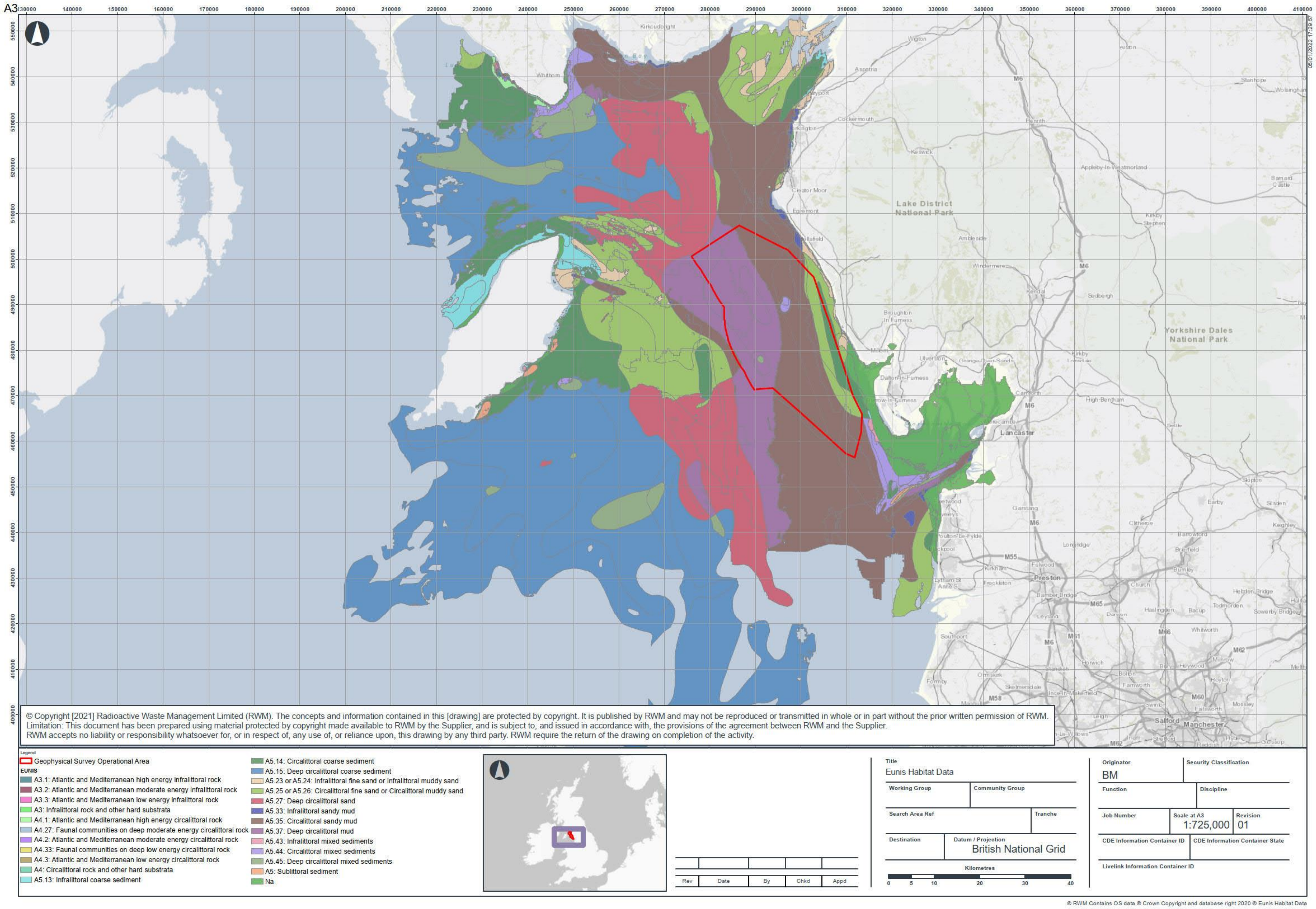

Figure C40. EUNIS Habitat Data (Source: EModNet, 2021)

Appendix D: Underwater sound supporting information

Contents

1. Overview

1.1. The following sections provide a high level summary of underwater sound modelling including assessment criteria and result tables that were used to drive the environmental assessment identifying any potential impacts of underwater sound from a geophysical survey. These are taken from a UWS full report produced as part of the environmental assessment.

2. Marine fauna and acoustic impact thresholds

2.1. Thresholds were identified for a range of marine animals relevant to the Copeland area which were then used to estimate impact zones around the survey area based on the results from underwater sound propagation modelling.

Acoustic impact thresholds

2.2. The derivation of appropriate threshold levels of noise on marine life exposed to impulsive type noise draws on the methodologies developed by the US National Marine Fisheries Service for cetaceans and pinnipeds (NMFS, 2018) and Popper *et al*. (2014) for fish and sea turtles. An overview of the salient points is given below.

Marine mammals

<u>Physiological impacts</u>

2.3. The NMFS report (NMFS, 2018) assigned marine mammals to functional hearing groups (FHG) where each group depended on differences and similarities in the animal's audiological physiology and behavioural psychophysics. In addition, cetaceans were further subdivided based on their hearing sensitivity. The latest hearing group classification (NFMA, 2018) for species relevant to the Copeland inshore survey area is given in Table D16.

Table D16: Functional hearing groups for marine mammal species known or likely to be present within the vicinity of the survey area

Functional hearing group	Representative species found in the Copeland inshore area
Low-frequency cetaceans (LF)	Baleen whales *e.g.*, minke, fin, humpback
Mid-frequency cetaceans (MF)	Toothed whales and dolphins *e.g.*, common, bottlenose, white-beaked and Risso's dolphins
High-frequency cetaceans (HF)	True porpoises *e.g.*, Harbour porpoise
Phocid pinnipeds (PW)	Harbour seal, grey seal

2.4. As marine mammals do not hear equally well across all frequencies, a series of frequency-dependent weightings were derived from the hearing sensitivity curves for animals in each FHG (NFMS, 2018). These have the effect of emphasising the frequencies over which the animals are most sensitive. Frequency-weighting curves (collectively known as M-weightings) are shown in Figure D41 for each relevant FHG. The M-weightings curves were used to modify the frequency spectrum of the impacting noise so that it more closely represents the noise as perceived by the target species. From these data, weighting values were extracted for each FHG and applied to the frequency band levels for the geophysical survey sound source.

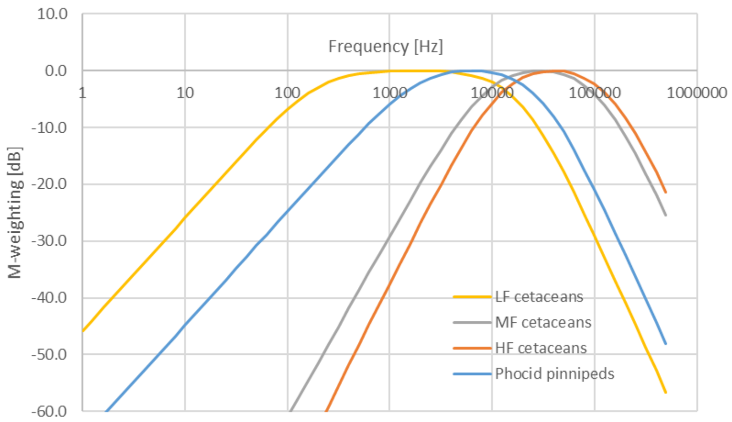

Figure D41: M-weighting curves for low-, medium- and high-frequency cetaceans and for pinnipeds

2.5. The technique demonstrated by Houser *et al*, 2017 was used to determine the apparent source levels perceived by each of the FHGs to be used for reference purposes only. These were applied the M-weight curves. As shown in Table D17 LF cetaceans will be the most sensitive with HF cetaceans being the least sensitive.

2.6.

Table D17: Apparent source levels perceived by each marine mammal functional hearing group

Functional hearing group	Acoustic array far-field source level dBPeak re 1 μPa
Unweighted source level	252.0
Low-frequency cetaceans (LF)	246.6
Mid-frequency cetaceans (MF)	205.9
High-frequency cetaceans (HF)	197.1
Phocid pinnipeds (PW)	233.4

2.7. The NMFS 2018, report proposed threshold levels representing the onset of permanent threshold shift (PTS) for marine mammals. These were based on the onset of temporary threshold shift (TTS)) which were expressed in terms of SPL and SEL[1]. The resulting impact thresholds for both PTS and TTS are given in Table D18.

[1] SPL and SEL metrics are used when looking at impulsive type noises. SEL, takes note not only of the period of time over which the receptor is exposed but also the sensitivity of the animal to the impacting sound

Table D18: Summary of acoustic impact threshold criteria for PTS and TTS for each functional hearing group when exposed to impulsive noise, using the NMFS 2018 thresholds

Functional hearing group	Unweighted SPL thresholds dB re 1 µPa Peak		M-weighted SEL thresholds dB re 1 µPa^2 s	
	PTS	TTS	PTS	TTS
Low-frequency cetaceans (LF)	219	213	183	168
Mid-frequency cetaceans (MF)	230	224	185	170
High-frequency cetaceans (HF)	202	196	155	140
Phocid pinnipeds (PW)	218	212	185	170

Behavioural impacts

2.8. For identifying thresholds for behavioural effects Southall et al. 2007 noted that responses by marine animals varied according to the sound level, frequency and duration of the noise. Although due to limited available data, there was a lack of clarity in the relationship and therefore behavioural response.

2.9. To address this uncertainty, guidance given by the US NMFS (NMFS, 2005) was used where it considers that the threshold likely to cause "behavioral disruption for impulsive sounds [Level B harassment] is 160 dB re 1 µPa (rms)"[2]. NMFS regards a Level B harassment as a response that occurs "to a point where such behavioral patterns are abandoned or significantly altered. As such for this assessment, a threshold level of 160 dB re 1 mPa (rms)[3] is proposed as representing a noise which results in the onset of a strong behavioural reaction in marine mammals when exposed to geophysical survey airgun array noise. Additional thresholds at 180 dB re 1 mPa (rms) and 140 dB re 1 mPa (rms) are included for comparison.

Fish and sea turtles

Physiological impacts

2.10. Popper *et al*. 2014 conducted a similar process for fish as Southall *et al*. 2007. Popper and Hawkins, 2019 updated this work and set out six FHGs shown in

2.11. Table D19. Thresholds for these groupds are shown in Table D5.

2.12. In identifying acoustic thresholds at which various impacts might occur, Popper *et al*. 2014 described impacts were described in terms of:

- Mortality and Potential Mortal Injury.
- Recoverable Injury.
- Temporary hearing damage (TTS).
- Masking (e.g. man made sound louder than natural sounds).
- Behavioural effects.

[2] Level B Harassment is defined as having the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild.
[3] https://www.westcoast.fisheries.noaa.gov/protected_species/marine_mammals/threshold_guidance.html

Table D19: Fish and sea turtle hearing groupsError! Bookmark not defined.

Functional hearing group	Description	Characteristics
Group 1	Fish with no swim bladder or gas chamber	These are relatively unsusceptible to barotrauma[4] and are sensitive only to particle motion rather than sound pressure[5] . This class includes flatfish, sharks and rays.
Group 2	Fish with swim bladders in which hearing does not involve the swim bladder	Although fish in this class have a swim bladder and thus the organ is able to respond to sound pressure, the swim bladder is not connected to the inner ear hence the hearing ability of fish depends only on particle motion. Fish in this class are relatively sensitive to only a narrow range of frequencies.
Group 3	Fishes with swim bladders that are close, but not intimately connected, to the ear	Fish in this class are sensitive to both particle motion and sound pressure. They are sensitive to a wider range of frequencies compared with Groups 1 and 2. This group includes members of the Gadidae, Anguillidae and Sciaenidae families.
Group 4	Fish where hearing involves a swim bladder	Fish in this class have a connection between the swim bladder and the inner ear and are sensitive to both particle velocity and sound pressure. Species in this class are sensitive to sounds over a wide frequency range (~several kHz) and have a higher sensitivity than fish in the preceding groups. The group includes members of the Holocentridae, Sciaenidae, Clupeidae families and the large group of otophysan fishes.
Group 5	Fish eggs and larvae	Studies show that the hearing abilities are similar to those of the adult of the species. Swim bladders may develop during the larval stage hence those species are particularly sensitive to barotrauma. Popper *et al*.Error! Bookmark not defined. shows that there is very little data on the effects of sound or vibration on fish eggs.
Group 6	Sea turtles	There is relatively limited data on sea turtle hearing therefore the area is poorly understood. Studies of the auditory physiology of sea turtles indicate that the ear structure is closer to that found in reptiles than sea mammals but that they are adapted to detect sound pressure changes underwater. Popper *et al*. Error! Bookmark not defined. maintains that until more data become available, fish hearing, rather than mammalian hearing, is the better model to use for sea turtles.

2.13. Threshold levels representing the onset of Mortality and Potential Mortal Injury; Recoverable Injury; and TTS for the fish eggs and larvae; and sea turtle subgroups do not currently exist due to insufficient data. Popper et al. 2104 acknowledges the difficulty in ascribing specific distances or a range of distances to the risk of an impact given the number of variables that underpin such a decision. They suggest that "… "near" might be considered to be in the tens of metres from the source, "intermediate" in the hundreds of

[4] Barotrauma is tissue injury caused by a difference in pressure between a gas-filled space inside an organ and the surrounding tissues. Low levels of damage involve stretching of the tissue in tension or shear. Higher levels involve rupture of the tissues which can lead to fatalities.

metres, and “far” in the thousands of metres”.

Table D20: Summary of acoustic impact threshold criteria for fish functional hearing groups exposed to impulsive-type noise. Taken from Popper et al, 2014.

Functional hearing group	Mortality and Potential Mortal Injury	Recoverable Injury	TTS
Fish Group 1	>213 dB re 1 µPa Peak SPL >219 dB re 1 µPa^2.sec SEL	>213 dB re 1 µPa Peak SPL 216 dB re 1 µPa^2.sec SEL	186 dB re 1 µPa^2.sec SEL
Fish Group 2	>207 dB re 1 µPa Peak SPL 210 dB re 1 µPa^2.sec SEL	>207 dB re 1 µPa Peak SPL 203 dB re 1 µPa^2.sec SEL	186 dB re 1 µPa^2.sec SEL
Fish Group 3/4	>207 dB re 1 µPa Peak SPL 207 dB re 1 µPa^2.sec SEL	>207 dB re 1 µPa Peak SPL 203 dB re 1 µPa^2.sec SEL	186 dB re 1 µPa^2.sec SEL
Fish eggs and larvae	>207 dB re 1 µPa Peak SPL 210 dB re 1 µPa^2.sec SEL	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low
Sea turtles	>207 dB re 1 µPa Peak SPL 210 dB re 1 µPa^2.sec SEL	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low

Behavioural impacts

2.14. Behavioural impacts were based on work undertaken by Hawkins et al (2014) which identified single strike sound exposure levels were 135.0 dB re 1 mPa2 s for sprat and 142.0 dB re 1 mPa2 s for mackerel. Sprat are members of the herring family and, given their audiological physiology, are known to be sensitive to underwater noise. From Table D20, were classified as Group 3/4. Mackerel lack a connection between the inner ear and swim bladder and are thus less sensitive to underwater noise and were classified as Group 2.

2.15. Based on the approach adopted for the South Fork Wind Farm project, a threshold of 175 dB re 1 µPa (rms) was used to represent the onset of avoidance behaviour in sea turtles.

3 Underwater acoustic propagation modelling

Introduction

3.1. The following sections describe the propagation modelling that was undertaken to estimate sound level variation with distance from the sound source, specifically the acoustic models used and the oceanographic and geo-acoustic[6] data required as input parameters for the models.

[6] The term "geo-acoustic" alludes to the type and structure of the sediments that comprise the seabed but instead, described in acoustic terms. These include, amongst others, the speed of sound in the sediment layer, the density of the rock and its layer thickness.

Description of the models and limitations

3.2. Not all programs are equally suitable for use: due consideration must be made to the nature of the problem to be addressed and this will guide the user to the most appropriate model.

3.3. The programs used for the analysis undertaken in this report are BELLHOP (Porter, 2011) – based on the ray-trace method; and RAM (Collins, 1983 and Collins, 1989). Both programs provide a solution that is valid over a limited frequency, water depth and range regime: parabolic-equation models are optimised for use at lower frequencies while ray-trace models tend to be most suitable for high frequencies. The geophysical sound source will generate noise over a wide range of frequencies hence it is considered acceptable to use both the BELLHOP and RAM models such that the whole frequency range of interest is covered.

3.4. The modelling results were dependent on the use of site- and time-specific data for Copeland inshore area. The sources of data used as inputs to the propagation modelling process are discussed below.

Transect Bathymetry

3.5. Water depth data was taken from the bathymetry database GEBCO 2020 as well as navigation charts (British Admiralty, 2013). In order to capture the depth variation over the wider project area, a set of 36 equally spaced transects were used at two modelling sites. These are referred to as Sites C1 and C2: their respective locations within the larger geophysical survey region are indicated in Figure D42 while the corresponding site coordinates are given in Table D21. The length of each modelling transect varied from approximately 5 km for some of the easterly going transects through to 100 km for the south-westerly going transects. This report focuses on site C1.

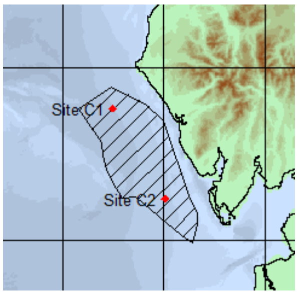

Figure D42: Location of modelling sites C1 and C2 within the Copeland inshore geophysical survey area (hatched region)

Table D21: Locations of acoustic propagation modelling sites in the Copeland inshore survey project area

Acoustic Modelling Location	Latitude	Longitude	Water depth (m)
C1	54° 23'N	003°45'W	37
C2	54° 7.2'N	003°29.4'W	22

Oceanographic Data

3.6. Oceanographic data was obtained through the World Ocean Atlas (WOA, 2009). This consisted of gridded monthly samples of temperature, salinity and depth and from which, sound speed profiles in the vicinity of the project area have been reconstructed with the aid of the Chen-Millero relationship (Chen and Millero, 1977).

3.7. Sound travels through water differently throughout the year which can be seen in speed profiles for each month (WOA, 2009). To assess the range of impacts this study focussed on months most likely to give rise to maximum and minimum acoustic propagation. Based on a high-level analysis of the sound speed profiles which indicated extremes of acoustic propagation, sound modelling was focussed on April and August.

Seabed Geoacoustics

3.8. The seabed sediments consist of a layer of muddy sand typically 29 m thick overlying a sandstone basement (BGS, 1987, EMODnet, Folk, 1954 and Long, 2006). Based on this Hamilton, 1963, 1970 and 1972 was used to determine geoacoustic parameters and from this, corresponding compressional wave (primary or P) and shear wave (secondary or S) sound speeds, density and P- and S-wave attenuation data were obtained Table D22.

Table D22: Seabed sediment properties for the vicinity of the project area

Parameter	Sediment	Basement
Layer	Muddy sand	Sandstone
P-wave velocity [m/s]	1579	3913
S-wave velocity [m/s]	310	2964
P-wave attenuation [dB/m/kHz]	0.628	0.354
S-wave attenuation [dB/m/kHz]	17.3	1.4
Density [kg/m^3]	1596	2360
Thickness [m]	29	∞

Background Noise

3.9. Background noise or oceanic ambient noise is considered to be a composite of a number of overlapping components (Wenz, 1962):

- at very low frequencies (1 Hz to 100 Hz) the dominant source is due to earthquake noise from distant activity and from turbulent pressure fluctuations caused by large-scale movements of bodies of water;
- at low frequencies (10 Hz to 1 kHz) vessel noise is dominant;
- at mid-range frequencies (50 Hz to 20 kHz) weather-related noise as prevails while biological activity such as animal vocalisations are also present;
- at high frequencies (>20 kHz), thermal noise becomes apparent.

3.10. In shallow water coastal regions by contrast, background noise levels are very variable being dependent on shipping activity and marine industrial activity as well as wind speed and rainfall (see e.g., Urick**Error! Bookmark not defined.**). Shipping activity in particular is denoted by clearly marked shipping lanes inside which noise levels are significantly louder than at locations outside (Neenan *et al* 2016 and Jalkanan *et al*, 2018). However, no data on underwater background sound levels have been found specifically for the Copeland inshore survey area and so an assumed proxy was identified based on similar inshore areas.

3.11. It is noted also that the Copeland inshore survey area lies close to offshore wind farms (Walney, Ormond, Barrow, West of Duddon Sands), ferry terminals (Heysham to Douglas) and various fishing ports. As such it is likely that vessel noise might also be a characteristic of the area. It is reasonable therefore to draw on a similar site for which noise data are available.

3.12. The North Sea contains numerous oil fields that are in full operation. In addition, a number of ports and harbours are serviced by vessels transiting the region and so has the potential to be similar to that found in Copeland. Measurements of background sound in the coastal fringe of the North Sea by Nedwell et al. 2008, indicate a background sound level range of 100-135 dB re 1 µPa with a modal value of 120 dB re 1 µPa. As such for this study background sound levels in the vicinity of the survey area were considered to be in the range of 110±10 dBrms re 1 µPa. The uncertainty on the use of coastal North Sea data as a best estimate was considered for in the assessments.

Source Modelling Parameters

3.13. To produce results that are viable for environmental assessments, the sound source frequency bandwidth was divided into 1/3rd octave bands (Kinsler, 1999) where each band has a given spectral level, centre frequency and bandwidth; and then to use a frequency-domain type program for subsequent propagation modelling. The 1/3rd octave centre frequencies thus selected cover the frequency range of interest for the geophysical survey activity and are listed in Table D23.

Table D23: Acoustic modelling frequencies

Parameter	Value
Frequency Hz	*10, 12.5, 16, 20, 25, 31, 40, 50, 63, 80, 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1k, 1.25k, 1.6k, 2k, 2.5k, 3.15k, 4k, 5k, 6.3k, 8k, 10k, 12.5k, 16k, 20k, 25k, 31.5k, 63k, 80k, 100k, 125k*

Sound Propagation Modelling Scenarios

3.14. Using the bathymetric and geo-acoustic data given in the preceding sections, propagation loss data was generated along each of the 36 transects radiating from each modelling centre using sound speed profile data for the months of April and August.

3.15. The propagation loss data is generated at each of the 1/3rd octave band frequencies given in Table D23. The frequency-dependent propagation loss (indicated by TL in equation 2-

7) is subtracted from the 1/3rd octave band levels in order to derive propagated SPL data as a function of distance, depth and frequency.

3.16. Propagation on sound through the water was based on Urick (1983). The higher frequencies propagate while the lower ones become quickly absorbed into the seabed. In this context, "lower" is defined as those whose wavelength is greater than H/4 where H is the water depth.

3.17. In terms of assessing distances for differing impacts, the distances where determined by finding the maximum range in the water column at which the SPL or SEL is greater than or equal to a given impact threshold value. This procedure was repeated along each transect and the longest of all the maximum ranges is assumed to be the maximum distance from the sound source at which a particular potential impact could occur.

4. Underwater acoustic propagation modelling results for site C1

4.1. An in depth assessment was undertaken on underwater sound propagation on site C1 for April and August to validate understanding noted in section 3 above and to support the detailed impact assessments.

April oceanography

4.2. The underwater sound source for the geophysical will be broadband in frequency and has an overall far-field source level directly below the array of 252 dBpeak re 1 μPa at 1 m. For a water depth of 29 m (representing the water depth at the modelling centred at Site C1), the cut-off point between propagating and non-propagating frequencies is approximately 200 Hz. Above a frequency of approximately 20 kHz, losses due to absorption in the water become increasingly apparent. Between these two frequencies, sound will propagate to a greater or lesser degree and acoustic losses will arise through refraction in the water column and reflections from the seabed and sea surface.

4.3. Figure D43 shows SPL as a function of depth and distance from Site C1 modelled along the 0° transect (due North) for the sound source using the April SSP. Over this transect, SPLs fall from 252 dBpeak re 1 mPa at 0 m to approximately 160 dBpeak re 1 mPa at 33 km. This was shown to be due to acoustic energy being increasingly transmitted into the seabed over the distance before the sound propagation being stopped at 45km due to a water decrease in water depth. After 45km SPLs are close to background noise levels (see Section 0) lying in the range 110-120 dBpeak re 1 mPa.

4.4. Figure D44 shows SPL modelled over the 70° transect – this being one of the shortest modelling transects and one where water depths decrease rapidly as the coastline is approached. Upslope propagation is evident along this transect where SPLs fall rapidly from 252 dBpeak re 1 mPa at 0 m to 155 dBpeak re 1 mPa at a distance of 14 km. The propagation path due to the weak sound channel is also evident as the geophysical noise cycles between seabed and sea surface.

4.5. Figure D45 shows modelled SPLs along the 230° transect. This extends from the modelling site and out into the Irish Sea, passing just to the south of the Isle of Man. The figure shows that water depths increase slightly over the first 10 km and this avoids the rapid diminishment of SPLs that are evident in the previous figures. The sudden decrease in water depth to 5 m at a distance of 20 km effectively constrains relatively high levels of noise from propagating much further with the exception of the noise which is trapped in the sub-surface sound channel. As a result, SPLs remain above 150 dB re 1 mPa out to a distance of 100 m.

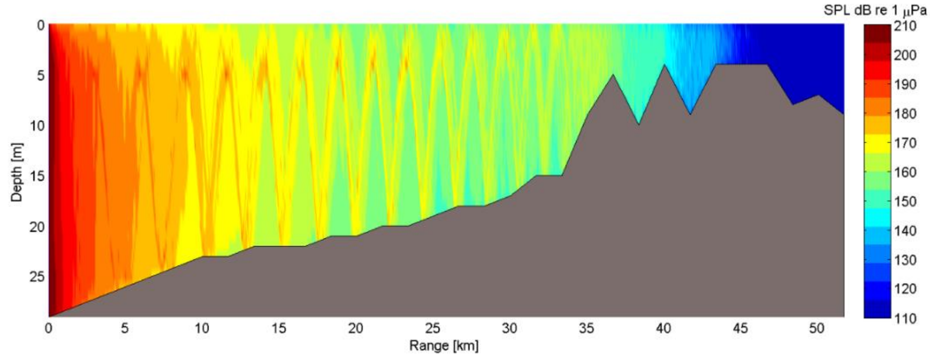

Figure D43: Contour plot of SPL as a function of range and depth of geophysical underwater sound modelled along a transect at a bearing of 0° from Site C1, using an April sound speed profile. The grey region indicates the seabed.

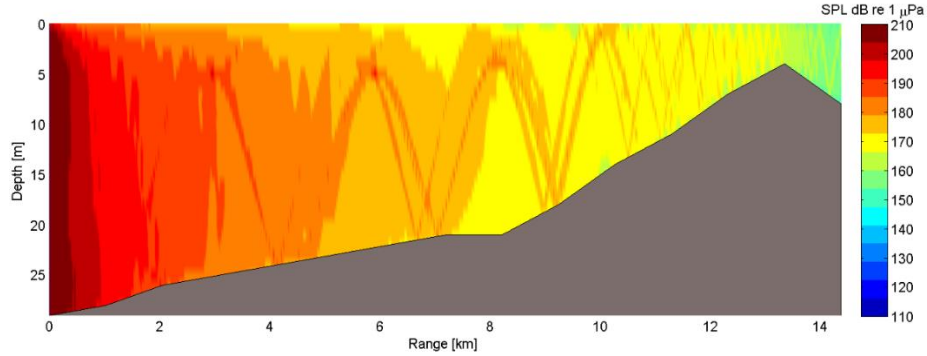

Figure D44: Contour plot of SPL as a function of range and depth of geophysical underwater sound modelled along a transect at a bearing of 70° from Site C1, using an April sound speed profile. The grey region indicates the seabed.

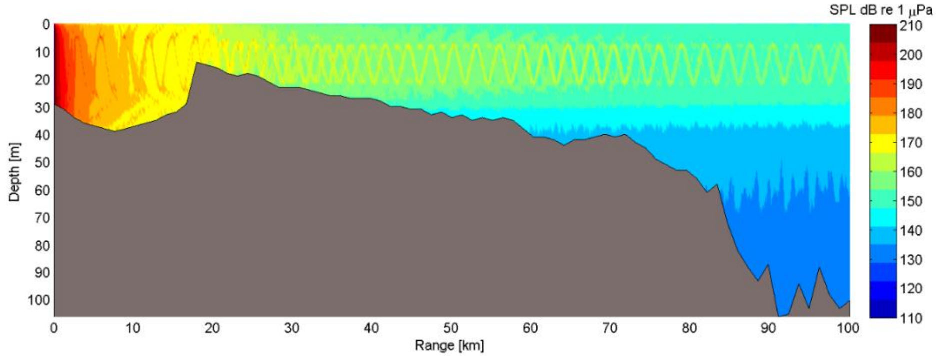

Figure D45: Contour plot of SPL as a function of range and depth of geophysical underwater sound modelled along a transect at a bearing of 230° from Site C1, using an April sound speed profile. The grey region indicates the seabed.

August oceanography

4.6. Figure D46 shows that the SPL falls uniformly from 252 dBpeak re 1 mPa at 0 m to around 110-120 dBpeak re 1 mPa at 36 km. At the modelling site, during the month of August, the SSP is downwardly refracting over the entire water column and therefore limits sound propagation. The nature of the SSP directs the underwater sound towards the seabed into which it is significantly attenuated. As a result, at any given distance and depth, the SPL is much lower during August than during April.

4.7. Over the 70° transect (Figure D47) the downwardly refracting SSP along with the shallower water depth ensures that, at a distance of 14 km, SPLs have fallen to background levels. Over the 230° transect sound propagation is limited to the basin, within 20km of the sound source, with the main propagation being along the seabed for up to 85km Figure D48. At the sea surface, SPLs fall to background levels within approximately 50 km.

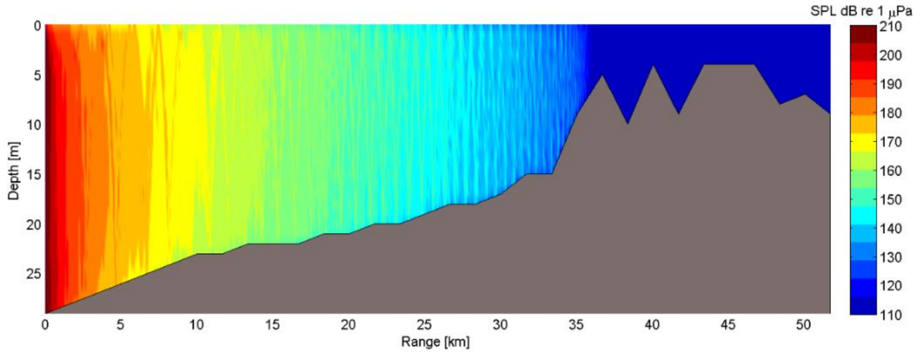

Figure D46: Contour plot of SPL as a function of range and depth of geophysical underwater sound modelled along a transect at a bearing of 0° from Site C1, using an August sound speed profile. The grey region indicates the seabed.

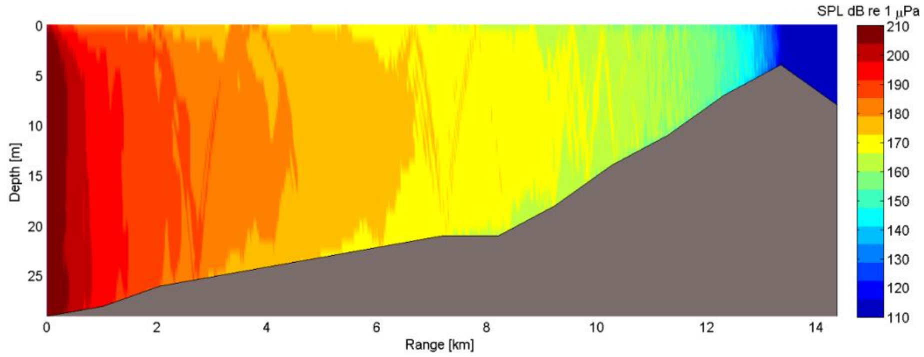

Figure D47: Contour plot of SPL as a function of range and depth of geophysical underwater sound modelled along a transect at a bearing of 70° from Site C1, using an August sound speed profile. The grey region indicates the seabed.

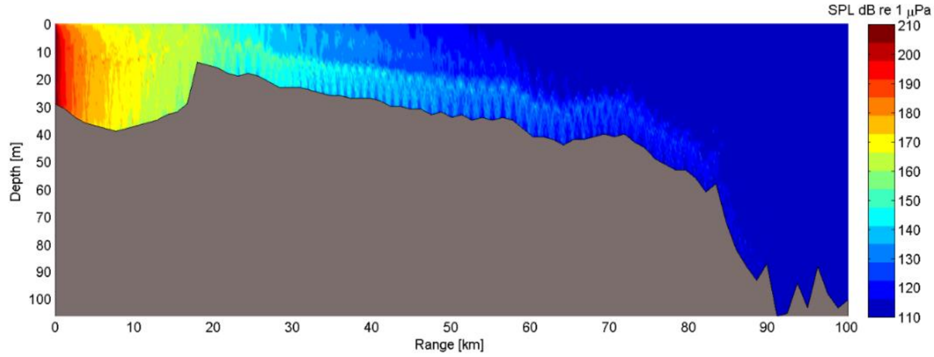

Figure D48: Contour plot of SPL as a function of range and depth of geophysical underwater sound modelled along a transect at a bearing of 230° from Site C1, using an August sound speed profile. The grey region indicates the seabed.

5. Acoustic impact modelling results

Introduction

5.1. This section compares the SPLs and SELs with threshold levels that are associated with various acoustic impacts. Physiological impacts, namely PTS and TTS, were quantified in terms of both SPL and SEL, while behavioural impacts were given in SPL terms only. In line with Southall et al. 2007 the most precautionary threshold was used for the assessment of FHGs and species, i.e., the one giving the longest impact distance.

Stationary sound source scenario

5.2. In line with NMFS guidance (NMFS, 2018) a range of exposure durations were considered varying from a single-strike exposure duration up to a 24-hour exposure duration to account for the length of time an animal could be exposed to underwater sound from the sound source. The shorter exposure durations are appropriate for animals transiting rapidly through the survey area while the longer periods are deemed more appropriate for slower moving animals and for those species which are habitat-constrained.

5.3. Summaries of maximum impact distances for each marine mammal, fish and sea turtle FHG are given for physiological and behavioural impacts using SPL and SEL metrics for each of the modelling scenarios listed in Table D24 with further details in the Annex.

Table D24: Summary of modelling scenarios

Site	Month	Transects	Source level (peak)	Annex Tables
C1	April	0° - 360°	252 dB re 1 mPa at 1 m	A.1 – A.4
C1	August	0° - 360°	252 dB re 1 mPa at 1 m	A.5 – A.8
C1	April	0° only	249 dB re 1 mPa at 1 m	A.9 – A.12
C1	August	0° only	249 dB re 1 mPa at 1 m	A.13 – A.16

Site	Month	Transects	Source level (peak)	Annex Tables
C2	April	0° - 360°	252 dB re 1 mPa at 1 m	A.17 – A.20
C2	August	0° - 360°	252 dB re 1 mPa at 1 m	A.21 – A.24

Moving sound source-receptor scenario

5.4. As the sound source and some marine animals will move during the survey, in addition to the above assessment a moving receptor (sometimes referred to as a fleeing-animal) scenario has been considered (Theobald et al, 2009). Such models provide some boundary conditions for possible real-world source-receptor movement scenarios and these can inform an assessment that draws on a cumulative SEL threshold criterion.

5.5. For the receptor \ vessel scenarios that were considered, it was assumed that the survey vessel was transiting at a speed of 2.3 m/s (corresponding to a typical survey vessel tow speed of 4.5 knots, OGP, 2011) and at a bearing of 270° (due west) from a nominal point of origin. The assessment was also based on an animal swimming away from the sound source on a constant bearing of 0° (due north) and 90° (due east) at a speed of 2.0 m/s. Typical swim speeds for representative species within each FHG, are given in Table D25. The assessment also accounted for JNCC guidance with there being no immediate start to the sound source whilst cetaceans are within 500m through the use of a soft start. This consideration was accounted for in the impact model and, for comparison, a 0 m offset was also considered.

Table D25: Summary of representative swim speeds for each FHG

FHG	Species	Swim speed	Reference
LF	Minke whale	6 km/hr	Risch *et al*. 2014
MF	Bottlenose dolphin	7 km/hr	Williams *et al*. 1993
HF	Harbour porpoise	7.3-15 km/hr	Otani *et al*. 2006
PW	Grey seal	10 km/hr	Oceanwide Expeditions
Fish Group 1	Basking shark	4 km/hr	Sims *et al*. 2000
Fish Group 2	Salmon	3.5 km/hr	Hvas and Oppedal, 2017
Fish Group 3/4	Juvenile fish (bream)	0.4 km/hr	Clough *et al*. 2004
Sea turtle	Generic	1.4 - 9.3 km/hr	Ocean Life

5.6. Based on a total operational period of 20000 seconds (i.e. the approximate time required for the geophysical vessel to transit over 2 survey lines), it was identified that for a HF cetacean cumulative SEL reaches the TTS threshold after an elapsed time of 2500 seconds (~42 minutes, Figure D49) by which time the animal is 7.9 km away from the sound source. The PTS threshold is not reached at all.

5.7. Table D26 gives the elapsed times required for a given marine mammal FHG to meet the PTS and TTS criteria for 3 moving source/receptor scenarios where each one commences with an initial animal offset of 500 m and the soft-start protocol.

5.8. The first scenario summarises the results illustrated in Figure D49. For this, the PTS impact criterion is reached after 2585 seconds for LF cetaceans and not at all for all other FHGs. The TTS impact criterion is met at elapsed times varying between 1030 seconds for LF cetaceans and 2150 seconds for HF cetaceans. The second scenario included the optimum source-receptor separation where the animal moves directly away from the survey vessel. For this scenario, the PTS impact criterion is not met at all for any of the FHGs. The TTS impact criterion is not met for MF cetaceans and after an elapsed time of 2670 seconds for HF cetaceans. The third scenario has the animal moving at a bearing of 315° where the cumulative SELs meet the PTS impact criterion after 1850 seconds for LF cetaceans while the TTS criterion is met at 1805 seconds for HF cetaceans.

5.9. As shown in

5.10. Table D27 the Mortality and Potential Mortal Injury impact criterion is not met for any of the animal groupings and scenarios considered. Cumulative SELs meet the Recoverable Injury criterion after 18495 seconds for Fish Groups 2, 3 and 4 and not at all for all other groupings. By contrast, the TTS impact criterion is met after 2140 seconds for Fish Groups 1, 2, 3 and 4.

5.11. The results show that the elapsed times as given in Table D28, are all greater for a moving source\receptor model than for a stationary receptor model. For Fish Groups 3 and 4, the Recoverable Injury criterion is met after 19265 seconds and the TTS impact criterion for Fish Group 1 is reached after 3065 seconds.

5.12. When assuming the sound source reaches full strength while an animal is within 500m PTS and TTS impact threshold conditions are met after 1 second for LF cetaceans and PW pinnipeds (Table D29). Mortality and Potential Mortal Injury criterion for stationary fish in Group 1 is met after an elapsed time of 18465 seconds but is not met at all for a moving receptor fish (Table D30 and Table D31). For all fish groupings the TTS criterion is met after 1 second and not at all for sea turtles.

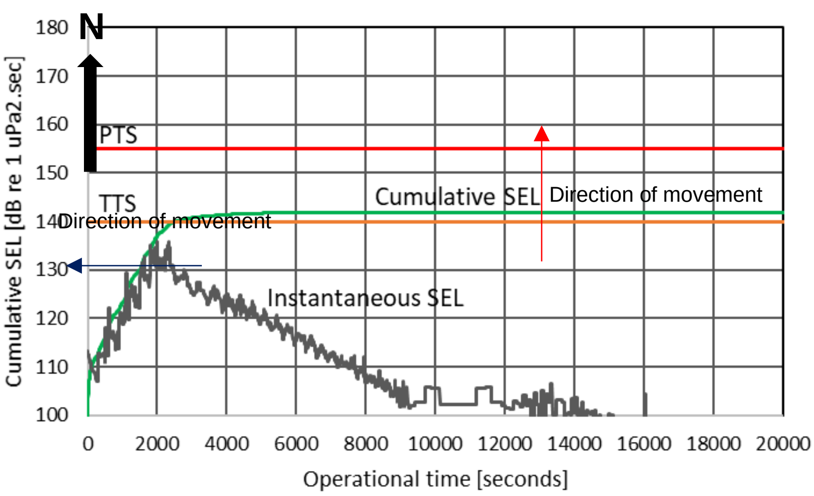

Figure D49: Instantaneous and Cumulative SEL on a moving HF cetacean as a function of elapsed survey time

Table D26: Summary of elapsed times to reach TTS and PTS for moving source/marine mammal receptor scenarios with a 500 m initial animal offset (NR – Not Reached)

FHG	Vessel bearing	Vessel speed	Animal bearing	Animal speed	Max SEL dB re 1 mPa^2.s	Elapsed time [sec] to reach:	
						PTS	TTS
LF	270°	4.5 kts	0°	3.25 m/s	185.1	2585	1030
			90°	3.25 m/s	181.2	NR	1320
			315°	3.25 m/s	190.9	1850	725
MF	270°	4.5 kts	0°	1.5 m/s	153.6	NR	NR
			90°	1.5 m/s	150.5	NR	NR
			315°	1.5 m/s	158.3	NR	NR
HF	270°	4.5 kts	0°	1.5 m/s	145.1	NR	2150
			90°	1.5 m/s	141.9	NR	2670
			315°	1.5 m/s	149.8	NR	1805
PW	270°	4.5 kts	0°	2.78 m/s	176.3	NR	1960
			90°	2.78 m/s	172.4	NR	2260
			315°	2.78 m/s	182.1	NR	1595

Table D27: Summary of elapsed times to reach TTS and PTS for moving source / stationary fish receptor scenario with a 500 m initial animal offset (NR – Not Reached; NA – Not Available)

FHG	Vessel bearing	Vessel speed	Animal bearing	Animal speed	Max SEL dB re 1 mPa^2.s	Elapsed time [sec] to reach:		
						Mort	Recov	TTS
Fish 1	270°	4.5 kts	0°	0 m/s	206.2	NR	NR	2140
			90°	0 m/s	206.2	NR	NR	2140
			315°	0 m/s	206.2	NR	NR	2140
Fish 2	270°	4.5 kts	0°	0 m/s	206.2	NR	18495	2140
			90°	0 m/s	206.2	NR	18495	2140
			315°	0 m/s	206.2	NR	18495	2140
Fish 3/4	270°	4.5 kts	0°	0 m/s	206.2	NR	18495	2140
			90°	0 m/s	206.2	NR	18495	2140
			315°	0 m/s	206.2	NR	18495	2140
Eggs & larvae	270°	4.5 kts	0°	0 m/s	206.2	NR	NA	NA
			90°	0 m/s	206.2	NR	NA	NA

			315°	0 m/s	206.2	NR	NA	NA

Table D28: Summary of elapsed times to reach TTS and PTS for moving source/ moving receptor scenarios with a 500 m initial animal offset (NR – Not Reached; NA – Not Available)

FHG	Vessel bearing	Vessel speed	Animal bearing	Animal speed	Max SEL dB re 1 mPa^2.s	Elapsed time [sec] to reach:		
						Mort	Recov	TTS
Fish 1	270°	4.5 kts	0°	1.11 m/s	190.9	NR	NR	2270
			90°	1.11 m/s	187.6	NR	NR	3065
			315°	1.11 m/s	196.0	NR	NR	1820
Fish 2	270°	4.5 kts	0°	1.0 m/s	191.4	NR	NR	2275
			90°	1.0 m/s	188.0	NR	NR	3045
			315°	1.0 m/s	195.9	NR	NR	1835
Fish 3/4	270°	4.5 kts	0°	0.11 m/s	200.9	NR	NR	2140
			90°	0.11 m/s	198.9	NR	NR	2225
			315°	0.11 m/s	204.3	NR	19265	2095
Sea turtles	270°	4.5 kts	0°	1.94 m/s	188.9	NR	NA	NA
			90°	1.94 m/s	184.9	NR	NA	NA
			315°	1.94 m/s	195.6	NR	NA	NA

Table D29: Summary of elapsed times to reach TTS and PTS for moving source/marine mammal receptor scenarios with a 0 m initial animal offset (NR – Not Reached)

FHG	Vessel bearing	Vessel speed	Animal bearing	Animal speed	Max SEL dB re 1 mPa^2.s	Elapsed time [sec] to reach:	
						PTS	TTS
LF	270°	4.5 kts	0°	3.25 m/s	203.2	1	1
			90°	3.25 m/s	201.4	1	1
			315°	3.25 m/s	205.1	1	1
MF	270°	4.5 kts	0°	1.5 m/s	164.2	NR	NR
			90°	1.5 m/s	162.8	NR	NR
			315°	1.5 m/s	166.7	NR	NR
HF	270°	4.5 kts	0°	1.5 m/s	155.4	1935	1
			90°	1.5 m/s	154.0	NR	1
			315°	1.5 m/s	157.9	35	1
PW	270°	4.5 kts	0°	2.78 m/s	190.2	1	1
			90°	2.78 m/s	188.3	1	1
			315°	2.78 m/s	193.0	1	1

Table D30: Summary of elapsed times to reach TTS and PTS for moving source/stationary fish receptor scenario with a 0 m initial animal offset (NR – Not Reached; NA – Not Available)

FHG	Vessel bearing	Vessel speed	Animal bearing	Animal speed	Max SEL dB re 1 $mPa^2.s$	Elapsed time [sec] to reach:		
						Mort	Recov	TTS
Fish 1	270°	4.5 kts	0°	0 m/s	248.7	18465	18465	1
			90°	0 m/s	248.7	18465	18465	1
			315°	0 m/s	248.7	18465	18465	1
Fish 2	270°	4.5 kts	0°	0 m/s	248.7	13910	1	1
			90°	0 m/s	248.7	13910	1	1
			315°	0 m/s	248.7	13910	1	1
Fish 3/4	270°	4.5 kts	0°	0 m/s	248.7	15	2	1
			90°	0 m/s	248.7	15	2	1
			315°	0 m/s	248.7	15	2	1
Eggs & larvae	270°	4.5 kts	0°	0 m/s	248.7	13910	NA	NA
			90°	0 m/s	248.7	13910	NA	NA
			315°	0 m/s	248.7	13910	NA	NA

Table D31: Summary of elapsed times to reach TTS and PTS for moving source/moving fish receptor scenario with a 0 m initial animal offset (NR – Not Reached; NA – Not Available)

FHG	Vessel bearing	Vessel speed	Animal bearing	Animal speed	Max SEL dB re 1 $mPa^2.s$	Elapsed time [sec] to reach:		
						Mort	Recov	TTS
Fish 1	270°	4.5 kts	0°	1.11 m/s	209.5	NR	NR	1
			90°	1.11 m/s	208.2	NR	NR	1
			315°	1.11 m/s	211.3	NR	NR	1
Fish 2	270°	4.5 kts	0°	1.0 m/s	209.5	NR	2	1
			90°	1.0 m/s	208.2	NR	2	1
			315°	1.0 m/s	211.3	40	2	1
Fish 3/4	270°	4.5 kts	0°	0.11 m/s	210.5	15	2	1
			90°	0.11 m/s	210.3	15	2	1
			315°	0.11 m/s	211.3	15	2	1
Sea turtles	270°	4.5 kts	0°	1.94 m/s	208.9	NR	NA	NA
			90°	1.94 m/s	207.4	NR	NA	NA
			315°	1.94 m/s	211.6	40	NA	NA

6. Summary and conclusions

6.1. Based on the planned survey a nominal maximum acoustic source level of 252 dBpeak re 1 mPa at 1 m which provides a low-frequency spectrum of the emitted signal was assumed for the UWS modelling.

6.2. The published literature was accessed to determine threshold sound levels relating to potential acoustic impacts on marine life. For marine mammals the potential impacts considered were auditory impairment (Permanent and Temporary Threshold Shift) assessed using SPL peak level and m-weighted SEL metrics derived from studies reviewed in the NMFS report; and behavioural reactions which were assessed using SPL rms metrics using guidance from NMFS (NMFS, 2018). For fish and sea turtles, physiological impacts of Mortality and Potential Mortal Injury; Recoverable Injury; and TTS were assessed using SPL rms metrics derived from studies by Popper et al., 2014, while behavioural impacts, based on SPL rms metrics, were derived from work by Hawkins et al. 2014 and Finneran and Jenkins 2012.

6.3. Underwater acoustic propagation modelling was carried out over a total of 36 transects radiating from each of two survey locations, using site- and time- specific environmental data relating to the Copeland inshore survey area. The results were applied to the acoustic source level data characterising the noise generated by the geophysical survey sound source.

6.4. The scale of acoustic impacts arising was determined by comparing the propagated noise levels with threshold values representing each acoustic impact. For a stationary source and receptor, impact distances for each animal group/month/acoustic source level/site combination are summarised in the Annex to this section and supplied for use in the environmental assessment shown in Appendix A. In addition, a moving source/receptor scenario was modelled whereby the geophysical source moves at a constant speed in a given direction while an animal moves at a different speed in another direction. The cumulative SEL is modelled and, for marine mammals, the time determined for the PTS and TTS impact criteria to be met while for fish and sea turtles, the time required for the Mortality and Potential Mortal Injury; Recoverable Injury and TTS impact criteria are determined.

Annex A - Impact Ranges: Copeland - Site C1

April (All transects, SL = 252 dB re 1 mPa at 1 m)

Table A.32: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of April at Site C1

FHG	Impact	Threshold	Min	Max	Mean
LF	PTS	219 dB re 1 mPa peak	0	47	16
	TTS	213 dB re 1 µPa peak	71	126	107
MF	PTS	230 dB re 1 µPa peak	0	0	0
	TTS	224 dB re 1 µPa peak	0	19	3
HF	PTS	202 dB re 1 µPa peak	438	528	500
	TTS	196 dB re 1 µPa peak	938	1289	1132
PW	PTS	218 dB re 1 µPa peak	0	57	23
	TTS	212 dB re 1 µPa peak	71	142	114
All MM	Level B+20 dB	180 dB re 1 mPa rms	438	528	500
	Level B	160 dB re 1 µPa rms	4263	5303	4845
	Level B-20 dB	140 dB re 1 µPa rms	11638	83066	41219

Table A.33: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of April at Site C1

FHG	Impact	Threshold	Min	Max	Mean
Fish 1	Mort, Reco	213 dB re 1 µPa peak	71	126	107
Fish 2/3/4	Mort, Reco	207 dB re 1 µPa peak	198	284	245
Sea turtle	Mort	207 dB re 1 µPa peak	198	284	245
Eggs & larvae	Mort	207 dB re 1 µPa peak	198	284	245
Sea turtle	Aver. Beh	175 dB re 1 µPa rms	793	1178	974

Table A.34: Summary of impact ranges in metres at which m-weighted SEL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of April at Site C1

Op period	FHG	Impact	Threshold	Min	Max	Mean
30 minutes	LF	PTS	183 dB re 1 mPa^2.s	10224	19954	15054
		TTS	168 dB re 1 mPa^2.s	12436	99381	50344
	MF	PTS	185 dB re 1 mPa^2.s	<1	33	7
		TTS	170 dB re 1 mPa^2.s	281	389	342
	HF	PTS	155 dB re 1 mPa^2.s	991	1357	1125
		TTS	140 dB re 1 mPa^2.s	10066	18004	13888
	PW	PTS	185 dB re 1 mPa^2.s	1785	2720	2197
		TTS	170 dB re 1 mPa^2.s	11066	29359	21040
1 hour	LF	PTS	183 dB re 1 mPa^2.s	10973	29359	20568
		TTS	168 dB re 1 mPa^2.s	12941	100030	52346
	MF	PTS	185 dB re 1 mPa^2.s	<1	53	25
		TTS	170 dB re 1 mPa^2.s	469	605	555
	HF	PTS	155 dB re 1 mPa^2.s	1685	1831	1747
		TTS	140 dB re 1 mPa^2.s	10973	23995	18945
	PW	PTS	185 dB re 1 mPa^2.s	3272	4710	3837
		TTS	170 dB re 1 mPa^2.s	11252	45803	27951
2 hour	LF	PTS	183 dB re 1 mPa^2.s	11199	45803	27476
		TTS	168 dB re 1 mPa^2.s	13300	100030	53053
	MF	PTS	185 dB re 1 mPa^2.s	<1	75	39
		TTS	170 dB re 1 mPa^2.s	796	1206	1047
	HF	PTS	155 dB re 1 mPa^2.s	2800	3329	3145
		TTS	140 dB re 1 mPa^2.s	11199	34143	24115
	PW	PTS	185 dB re 1 mPa^2.s	4858	6310	6009
		TTS	170 dB re 1 mPa^2.s	11372	62816	36206
4 hour	LF	PTS	183 dB re 1 mPa^2.s	11372	62816	35870
		TTS	168 dB re 1 mPa^2.s	13300	100030	53506
	MF	PTS	185 dB re 1 mPa^2.s	71	138	112
		TTS	170 dB re 1 mPa^2.s	1663	1811	1727
	HF	PTS	155 dB re 1 mPa^2.s	4362	6194	5129
		TTS	140 dB re 1 mPa^2.s	11372	52185	31390
	PW	PTS	185 dB re 1 mPa^2.s	7859	14103	9353
		TTS	170 dB re 1 mPa^2.s	11824	91270	43992
12 hour	LF	PTS	183 dB re 1 mPa^2.s	12169	99281	47725
		TTS	168 dB re 1 mPa^2.s	13300	100030	53743
	MF	PTS	185 dB re 1 mPa^2.s	198	301	259
		TTS	170 dB re 1 mPa^2.s	3272	4710	3823
	HF	PTS	155 dB re 1 mPa^2.s	8498	14103	10851
		TTS	140 dB re 1 mPa^2.s	12169	83066	43021
	PW	PTS	185 dB re 1 mPa^2.s	10893	29359	19324
		TTS	170 dB re 1 mPa^2.s	12795	100030	51815
24 hour	LF	PTS	183 dB re 1 mPa^2.s	12662	100030	51691
		TTS	168 dB re 1 mPa^2.s	13300	100030	53852
	MF	PTS	185 dB re 1 mPa^2.s	397	499	460
		TTS	170 dB re 1 mPa^2.s	5674	9092	6250
	HF	PTS	155 dB re 1 mPa^2.s	10839	23864	16727
		TTS	140 dB re 1 mPa^2.s	12728	99281	49132
	PW	PTS	185 dB re 1 mPa^2.s	11159	35805	24564
		TTS	170 dB re 1 mPa^2.s	13300	100030	52933

Table A.35: Summary of impact ranges in metres at which SEL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of April at Site C1

Op period	FHG	Impact	Threshold	Min	Max	Mean
Single strike	Fish 1	Mort	219 dB re 1 mPa^2.s	<1	<1	<1
	Fish 1	Reco	216 dB re 1 mPa^2.s	<1	<1	<1
	Fish 2	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Fish 2	Reco	203 dB re 1 mPa^2.s	<1	19	3
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	<1	<1	<1
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	<1	19	3
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	175	240	214
	Sea turtle	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Mackerel	Beh 50%	142 dB re 1 mPa^2.s	11372	62816	35626
	Sprat	Beh 50%	135 dB re 1 mPa^2.s	12595	99730	51211
30 minutes	Fish 1	Mort	219 dB re 1 mPa^2.s	175	231	208
	Fish 1	Reco	216 dB re 1 mPa^2.s	263	339	313
	Fish 2	Mort	210 dB re 1 mPa^2.s	595	790	686
	Fish 2	Reco	203 dB re 1 mPa^2.s	1300	1811	1595
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	892	1197	1061
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1300	1811	1595
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	8761	14103	10494
	Sea turtle	Mort	210 dB re 1 mPa^2.s	595	790	686
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	595	790	686
1 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	263	339	313
	Fish 1	Reco	216 dB re 1 mPa^2.s	438	518	491
	Fish 2	Mort	210 dB re 1 mPa^2.s	892	1197	1061
	Fish 2	Reco	203 dB re 1 mPa^2.s	1792	2389	2148
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1289	1636	1433
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1792	2389	2148
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	10253	21031	16232
	Sea turtle	Mort	210 dB re 1 mPa^2.s	892	1197	1061
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	892	1197	1061
2 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	438	518	491
	Fish 1	Reco	216 dB re 1 mPa^2.s	595	790	686
	Fish 2	Mort	210 dB re 1 mPa^2.s	1289	1641	1438
	Fish 2	Reco	203 dB re 1 mPa^2.s	2379	3225	2741
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1685	2179	1929
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	2379	3225	2741
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	11012	30494	21385
	Sea turtle	Mort	210 dB re 1 mPa^2.s	1289	1641	1438

Op period	FHG	Impact	Threshold	Min	Max	Mean
	Eggs & larvae	Mort	210 dB re 1 mPa².s	1289	1641	1438
4 hour	Fish 1	Mort	219 dB re 1 mPa².s	595	792	687
	Fish 1	Reco	216 dB re 1 mPa².s	892	1197	1065
	Fish 2	Mort	210 dB re 1 mPa².s	1691	2179	1932
	Fish 2	Reco	203 dB re 1 mPa².s	2900	4817	3911
	Fish 3/4	Mort	207 dB re 1 mPa².s	2181	2801	2519
	Fish 3/4	Reco	203 dB re 1 mPa².s	2900	4817	3911
	Fish 1/2/3/4	TTS	186 dB re 1 mPa².s	11199	45803	28236
	Sea turtle	Mort	210 dB re 1 mPa².s	1691	2179	1932
	Eggs & larvae	Mort	210 dB re 1 mPa².s	1691	2179	1932
12 hour	Fish 1	Mort	219 dB re 1 mPa².s	1091	1465	1304
	Fish 1	Reco	216 dB re 1 mPa².s	1487	1831	1698
	Fish 2	Mort	210 dB re 1 mPa².s	2479	3367	2905
	Fish 2	Reco	203 dB re 1 mPa².s	5670	8065	6668
	Fish 3/4	Mort	207 dB re 1 mPa².s	3569	5072	4459
	Fish 3/4	Reco	203 dB re 1 mPa².s	5670	8065	6668
	Fish 1/2/3/4	TTS	186 dB re 1 mPa².s	11638	83066	41401
	Sea turtle	Mort	210 dB re 1 mPa².s	2479	3367	2905
	Eggs & larvae	Mort	210 dB re 1 mPa².s	2479	3367	2905
24 hour	Fish 1	Mort	219 dB re 1 mPa².s	1487	1831	1702
	Fish 1	Reco	216 dB re 1 mPa².s	1884	2578	2290
	Fish 2	Mort	210 dB re 1 mPa².s	3569	5072	4460
	Fish 2	Reco	203 dB re 1 mPa².s	8375	14103	10179
	Fish 3/4	Mort	207 dB re 1 mPa².s	4981	7732	5999
	Fish 3/4	Reco	203 dB re 1 mPa².s	8375	14103	10179
	Fish 1/2/3/4	TTS	186 dB re 1 mPa².s	12169	99281	48700
	Sea turtle	Mort	210 dB re 1 mPa².s	3569	5072	4460
	Eggs & larvae	Mort	210 dB re 1 mPa².s	3569	5072	4460

August (All transects, SL = 252 dB re 1 mPa at 1 m)

Table A.36: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of August at Site C1

FHG	Impact	Threshold	Min	Max	Mean
LF	PTS	219 dB re 1 mPa peak	0	47	16
	TTS	213 dB re 1 mPa peak	71	122	102
MF	PTS	230 dB re 1 mPa peak	0	0	0
	TTS	224 dB re 1 mPa peak	0	19	3
HF	PTS	202 dB re 1 mPa peak	375	518	488
	TTS	196 dB re 1 mPa peak	793	987	890
PW	PTS	218 dB re 1 mPa peak	0	55	22
	TTS	212 dB re 1 mPa peak	71	133	109
All MM	Level B+20 dB	180 dB re 1 mPa rms	375	518	488
	Level B	160 dB re 1 mPa rms	3095	4180	3475
	Level B-20 dB	140 dB re 1 mPa rms	10467	22330	17115

Table A.37: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of August at Site C1

FHG	Impact	Threshold	Min	Max	Mean
Fish 1	Mort, Reco	213 dB re 1 mPa peak	71	122	102
Fish 2/3/4	Mort, Reco	207 dB re 1 mPa peak	188	267	231
Sea turtle	Mort	207 dB re 1 mPa peak	188	267	231
Eggs & larvae	Mort	207 dB re 1 mPa peak	188	267	231
Sea turtle	Aver. Beh	175 dB re 1 mPa rms	750	854	820

Table A.38: Summary of impact ranges in metres at which m-weighted SEL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of August at Site C1

Op period	FHG	Impact	Threshold	Min	Max	Mean
30 minutes	LF	PTS	183 dB re 1 mPa^2.s	6653	10974	7796
		TTS	168 dB re 1 mPa^2.s	10733	26723	19861
	MF	PTS	185 dB re 1 mPa^2.s	<1	38	8
		TTS	170 dB re 1 mPa^2.s	263	349	318
	HF	PTS	155 dB re 1 mPa^2.s	844	1020	943
		TTS	140 dB re 1 mPa^2.s	6103	8662	7096
	PW	PTS	185 dB re 1 mPa^2.s	1685	2153	1995
		TTS	170 dB re 1 mPa^2.s	8127	12465	10138
1 hour	LF	PTS	183 dB re 1 mPa^2.s	8206	12518	10070
		TTS	168 dB re 1 mPa^2.s	10826	32392	22162
	MF	PTS	185 dB re 1 mPa^2.s	<1	53	23
		TTS	170 dB re 1 mPa^2.s	469	578	532
	HF	PTS	155 dB re 1 mPa^2.s	1495	2045	1808
		TTS	140 dB re 1 mPa^2.s	8033	11747	9529
	PW	PTS	185 dB re 1 mPa^2.s	2379	3866	2849
		TTS	170 dB re 1 mPa^2.s	9882	16509	13037
2 hour	LF	PTS	183 dB re 1 mPa^2.s	9815	16509	12800
		TTS	168 dB re 1 mPa^2.s	10893	36435	24235
	MF	PTS	185 dB re 1 mPa^2.s	<1	75	39
		TTS	170 dB re 1 mPa^2.s	776	992	855
	HF	PTS	155 dB re 1 mPa^2.s	1991	3065	2332
		TTS	140 dB re 1 mPa^2.s	9523	16509	12130
	PW	PTS	185 dB re 1 mPa^2.s	3581	5783	4188
		TTS	170 dB re 1 mPa^2.s	10294	19995	15676
4 hour	LF	PTS	183 dB re 1 mPa^2.s	10294	19894	15397
		TTS	168 dB re 1 mPa^2.s	10973	44100	26648
	MF	PTS	185 dB re 1 mPa^2.s	71	133	111
		TTS	170 dB re 1 mPa^2.s	1293	2045	1683
	HF	PTS	155 dB re 1 mPa^2.s	3283	4480	3726
		TTS	140 dB re 1 mPa^2.s	10214	18479	14863
	PW	PTS	185 dB re 1 mPa^2.s	4957	7035	5658
		TTS	170 dB re 1 mPa^2.s	10653	23825	18018
12 hour	LF	PTS	183 dB re 1 mPa^2.s	10667	25200	19072
		TTS	168 dB re 1 mPa^2.s	11026	49350	30179
	MF	PTS	185 dB re 1 mPa^2.s	198	289	253
		TTS	170 dB re 1 mPa^2.s	2391	3965	2950
	HF	PTS	155 dB re 1 mPa^2.s	5303	8558	6389
		TTS	140 dB re 1 mPa^2.s	10667	23919	18653
	PW	PTS	185 dB re 1 mPa^2.s	7516	11068	9194
		TTS	170 dB re 1 mPa^2.s	10800	31197	21716
24 hour	LF	PTS	183 dB re 1 mPa^2.s	10786	29419	21227
		TTS	168 dB re 1 mPa^2.s	11119	52185	32259
	MF	PTS	185 dB re 1 mPa^2.s	375	479	435
		TTS	170 dB re 1 mPa^2.s	3700	5783	4304
	HF	PTS	155 dB re 1 mPa^2.s	7262	11068	8708
		TTS	140 dB re 1 mPa^2.s	10800	29419	20939
	PW	PTS	185 dB re 1 mPa^2.s	9445	15342	11690
		TTS	170 dB re 1 mPa^2.s	10893	34388	23762

Table A.39: Summary of impact ranges in metres at which SEL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of August at Site C1

Op period	FHG	Impact	Threshold	Min	Max	Mean
Single strike	Fish 1	Mort	219 dB re 1 mPa^{2}.s	<1	<1	<1
	Fish 1	Reco	216 dB re 1 mPa^{2}.s	<1	<1	<1
	Fish 2	Mort	210 dB re 1 mPa^{2}.s	<1	<1	<1
	Fish 2	Reco	203 dB re 1 mPa^{2}.s	<1	19	3
	Fish 3/4	Mort	207 dB re 1 mPa^{2}.s	<1	<1	<1
	Fish 3/4	Reco	203 dB re 1 mPa^{2}.s	<1	19	3
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^{2}.s	175	222	204
	Sea turtle	Mort	210 dB re 1 mPa^{2}.s	<1	<1	<1
	Eggs & larvae	Mort	210 dB re 1 mPa^{2}.s	<1	<1	<1
	Mackerel	Beh 50%	142 dB re 1 mPa^{2}.s	10294	19894	15378
	Sprat	Beh 50%	135 dB re 1 mPa^{2}.s	10786	28717	20570
30 minutes	Fish 1	Mort	219 dB re 1 mPa^{2}.s	165	216	201
	Fish 1	Reco	216 dB re 1 mPa^{2}.s	198	325	266
	Fish 2	Mort	210 dB re 1 mPa^{2}.s	469	652	586
	Fish 2	Reco	203 dB re 1 mPa^{2}.s	1094	1380	1250
	Fish 3/4	Mort	207 dB re 1 mPa^{2}.s	788	890	839
	Fish 3/4	Reco	203 dB re 1 mPa^{2}.s	1094	1380	1250
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^{2}.s	5429	8558	6396
	Sea turtle	Mort	210 dB re 1 mPa^{2}.s	469	652	586
	Eggs & larvae	Mort	210 dB re 1 mPa^{2}.s	469	652	586
1 hour	Fish 1	Mort	219 dB re 1 mPa^{2}.s	198	325	266
	Fish 1	Reco	216 dB re 1 mPa^{2}.s	375	499	443
	Fish 2	Mort	210 dB re 1 mPa^{2}.s	788	890	839
	Fish 2	Reco	203 dB re 1 mPa^{2}.s	1487	1971	1664
	Fish 3/4	Mort	207 dB re 1 mPa^{2}.s	996	1269	1158
	Fish 3/4	Reco	203 dB re 1 mPa^{2}.s	1487	1971	1664
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^{2}.s	7138	10974	8375
	Sea turtle	Mort	210 dB re 1 mPa^{2}.s	788	890	839
	Eggs & larvae	Mort	210 dB re 1 mPa^{2}.s	788	890	839
2 hour	Fish 1	Mort	219 dB re 1 mPa^{2}.s	375	499	445
	Fish 1	Reco	216 dB re 1 mPa^{2}.s	469	652	586
	Fish 2	Mort	210 dB re 1 mPa^{2}.s	996	1269	1159
	Fish 2	Reco	203 dB re 1 mPa^{2}.s	1992	2761	2342
	Fish 3/4	Mort	207 dB re 1 mPa^{2}.s	1388	1918	1521
	Fish 3/4	Reco	203 dB re 1 mPa^{2}.s	1992	2761	2342
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^{2}.s	8499	13957	10632
	Sea turtle	Mort	210 dB re 1 mPa^{2}.s	996	1269	1159

Op period	FHG	Impact	Threshold	Min	Max	Mean
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	996	1269	1159
4 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	469	652	586
	Fish 1	Reco	216 dB re 1 mPa^2.s	788	890	842
	Fish 2	Mort	210 dB re 1 mPa^2.s	1388	1918	1522
	Fish 2	Reco	203 dB re 1 mPa^2.s	2720	3728	3083
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1785	2477	2039
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	2720	3728	3083
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	9922	17011	13231
	Sea turtle	Mort	210 dB re 1 mPa^2.s	1388	1918	1522
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	1388	1918	1522
12 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	900	1065	1007
	Fish 1	Reco	216 dB re 1 mPa^2.s	1289	1502	1394
	Fish 2	Mort	210 dB re 1 mPa^2.s	2181	2981	2554
	Fish 2	Reco	203 dB re 1 mPa^2.s	4065	6090	4838
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	2885	3780	3206
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	4065	6090	4838
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	10480	22371	17153
	Sea turtle	Mort	210 dB re 1 mPa^2.s	2181	2981	2554
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	2181	2981	2554
24 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	1289	1502	1395
	Fish 1	Reco	216 dB re 1 mPa^2.s	1586	2047	1783
	Fish 2	Mort	210 dB re 1 mPa^2.s	2885	3780	3209
	Fish 2	Reco	203 dB re 1 mPa^2.s	5319	7884	6243
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	3801	5303	4424
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	5319	7884	6243
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	10667	26460	19415
	Sea turtle	Mort	210 dB re 1 mPa^2.s	2885	3780	3209
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	2885	3780	3209

Impact Ranges: Copeland - Site C1

April (0° transect, SL = 249 dB re 1 mPa at 1 m)

Table A.40: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of April at Site C1

FHG	Impact	Threshold	Min	Max	Mean
LF	PTS	219 dB re 1 mPa peak	0	0	0
	TTS	213 dB re 1 □Pa peak	52	52	52
MF	PTS	230 dB re 1 □Pa peak	0	0	0
	TTS	224 dB re 1 □Pa peak	0	0	0
HF	PTS	202 dB re 1 □Pa peak	362	362	362
	TTS	196 dB re 1 □Pa peak	775	775	775
PW	PTS	218 dB re 1 □Pa peak	0	0	0
	TTS	212 dB re 1 □Pa peak	52	52	52
All MM	Level B+20 dB	180 dB re 1 mPa rms	362	362	362
	Level B	160 dB re 1 □Pa rms	3616	3616	3616
	Level B-20 dB	140 dB re 1 □Pa rms	31461	31461	31461

Table A.41: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of April at Site C1

FHG	Impact	Threshold	Min	Max	Mean
Fish 1	Mort, Reco	213 dB re 1 □Pa peak	52	52	52
Fish 2/3/4	Mort, Reco	207 dB re 1 □Pa peak	155	155	155
Sea turtle	Mort	207 dB re 1 □Pa peak	155	155	155
Eggs & larvae	Mort	207 dB re 1 □Pa peak	155	155	155
Sea turtle	Aver. Beh	175 dB re 1 □Pa rms	723	723	723

Table A.42: Summary of impact ranges in metres at which m-weighted SEL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of April at Site C1

Op period	FHG	Impact	Threshold	Min	Max	Mean
30 minutes	LF	PTS	183 dB re 1 mPa^2.s	14103	14103	14103
		TTS	168 dB re 1 mPa^2.s	35749	35749	35749
	MF	PTS	185 dB re 1 mPa^2.s	<1	<1	<1
		TTS	170 dB re 1 mPa^2.s	207	207	207
	HF	PTS	155 dB re 1 mPa^2.s	620	620	620
		TTS	140 dB re 1 mPa^2.s	9092	9092	9092
	PW	PTS	185 dB re 1 mPa^2.s	1705	1705	1705
		TTS	170 dB re 1 mPa^2.s	16531	16531	16531
1 hour	LF	PTS	183 dB re 1 mPa^2.s	16531	16531	16531
		TTS	168 dB re 1 mPa^2.s	36782	36782	36782
	MF	PTS	185 dB re 1 mPa^2.s	<1	<1	<1
		TTS	170 dB re 1 mPa^2.s	362	362	362
	HF	PTS	155 dB re 1 mPa^2.s	1188	1188	1188
		TTS	140 dB re 1 mPa^2.s	14103	14103	14103
	PW	PTS	185 dB re 1 mPa^2.s	2325	2325	2325
		TTS	170 dB re 1 mPa^2.s	23402	23402	23402
2 hour	LF	PTS	183 dB re 1 mPa^2.s	23402	23402	23402
		TTS	168 dB re 1 mPa^2.s	37195	37195	37195
	MF	PTS	185 dB re 1 mPa^2.s	52	52	52
		TTS	170 dB re 1 mPa^2.s	568	568	568
	HF	PTS	155 dB re 1 mPa^2.s	1756	1756	1756
		TTS	140 dB re 1 mPa^2.s	23402	23402	23402
	PW	PTS	185 dB re 1 mPa^2.s	3771	3771	3771
		TTS	170 dB re 1 mPa^2.s	27690	27690	27690
4 hour	LF	PTS	183 dB re 1 mPa^2.s	27690	27690	27690
		TTS	168 dB re 1 mPa^2.s	38332	38332	38332
	MF	PTS	185 dB re 1 mPa^2.s	52	52	52
		TTS	170 dB re 1 mPa^2.s	1188	1188	1188
	HF	PTS	155 dB re 1 mPa^2.s	3255	3255	3255
		TTS	140 dB re 1 mPa^2.s	24435	24435	24435
	PW	PTS	185 dB re 1 mPa^2.s	6251	6251	6251
		TTS	170 dB re 1 mPa^2.s	32907	32907	32907
12 hour	LF	PTS	183 dB re 1 mPa^2.s	35232	35232	35232
		TTS	168 dB re 1 mPa^2.s	39985	39985	39985
	MF	PTS	185 dB re 1 mPa^2.s	155	155	155
		TTS	170 dB re 1 mPa^2.s	2273	2273	2273
	HF	PTS	155 dB re 1 mPa^2.s	9092	9092	9092
		TTS	140 dB re 1 mPa^2.s	32907	32907	32907
	PW	PTS	185 dB re 1 mPa^2.s	14103	14103	14103
		TTS	170 dB re 1 mPa^2.s	36575	36575	36575
24 hour	LF	PTS	183 dB re 1 mPa^2.s	36420	36420	36420
		TTS	168 dB re 1 mPa^2.s	40191	40191	40191
	MF	PTS	185 dB re 1 mPa^2.s	258	258	258
		TTS	170 dB re 1 mPa^2.s	3616	3616	3616
	HF	PTS	155 dB re 1 mPa^2.s	14103	14103	14103
		TTS	140 dB re 1 mPa^2.s	36162	36162	36162
	PW	PTS	185 dB re 1 mPa^2.s	23402	23402	23402
		TTS	170 dB re 1 mPa^2.s	37040	37040	37040

Table A.43: Summary of impact ranges in metres at which SEL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of April at Site C1

Op period	FHG	Impact	Threshold	Min	Max	Mean
Single strike	Fish 1	Mort	219 dB re 1 mPa^2.s	<1	<1	<1
	Fish 1	Reco	216 dB re 1 mPa^2.s	<1	<1	<1
	Fish 2	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Fish 2	Reco	203 dB re 1 mPa^2.s	<1	<1	<1
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	<1	<1	<1
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	<1	<1	<1
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	103	103	103
	Sea turtle	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Mackerel	Beh 50%	142 dB re 1 mPa^2.s	27690	27690	27690
	Sprat	Beh 50%	135 dB re 1 mPa^2.s	36162	36162	36162
30 minutes	Fish 1	Mort	219 dB re 1 mPa^2.s	103	103	103
	Fish 1	Reco	216 dB re 1 mPa^2.s	207	207	207
	Fish 2	Mort	210 dB re 1 mPa^2.s	465	465	465
	Fish 2	Reco	203 dB re 1 mPa^2.s	1188	1188	1188
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	775	775	775
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1188	1188	1188
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	9092	9092	9092
	Sea turtle	Mort	210 dB re 1 mPa^2.s	465	465	465
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	465	465	465
1 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	207	207	207
	Fish 1	Reco	216 dB re 1 mPa^2.s	310	310	310
	Fish 2	Mort	210 dB re 1 mPa^2.s	775	775	775
	Fish 2	Reco	203 dB re 1 mPa^2.s	1705	1705	1705
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1188	1188	1188
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1705	1705	1705
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	14103	14103	14103
	Sea turtle	Mort	210 dB re 1 mPa^2.s	775	775	775
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	775	775	775
2 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	310	310	310
	Fish 1	Reco	216 dB re 1 mPa^2.s	465	465	465
	Fish 2	Mort	210 dB re 1 mPa^2.s	1188	1188	1188
	Fish 2	Reco	203 dB re 1 mPa^2.s	2273	2273	2273
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1498	1498	1498
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	2273	2273	2273
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	16531	16531	16531

Op period	FHG	Impact	Threshold	Min	Max	Mean
	Sea turtle	Mort	210 dB re 1 mPa^2.s	1188	1188	1188
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	1188	1188	1188
4 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	465	465	465
	Fish 1	Reco	216 dB re 1 mPa^2.s	775	775	775
	Fish 2	Mort	210 dB re 1 mPa^2.s	1498	1498	1498
	Fish 2	Reco	203 dB re 1 mPa^2.s	2893	2893	2893
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	2066	2066	2066
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	2893	2893	2893
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	23402	23402	23402
	Sea turtle	Mort	210 dB re 1 mPa^2.s	1498	1498	1498
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	1498	1498	1498
12 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	878	878	878
	Fish 1	Reco	216 dB re 1 mPa^2.s	1446	1446	1446
	Fish 2	Mort	210 dB re 1 mPa^2.s	2480	2480	2480
	Fish 2	Reco	203 dB re 1 mPa^2.s	5011	5011	5011
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	2945	2945	2945
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	5011	5011	5011
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	31461	31461	31461
	Sea turtle	Mort	210 dB re 1 mPa^2.s	2480	2480	2480
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	2480	2480	2480
24 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	1446	1446	1446
	Fish 1	Reco	216 dB re 1 mPa^2.s	1756	1756	1756
	Fish 2	Mort	210 dB re 1 mPa^2.s	2945	2945	2945
	Fish 2	Reco	203 dB re 1 mPa^2.s	6819	6819	6819
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	4288	4288	4288
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	6819	6819	6819
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	35232	35232	35232
	Sea turtle	Mort	210 dB re 1 mPa^2.s	2945	2945	2945
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	2945	2945	2945

August (0° transect, SL = 249 dB re 1 mPa at 1 m)

Table A.44: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of August at Site C1

FHG	Impact	Threshold	Min	Max	Mean
LF	PTS	219 dB re 1 mPa peak	<1	<1	<1
	TTS	213 dB re 1 mPa peak	52	52	52
MF	PTS	230 dB re 1 mPa peak	<1	<1	<1
	TTS	224 dB re 1 mPa peak	<1	<1	<1
HF	PTS	202 dB re 1 mPa peak	310	310	310
	TTS	196 dB re 1 mPa peak	620	620	620
PW	PTS	218 dB re 1 mPa peak	<1	<1	<1
	TTS	212 dB re 1 mPa peak	52	52	52
All MM	Level B+20 dB	180 dB re 1 mPa rms	310	310	310
	Level B	160 dB re 1 mPa rms	2686	2686	2686
	Level B-20 dB	140 dB re 1 mPa rms	12915	12915	12915

Table A.45: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of August at Site C1

FHG	Impact	Threshold	Min	Max	Mean
Fish 1	Mort, Reco	213 dB re 1 mPa peak	52	52	52
Fish 2/3/4	Mort, Reco	207 dB re 1 mPa peak	155	155	155
Sea turtle	Mort	207 dB re 1 mPa peak	155	155	155
Eggs & larvae	Mort	207 dB re 1 mPa peak	155	155	155
Sea turtle	Aver. Beh	175 dB re 1 mPa rms	568	568	568

Table A.46: Summary of impact ranges in metres at which m-weighted SEL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of August at Site C1

Op period	FHG	Impact	Threshold	Min	Max	Mean
30 minutes	LF	PTS	183 dB re 1 mPa^2.s	5476	5476	5476
		TTS	168 dB re 1 mPa^2.s	16273	16273	16273
	MF	PTS	185 dB re 1 mPa^2.s	<1	<1	<1
		TTS	170 dB re 1 mPa^2.s	207	207	207
	HF	PTS	155 dB re 1 mPa^2.s	568	568	568
		TTS	140 dB re 1 mPa^2.s	4804	4804	4804
	PW	PTS	185 dB re 1 mPa^2.s	1343	1343	1343
		TTS	170 dB re 1 mPa^2.s	7904	7904	7904
1 hour	LF	PTS	183 dB re 1 mPa^2.s	7904	7904	7904
		TTS	168 dB re 1 mPa^2.s	18753	18753	18753
	MF	PTS	185 dB re 1 mPa^2.s	<1	<1	<1
		TTS	170 dB re 1 mPa^2.s	310	310	310
	HF	PTS	155 dB re 1 mPa^2.s	982	982	982
		TTS	140 dB re 1 mPa^2.s	7181	7181	7181
	PW	PTS	185 dB re 1 mPa^2.s	2066	2066	2066
		TTS	170 dB re 1 mPa^2.s	9970	9970	9970
2 hour	LF	PTS	183 dB re 1 mPa^2.s	9970	9970	9970
		TTS	168 dB re 1 mPa^2.s	21077	21077	21077
	MF	PTS	185 dB re 1 mPa^2.s	52	52	52
		TTS	170 dB re 1 mPa^2.s	568	568	568
	HF	PTS	155 dB re 1 mPa^2.s	1705	1705	1705
		TTS	140 dB re 1 mPa^2.s	8834	8834	8834
	PW	PTS	185 dB re 1 mPa^2.s	2635	2635	2635
		TTS	170 dB re 1 mPa^2.s	11675	11675	11675
4 hour	LF	PTS	183 dB re 1 mPa^2.s	11675	11675	11675
		TTS	168 dB re 1 mPa^2.s	23764	23764	23764
	MF	PTS	185 dB re 1 mPa^2.s	52	52	52
		TTS	170 dB re 1 mPa^2.s	878	878	878
	HF	PTS	155 dB re 1 mPa^2.s	2325	2325	2325
		TTS	140 dB re 1 mPa^2.s	11365	11365	11365
	PW	PTS	185 dB re 1 mPa^2.s	4029	4029	4029
		TTS	170 dB re 1 mPa^2.s	14155	14155	14155
12 hour	LF	PTS	183 dB re 1 mPa^2.s	14723	14723	14723
		TTS	168 dB re 1 mPa^2.s	27328	27328	27328
	MF	PTS	185 dB re 1 mPa^2.s	155	155	155
		TTS	170 dB re 1 mPa^2.s	2066	2066	2066
	HF	PTS	155 dB re 1 mPa^2.s	4133	4133	4133
		TTS	140 dB re 1 mPa^2.s	14723	14723	14723
	PW	PTS	185 dB re 1 mPa^2.s	6561	6561	6561
		TTS	170 dB re 1 mPa^2.s	18081	18081	18081
24 hour	LF	PTS	183 dB re 1 mPa^2.s	18081	18081	18081
		TTS	168 dB re 1 mPa^2.s	29653	29653	29653
	MF	PTS	185 dB re 1 mPa^2.s	258	258	258
		TTS	170 dB re 1 mPa^2.s	2583	2583	2583
	HF	PTS	155 dB re 1 mPa^2.s	6044	6044	6044
		TTS	140 dB re 1 mPa^2.s	16841	16841	16841
	PW	PTS	185 dB re 1 mPa^2.s	8834	8834	8834
		TTS	170 dB re 1 mPa^2.s	20819	20819	20819

Table A.47: Summary of impact ranges in metres at which SEL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of August at Site C1

Op period	FHG	Impact	Threshold	Min	Max	Mean
Single strike	Fish 1	Mort	219 dB re 1 mPa^2.s	<1	<1	<1
	Fish 1	Reco	216 dB re 1 mPa^2.s	<1	<1	<1
	Fish 2	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Fish 2	Reco	203 dB re 1 mPa^2.s	<1	<1	<1
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	<1	<1	<1
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	<1	<1	<1
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	103	103	103
	Sea turtle	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Mackerel	Beh 50%	142 dB re 1 mPa^2.s	11675	11675	11675
	Sprat	Beh 50%	135 dB re 1 mPa^2.s	16841	16841	16841
30 minutes	Fish 1	Mort	219 dB re 1 mPa^2.s	103	103	103
	Fish 1	Reco	216 dB re 1 mPa^2.s	207	207	207
	Fish 2	Mort	210 dB re 1 mPa^2.s	465	465	465
	Fish 2	Reco	203 dB re 1 mPa^2.s	982	982	982
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	620	620	620
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	982	982	982
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	4856	4856	4856
	Sea turtle	Mort	210 dB re 1 mPa^2.s	465	465	465
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	465	465	465
1 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	207	207	207
	Fish 1	Reco	216 dB re 1 mPa^2.s	310	310	310
	Fish 2	Mort	210 dB re 1 mPa^2.s	620	620	620
	Fish 2	Reco	203 dB re 1 mPa^2.s	1292	1292	1292
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	827	827	827
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1292	1292	1292
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	5683	5683	5683
	Sea turtle	Mort	210 dB re 1 mPa^2.s	620	620	620
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	620	620	620
2 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	310	310	310
	Fish 1	Reco	216 dB re 1 mPa^2.s	465	465	465
	Fish 2	Mort	210 dB re 1 mPa^2.s	827	827	827
	Fish 2	Reco	203 dB re 1 mPa^2.s	1653	1653	1653
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1188	1188	1188
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1653	1653	1653

Op period	FHG	Impact	Threshold	Min	Max	Mean
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	8007	8007	8007
	Sea turtle	Mort	210 dB re 1 mPa^2.s	827	827	827
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	827	827	827
4 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	465	465	465
	Fish 1	Reco	216 dB re 1 mPa^2.s	620	620	620
	Fish 2	Mort	210 dB re 1 mPa^2.s	1188	1188	1188
	Fish 2	Reco	203 dB re 1 mPa^2.s	2325	2325	2325
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1498	1498	1498
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	2325	2325	2325
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	10074	10074	10074
	Sea turtle	Mort	210 dB re 1 mPa^2.s	1188	1188	1188
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	1188	1188	1188
12 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	775	775	775
	Fish 1	Reco	216 dB re 1 mPa^2.s	982	982	982
	Fish 2	Mort	210 dB re 1 mPa^2.s	1756	1756	1756
	Fish 2	Reco	203 dB re 1 mPa^2.s	3410	3410	3410
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	2531	2531	2531
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	3410	3410	3410
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	13535	13535	13535
	Sea turtle	Mort	210 dB re 1 mPa^2.s	1756	1756	1756
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	1756	1756	1756
24 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	982	982	982
	Fish 1	Reco	216 dB re 1 mPa^2.s	1446	1446	1446
	Fish 2	Mort	210 dB re 1 mPa^2.s	2531	2531	2531
	Fish 2	Reco	203 dB re 1 mPa^2.s	4856	4856	4856
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	3203	3203	3203
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	4856	4856	4856
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	15601	15601	15601
	Sea turtle	Mort	210 dB re 1 mPa^2.s	2531	2531	2531
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	2531	2531	2531

Impact Ranges: Copeland - Site C2

April (All transects, SL = 252 dB re 1 mPa at 1 m)

Table A.48: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of April at Site C2

FHG	Impact	Threshold	Min	Max	Mean
LF	PTS	219 dB re 1 mPa peak	<1	59	23
	TTS	213 dB re 1 □Pa peak	79	151	118
MF	PTS	230 dB re 1 □Pa peak	<1	<1	<1
	TTS	224 dB re 1 □Pa peak	<1	26	5
HF	PTS	202 dB re 1 □Pa peak	368	578	495
	TTS	196 dB re 1 □Pa peak	772	1254	986
PW	PTS	218 dB re 1 □Pa peak	<1	67	29
	TTS	212 dB re 1 □Pa peak	79	160	121
All MM	Level B+20 dB	180 dB re 1 mPa rms	368	578	495
	Level B	160 dB re 1 □Pa rms	2281	4230	3196
	Level B-20 dB	140 dB re 1 □Pa rms	9141	31930	18444

Table A.49: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of April at Site C2

FHG	Impact	Threshold	Min	Max	Mean
Fish 1	Mort, Reco	213 dB re 1 □Pa peak	79	151	118
Fish 2/3/4	Mort, Reco	207 dB re 1 □Pa peak	197	335	272
Sea turtle	Mort	207 dB re 1 □Pa peak	197	335	272
Eggs & larvae	Mort	207 dB re 1 □Pa peak	197	335	272
Sea turtle	Aver. Beh	175 dB re 1 □Pa rms	736	1138	929

Table A.50: Summary of impact ranges in metres at which m-weighted SEL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of April at Site C2

Op period	FHG	Impact	Threshold	Min	Max	Mean
30 minutes	LF	PTS	183 dB re 1 μPa^2.s	3966	8370	6116
		TTS	168 dB re 1 μPa^2.s	9736	49562	27867
	MF	PTS	185 dB re 1 μPa^2.s	<1	44	16
		TTS	170 dB re 1 μPa^2.s	257	526	388
	HF	PTS	155 dB re 1 μPa^2.s	736	1344	1024
		TTS	140 dB re 1 μPa^2.s	6346	22157	8051
	PW	PTS	185 dB re 1 μPa^2.s	1182	2655	1847
		TTS	170 dB re 1 μPa^2.s	7536	22157	9902
1 hour	LF	PTS	183 dB re 1 μPa^2.s	6201	22157	8290
		TTS	168 dB re 1 μPa^2.s	9847	67846	36172
	MF	PTS	185 dB re 1 μPa^2.s	<1	67	29
		TTS	170 dB re 1 μPa^2.s	394	830	614
	HF	PTS	155 dB re 1 μPa^2.s	1093	2040	1537
		TTS	140 dB re 1 μPa^2.s	8423	22157	11377
	PW	PTS	185 dB re 1 μPa^2.s	1676	3603	2549
		TTS	170 dB re 1 μPa^2.s	8890	22157	13956
2 hour	LF	PTS	183 dB re 1 μPa^2.s	8032	22157	11168
		TTS	168 dB re 1 μPa^2.s	9860	96978	47104
	MF	PTS	185 dB re 1 μPa^2.s	60	138	103
		TTS	170 dB re 1 μPa^2.s	600	1321	974
	HF	PTS	155 dB re 1 μPa^2.s	1676	3157	2434
		TTS	140 dB re 1 μPa^2.s	9088	23169	15927
	PW	PTS	185 dB re 1 μPa^2.s	2385	5070	3486
		TTS	170 dB re 1 μPa^2.s	9168	31930	18973
4 hour	LF	PTS	183 dB re 1 μPa^2.s	9009	26372	15513
		TTS	168 dB re 1 μPa^2.s	9902	99620	51602
	MF	PTS	185 dB re 1 μPa^2.s	81	194	139
		TTS	170 dB re 1 μPa^2.s	994	2028	1472
	HF	PTS	155 dB re 1 μPa^2.s	2683	4710	3377
		TTS	140 dB re 1 μPa^2.s	9511	37307	20700
	PW	PTS	185 dB re 1 μPa^2.s	3568	7358	4963
		TTS	170 dB re 1 μPa^2.s	9736	42463	25564
12 hour	LF	PTS	183 dB re 1 μPa^2.s	9657	42463	25022
		TTS	168 dB re 1 μPa^2.s	9929	100020	53295
	MF	PTS	185 dB re 1 μPa^2.s	197	437	316
		TTS	170 dB re 1 μPa^2.s	1872	3510	2712
	HF	PTS	155 dB re 1 μPa^2.s	5201	8379	6604
		TTS	140 dB re 1 μPa^2.s	9847	52929	31402
	PW	PTS	185 dB re 1 μPa^2.s	6346	22157	8632
		TTS	170 dB re 1 μPa^2.s	9847	85638	40470
24 hour	LF	PTS	183 dB re 1 μPa^2.s	9847	58799	32934
		TTS	168 dB re 1 μPa^2.s	9971	100020	53923
	MF	PTS	185 dB re 1 μPa^2.s	344	760	540
		TTS	170 dB re 1 μPa^2.s	2882	5330	3894
	HF	PTS	155 dB re 1 μPa^2.s	8032	22157	9978
		TTS	140 dB re 1 μPa^2.s	9874	85638	40874
	PW	PTS	185 dB re 1 μPa^2.s	8490	22157	12207
		TTS	170 dB re 1 μPa^2.s	9888	97276	49218

Table A.51: Summary of impact ranges in metres at which SEL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of April at Site C2

Op period	FHG	Impact	Threshold	Min	Max	Mean
Single strike	Fish 1	Mort	219 dB re 1 mPa^2.s	<1	<1	<1
	Fish 1	Reco	216 dB re 1 mPa^2.s	<1	<1	<1
	Fish 2	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Fish 2	Reco	203 dB re 1 mPa^2.s	<1	23	5
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	<1	13	<1
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	<1	23	5
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	184	285	247
	Sea turtle	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Mackerel	Beh 50%	142 dB re 1 mPa^2.s	8890	23104	14594
	Sprat	Beh 50%	135 dB re 1 mPa^2.s	9736	52492	29686
30 minutes	Fish 1	Mort	219 dB re 1 mPa^2.s	167	282	234
	Fish 1	Reco	216 dB re 1 mPa^2.s	199	400	326
	Fish 2	Mort	210 dB re 1 mPa^2.s	535	810	685
	Fish 2	Reco	203 dB re 1 mPa^2.s	1084	1830	1408
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	736	1140	943
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1084	1830	1408
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	3768	7404	5136
	Sea turtle	Mort	210 dB re 1 mPa^2.s	535	810	685
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	535	810	685
1 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	199	400	328
	Fish 1	Reco	216 dB re 1 mPa^2.s	343	570	467
	Fish 2	Mort	210 dB re 1 mPa^2.s	736	1140	943
	Fish 2	Reco	203 dB re 1 mPa^2.s	1380	2220	1777
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	894	1562	1242
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1380	2220	1777
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	4571	9690	6413
	Sea turtle	Mort	210 dB re 1 mPa^2.s	736	1140	943
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	736	1140	943
2 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	343	570	467
	Fish 1	Reco	216 dB re 1 mPa^2.s	535	810	685
	Fish 2	Mort	210 dB re 1 mPa^2.s	895	1562	1249
	Fish 2	Reco	203 dB re 1 mPa^2.s	1700	2853	2228
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1281	2048	1672
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1700	2853	2228
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	6445	22157	8559
	Sea turtle	Mort	210 dB re 1 mPa^2.s	895	1562	1249

Op period	FHG	Impact	Threshold	Min	Max	Mean
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	895	1562	1249
4 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	535	810	686
	Fish 1	Reco	216 dB re 1 mPa^2.s	736	1140	944
	Fish 2	Mort	210 dB re 1 mPa^2.s	1281	2048	1672
	Fish 2	Reco	203 dB re 1 mPa^2.s	2070	3690	2794
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1600	2640	2069
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	2070	3690	2794
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	8468	22157	11343
	Sea turtle	Mort	210 dB re 1 mPa^2.s	1281	2048	1672
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	1281	2048	1672
12 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	887	1373	1113
	Fish 1	Reco	216 dB re 1 mPa^2.s	1159	1860	1494
	Fish 2	Mort	210 dB re 1 mPa^2.s	1775	3150	2382
	Fish 2	Reco	203 dB re 1 mPa^2.s	2975	5370	4042
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	2169	4030	2971
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	2975	5370	4042
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	9141	31930	18670
	Sea turtle	Mort	210 dB re 1 mPa^2.s	1775	3150	2382
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	1775	3150	2382
24 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	1159	1860	1494
	Fish 1	Reco	216 dB re 1 mPa^2.s	1400	2280	1854
	Fish 2	Mort	210 dB re 1 mPa^2.s	2169	4030	2974
	Fish 2	Reco	203 dB re 1 mPa^2.s	3768	7358	5099
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	2776	5070	3745
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	3768	7358	5099
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	9736	42463	25300
	Sea turtle	Mort	210 dB re 1 mPa^2.s	2169	4030	2974
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	2169	4030	2974

August (All transects, SL = 252 dB re 1 mPa at 1 m)

Table A.52: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of August at Site C2

FHG	Impact	Threshold	Min	Max	Mean
LF	PTS	219 dB re 1 mPa peak	<1	55	20
	TTS	213 dB re 1 mPa peak	79	146	114
MF	PTS	230 dB re 1 mPa peak	<1	<1	<1
	TTS	224 dB re 1 mPa peak	<1	23	5
HF	PTS	202 dB re 1 mPa peak	368	519	454
	TTS	196 dB re 1 mPa peak	690	1052	843
PW	PTS	218 dB re 1 mPa peak	0	67	28
	TTS	212 dB re 1 mPa peak	79	152	118
All MM	Level B+20 dB	180 dB re 1 mPa rms	368	519	454
	Level B	160 dB re 1 mPa rms	2082	3233	2650
	Level B-20 dB	140 dB re 1 mPa rms	8124	13080	10688

Table A.53: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of August at Site C2

FHG	Impact	Threshold	Min	Max	Mean
Fish 1	Mort, Reco	213 dB re 1 mPa peak	79	146	114
Fish 2/3/4	Mort, Reco	207 dB re 1 mPa peak	197	290	252
Sea turtle	Mort	207 dB re 1 mPa peak	197	290	252
Eggs & larvae	Mort	207 dB re 1 mPa peak	197	290	252
Sea turtle	Aver. Beh	175 dB re 1 mPa rms	600	888	777

Table A.54: Summary of impact ranges in metres at which m-weighted SEL has fallen to threshold level for marine mammals exposed to underwater noise from a geophysical survey during the month of August at Site C2

Op period	FHG	Impact	Threshold	Min	Max	Mean
30 minutes	LF	PTS	183 dB re 1 mPa^2.s	3701	6265	4841
		TTS	168 dB re 1 mPa^2.s	8481	16468	13431
	MF	PTS	185 dB re 1 mPa^2.s	<1	44	16
		TTS	170 dB re 1 mPa^2.s	257	471	374
	HF	PTS	155 dB re 1 mPa^2.s	689	1207	926
		TTS	140 dB re 1 mPa^2.s	4827	6693	5604
	PW	PTS	185 dB re 1 mPa^2.s	1084	2220	1633
		TTS	170 dB re 1 mPa^2.s	5320	8514	6720
1 hour	LF	PTS	183 dB re 1 mPa^2.s	4577	7449	6006
		TTS	168 dB re 1 mPa^2.s	8692	19773	15822
	MF	PTS	185 dB re 1 mPa^2.s	<1	66	28
		TTS	170 dB re 1 mPa^2.s	394	760	577
	HF	PTS	155 dB re 1 mPa^2.s	985	1927	1451
		TTS	140 dB re 1 mPa^2.s	6346	8564	7435
	PW	PTS	185 dB re 1 mPa^2.s	1491	2880	2223
		TTS	170 dB re 1 mPa^2.s	6995	10758	8582
2 hour	LF	PTS	183 dB re 1 mPa^2.s	6049	9212	7571
		TTS	168 dB re 1 mPa^2.s	8904	23807	18377
	MF	PTS	185 dB re 1 mPa^2.s	<1	134	75
		TTS	170 dB re 1 mPa^2.s	595	1163	875
	HF	PTS	155 dB re 1 mPa^2.s	1675	2779	2131
		TTS	140 dB re 1 mPa^2.s	7873	11262	9551
	PW	PTS	185 dB re 1 mPa^2.s	2089	3974	2939
		TTS	170 dB re 1 mPa^2.s	8151	13003	10657
4 hour	LF	PTS	183 dB re 1 mPa^2.s	7860	11400	9271
		TTS	168 dB re 1 mPa^2.s	9062	29350	20988
	MF	PTS	185 dB re 1 mPa^2.s	84	189	143
		TTS	170 dB re 1 mPa^2.s	894	1871	1311
	HF	PTS	155 dB re 1 mPa^2.s	2266	3630	3018
		TTS	140 dB re 1 mPa^2.s	8336	13914	11790
	PW	PTS	185 dB re 1 mPa^2.s	2956	5148	4014
		TTS	170 dB re 1 mPa^2.s	8468	15774	12919
12 hour	LF	PTS	183 dB re 1 mPa^2.s	8375	15774	12557
		TTS	168 dB re 1 mPa^2.s	9406	39156	25108
	MF	PTS	185 dB re 1 mPa^2.s	197	390	302
		TTS	170 dB re 1 mPa^2.s	1789	2943	2378
	HF	PTS	155 dB re 1 mPa^2.s	4066	5718	4969
		TTS	140 dB re 1 mPa^2.s	8758	19345	15408
	PW	PTS	185 dB re 1 mPa^2.s	4875	7259	6090
		TTS	170 dB re 1 mPa^2.s	8758	21395	16837
24 hour	LF	PTS	183 dB re 1 mPa^2.s	8666	18850	14802
		TTS	168 dB re 1 mPa^2.s	9847	41789	27875
	MF	PTS	185 dB re 1 mPa^2.s	357	593	486
		TTS	170 dB re 1 mPa^2.s	2485	4533	3427
	HF	PTS	155 dB re 1 mPa^2.s	5870	8514	6786
		TTS	140 dB re 1 mPa^2.s	8917	22684	17920
	PW	PTS	185 dB re 1 mPa^2.s	6346	9821	7824
		TTS	170 dB re 1 mPa^2.s	8917	25008	19276

Table A.55: Summary of impact ranges in metres at which SEL has fallen to threshold level for fish exposed to underwater noise from a geophysical survey during the month of August at Site C2

Op period	FHG	Impact	Threshold	Min	Max	Mean
Single strike	Fish 1	Mort	219 dB re 1 mPa^2.s	<1	<1	<1
	Fish 1	Reco	216 dB re 1 mPa^2.s	<1	<1	<1
	Fish 2	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Fish 2	Reco	203 dB re 1 mPa^2.s	<1	23	5
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	<1	<1	<1
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	<1	23	5
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	167	278	226
	Sea turtle	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	<1	<1	<1
	Mackerel	Beh 50%	142 dB re 1 mPa^2.s	7561	11400	9205
	Sprat	Beh 50%	135 dB re 1 mPa^2.s	8520	18850	14059
30 minutes	Fish 1	Mort	219 dB re 1 mPa^2.s	161	248	216
	Fish 1	Reco	216 dB re 1 mPa^2.s	197	378	292
	Fish 2	Mort	210 dB re 1 mPa^2.s	493	731	608
	Fish 2	Reco	203 dB re 1 mPa^2.s	892	1373	1145
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	686	905	797
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	892	1373	1145
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	3074	5280	4211
	Sea turtle	Mort	210 dB re 1 mPa^2.s	493	731	608
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	493	731	608
1 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	197	378	292
	Fish 1	Reco	216 dB re 1 mPa^2.s	296	501	415
	Fish 2	Mort	210 dB re 1 mPa^2.s	686	905	797
	Fish 2	Reco	203 dB re 1 mPa^2.s	1182	1884	1524
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	800	1268	1057
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1182	1884	1524
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	3867	6720	5134
	Sea turtle	Mort	210 dB re 1 mPa^2.s	686	905	797
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	686	905	797
2 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	296	501	415
	Fish 1	Reco	216 dB re 1 mPa^2.s	493	731	608
	Fish 2	Mort	210 dB re 1 mPa^2.s	800	1268	1057
	Fish 2	Reco	203 dB re 1 mPa^2.s	1479	2354	1891
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1084	1609	1341
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1479	2354	1891
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	5201	8160	6364
	Sea turtle	Mort	210 dB re 1 mPa^2.s	800	1268	1057

Op period	FHG	Impact	Threshold	Min	Max	Mean
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	800	1268	1057
4 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	493	731	608
	Fish 1	Reco	216 dB re 1 mPa^2.s	686	905	797
	Fish 2	Mort	210 dB re 1 mPa^2.s	1084	1609	1341
	Fish 2	Reco	203 dB re 1 mPa^2.s	1773	2853	2355
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1380	2237	1791
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	1773	2853	2355
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	6247	9821	7834
	Sea turtle	Mort	210 dB re 1 mPa^2.s	1084	1609	1341
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	1084	1609	1341
12 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	788	1138	957
	Fish 1	Reco	216 dB re 1 mPa^2.s	1070	1413	1230
	Fish 2	Mort	210 dB re 1 mPa^2.s	1590	2462	2019
	Fish 2	Reco	203 dB re 1 mPa^2.s	2578	4230	3340
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	1987	2994	2499
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	2578	4230	3340
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	8151	13080	10749
	Sea turtle	Mort	210 dB re 1 mPa^2.s	1590	2462	2019
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	1590	2462	2019
24 hour	Fish 1	Mort	219 dB re 1 mPa^2.s	1070	1413	1230
	Fish 1	Reco	216 dB re 1 mPa^2.s	1281	1982	1628
	Fish 2	Mort	210 dB re 1 mPa^2.s	1987	2994	2499
	Fish 2	Reco	203 dB re 1 mPa^2.s	3056	5250	4176
	Fish 3/4	Mort	207 dB re 1 mPa^2.s	2400	4020	3117
	Fish 3/4	Reco	203 dB re 1 mPa^2.s	3056	5250	4176
	Fish 1/2/3/4	TTS	186 dB re 1 mPa^2.s	8402	15774	12721
	Sea turtle	Mort	210 dB re 1 mPa^2.s	1987	2994	2499
	Eggs & larvae	Mort	210 dB re 1 mPa^2.s	1987	2994	2499

Appendix E: Regulator Consultation Communication

Marine Management Organisation

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NE4 7YH

Our reference:
ENQ/2021/00099

Ruth Letourneur
RWM Limited
By email only

18 October 2021

Dear Ruth,

Geological Disposal Facility - geophysical investigation

Thank you for your request for advice on the proposed approach to underwater sound modelling for seismic surveys off the coast of Copeland in Cumbria.

The submitted documents were sent to the MMO's technical advisors, Centre for Environment, Fisheries and Aquaculture Science (Cefas), who provided comments to inform the MMO's advice detailed below.

Underwater sound

1.1. The Radioactive Waste Management Underwater Sound Modelling PowerPoint presents three potential approaches to the noise assessment: (i) no project specific modelling, adopt literature based on impact zones; (ii) simple modelling of propagation loss estimated using geometric spreading laws; and (iii) detailed modelling allowing for parameterised scenarios. The project has adopted the third approach: detailed modelling allowing for parameterised scenarios, which the MMO believe is appropriate for this project. we have a few specific comments on the proposed approach and suitability, please see points 1.2 – 1.10 below.

Propagation model (page 12 of PowerPoint document):

1.2. A combination of models is selected for the determination of sound propagation: BELLHOP (ray trace method which is appropriate at high frequencies) and RAM (parabolic equation which covers low frequencies). This is appropriate. However, we note that the peak sound pressure needs to be considered. For example, seismic surveys are an impulsive source, and the marine mammal noise exposure criteria consist of dual thresholds based on the peak sound pressure level (SPL peak) and the cumulative sound exposure level (SEL_{cum}). Likewise, for fish, the noise thresholds for geophysical survey sound sources are based on the SPL peak and the SEL_{cum}.

1.3. Therefore, for assessing the **peak pressure**, an appropriate propagation (time domain) model will be required. One option would be to use a specific airgun model (e.g. AGORA)[23]. The other option would be to use the BELLHOP and RAM model and then convert between the metrics following guidance in the published (peer reviewed) literature [i.e. from SEL to SPL peak - see Galindo-Romero et al. (2015)].

Model input parameters – source levels (page 14 of the PowerPoint document and page 1 of the word document):

1.4. The source levels selected for the modelling are as follows (blue bullet points below). The SPL(rms) source level of 230 dB re 1 µPa at 1 m appears to be quite loud (one order of magnitude higher than piling). The MMO request that justification is provided for these source levels. For example, are the source levels based on a single airgun?

- SPL (zero-to-peak) = 252 dB re 1 µPa at 1 m
- SPL (peak-to-peak) = 259 dB re 1 µPa at 1 m
- SPL (rms) = 230 dB re 1 µPa at 1 m
- SELss = 236 dB re 1 µPa2-s at 1 m
- SEL_{cum} (24 hour) = 279 dB re 1 µPa2-s at 1 m

1.5. There is the discrepancy between the SPL(rms) source level of 230 dB re 1 µPa at 1 m and the SELss source level of 236 dB re 1 µPa at 1 m. Furthermore, seismic airguns are an impulsive source, so the RMS metric is not entirely appropriate or even relevant (the SPLrms metric would be appropriate for continuous sources).
The MMO suspect the RMS level just comes from "spreading out" the single pulse over the 5 second interval between pulses but it would be helpful for the applicant to clarify this. For the SEL assessment, the SELss would be the starting point, followed by adding up the exposure from all pulses with 24 hours (or the assessment period considered).

[23] Sertlek and Ainslie (2015). AGORA: Airgun source signature model: its application for the Dutch seismic survey, UAC Conference Proceedings. Available at: https://www.researchgate.net/publication/286360188_AGORA_Airgun_source_signature_model_its_application_for_the_Dutch_seismic_survey (Accessed 12th October 2021)

Model input parameters – sound metrics (page 16 of the PowerPoint document:

1.6. For the worst-case scenario, the modelling must take into account the entire activity within a 24-hour period (e.g. the total array, the number of airguns / multiple sources).

Underwater sound impact threshold criteria (page 19 of the PowerPoint document):

1.7. The document refers to appropriate noise exposure criteria / thresholds for marine mammals (i.e. NMFS, 2018 and Southall et al., 2019) and for fish and turtles (i.e. Popper et al., 2014).

1.8. Currently, there are no set thresholds for assessing behavioural effects and responses. Behavioural effects are particularly difficult to assess; they are highly

---

dependent on behavioural context (Ellison et al., 2012; Popper et al., 2014) and responses may not scale with received sound level (Gomez et al., 2016). Consequently, there is considerable uncertainty in assessing the risk of behavioural responses, and the application of simplistic sound level thresholds for behaviour should generally be avoided. Recent studies have considered more sophisticated approaches to quantify the risk of behavioural responses, for example through dual criteria based on dose-response curves for proximity to the sound source and received sound level (Dunlop et al., 2017). Approaches based directly on the “distance of effect” reported for in-situ behavioural studies (e.g. Merchant et al., 2017) can also be used as an empirical estimate of the risk of behavioural responses (Gomez et al., 2016), provided that the sound level of the noise source in the cited study is not substantially exceeded in the assessment scenario.

1.9. The assessment proposes to use the following thresholds for behaviour (bullet points below).

- Marine mammals: NOAA ‘Level B Harassment’ of 160 dB rms for impulsive sound.
- Fish: The US Fisheries and Wildlife Service’ threshold of 150 dB rms.

Notwithstanding the comments above, given that seismic surveys are impulsive sources, one suggestion could be to derive thresholds from the peer-reviewed literature. For example, Hawkins and Popper (2014) reported startle responses of schools of wild sprat and mackerel shoals (mackerel do not possess a swim bladder) at a single-pulse sound exposure level of **135 dB re 1 μPa^{2}s and 142 dB re 1 μPa^{2}s** respectively. Schools of sprat were observed to disperse or change depth on 50% of presentations. These single-pulse sound exposure levels could be taken to be a conservative indicator for the risk of behavioural responses and potential displacement and could be applied to estimate potential behavioural response ranges.

1.10. It is recommended that noise modelling assumes a stationary receptor when assessing potential impacts on fish species.

1.11. The MMO believe the approach to undertake detailed modelling allowing for parameterised scenarios is appropriate (and necessary) given the nature of the proposals.

1.12. The overall approach to undertake detailed modelling allowing for parameterised scenarios is appropriate (and necessary) given the nature of the proposals. The MMO do have some specific comments and recommendations regarding the model parameters and thresholds; please see comments under points 1.1 – 1.10 for further details but in summary:

- Consideration of an appropriate propagation mode will be required for assessing the peak pressure (points 1.2 – 1.3 above).

- Can justification for these source levels be provided? For example, are the source levels based on a single airgun? (point 1.4).

- Please could clarification be provided on the discrepancy between the SPL(rms) source level of 230 dB re 1 µPa at 1 m and the SELss source level of 236 dB re 1 µPa at 1 m? Furthermore, seismic airguns are an impulsive source, so the RMS metric is not entirely appropriate or even relevant (point 1.5).

- The modelling must take into account the entire activity within a 24-hour period (e.g. the total array, the number of airguns / multiple sources) (point 1.6).

- Instead of using a threshold of 150 dB rms to assess fish behavioural responses, the single-pulse sound exposure levels of 135 dB re 1 $\mu Pa^2 s$ and 142 dB re 1 $\mu Pa^2 s$ could be taken to be a conservative indicator for the risk of behavioural responses. Approaches based directly on the “distance of effect” reported for in-situ behavioural studies could also be used as an empirical estimate of the risk of behavioural responses (points 1.8 – 1.9).

Fisheries

2.1. The proposals include the use of thresholds for seismic airguns as described in Popper et al. (2014) which classes fish into three categories for the effects of mortality and potential mortal injury, recoverable injury and temporary threshold shift (TTS); fish with no swim bladder, fish with swim bladder not involved in hearing, fish with sim bladder involved in hearing, and eggs and larvae. The MMO agree that this is appropriate.

2.2. The behavioural criteria described by Popper et al. (2014) are considered appropriate, conservative, and have been peer-reviewed. Nonetheless, it is recognised that the lack of numerical criteria to inform modelling for behavioural responses in fish can be challenging. As an alternative, proposals to use the 150 dB re 1 μPa rms threshold described in Stadler and Woodbury (2009) are included. The MMO do have concerns regarding the appropriateness of this threshold, particularly as the origin of this value is not known, and thus it may not be scientifically robust. As an alternative to this threshold, we recommend that the received levels of a 135 dB single pulse sound exposure level (SELss) is modelled instead, i.e., for locations such as fish spawning grounds. This threshold is based on observations of startle responses in sprat taken from Hawkins et al. (2014).

2.3. Modelling for fish should be based on a stationary receptor.

2.4. The approach seems appropriate, however, please refer to Underwater comments above for overarching technical comments regarding the suitability of the model and parameters chosen.

2.5. We have outlined some useful resources and links to data below which may help with characterising the environment for fisheries and informing the environmental impact assessment;

- For consideration of the potential impacts to fish and their spawning and nursery grounds, I recommend the Applicant refers to Coull et al. (1998) and Ellis et al. (2012).

- The Northern Irish Herring Larvae Survey (NINEL) has been carried out by the Agri-Food and Biosciences Institute (AFBI) in November each year since 1993.
  Survey data and reports can be downloaded from ICES:
  https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Repo rt/EOSG/2021/WGSINS%20Report%202020.pdf#:~:text=The%20Northern%20Iri sh%20Herring%20Larvae%20survey%20monitored%20the,a%20sprat%20r ecruit ment%20index%20of%20the%20North%20Sea.

- Data on migratory species present in coastal areas and estuaries in the region can be acquired from the National Fish Populations Database (NFPD) which contains information on fisheries monitoring undertaken in rivers, transitional and coastal waters by the Environment Agency

Please do not hesitate to get in contact should you require any additional information or clarity on any of the points raised in this advice note.

Yours faithfully,

[redacted]

[redacted]
E [redacted]

Annex 1: References

Underwater Noise

Dunlop, R. A., Noad, M. J., McCauley, R. D., Scott-Hayward, L., Kniest, E., Slade, R., … Cato, D. H. (2017). Determining the behavioural dose response relationship of marine mammals to air gun noise and source proximity. Journal of Experimental Biology, 220, 2878–2886. https:// doi.org/10.1242/jeb.160192.

Ellison, W. T., Southall, B. L., Clark, C. W., & Frankel, A. S. (2012). A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds.
Conservation Biology, 26, 21–28.
https://doi.org/10.1111/j.1523-1739.2011.01803.x

Galindo-Romero, M., Lippert, T. and Gavrilov, A. (2015). Empirical prediction of peak pressure levels in anthropogenic impulsive noise. Part I: Airgun arrays signals. J. Acoust. Soc. Am. 138 (6), December 2015.

Gomez, C., Lawson, J. W., Wright, A. J., Buren, A. D., Tollit, D., & Lesage, V. (2016). A systematic review on the behavioural responses of wild marine mammals to noise: The disparity between science and policy.
Canadian Journal of Zoology, 94, 801–819. https://doi.org/10.1139/ cjz-2016-0098

Hawkins, A.D., Roberts, L. and Cheesman, S. (2014). Repsonses of free-living coastal pelagic fish to impulsive sounds. J. Acoust. Soc. Am. 135 (5), May 2014.

Merchant, N. D., Faulkner, R. C., & Martinez, R. (2017). Marine noise budgets in practice. Conservation Letters. https://doi.org/10.1111/ conl.12420.

National Marine Fisheries Service. (2018). 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 p.

Popper, A. N. Hawkins, A. D. Fay, R. R. Mann, D. Bartol, S. Carlson, Th. Coombs, S. Ellison, W. T. Gentry,
R. Hal vorsen, M. B. Lokkeborg, S. Rogers, P. Southall, B. L. Zeddies, D. G. and Tavolga, W. N. (2014)
Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited
Standards Committee S3/SC1 and registered with ANSI. Springer and ASA Press, Cham, Switzerland.

Southall, B., J. J. Finneran, C. Reichmuth, P. E. Nachtigall, D. R. Ketten, A. E. Bowles, W. T. Ellison, D.
Nowacek, and P. Tyack. (2019). Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. Aquatic Mammals 45:125-232 **Fisheries**

Coull, K.A., Johnstone, R., and S.I. Rogers. (1998). Fisheries Sensitivity Maps in British Waters. Published and distributed by UKOOA Ltd.

Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. (2012). Spawning and nursery grounds of selected fish species in UK waters. Sci. Ser. Tech. Rep., Cefas, Lowestoft, 147: 56 pp.

Hawkins, A., Roberts, L., Cheesman, S. (2014). Responses of Free-Living Coastal Pelagic Fish to Impulsive Sounds. The Journal of the Acoustical Society of America, 135(5), 31013116.

Popper, A. N., Hawkins, A. D., Fay, R. R., Mann, D. A., Bartol, S., Carlson, T. J., Tavolga, W. N. (2014). ASA S3/SC1.4 TR-2014 Sound exposure guidelines for fishes and sea turtles: A technical report prepared by ANSI Accredited Standards Committee S3/SC1 and registered with ANSI. American National Standards Institute.

Stadler, J. H., and Woodbury, D. P. (2009). “Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria,” in Internoise 2009 Innovations in Practical Noise Control.

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Our reference:
ENQ/2021/00099

Ruth Letourneur
RWM Limited
By email only

9 December 2021

Dear Ruth,

Geological Disposal Facility - geophysical investigation

Thank you for your request for advice on the assessments of the survey criteria and underwater sound modelling for seismic surveys off the coast of Copeland in Cumbria.

The submitted documents were sent to the MMO's technical advisors, Centre for Environment, Fisheries and Aquaculture Science (Cefas), who provided comments to inform the MMO's advice detailed below.

1. Underwater noise

Approach of the underwater sound modelling

1.1. The MMO are of the opinion that the underwater sound modelling performed was appropriate for the proposed works. The applicant has applied both a range dependent acoustic model (RAM) and ray tracing model [Section 3.2.1 Model selection of the Marine Environmental Assessment ore-application report] which as stated provides a modelling solution that is valid over the wide frequency of sound produced. This is important as the applicant are investigating potential impacts on a wide range of aquatic species, from marine mammals to fishes, which have differing auditory capabilities.

1.2. Table 4.3, in the underwater sound modelling report appears to show the SPLpeak source level, and also the weighted source levels for each functional hearing group. However, please note that as per the (National Marine Fisheries Service, 2018) guidance, it is the SELcum thresholds that are weighted and not the peak pressure (the peak pressure is unweighted). It would be helpful if the applicant could clarify their approach here.

Table 4.3 Apparent source levels perceived by each marine mammal functional hearing group - Underwater Sound Modelling Report

Functional hearing group	Acoustic array far-field source level dB_{Peak} re 1 μPa
Unweighted source level	252.0
LF cetaceans	246.6
MF cetaceans	205.9
HF cetaceans	197.1
PW pinnipeds	233.4

Table 4.3: Apparent source levels perceived by each marine mammal functional hearing group

Survey criteria

1.3. The applicant has included the use of a Marine Mammal Observer and Passive Acoustic Monitor (PAM) operator based on JNCC guidance. Furthermore, the applicant has specified the geophysical survey design will be reported and data provided into the Marine Noise Registry. The MMO agree with these measures.

1.4. The applicant has also specified that the survey will take place during the month of July, and that regardless of weather conditions 'the survey will still only occur during
July, and the total number of days that the sound source will be fired will not exceed 20'. As July is not a key spawning period for fishes and marine mammals (see below comment 14), The MMO is pleased to see this temporal consideration has been factored into the survey design and proposal, it is the MMO's opinion that it will reduce potential effects of underwater noise.

Acknowledgement of previous advice

1.5. The pre-application report incorporated feedback and advice provided previously by the Marine Management Organisation, Natural England, Cefas, and the Joint Nature Conservancy Committee, as was highlighted in section

2.3 ‘Differences between planned activities and original environmental assessment’.

1.6. The summary table [Table 1: Comparison of geophysical parameters and factors] shown below for reference, was particularly helpful in identifying the areas where parameters had been updated. Firstly, the applicant has narrowed the survey area and timing of survey which, in the MMO’s opinion, greatly reduces the potential impact of underwater noise on aquatic life as July is not a key spawning period for fishes [Table 4: Spawning times of species] and/ or harbour porpoise sightings in the survey area [with peak number in late winter and spring; Section 5.2.4.1 Appendix A].

1.7. The applicant has also specified an additional streamer in line with the 3D followed by 2D geophysical survey technique proposed. As the applicant is still proposing to follow JNCC guidance (Marine Mammal Observer, PAM, mammal reporting and MNR) no additional information or mitigation is required.

Table 1 Comparison of geophysical parameters and factors, taken from the Marine Environmental Assessment pre-application report to support inshore geophysical surveys – Copeland report.

Table 1 Comparison of geophysical parameters and factors

Geophysical survey factor	Environmental risk assessment parameters (Appendix A)	Pre-app environmental assessment parameters
Area	Large inshore area (approx. 1400km2)	Smaller targeted inshore area (approx. 1000km2)
Timing of survey	June-September survey window	July survey
Length of survey (i.e. when sound source is active)	15-20 days cumulative	17.5 days cumulative[1]
Sound array	Airgun sound array with six 2-3km streamers	Airgun sound array with six 2km streamers then one 3km streamer
Vessel	100m long deep water vessel	100m long deep water vessel
JNCC guidance	Marine Mammal Observer, PAM, mammal reporting & MNR	Marine Mammal Observer, PAM, mammal reporting & MNR
Sound source level	SPL_{0-p} = 252 dB re 1 µPa @ 1m	SPL_{0-p} = 252 dB re 1 µPa @ 1m

Table 4 Spawning times of fish species taken from the Marine Environmental Assessment pre-application report to support inshore geophysical surveys – Copeland report.

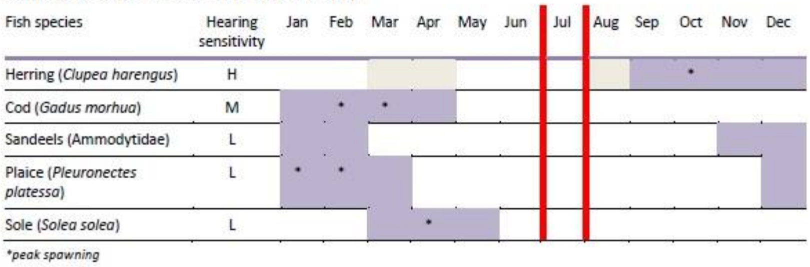

Table 4. Spawning times of species where high intensity spawning grounds occur in survey area (source: Ellis *et al.*, 2012)

Fish species	Hearing sensitivity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Herring (*Clupea harengus*)	H										*		
Cod (*Gadus morhua*)	M		*	*									
Sandeels (Ammodytidae)	L												
Plaice (*Pleuronectes platessa*)	L	*	*										
Sole (*Solea solea*)	L				*								

**peak spawning*

Comments on conclusions

1.8. Underwater sound modelling was used to identify zones of influences and potential impacts on receptors. However, a thorough quantitative check of the modelling results/predictions was not possible in the allocated timeframe. It was concluded that the 'potential for lethal effects, physical and auditory injury were negligible' and 'the potential for behavioural disturbance was considered to be low within the context of the wider population of European Protected Species' [Section 8 Conclusions of Environmental Risk Assessment'. The MMO agree with the applicant that there is a low risk of significant impact in terms of auditory (instantaneous injury). In terms of cumulative exposure, the seismic airgun is a moving source, and it is expected that an animal would also be moving, so cumulative exposure is likely to be less of a concern. However, for fish, effects such as disturbance and displacement can be expected at significant ranges out to tens of kilometres (as shown by the noise modelling).

1.9. In summary, the MMO agree with the conclusions reached by the environmental risk assessment and deem that underwater noise from the seismic survey operations is unlikely to pose a significant risk to marine mammals and fishes in terms of auditory injury within the survey area and timeframe proposed. However, for fish, effects such as disturbance and displacement can be expected at substantial ranges out to tens of kilometers (as shown by the noise modelling).

2. Fisheries

Approach to underwater sound modelling

2.1. The MMO consider the approach to modelling to be appropriate in relation to fisheries. The modelling has used the appropriate hearing thresholds for seismic airguns taken from Popper et al. (2014) for impacts and effects to fish and their eggs and larvae. The MMO is pleased to note that the Applicant has taken our previous comments into account and included the 142 dB re 1 µPa2.s and 135 dB re 1 µPa2.s thresholds for modelling of behavioural responses in fish based on the observed startle responses in mackerel and sprat (respectively) by Hawkins et al. (2014). Modelled scenarios based on a stationary and fleeing receptor have been presented.

Survey criteria

2.2. The MMO agree with the survey criteria in respect of fisheries. The Applicant is proposing to undertake the survey in July and has clearly stated that regardless of weather conditions, the survey will only take place during this month, over a maximum period of 20 days. As July is outside the key spawning periods of marine fishes in the Copeland area (namely herring, cod, sandeel, plaice and sole), and is outside the migratory periods for lamprey, Atlantic salmon and smelt, all of which are qualifying features of protected areas in the vicinity of Copeland. As such, the MMO is satisfied that significant impacts to these species are unlikely to occur as a result of the seismic surveys. The careful consideration of the timing of this survey is welcomed as an appropriate method of mitigation for marine and migratory fishes.

2.3. The report also recognises that seismic surveys have the potential to significantly affect plankton but highlights that the Copeland seismic survey is scheduled to take place outside the main Irish Sea spring bloom season, which peaks between March and May (Gowen and Stewart, 2005), with a peak in secondary (zooplankton) production some weeks later. Owing to the timing of the survey in July the MMO support the Applicant's conclusion that significant impacts to plankton are unlikely to occur.

Comments on conclusions

2.4. The environmental assessment and underwater noise modelling have shown that behavioural impacts in fishes are expected to occur over large distances, however, the duration of the impact will be short in duration and temporary. Significant physiological impacts to marine and migratory fishes have been suitably mitigated through appropriate timing of the survey, which avoids the key sensitive and migratory seasons of fish in the Copeland area. No further mitigation measures are proposed to remove or reduce the effects of underwater noise on fish. The MMO therefore agree with the conclusions.

Please do not hesitate to get in contact should you require any additional information or clarity on any of the points raised in this advice note.

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Annex 1: References

Underwater Noise

Dunlop, R. A., Noad, M. J., McCauley, R. D., Scott-Hayward, L., Kniest, E., Slade, R., … Cato, D. H. (2017). Determining the behavioural dose response relationship of marine mammals to air gun noise and source proximity. Journal of Experimental Biology, 220, 2878–2886. https:// doi.org/10.1242/jeb.160192.

Ellison, W. T., Southall, B. L., Clark, C. W., & Frankel, A. S. (2012). A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds.
Conservation Biology, 26, 21–28.
https://doi.org/10.1111/j.1523-1739.2011.01803.x

Galindo-Romero, M., Lippert, T. and Gavrilov, A. (2015). Empirical prediction of peak pressure levels in anthropogenic impulsive noise. Part I: Airgun arrays signals. J. Acoust. Soc. Am. 138 (6), December 2015.

Gomez, C., Lawson, J. W., Wright, A. J., Buren, A. D., Tollit, D., & Lesage, V. (2016). A systematic review on the behavioural responses of wild marine mammals to noise: The disparity between science and policy.
Canadian Journal of Zoology, 94, 801–819. https://doi.org/10.1139/ cjz-2016-0098

Hawkins, A.D., Roberts, L. and Cheesman, S. (2014). Repsonses of free-living coastal pelagic fish to impulsive sounds. J. Acoust. Soc. Am. 135 (5), May 2014.

Merchant, N. D., Faulkner, R. C., & Martinez, R. (2017). Marine noise budgets in practice. Conservation Letters. https://doi.org/10.1111/ conl.12420.

National Marine Fisheries Service. (2018). 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0):
Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts.
U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 p.

Popper, A. N. Hawkins, A. D. Fay, R. R. Mann, D. Bartol, S. Carlson, Th. Coombs, S. Ellison, W. T. Gentry,
R. Hal vorsen, M. B. Lokkeborg, S. Rogers, P. Southall, B. L. Zeddies, D. G. and Tavolga, W. N. (2014)
Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited
Standards Committee S3/SC1 and registered with ANSI. Springer and ASA Press, Cham, Switzerland.

Southall, B., J. J. Finneran, C. Reichmuth, P. E. Nachtigall, D. R. Ketten, A. E. Bowles, W. T. Ellison, D.

Nowacek, and P. Tyack. (2019). Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. Aquatic Mammals 45:125-232 **Fisheries**

Coull, K.A., Johnstone, R., and S.I. Rogers. (1998). Fisheries Sensitivity Maps in British Waters. Published and distributed by UKOOA Ltd.

Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. (2012). Spawning and nursery grounds of selected fish species in UK waters. Sci. Ser. Tech. Rep., Cefas, Lowestoft, 147: 56 pp.

Hawkins, A., Roberts, L., Cheesman, S. (2014). Responses of Free-Living Coastal Pelagic Fish to Impulsive Sounds. The Journal of the Acoustical Society of America, 135(5), 31013116.

Popper, A. N., Hawkins, A. D., Fay, R. R., Mann, D. A., Bartol, S., Carlson, T. J., Tavolga, W. N. (2014). ASA S3/SC1.4 TR-2014 Sound exposure guidelines for fishes and sea turtles: A technical report prepared by ANSI Accredited Standards Committee S3/SC1 and registered with ANSI. American National Standards Institute.

Stadler, J. H., and Woodbury, D. P. (2009). “Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria,” in Internoise 2009 Innovations in Practical Noise Control.

Date: 03 December 2021
Our ref: DAS/356293
Your ref: Charged Advice Request for RWM's Environmental Report and Appendices for Geophysical Surveys

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Cheshire
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0300 060 3900

BY EMAIL ONLY

Dear Dr Ruth Letourneur

Discretionary Advice Service (Charged Advice)
356293
Development proposal and location: Environmental Report and Appendices for Geophysical Surveys, Cumbria

Thank you for your consultation on the above dated 05 November 2021, which was received on 05 November 2021.

This advice is being provided as part of Natural England's Discretionary Advice Service. Radioactive Waste Management (RWM) has asked Natural England to provide advice upon:

- RWM's Environmental Report (ER) and Appendices for Geophysical Surveys.

This advice is provided in accordance with the Quotation and Agreement dated 16 June 2021.

The following advice is based upon the information within:

1. 20211105 MEA Pre-app report
2. 20211105_AnnexA_Copeland ERA_RWM
3. 20211105_AnnexB_C&D_Copeland ERA_RWM
4. 20211105_AppendixA_ERA_RWM

As discussed in the meeting dated 25th November 2021, the purpose of this letter is to outline any major concerns Natural England has regarding the project as presented in RWM's ER documents. Natural England will provide a review tracker spreadsheet with detailed comments at a later date.

It is Natural England's understanding that the final outcomes and conclusions of the environmental assessments are provided within the *MEA pre-app report* and that these relate to a spatially and temporally modified version of the survey presented in *Appendix A*. Therefore the advice in this letter is based on the information provided within the *MEA pre-app report*.

Following the information received from you regarding this proposal, we write to confirm that it is Natural England's view that **the proposal is likely to be environmentally acceptable, subject to Natural England's detailed advice** (forthcoming)**.**

> *i.* Furthermore, based on the information available to date, Natural England anticipates that the proposal is not likely to have a significant effect on a European or Ramsar site and therefore is **not likely to require an Appropriate Assessment** under the Conservation of Habitats and Species Regulations 2017.
> *ii.* Natural England also anticipates that the proposal is **not likely to cause significant damage to a Site of Special Scientific Interest (SSSI)[24] or hinder the conservation objectives of a Marine Conservation Zone (MCZ)[25].**

European Protected Species (EPS) Licence
Natural England anticipates there will be behavioural impacts to European Protected Species (EPS) and therefore agrees with your decision to apply for an EPS licence for harbour porpoises, common dolphin, bottlenose dolphin, minke whale and sea turtles. The EPS Licence application should be submitted to the Marine Management Organisation (MMO) as the competent authority responsible for wildlife licensing of activity in English waters.

It is Natural England's understanding that the geophysical survey has been designed based on JNCC guidance[26], and therefore will include a Marine Mammal Observer (MMO) and Passive Acoustic Monitoring (PAM) in the survey. Natural England welcomes the proposed mitigation measures in Section 5.1. Mitigation measures for EPS will be secured through license conditions and these may include those you have proposed plus potential additional measures required by statutory consultees. Natural England will be consulted on the EPS licence application.

This advice is offered based on the information provided to date. It is given without prejudice to any advice that Natural England may offer in accordance with its statutory role under the Conservation of Habitats and Species Regulations 2017, the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000), or the Marine and Coastal Access Act 2009. Formal comment on the EPS license application will be provided following consultation.

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[24] Under the Wildlife and Countryside Act 1981 (as amended)
[25] Under the Marine and Coastal Access Act 2009
[26] JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys (2017) - https://data.jncc.gov.uk/data/e2a46de5-43d4-43f0-b296-c62134397ce4/jncc-guidelines-seismicsurvey-aug2017-web.pdf

Should the proposal be amended in a way which significantly affects its impact on the natural environment, Natural England would welcome further consultation.

Senior adviser to QA letter and check box below

☒ The advice provided in this letter has been through Natural England's Quality Assurance process

The advice provided within the Discretionary Advice Service is the professional advice of the Natural England adviser named below. It is the best advice that can be given based on the information provided so far. Its quality and detail is dependent upon the quality and depth of the information which has been provided. It does not constitute a statutory response or decision, which will be made by Natural England acting corporately in its role as statutory consultee to the competent authority after an application has been submitted. The advice given is therefore not binding in any way and is provided without prejudice to the consideration of any statutory consultation response or decision which may be made by Natural England in due course. The final judgement on any proposals by Natural England is reserved until an application is made and will be made on the information then available, including any modifications to the proposal made after receipt of discretionary advice. All pre-application advice is subject to review and revision in the light of changes in relevant considerations, including changes in relation to the facts, scientific knowledge/evidence, policy, guidance or law. Natural England will not accept any liability for the accuracy, adequacy or completeness of, nor will any express or implied warranty be given for, the advice. This exclusion does not extend to any fraudulent misrepresentation made by or on behalf of Natural England.

Yours sincerely,

[redacted]

Cumbria Area
Team
[redacted]

Cc commercialservices@naturalengland.org.uk

Date: 17 December 2021
Our ref: DAS/356293
Your ref: Charged Advice Request for RWM's Environmental Report and Appendices for Geophysical Surveys

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BY EMAIL ONLY

Dear Dr Ruth Letourneur

Discretionary Advice Service (Charged Advice)
356293
Development proposal and location: Environmental Report and Appendices for Geophysical Surveys, Cumbria

Thank you for your consultation on the above dated 05 November 2021, which was received on 05 November 2021.

This advice is being provided as part of Natural England's Discretionary Advice Service. Radioactive Waste Management (RWM) has asked Natural England to provide advice upon:

- RWM's Environmental Report (ER) and Appendices for Geophysical Surveys.

This advice is provided in accordance with the Quotation and Agreement dated 16 June 2021.

The following advice is based upon the information within:

1. 20211105 MEA Pre-app report
2. 20211105_AnnexA_Copeland ERA_RWM
3. 20211105_AnnexB_C&D_Copeland ERA_RWM
4. 20211105_AppendixA_ERA_RWM

As discussed in the meeting dated 25 November 2021, our detailed advice is provided within a review tracker in spreadsheet format. Please refer to **Appendix 1: 356293 NE Review Tracker for RWM's Environmental Report and Appendices for Geophysical Surveys**. for detailed comments on the above documents. Where appropriate, the 'Suggested Resolutions' column has been populated by Natural

England. The ‘Actions Taken to Resolve Issue or Comment’ column has been provided for RWM to populate and return to Natural England.

Please note, the details provided within this letter and Appendix 1 are linked to the initial advice letter Natural England sent on 03 December 2021.

This advice is offered based on the information provided to date. It is given without prejudice to any advice that Natural England may offer in accordance with its statutory role under the Conservation of Habitats and Species Regulations 2017, the Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000), or the Marine and Coastal Access Act 2009. Formal comment on the EPS license application will be provided following consultation.

Should the proposal be amended in a way which significantly affects its impact on the natural environment, Natural England would welcome further consultation.

Senior adviser to QA letter and check box below

☒ The advice provided in this letter has been through Natural England’s Quality Assurance process

The advice provided within the Discretionary Advice Service is the professional advice of the Natural England adviser named below. It is the best advice that can be given based on the information provided so far. Its quality and detail is dependent upon the quality and depth of the information which has been provided. It does not constitute a statutory response or decision, which will be made by Natural England acting corporately in its role as statutory consultee to the competent authority after an application has been submitted. The advice given is therefore not binding in any way and is provided without prejudice to the consideration of any statutory consultation response or decision which may be made by Natural England in due course. The final judgement on any proposals by Natural England is reserved until an application is made and will be made on the information then available, including any modifications to the proposal made after receipt of discretionary advice. All pre-application advice is subject to review and revision in the light of changes in relevant considerations, including changes in relation to the facts, scientific knowledge/evidence, policy, guidance or law. Natural England will not accept any liability for the accuracy, adequacy or completeness of, nor will any express or implied warranty be given for, the advice. This exclusion does not extend to any fraudulent misrepresentation made by or on behalf of Natural England.

Yours sincerely,

[redacted]

Cumbria Area
Team

[redacted]

Cc commercialservices@naturalengland.org.uk

Dear Ruth,

Thank you for your email regarding the proposed geophysical survey.

It is my understanding that that the survey vessel will be towing six cables each approximately 2,400m long at a depth of 5m below sea surface and horizontally 50m apart (total footprint of vessel and cables are approximately 2500m x 250m). The cables will be equipped with steering devices to help keep the cables at the designed depth and lateral distance from each other. The cables will be marked with surface buoys at the front and rear of each cable, rear surface buoys would be equipped with light and radar reflectors and their positions constantly monitored from the vessel using GPS tracking. There will also be 2-3 other vessels acting as guard vessels.

It is outside of the MCA's remit to state whether this is an exempted activity, and you will need to be satisfied that there is no danger or obstruction to navigation for this to be exempt. Considering your survey plans, and the location in a high density traffic area, there is a clear increase in risk to shipping and navigation. However, it is our opinion on this occasion that this increase in risk can be mitigated to ALARP on the understanding that the following risk mitigation measures are adhered to:

1) All relevant maritime safety requirements are complied with;
2) Issue local notifications to marine users, including fisherman's organisations, relevant authorities and other local stakeholders, to ensure that they are made fully aware of the activity at least five days before commencement of the works;
3) Notify the UK Hydrographic Office (email: sdr@ukho.gov.uk) to permit the promulgation of maritime safety information and updating of nautical charts and publications through the national Notice to Mariners system, at least ten days before commencement of the works. Details required - start date/ end date, work to be done, positions of the work area (WGS84), marking of the work area.
4) HM Coastguard are notified in advance via zone32@hmcg.gov.uk 5 days in advance and again on the day the survey commences, via telephone;
5) Guard vessels must be present at all times when the cables are being towed, to provide adequate coverage for the size of survey area;
6) The applicant must liaise with the local MCA Marine Office with regards to the vessel certification and any required loadline exemption / towage certification.

Please can you confirm your acceptance of the above risk mitigation.

Please do also keep us posted on your wider plans for GDF as they progress so we can consider/advise from a shipping and navigation perspective.

Many thanks

[redacted]

[redacted] [redacted]

[redacted] Helen.Croxson@mcga.gov.uk

Maritime & Coastguard Agency
Bay 2/25, Spring Place
105 Commercial Road,
Southampton SO15 1EG

Safer Lives, Safer Ships, Cleaner Seas
www.gov.uk/mca

Dear Ruth,

Thank you very much for the confirmation regarding the risk mitigation measures detailed below. We have no further comments at this time.

Many thanks

[redacted]

[redacted] Helen.Croxson@mcga.gov.uk

Maritime & Coastguard Agency
Bay 2/25, Spring Place
105 Commercial Road,
Southampton SO15 1EG

Safer Lives, Safer Ships, Cleaner Seas
www.gov.uk/mca

Please note my working days are Tuesday to Friday mornings.

Good Morning Ruth,

When assessing the navigational risk for your survey you will need to identify if there are any major shipping routes passing through there.
I am not sure if your area would extend far enough offshore to interact with Heysham to Belfast ferries or if it will be just local fishing and recreation users with some near coastal traffic.
If your area does interact with the shipping lanes then direct communication with the operators would be advisable.

We would suggest you contact any local yacht clubs and fishing representatives to make them aware that the survey will be taking place.
The vessel carrying out the survey will hopefully be well aware of its obligations whilst carrying out the survey so we have no comments on that.
The MCA [redacted] will no doubt have comment on that.

Trinity House would have no objections to the survey so long as it doesn't affect any aids to navigation (buoys) in the area, and there are adequate notices to mariners promulgated so that everyone is aware.
We would not consider the activity creates an undue risk if there is adequate information provided to the marine users in the area before and during the activity.

If you need to know more about promulgating information locally I would suggest contacting Tom Watson at Kingfisher who does the notices to mariners for the windfarms and other survey work in that area.
[redacted]

Best regards
[redacted]

[redacted]

Trinity House, Tower Hill, London, EC3N 4DH
Tel: [redacted]
Mob:
email: [redacted]

Appendix F -References

Andersen, S.M., Teilmann, J., Dietz, R., Schmidt, N.M. and Miller, L.A. (2012). Behavioural responses of harbour seals to human-induced disturbances. *Aquatic Conservation: Marine and Freshwater Ecosystem*, 22(1), pp. 113–121.

Anderwald, P. and Evans, P.G.H. (2008). Minke whale populations in the North-Atlantic – an overview with special reference to UK waters. In: *An Integrated Approach to Non-lethal Research on Minke Whales in European Waters*. Robinson, K.R., Stevick, P.T. and MacLeod, C.D. (Eds.). *European Cetacean Society Special Publication Series*, 47, pp. 8-13.

André, M., Solé, M., Lenoir, M., Durfort, M., Quero, C., Mas, A., Lombarte, A., van der Schaar, M., López-Bejar, M., Morell, M., Zaugg, S. and Houégnigan, L. (2011). Low-frequency sounds induce acoustic trauma in cephalopods. *Frontiers in Ecology and the Environment*, 10, pp. 18-28.

Austin, R.A., Hawkes, L.A., Doherty, P.D., Henderson, S.M., Inger, R., Johnson, L., Pikesley, S.K., Solandt, J.L., Speedie, C. and Witt, M.J. (2019). Predicting habitat suitability for basking sharks (Cetorhinus maximus) in UK waters using ensemble ecological niche modelling. *Journal of Sea Research*, 153, 101767.

Barry, J., Kennedy, R.J., Rosell, R. and Roche, W.K. (2020). Atlantic salmon smolts in the Irish Sea: First evidence of a northerly migration trajectory. *Fisheries Management and Ecology*, 27(5), pp. 517-522.

BBC. (2015). Rare leatherback turtle spotted off Cumbrian coast. [Online]. Available at: https://www.bbc.co.uk/news/uk-england-cumbria-34001701. [Accessed 10-10-21].

BBC. (2019). Cumbrian grey seal pup arrives six weeks early. [Online]. Available at: https://www.bbc.co.uk/news/uk-england-cumbria-58499957. [Accessed 10-10-21].

BEIS, Implementing Geological Disposal - Working with Communities, December 2018.

BGS (1987), Seabed sediments around the United Kingdom (North Sheet), British Geological Survey Publications.

Blix, A.S. and Folkow, L.P., 1995. Daily energy expenditure in free living minke whales. Acta Physiologica Scandinavica, 153(1), pp.61-66.

Bexton, S., Thompson, D., Brownlow, A., Barley, J., Milne, R. and Bidewell, C. (2012). Unusual Mortality of Pinnipeds in the United Kingdom Associated with Helical (Corkscrew) Injuries of Anthropogenic Origin. *Aquatic Mammals*. 38(3), 229 pp.

Bloomfield, A. and Solandt, J-L. (2006). The Marine Conservation Society Basking Shark Watch 20-year report (1987-2006). Ross on Wye, UK: Marine Conservation Society, 62 pp.

Bolle, L.J., de Jong, C.A.F., Bierman, S.M., Van Beek P.J.G., Van Keeken, O.A., Wessels, P.W., Van Damme C.J.G., Winter H.V., De Haan, D. and Dekeling, R.P.A. (2012). Common sole larvae survive high levels of pile-driving sound in controlled exposure experiments. *PLoS ONE*. 5, pp.1932-6203.

Booman, C., Dalen, H., Leivestad, H., Levsen, A., van der Meeren, T. and og Toklum, K. (1996). Effekter av luftkanonskyting pa egg, larver og ynell (Effects of airgun shooting on eggs, larvae, and personnel). Havforskningsinstituttet, ISSN 0071–5638.

Booth, C.G., Embling, C., Gordon, J., Calderan, S.V. and Hammond, P.S. (2013). Habitat preferences and distribution of the harbour porpoise Phocoena phocoena west of Scotland. *Marine Ecology Progress Series*, 478, pp. 273-285.

Booth, C.G., King, S.L. and Lacey, C. (2013). Argyll Array Wind farm Basking Draft Chapter for Environmental Statement. SMRU Ltd report number SMRUL-WSP-2013-001. January 2013 (unpublished).

Boyer, Tim P.; Garcia, Hernan E.; Locarnini, Ricardo A.; Zweng, Melissa M.; Mishonov, Alexey V.; Reagan, James R.; Weathers, Katharine A.; Baranova, Olga K.; Seidov, Dan; Smolyar, Igor V. (2018). World Ocean Atlas 2018. [indicate subset used]. NOAA National Centers for Environmental Information. Dataset. https://accession.nodc.noaa.gov/NCEI-WOA18. Accessed [31.09.21].

Bristow, T. and Reeves, E.I.S. (2001). Site fidelity and behaviour of bottlenose dolphins (*Tursiops truncatus*) in Cardigan Bay, Wales. *Aquatic Mammals,* 27, pp. 1-10.

Buckingham, M.J. (1992). Ocean-acoustic propagation models. *Journal d'Acoustique*, pp. 223-287.

Camphuysen, C.J. (2002). Post-fledging dispersal of common guillemot *Uria aalge* guarding chicks in the North Sea: The effect of predator presence and prey availability at sea. *Ardea* 90.1:103 -119.

Canning, S., Lye, G., Givens, L. and Pendlebury, C. (2013). E.ON Climate and Renewables, Analysis of Marine Ecology Monitoring Plan Data from the Robin Rigg Offshore Wind Farm, Scotland (Operational Year 2), Technical Report. Chapter 6: Marine Mammals. *Report Number: 1012206*.

Carrillo, M.A.N.U.E.L. and Ritter, F.A.B.I.A.N., 2010. Increasing numbers of ship strikes in the Canary Islands: proposals for immediate action to reduce risk of vessel-whale collisions. Journal of cetacean research and management, 11(2), pp.131-138.

Carroll, A., Przeslawski, R., Gunning, M.-E., Bruce, B. and Duncan, A.J. (2017). A critical review of the potential impacts of marine geophysical surveys on fish and invertebrates. *Marine Pollution Bulletin*, 114, pp. 9-24. Doi: 10.1016/j.marpolbul.2016.11.038.

Carter, M.I.D., Boehme, L., Duck, C.D., Grecian, W.J., Hastie, G.D., McConnell, B.J., Miller, D.L., Morris, C.D., Moss, S.E.W., Thompson, D., Thompson, P.M. and Russell, D.J.F. (2020). *Habitat-based predictions of at-sea distribution for grey and harbour seals in the British Isles*. Sea Mammal Research Unit, University of St Andrews, Report to BEIS, OESEA-16-76/OESEA-17-78.

Carter, M.I., Russell, D.J., Embling, C.B., Blight, C.J., Thompson, D., Hosegood, P.J. and Bennett, K.A. (2017). Intrinsic and extrinsic factors drive ontogeny of early-life at-sea behaviour in a marine top predator. Scientific Reports, 7(1), pp.1-14.

Casper, B.M. (2011). Hearing and lateral line | The ear and hearing in sharks, skates, and rays. *Encyclopedia of Fish Physiology*, 1, pp. 292-297. https://doi.org/10.1016/B978-0-12-374553-

8.00013-7. [Abstract Online]. Available at https://www.researchgate.net/publication/288174246_Hearing_and_lateral_line_The_ear_and_hearing_in_sharks_skates_and_rays.

Casper, B.M., Halvorsen, M.B. and Popper, A.N. (2012). Are sharks even bothered by a noisy environment? *Advances in Experimental Med. Biology*, 739, pp. 93–97. [Online]. Available from: https://www.researchgate.net/publication/42438536_Anthropogenic_noise_Is_this_an_issue_for_elasmobranch_fishes.

CIEEM (2018) Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine version 1.1. Chartered Institute of Ecology and Environmental Management, Winchester. [Online]. Available from: https://cieem.net/resource/guidelines-for-ecological-impact-assessment-ecia/.

Centre for Environment, Fisheries and Aquaculture Science, Environment Agency, and Natural Resources Wales. (2021). Salmon Stocks and Fisheries in England and Wales in 2020. [Online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1019223/SalmonReport-2020-summary.pdf. [Accessed: 24 September 2021].

Chapuis, L., Collin, S.P., Yopak, K.E., Mccauley, R.D., Kempster, R.M., Ryan, L.A., Schmidt, C., Kerr, C.C., Gennari, E., Egeberg, C.A. and Hart, N.S. (2019). The effect of underwater sounds on shark behaviour. *Scientific Reports*, 9, 6924. Doi: 10.1038/s41598-019-43078-w.

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

Clough, S.C., Lee-Elliott, I.E., Turnpenny, A.W.H., Holden, S.D.J., and Hinks, C. (2004). Swimming Speeds in Fish: phase 2 Literature Review. R&D Technical Report W2-049/TR2. [Online]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/290592/scho0404bipx-e-e.pdf).

Collins, M. D., “Applications and time-domain solution of higher-order parabolic equations in underwater acoustics”, Journal of the Acoustical Society of America, 86(3), 1097–1102, 1989.

Cooper. J. (1982). Methods of reducing mortality of seabirds caused by underwater blasting. *Cormorant,* 10, pp. 109-113.

Coram, A., Gordon, J., Thompson, D. and Northridge, S. (2014). *Evaluating and assessing the relative effectiveness of non-lethal measures, including Acoustic Deterrent Devices, on marine mammals*. Scottish Government.

Coull, K.A., Johnstone, R. and Rogers, S.I. (1998). Fisheries Sensitivity Maps in British Waters Published and distributed by UKOOA Ltd., Aberdeen, 63 pp.

Cowx, I.G. and Fraser, D. (2003). Monitoring the Atlantic Salmon, Conserving Natura 2000 Rivers Monitoring Series No. 7. *English Nature*, Peterborough.

Cox, S.L., Miller, P.I., Embling, C.B., Scales, K.L., Bicknell, A.W., Hosegood, P.J., Morgan, G., Ingram, S.N. and Votier, S.C. (2016). Seabird diving behaviour reveals the functional significance of shelf-sea fronts as foraging hotspots. *Royal Society open Science*, 3 (9), 160317. doi:10.1098/rsos.160317.

Crowell, S. (2014). In-air and underwater hearing in ducks. Doctoral dissertation, University of Maryland.

Crowell, S.E., Wells-Berlin, A.M., Carr, C.E., Olsen, G.H., Therrien, R.E., Yannuzzi, S.E. and Ketten, D.R. (2015). A comparison of auditory brainstem responses across diving bird species. *Journal of Comparative Physiology A*, 201, pp. 803-815. CSIP. (2015). Annual Report for the period 1st January – 31st December 2015 (Contract Number MB0111).

CSA Ocean Sciences Inc. 2021. Marine Mammal, Sea Turtle, and Sturgeon Impacts and Underwater Acoustic Assessment. Technical Appendix for South Fork Wind 112 pp.

C-T. Chen and F. J. Millero, (1977), "Speed of Sound in Seawater at High Pressures". J. Acoust. Soc Am, 32(10), p 1357

Cumberland News. (2018). Stranded animals wash up on Cumbria's coast. [Online]. Available at: https://www.newsandstar.co.uk/news/16949997.stranded-animals-wash-cumbrias-coast/. [Accessed: 02/09/2021].

Cumbria Biodiversity Data Centre (CBDC) and Cumbria Mammal Group (CMG). (2017). Cumbria Mammal Atlas. [Online]. Available at: http://www.cbdc.org.uk/uploads/Mammal_Atlas/Download/Atlas_Maps.pdf. [Accessed: 08/09/2021].

Cumbrian Wildlife Trust (CWT). (2015). 2015 Grey seal video clips. [Online]. Available at: https://www.cumbriawildlifetrust.org.uk/wildlife/cams/seal-web-cam-2015-clips-south-walney. [Accessed 10-10-21].

Cumbrian Wildlife Trust (CWT). (2021). Record number of seals are counted at South Walney. [Online]. Available at: https://www.cumbriawildlifetrust.org.uk/news/record-number-seals-are-counted-south-walney. [Accessed: 08/09/2021].

Cumbrian Wildlife Trust (CWT). (2021). Where to see seal pups. [Online]. Available at: https://www.wildlifetrusts.org/where_to_see_seal_pups [Accessed 10-10-21].

Currie, F. and Elliott, G. (1997). Forests and Birds: A Guide to Managing Forests for Rare Birds. Forestry Authority, Cambridge and Royal Society for the Protection of Birds, Sandy, UK.

Dahne, G.E. (2013). Effects of pile-driving on harbour porpoise *Phocoena phocoena* at the first offshore windfarm in Germany. *Environmental Research Letters*, 8, 16 pp. Doi: 10.1088/1748-9326/8/2/025002.

Danil, K. and St. Leger, J.A. (2011). Seabird and Dolphin Mortality Associated with Underwater Detonation Exercises. *Marine Technology Society Journal,* 45(6), pp. 89-95. Doi: 10.4031/MTSJ.45.6.5.

Deaville. (2015). Annual Report for the period 1st January – 31st December 2015. UK CSIP. Contract number MB0111.

Dempsey, C.H. and Bamber, R.N. (1983). Spawning of herring (Clupea harengus L.) in the Blackwater Estuary, spring 1979. *ICES Journal of Marine Science*, 41(1), pp. 85-92.

Department for Environment, Food and Rural Affairs (DEFRA). (2005). Cetaceans Strandings Investigation and Co-ordination in the UK. Report to Defra for the period 1st January 2000 - 31st December 2004. Report No. ECM 516T/05

Department for Environment, Food and Rural Affairs (DEFRA). (2019). Solway Firth Marine Conservation Zone. [Online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/915681/mcz-solway-firth-2019.pdf [Accessed 10-10-21].

de Vincenzi, G., Micarelli, P., Viola, S., Buffa, G., Sciacca, V., Maccarrone, V., Corrias, V., Reinero, F.R., Giacoma, C. and Filiciotto, F. (2021). Biological Sound vs. Anthropogenic Noise: Assessment of Behavioural Changes in Scyliorhinus canicular Exposed to Boats Noise. *Animals*, 11(1), 174. Doi: 10.3390/ani11010174.

Dickey-Collas, M., Nash, R.D. and Brown, J. (2001). The location of spawning of Irish Sea herring (Clupea harengus). *Journal of the Marine Biological Association of the United Kingdom*, 81(4), pp. 713-714.

Dipper, F. (2001). British sea fishes. Underwater World.

Dolton, H.R., Gell, F.R., Hall, J., Hall, G., Hawkes, L.A. and Witt, M.J. (2020). Assessing the importance of Isle of Man waters for the basking shark Cetorhinus maximus. *Endangered Species Research*, 41, pp. 209-223. [Online]. Available at: https://www.researchgate.net/publication/337764375_Assessing_the_importance_of_Isle_of_Man_waters_for_the_basking_shark_Cetorhinus_maximus.

Doyle, T.K., Houghton, J.D., O'Súilleabháin, P.F., Hobson, V.J., Marnell, F., Davenport, J. and Hays, G.C. (2008). Leatherback turtles satellite-tagged in European waters. Endangered Species Research, 4(1-2), pp. 23-31.

Duck, C. (2010). Charting Progress 2 Healthy and Biological Diverse Seas Feeder Report: Section 3.5: Seals. Published by Department for Environment Food and Rural Affairs on behalf of UKMMAS. P506-539. In: UKMMAS. (2010). *Charting Progress 2 Healthy and Biological Diverse Seas Feeder Report*. Frost, M and Hawkridge, J. (Eds.).

Dunlop, R.A., Noad, M.J., McCauley, R.D., Scott-Haywood, L., Kniest, E., Slade, R., Paton, D. and Cato, D.H. (2017). Determining the behavioural dose-response relationship of marine mammals to air gun noise and source proximity. *Journal of Experimental Biology*, 220, pp. 2878-2886. Doi: 10.1242/jeb.160192

Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. (2012). *Spawning and Nursery Grounds of Selected Fish Species in UK Waters*. Science Series Technical Report, CEFAS Lowestoft, 147, 56 pp.

Ellison, W.T., Southall, B.L., Clark, C.W., and Frankel, A.S. (2012). A New Context-Based Approach to Assess Marine Mammal Behavioral Responses to Anthropogenic Sounds. *Conservation Biology*, 26(1), pp. 21–28. Doi: 10.1111/j.1523-1739.2011.01803.x.

The EMODnet Geology Portal at https://www.emodnet-geology.eu/

European Marine Observation and Data Network (EMODnet). (2021). Seabed Habitats; Spatial Data Downloads. [Online] Available at: https://www.emodnet-seabedhabitats.eu/access-data/download-data/?linkid=1

Engås, A., Løkkeborg, S., Ona, E. and Soldal, A.V. (1996). Effects of geophysical shooting on local abundance and catch rates of cod (Gadus morhua) and haddock (Melanogrammus aeglefinus). *Canadian Journal of Fisheries and Aquatic Science*, 53, pp. 2238–2249.

Erbe, C., Marley, S., Schoeman, R., Smith, J.N., Trigg, L. and Embling, C.B. (2019). The Effects of Ship Noise on Marine Mammals—A Review. *Frontiers in Marine Science*, *6*, 606 pp.

Etter, P.C. (2013). *Underwater Acoustic Modelling and Simulation*, 4th Edition, CRC Press, 2013, ISBN -10: 9781466564930.

Evans, P.G.H. (1992). *Status Review of Cetaceans in British and Irish Waters. Report to UK Department of the Environment*. UK Mammal Society Cetacean Group, Oxford.

Evans P.G. and Anderwald, P. (2005). Cetaceans in Liverpool Bay and Northern Irish Sea: An Update for the Period 2001-2005. Sea Watch Foundation.

Evans, P.G.H., Anderwald, P. and Baines, M.E. (2003). *UK Cetacean Status Review*. Sea Watch Foundation. Report to English Nature and Countryside Council for Wales, Oxford.

Evans, P.G.H., Pierce, G.J., Veneruso, G., Weir, C.R., Gibas, D., Anderwald, P. and Begoña Santos, M. (2015). *Analysis of long-term effort-related land-based observations to identify whether coastal areas of harbour porpoise and bottlenose dolphin have persistent high occurrence and abundance (revised June 2015).* JNCC Report No. 543, JNCC, Peterborough ISSN 0963-8091.

Evans, P.G.H. and Shepherd, B.S. (2001). Cetaceans in Liverpool Bay and Northern Irish Sea. Unpublished Consultancy Report to CMACS. Sea Watch Foundation, Oxford. 20 pp.

Farcas, A., Thompson, P.M. and Merchant, N.D. (2016). Underwater noise modelling for environmental impact assessment. *Environmental Impact Assessment Review*, 57, pp. 114-122. Doi: 10.1016/j.eiar.2015.11.012

Faulkner, R.C., Farcas, A. and Merchant, N.D. (2018). Guiding principles for assessing the impact of underwater noise. *Journal of Applied Ecology*, 55(6), pp. 2531-2536. Doi: 10.1111/1365-2664.13161.

Faulkner, R.C., Farcas, A. and Merchant, N.D. (2019). *Risk Assessment of Permanent Auditory Injury in Marine Mammals: Differences Arising from the Application of the Southall and NOAA Criteria*. Scottish Marine and Freshwater Science Report. CEFAS Lowestoft, 10, 32 pp.

Fay, R.R. and Popper, A. N. (2000). Evolution of hearing in vertebrates: The inner ears and processing. *Hearing Research*, 149(1-2), pp. 1-10. Doi: 10.1016/s0378-5955(00)00168-4.

Felce, T., Stone, E., Gell, F.G. and Hanley, L. (2013). Marine Mammals-Cetaceans. In Hanley et al., (eds.), *Manx Marine Environmental Assessment*. Isle of Man Marine Plan. Isle of Man Government, 51 pp.

Finneran, J.J. and Jenkins, A.K. (2012). Criteria and Thresholds For U.S. Navy Acoustic And Explosive Effects Analysis. Space and Naval Warfare Systems Center Pacific, 53610 Catalina Boulevard, San Diego, CA, 92147.

Fletcher, J. (2021). The Mail - Experts have say after porpoise with 'bite' wound found on Walney (25 January 2021). [Online]. Available at:

https://www.nwemail.co.uk/news/19032858.dr-emily-baxter-offers-advice-porpoise-bite-wound-found-walney-beach/ [Accessed: 02/09/2021].

Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary rock nomenclature. The Journal of Geology, 62, 344-359.

Frost, P.G.H., Shaughnessy, P.D., Semmelink, A., Sketch, M. and Siegfried, W.R. (1975). The response of jackass penguins to killer whale vocalisations. *South African Journal of Science*, 71, pp. 157-158.

Furness, B. and Wade, H. (2012). *Vulnerability of Scottish seabirds to offshore wind turbines*. Report commissioned by Marine Scotland. 39pp.

Garthe, S., Benvenuti, S., and Montevecchi, W. (2000). Pursuit plunging by northern gannets (Sula bassana) feeding on capelin (*Mallotus villosus*). *Proceedings of The Royal Society B*, 267, pp. 1717-1722. Doi: 10.1098/rspb.2000.1200.

Garthe, S. and Hüppop, O. (2004). Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. *Journal of Applied Ecology*, 41, pp. 724-734. Doi: 10.1111/j.0021-8901.2004.00918.x

General Bathymetric Chart of the Oceans (GEBCO). (2020). GEBCO_2020 Grid. [Online]. Available at: https://www.gebco.net/data_and_products/gridded_bathymetry_data/gebco_2020/.

Glynn, F., Houghton, J.D. and Provan, J. (2015). Population genetic analyses reveal distinct geographical blooms of the jellyfish Rhizostoma octopus (Scyphozoa). *Biological Journal of the Linnean Society*, 116(3), pp. 582-592.

Gomez, C., Lawson, J.W., Wright, A.J., Buren, A.D., Tollit, D. and Lesage, V. (2016). A systematic review on the behavioural responses of wild marine mammals to noise: The disparity between science and policy. *Canadian Journal of Zoology*, 94, pp. 801–819. Doi: 10.1139/cjz-2016-0098.

Gordon, J.C.D., Gillepsie, D., Potter, J., Frantzis, A., Simmonds, M.P., Swift, R. and Thompson, D. (2003). A review of the effects of geophysical surveys on marine mammals. *Marine Technology Society Journal,* 37, pp. 16–34. Doi: 10.4031/002533203787536998.

Gowen, R.J. and Stewart, B.M. (2005). The Irish Sea: Nutrient status and phytoplankton. *Journal of Sea Research*, 54(1), pp. 36–50. Doi: 10.1016/j.seares.2005.02.003.

Graham, J., Rowland, C., Ribbens, J. and Colcough, S. (2021). *European smelt (Osmerus eperlanus (L.)) Recovery Management Plan for the Solway Firth Marine Conservation Zone (MCZ).* Galloway Fisheries Trust report for Natural England. Natural England. [Online]. Available at: file:///C:/Users/richard.gibbs/Downloads/NECR360%20Edition%201%20European%20smelt%20(Osmerus%20eperlanus%20(L.))%20Recovery%20Management%20Plan%20for%20the%20Solway%20Firth%20MCZ.pdf.

Gregory, P.R. and Rowden, A.A. (2001). Behaviour patterns of bottlenose dolphins (*Tursiops truncatus*) relative to tidal state, time of day and boat traffic in Cardigan Bay, West Wales. *Aquatic Mammals,* 27(2), pp.105 – 113.

Hamilton, E.L., (1963). Sediment Sound Velocity Measurements made In Situ from Bathyscaph TRIESTE, Journal of Geophysical Research 68 pp. 5991-5998.

Hamilton, E.L., (1970). Sound velocity and related properties of marine sediments, North Pacific, Journal of Geophysical Research 75 pp. 4423-4446.

Hamilton, E.L., (1972). Compressional-wave attenuation in marine sediments, Geophysics 37 pp. 620-646.

Hammond, P.S., Berggren, P., Benke, H., Borchers, D.L., Collet, A., Heide-Jørgensen, M.P., Heimlich, S., Hiby, A.R. and Leopold, M.F. (2002). Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. *Journal of Applied Ecology*, 39(2), pp. 361–376. Doi: 10.1046/j.1365-2664.2002.00713.x.

Hammond, P.S., Lacey, C., Gilles, A., Viquerat, S., Börjesson, P., Herr, H., Macleod, K., Ridoux, V., Santos, M.B., Scheidat, M., Teilmann, J., Vingada, J. and Øien, N. (2017). Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. 40 pp. [Online]. Available at: https://synergy.st-andrews.ac.uk/scans3/files/2017/05/SCANS-III-design-based-estimates-2017-05-12-final-revised.pdf.

Hammond, P.S., Macleod, K., Berggren, P., Borchers, D.L., Burt, L., Cañadas, A., Desportes, G., Donovan, G. P., Gilles, A., Gillespie, D., Gordon, J., Hiby, L., Kuklik, I., Leaper, R., Lehnert, K., Heinänen, S. and Skov, H. (2015). *The identification of discrete and persistent areas of relatively high harbour porpoise density in the wider UK marine area*. JNCC Report No. 544, Joint Nature Conservation Committee, Peterborough, UK, 108 pp.

Hammond, P.S., Macleod, K., Berggren, P., Borchers, D.L., Burt, L., Cañadas, A., Desportes, G., Donovan, G. P., Gilles, A., Gillespie, D., Gordon, J., Hiby, L., Kuklik, I., Leaper, R., Lehnert, K., Leopold, M., Lovell, P., Øien, N., Paxton, C.G.M., Ridoux, V., Rogan, E., Samarra, F., Scheidat, M., Sequeira, M., Siebert, U., Skov, H., Swift, R., Tasker, M.L., Teilmann, J., Van Canneyt, O. and Vázquez, J.A. (2013). Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. *Biological Conservation*, 164, pp. 107 – 122.

Hammond, P.S., Northridge, S.P., Thompson, D., Gordon, J.C.D., Hall, A.J., Aarts, G. and Matthiopoulos, J. (2005). Background information on marine mammals for Strategic Environmental Assessment 6. Sea Mammal Research Unit, University of St Andrews. [Online]. Available at: http://www.offshoresea.org.uk/site/scripts/consultation_download_info.php?downloadID=147.

Hansen, K.A., Maxwell, A., Siebert U Larsen, O.N. and Wahlberg, M. (2017). Great cormorants (*Phalacrocorax carbo*) can detect auditory cues while diving. *The Science of Nature,* 104, 45.

Harris, R. (2007). *Lepidochelys kempii* Kemp's Ridley turtle. In Tyler-Walters H. and Hiscock K. (Eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews.* Plymouth: Marine Biological Association of the United Kingdom. [Online]. Available at: https://www.marlin.ac.uk/species/detail/2168.

Harris, R.E., Miller, G.W. and Richardson, W.J. (2001). Seal responses to airgun sounds during summer geophysical surveys in the Alaskan Beaufort Sea. *Marine Mammal Science*, 17(4), pp. 795-812. Doi: 10.1111/j.1748-7692.2001.tb01299.x.

Hastings, M.C. (2008). Coming to terms with the effects of ocean noise on marine animals. *Acoustics Today,* 4(2), pp. 22–34. Doi: 10.1121/1.2961166.

Hatcher, D., and Garrett, H. (2008). Core Management Plan Including Conservation Objectives for River Dee and Bala Lake/Afon Dyfrdwy A Llyn Tegid SAC. Countryside Council For Wales.

Hawkins A. D., L. Roberts and S. Cheesman. (2014). Responses of free-living coastal pelagic fish to impulsive sounds. Journal of the Acoustical Society of America 135, 3101.

Hayes, E., Godley, B.J., Nimak-Wood, M. and Witt, M.J. (2018). Basking shark breaching behaviour observations west of Shetland. *Marine Biodiversity Records,* 11 (17), pp. 11-17. Doi: 10.1186/s41200-018-0151-4.

Heessen, H.J.L. and Daan, N. (1994). Cod distribution and temperature in the North Sea. *ICES Marine Science Symposia*, 198, pp. 244–253.

Heessen, H.J.L., Daan, N. and Ellis, J.R. (2015). *Fish atlas of the Celtic Sea, North Sea, and Baltic Sea*. Wageningen: Wageningen Academic Publishers.

Heinänen, S. and Skov, H. 2015. The identification of discrete and persistent areas of relatively high harbour porpoise density in the wider UK marine area, JNCC Report No. 544, JNCC, Peterborough, ISSN 0963-8091. [Online]. Available from: https://data.jncc.gov.uk/data/f7450390-9a89-4986-8389-9bff5ea1978a/JNCC-Report-544-FINAL-WEB.pdf. [Accessed 13-10-21].

Hiby, L. and Lovell, P. (1998). Using Aircraft in Tandem Formation to Estimate Abundance of Harbour Porpoise. *Biometrics*, 54(4), pp. 1280–1289. Doi: 10.2307/2533658.

Hildebrand, J. (2004). *Impacts of anthropogenic sound on cetaceans*. Unpublished paper submitted to the International Whaling Commission Scientific Committee. SC/56 E 13.

Hislop, J.R.G. and Hall, W.B. (1974). The fecundity of whiting, *Merlangius merlangus* (L.) in the North Sea, the Minch and at Iceland. *ICES Journal of Marine Science*, 36(1), pp. 42–49.

Hislop, J.R.G., Robb, A.P., Bell, M.A. and Armstrong, D.W. (1991). The diet and food consumption of whiting (*Merlangius merlangus*) in the North Sea. *ICES Journal of Marine Science*, 48(2), pp. 139–156.

Hoek, W. (1992). An unusual aggregation of harbour porpoises (*Phocoena phocoena*). *Marine Mammal Science,* 8, pp. 152–155. Doi: 10.1111/j.1748-7692.1992.tb00374.x.

Hoelzel, A.R. (2002). *Marine Mammal Biology: An evolutionary approach*. New Jersey: Blackwell Publishing.

Holland, G.J., Greenstreet, S.P.R., Gibb, I.M., Fraser H.M. and Robertson, M.R. (2005). Identifying Sandeel Ammodytes marinus sediment habitat preferences in the marine environment. *Marine Ecology Progress Series,* 303, pp. 269–282.

Holland, G.J., Greenstreet, S.P.R., Gibb, I.M., Fraser H.M. and Robertson, M.R. (2005). Identifying Sandeel *Ammodytes marinus* sediment habitat preferences in the marine environment. *Marine Ecology Progress Series*, 303, pp. 269 – 282.

Houghton, J.D., Doyle, T.K., Wilson, M.W., Davenport, J. and Hays, G.C. (2006). Jellyfish aggregations and leatherback turtle foraging patterns in a temperate coastal environment. *Ecology*, 87(8), pp. 1967-1972. Doi: 10.1890/0012-9658(2006)87[1967:jaaltf]2.0.co;2.

Houser D. S., W. Yost, R. Burkard, J. J. Finneran, C. Reichmuth and J. Mulsow, "A review of the history, development and application of auditory weighting functions in humans and marine mammals", J. Acoust. Soc. Am. 141 (3), March 2017.

Hume, J.B. (2017). A review of the geographic distribution, status and conservation of Scotland's lampreys. *The Glasgow Naturalist,* 26(4), 10 pp. Available at: https://www.glasgownaturalhistory.org.uk/gn26_4/Hume_lampreys_Scotland.pdf.

Hvas, Malthe & Oppedal, Frode. (2017). Sustained swimming capacity of Atlantic salmon. Aquaculture Environment Interactions. 9. 10.3354/aei00239

IAGC. (2002). *Marine Geophysical Operations. An Overview*. Produced by IAGC to provide a reference to other marine operations in general and the fishing industry in particular. [Online]. Available at: https://www.cnlopb.ca/wp-content/uploads/mkiseislab/mki_app_a.pdf [Accessed: 15/09/2021].

ICES. (2009). *Report of the Herring Assessment Working Group for the Area South of 62 N, 17-25 March 2009*. ICES Headquarters, Copenhagen. 648 pp.

ICES. (2021). ICES Working Group on Surveys on Ichthyoplankton in the North Sea and adjacent Seas (WGSINS; outputs from 2020 meeting) ICES Scientific Reports. 3:14. 31pp. https://doi.org/10.17895/ices.pub.7910 [Online]. Available from: https://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/EOSG/2021/WGSINS%20Report%202020.pdf

Inter-Agency Marine Mammal Working Group (IAMMWG). (2015). *Management Units for cetaceans in UK waters (January 2015)*. JNCC Report No. 547, Peterborough.

Inter-Agency Marine Mammal Working Group (IAMMWG). (2021). *Updated abundance estimates for cetacean Management Units in UK waters.* JNCC Report No. 680, JNCC Peterborough, ISSN 0963-8091.

International Council for the Exploration of the Seas (ICES). (2018). Greater North Sea Ecoregion – Ecosystem Overview. [Online]. Available at: https://www.ices.dk/sites/pub/Publication%20Reports/Advice/2018/2018/GreaterNorthSeaEcoregion_EcosystemOverview.pdf [Accessed:...].

International Council for the Exploration of the Seas (ICES). (2019). Working Group on Marine Mammal Ecology (WGMME). *ICES Scientific Reports*. 1(22), 142 pp.

International Union for Conservation of Nature (IUCN). (2019). The IUCN Red List of Threatened Species. Version 2019-2. [Online]. Available at: http://www.iucnredlist.org. [Accessed 30-09-21].

ION. (2021). *ION Southern North Sea Geophysical Survey 2021. Record of the Habitat Regulations Assessment Undertaken Under Regulation 5 of the Offshore Petroleum Activities (Conservation of Habitats) Regulations 2001 (As Amended).* Issued April 2021, Rev 3.0. Department for Business, Energy and Industrial Strategy. [Online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/fi le/985175/ION_Southern_North_Sea_Geophysical_Survey_2021_HRA_Rev_3.0.pdf [Accessed 10-10-21].

Jalkanan J-P, Johansson L., Liefvendahl M., Bensow R., Sigray P., Őstberg M, Karasalo I., Andersson M., Peltonen H., Pajala J., (2018), "Modelling of ships as a source of underwater noise", Ocean Science 14, 1373–1383, 2018.

Jensen, F., Kuperman, W., Porter, M. and Schmidt, H. (2000). *Computational Ocean Acoustics*. New York: Springer-Verlag. Doi: 10.1007/978-1-4419-8678-8.

Joint Nature Conservation Committee (JNCC). (2010). The protection of marine European Protected Species from injury and disturbance

Joint Nature Conservation Committee (JNCC). (2015*). A Conservation Literature Review for the Harbour Porpoise (Phocoena phocoena) IAMMWG, Camphuysen, C.J. and Siemensma, M.L. December 2015*. JNCC Report No. 566. [Online]. Available at: https://data.jncc.gov.uk/data/e3c85307-1294-4e2c-9864-f4dd0f195e1e/JNCC-Report-566-FINAL-WEB.pdf. [Accessed 10-10-21].

Joint Nature Conservation Committee (JNCC). (2017). JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys. 28 pp. [Accessed 10-10-21].

Joint Nature Conservation Committee (JNCC) (2018). Conservation status assessment for the species: S1350 - Common dolphin (*Delphinus delphis*). Available at: https://jncc.gov.uk/jncc-assets/Art17/S1350-UK-Habitats-Directive-Art17-2019.pdf [Accessed 10-10-21].

Joint Nature Conservation Committee (JNCC) (2018a). Conservation status assessment for S1095 - Sea lamprey (*Petromyzon marinus*).

Joint Nature Conservation Committee (JNCC) (2018b). Conservation status assessment for 1099 - River lamprey (*Lampetra fluviatilis*).

Joint Nature Conservation Committee (JNCC) (2013b). European Community Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC), Third Report by the United Kingdom under Article 17, on the implementation of the Directive from January 2007 to December 2012 Conservation status assessment for S1099 - River lamprey (Lampetra fluviatilis). [Online]. Available at: http://archive.jncc.gov.uk/pdf/Article17Consult_20131010/S1095_UK.pdf [Accessed: 22 September 2011].

Joint Nature Conservation Committee (JNCC). (2019). Article 17 Habitats Directive Report 2019: Species Conservation Status Assessments 2019. [Online]. Available at: https://jncc.gov.uk/our-work/article-17-habitats-directive-report-2019-species/ [Accessed 10-10-21].

Joint Nature Conservation Committee (JNCC). (2019). Bottlenose dolphin *Tursiops truncates.* [Online]. Available at: https://sac.jncc.gov.uk/species/S1349/.

Joint Nature Conservation Committee (JNCC). (2021). Distribution of SACs/SCIs/cSACs containing species 1351 *Phocoena phocoena*. [Online]. Available at: https://sac.jncc.gov.uk/species/S1351/map [Accessed: 02/09/2021].

Joint Nature Conservation Committee (JNCC) (2019). Conservation status assessment for S1365 - Common seal (*Phoca vitulina*).

Joint Nature Conservation Committee (JNCC) (2019). Conservation status assessment for S1364 - Grey seal (*Halichoerus grypus*).

Joint Nature Conservation Committee (JNCC). (2021). Grey seal *Halichoerus grypus*. [Online]. Available at: https://sac.jncc.gov.uk/species/S1364/. [Accessed: 08/09/2021].

Joint Nature Conservation Committee (JNCC). (2019). Harbour porpoise (*Phocoena phocoena*) Special Area of Conservation: North Anglesey Marine/Gogledd Môn Forol. [Online]. Available at: https://data.jncc.gov.uk/data/f4c19257-2341-46b3-8e29-49665cd8f3d2/NorthAnglesey-Conservation-Advice.pdf. [Accessed 10-10-21].

Joint Nature Conservation Committee (JNCC). (2019). Harbour porpoise (*Phocoena phocoena)* Special Area of Conservation: North Channel. [Online]. Available at: https://data.jncc.gov.uk/data/be0492aa-f1d6-4197-be22-e9a695227bdb/NorthChannel-conservation-advice.pdf. [Accessed 10-10-21].

Joint Nature Conservation Committee (JNCC). (2019). Harbour porpoise Special Area of Conservation seasonal areas. [Online]. Available at: https://hub.jncc.gov.uk/assets/6d383377-0c95-4338-ad33-91598fce59c8. [Accessed: 02/09/2021].

Joint Nature Conservation Committee (JNCC). (2021). Harbour seal *Phoca vitulina.* [Online]. Available at: https://sac.jncc.gov.uk/species/S1365/. [Accessed 10-10-21].

Joint Nature Conservation Committee (JNCC). (2021). Marine mammals and offshore industries. [Online]. Available at: https://jncc.gov.uk/our-work/marine-mammals-and-offshore-industries/. [Accessed: 01/09/2021].

Joint Nature Conservation Committee (JNCC). (2021). North Anglesey Marine MPA. [Online]. Available at: https://jncc.gov.uk/our-work/north-anglesey-marine-mpa/ [Accessed: 02/09/2021].

Joint Nature Conservation Committee (JNCC). (2021). North Channel MPA. [Online]. Available at: https://jncc.gov.uk/our-work/north-channel-mpa/ [Accessed: 02/09/2021].

Joint Nature Conservation Committee (JNCC). (2021). River Bladnoch. [Online]. Available at: https://sac.jncc.gov.uk/site/UK0030249. [Accessed 10-10-21].

Joint Nature Conservation Committee (JNCC). (2021). River Derwent and Bassenthwaite Lake. [Online]. Available at: https://sac.jncc.gov.uk/site/UK0030032. [Accessed 10-10-21].

Joint Nature Conservation Committee (JNCC). (2021). River Eden. [Online]. Available at: https://sac.jncc.gov.uk/site/UK0012643. [Accessed 10-10-21].

Joint Nature Conservation Committee (JNCC). and Natural England. (2012).

Joint Nature Conservation Committee (JNCC). Natural England. and Countryside Council for Wales. (2010). *The protection of marine European Protected Species from injury and disturbance*. Guidance for the marine area in England and Wales and the UK offshore marine area.

Kastak, D., Schusterman, R.J., Southall, B.L. and Reichmuth, C.J. (1999). Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. *Journal of the Acoustical Society of America*, 106, pp. 1142–1148. Doi: 10.1121/1.427122.

Kastak, D., Southall, B.L., Schusterman, R.J. and Kastak, C.R. (2005). Underwater temporary threshold shift in pinnipeds: Effects of noise level and duration. *Journal of the Acoustical Society of America*, 118, pp. 3154–3163. Doi: 10.1121/1.2047128. PMID: 16334695.

Kastelein, R.A., Bunskoek, P., Hagedoorn, M. and Au, W.W.L. (2002). Audiogram of a harbour porpoise Phocoena phocoena measured with narrow-band frequency-modulated signals. *Journal of the Acoustical Society of America,* 112, pp. 334–344. Doi: 10.1121/1.1480835.

Kastelein, R.A., Helder-Hoek, L., Van de Voorde, S., von Benda-Beckmann, A.M., Lam, F.P.A., Jansen, E. de Jong, C.A.F. and Ainslie, M.A. (2017). Temporary hearing threshold shift in a harbor porpoise (Phocoena phocoena) after exposure to multiple airgun sounds. *Journal of the Acoustical Society of America*, 142, pp. 2430-2442. Doi: 10.1121/1.5007720.

Kastelein, R.A., Van de Voorde, S. and Jennings, N. (2018). Swimming Speed of a Harbor Porpoise (Phocoena phocoena) During Playbacks of Offshore Pile Driving Sounds. *Aquatic Mammals*, 44(1), pp. 92-99. Doi: 10.1578/AM.44.1.2018.92.

Kavanagh, A.S., Kett, G., Richardson, N., Rogan, E. and Jessopp, M.J. (2018). High latitude winter sightings of common minke whale calves (*Balaenoptera acutorostrata*) in the Northeast Atlantic Marine Biodiversity Records. 11, 22 pp.

Kavanagh, A.S., Nykänen, M., Hunt, W., Richardson, N. and Jessop, M.J. (2019). Geophysical surveys reduce cetacean sightings across a large marine ecosystem. *Scientific Reports,* 9, 19164. Doi: 10.1038/s41598-019-55500-4.

Kelly, F.L. and King, J.J. (2001). A review of the ecology and distribution of three lamprey species, *Lampetra fluviatilis* (L), *Lampetra planeri* (L.), and *Petromyzon marinus* (L.): a context for conservation and biodiversity considerations in Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy*, 101(3), pp. 165-185.

Ketten D.R., Cramer, S., Arruda, J., Rye, K., Craig, J., Tussing, R., Lewis, W., Methany, J., Reidenberg, J., McCall, S., Dunn, D., Naples, V. and Potter, C. (2005). Experimental measures of blast trauma in sea turtles. Symposium on Environmental Consequences of Underwater Sound, Office of Naval Research, Arlington, VA. [Online]. Available at: https://csi.whoi.edu/sites/default/files/Kettendr_final%20report_blast%20with%20figs.pdf. [Accessed 10-10-21].

Kjesbu, O.S., Kryvi, H., Sundby, S. and Solemdal, P. (1992). Buoyancy variations in eggs of Atlantic cod (*Gadus morhua* L.) in relation to chorion thickness and egg size: theory and observations. *Journal of Fish Biology*, 41(4), pp. 581-599.

Kinsler, L.E., Frey, A.R., Coppens, A.B. & Sanders, J.V. (1999), Fundamentals of Acoustics, 4th edn. Wiley, NJ.

Klimley, A.P. and Myrberg, A.A. (1979). Acoustic stimuli underlying withdrawal from a sound source by adult lemon sharks, Negaprion brevirostris (Poey). *Bulletin of Marine Science*, 29, pp. 447–458. [Online]. Available at: https://www.ingentaconnect.com/content/umrsmas/bullmar/1979/00000029/00000004/art00001#. [Accessed 10-10-21].

Laist, D.W., Knowlton, A.R., Mead, J.G., Collet, A.S. and Podesta, M. (2001). Collisions between ships and whales. *Marine Mammal Science*. 17(1), pp. 35 – 75.

Lancashire and Cheshire Fauna Society. (2004). *Marine Turtles in Lancashire, Merseyside and Cheshire*. GENERAL REPORT 2004, p.17.

Langley, I., Rosas da Costa Oliver, T., Hiby, L., Stringell, T.B., Morris, C.W., O'Cadhla, O., Morgan, L., Lock, K., Perry, S., Westcott, S. and Boyle, D. (2020). Site use and connectivity of female grey seals (Halichoerus grypus) around Wales. Marine Biology, 167, pp.1-15.

Laughton, R. and Burns, S. (2003). *Assessment of sea lamprey distribution and abundance in the River Spey: Phase III*. Scottish Natural Heritage Commissioned Report No. 043 (ROAME No. F02AC604).

Lawson, J., Kober, K., Win, I., Allcock, Z., Black, J. Reid, J.B., Way, L. and O'Brien, S.H. (2016). *An assessment of the numbers and distribution of wintering waterbirds and seabirds in Liverpool Bay/Bae Lerpwl area of search*. JNCC Report No 576. JNCC, Peterborough.

Lenhardt, M.L. (1994). Geophysical and very low frequency sound induced behaviours in captive loggerhead marine turtles (Caretta caretta). Pages 238-241 in K.A. Bjorndal, A.B. Bolten, D.A. Johnson, and P.J. Eliazar, eds. Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351.

Lenhardt, M.L. and Sismour, E. (1995). Hearing in the Sea Lamprey (Petromyzon marinus) and the Long Nose Gar (Lepisosteus spatula). The Association for Research in Otolaryngology, Abstract: 259.

Lenhardt M.L., R.C. Klinger, and J.A. Musick. 1985. Marine turtle middle-ear anatomy. Journal of Auditory Research. 25:66-72.

Leung Ng, S. and Leung, S. (2003). Behavioural response of Indo-Pacific humpback dolphin (*Sousa chinensis*) to vessel traffic. *Marine Environmental Research,* 56(5), pp. 555 – 567. Doi: 10.1016/S0141-1136(03)00041-2.

Løkkeborg, S., Ona, E., Vold, A. and Salthaug, A. (2012). Sounds from geophysical air guns: gear- and species-specific effects on catch rates and fish distribution. *Canadian Journal of Fisheries and Aquatic Sciences*, 69(8), pp.1278–1291. Doi: 10.1139/F2012-059.

Løkkeborg, S., and Soldal, A.V. (1993). The influence of geophysical exploration with airguns on cod (Gadus morhua) behaviour and catch rates. *ICES Journal of Marine Science*, 196, pp.62–67.

Long, D., 2006. BGS detailed explanation of seabed sediment modified Folk classification. Available from: http://www.emodnet-seabedhabitats.eu/PDF/GMHM3_Detailed_explanation_of_seabed_sediment_classification.pdf

Lovell, J.M., Findlay, M.M., Moate, R.M. and Yan H.Y. (2005). The hearing abilities of the prawn (*Palaemon serratus*). *Comparative Biochemistry and Physiology (A),* 140(1), pp. 89-100. Doi: 10.1016/j.cbpb.2004.11.003.

Lucke, K., Lepper, P., Blanchet, M.-A. and Siebert, U. (2009). Temporary shift in masked hearing thresholds in a harbour porpoise *Phocoena phocoena* after exposure to geophysical airgun stimuli. *Journal of the Acoustical Society of America*, 125(6), pp.4060 – 4070. Doi: 10.1121/1.3117443

Lancashire Wildlife Trust (2018). Seal pup rescued from beach. [Online]. Available at https://www.lancswt.org.uk/blog/seal-pup-rescued-beach. [Accessed 15-10-21]

Macer, C.T. (1966). Sand eels (Ammodytidae) in the south western North Sea: their biology and fishery. *Fish Investment London Series II*, 24, 1 – 55.

MacGillivrary, A.O. (2006). An Acoustic Modelling Study of Geophysical Airgun Noise in Queen Charlotte Basin. MSc Thesis. University of Victoria. [Online]. Available at: https://dspace.library.uvic.ca/handle/1828/2188?show=full.

Macleod, K., Burt, M.L., Cañadas, A., Rogan, E., Santos, B., Uriarte, A., Van Canneyt, O., Vázquez, J.A. and Hammond, P. S. (2009). *Design-based estimates of cetacean abundance in offshore European Atlantic waters*. Appendix I in the Final Report of the Cetacean Offshore Distribution and Abundance in the European Atlantic. 16 pp.

Maes, J., Peeters, B., Ollevier, F., Parmentier, A., Thoelen, E., Franchois, H., Turnpenny, A.W.H., Lambert, D.R. and Nedwell, J.R. (1999). Evaluation of the fish guidance system at the cooling water inlet of the Nuclear Power Plant Doel 3/4. Katholieke Universiteit Leuven, Department Biology, Laboratory of Aquatic Ecology.

Maes, J., Turnpenny, A.W.H., Lambert, D.R., Nedwell, J.R., Parmentier, A. and Ollevier, F. (2004). Field evaluation of a sound system to reduce estuarine fish intake rates at a power plant cooling water inlet. *Journal of Fish Biology,* 64(4), pp. 938-946. Doi: 10.1111/j.1095-8649.2004.00360.x.

Maitland, P. S. (2003). Ecology of the River Brook and Sea Lamprey. Conserving Natura 2000 Rivers Ecology Series No. 5. English Nature, Peterborough.

Malcolm, I.A., Godfrey, J. and Youngson, A.F. (2010). Review of migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: implications for the development of marine renewables. *Scottish Marine and Freshwater Science*, 1(14), 72 pp.

Malcolm L. Windsor, M.L., Hutchinson, P., Hansen, L.P. and Reddin, D.G. (2012). Atlantic salmon at sea: Findings from recent research and their implications for management. NASCO document CNL (12)60. Edinburgh, UK. 20pp. [Online]. Available from: https://nasco.int/wp-content/uploads/2020/02/Salmon_at_sea.pdf. [Accessed 10-10-21].

Mann, D.A., Higgs, D.M., Tavolga, W.N., Souza, M.J. and Popper, A.N. (2001). Ultrasound detection by clupeiform fishes. *The Journal of the Acoustical Society of America*, 109(6), pp. 3048 – 3054. Doi: 10.1121/1.1368406.

Manx Basking Shark Watch (MBSW). (2021). [Online]. Available at: https://www.manxbaskingsharkwatch.org/sightings-analysis/.[Accessed 10-10-21].

Marine Scotland. (2017). Designated haul-out sites for seals (Protection of Seals Orders) - May 2017. [Online]. Available at: http://marine.gov.scot/maps/446. [Accessed: 08/09/2021].

Marine Scotland. (2014). The protection of Marine European Protected Species from injury and disturbance – Guidance for Scottish Inshore Waters. [Online] Available at: http://www.gov.scot/Resource/0044/00446679.pdf.

McCauley, R.D., Day, R.D., Swadling, K.M., Fitzgibbon, Q.P., Watson, R.A. and Semmens, J.M. (2017). Widely used marine geophysical survey air gun operations negatively impact zooplankton. *Nature: Ecology and Evolution*, 1(7), 195. Doi: 10.1038/s41559-017-0195.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner; M.N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J. and McCabe, K. (2000). Marine geophysical surveys: Analysis and propagation of air-gun signals; and effect of air-gun exposure on humpback whales, sea turtles, fishes, and squid. In "Environmental implications of offshore oil and gas development in Australia: further research." (APPEA Secretriat.) Pp. 364–521. (Australian Petroleum production and exploration Association Limited: Canberra.) Myrberg Jr, A. A. 2001. The acoustical biology of elasmobranchs. *Environmental Biology of Fishes*, 60(1-3), pp. 31-46.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.N., Penrose, J.D., Prince, R.I.T., Pearson, W.H., Skalski, J.R., Sulkin, S.D. and Malme, C.I. (1994). Effects of Geophysical Releases on the Survival and Development of Zoeal Larvae of Dungeness Crab (Cancer magister). *Marine Environmental Research*, 38(2), pp. 93-113. Doi: 10.1016/0141-1136(94)90003-5.

McCauley, R.D., Fewtrell, J. and Popper, A.N. (2003). High intensity anthropogenic sound damages fish ears, *Journal of the Acoustical Society of America*, 113, pp. 638–642. Doi: 10.1121/1.1527962.

McCormick, S.D., Hansen, L.P., Quinn, T.P. and Saunders, R.L. (1998). Movement, migration, and smolting of Atlantic salmon (*Salmo salar*). *Canadian Journal of Fisheries and Aquatic Sciences*, 55(S1), pp. 77-92.

McEvoy, L.A. and McEvoy, J. (1992). Multiple spawning in several commercial fish species and its consequences for fisheries management, cultivation and experimentation. *Journal of Fish Biology*, 41, pp. 125-136.

McGarry, T., Boisseau, O., Stephenson, S. and Compton, R. (2017). Understanding the Effectiveness of Acoustic Deterrent Devices (ADDs) on Minke Whale (*Balaenoptera acutorostrata*), a Low-Frequency Cetacean. Chepstow: The Carbon Trust.

Merchant, N.D., Faulkner, R.C. and Martinez, R. (2017). Marine noise budgets in practice. *Conservation Letters*, 11, pp.1-8. Doi: 10.1111/conl.12420.

Mickle, M.F., Miehls, S.M., Johnson, N.S. and Higgs, D.M. (2018). Hearing capabilities and behavioural response of sea lamprey (Petromyzon marinus) to low-frequency sounds. Canadian Journal of Fisheries and Aquatic Sciences, 76(9), pp.1541-1548.

MMO. (2014). *Mapping UK Shipping Density and Routes from AIS. A report produced for the Marine Management Organisation*, pp 35. MMO Project No: 1066. ISBN: 978- 1-909452-26-8. [Online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/317770/1066.pdf.

MMO. (2015). *Research and analysis: Underwater noise source literature review references and data table for anthropogenic sources* (MMO 1097). [Online]. Available at:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/486651/Underwater_noise_source_literature_review_references_and_value_table_for_anthropogenic_sources__MMO_1097_.csv/preview.

MMO. (2017). *Vessel Density Grid 2015.* [Online]. Available at: https://data.gov.uk/dataset/b7ae1346-7885-4e2d-aedf-c08a37d829ee/vessel-density-grid-2015#licence-info.

MMO (2018). Displacement and habituation of seabirds in response to marine activities. A report produced for the Marine Management Organisation. MMO Project No: 1139, May 2018, 69pp. [Online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/715604/Displacement_and_habituation_of_seabirds_in_response_to_marine_activities.pdf.

MMO. (2019). *Habitat Regulations Assessment for the North East, North West, South East and South West Marine Plans – Appropriate Assessment Information Report, including Screening Report.* A report produced for the Marine Management Organisation, pp 232. MMO Project No: 1188. [Online]. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/857273/AAIR_final.pdf.

Moore, J.A. Hartel, K.E. Craddock, J.E. and Galbraith, J.K. (2003). An annotated list of deepwater fishes from off the New England region, with new area records. *Northeastern Naturalist*, 10(2), pp. 159-248.

Morris, C.D. and Duck, C.D. (2018). Aerial thermal-imaging surveys of harbour and grey seals in Northern Ireland, August 2018.

Myrberg, A.A., Jr.; Gordon, C.R. and Klimley, A.P. (1976). Attraction of Free Ranging Sharks by Low Frequency Sound, with Comments on Its Biological Significance. In Sound Reception in Fish; Elsevier: Amsterdam, The Netherlands, 205–228.

Myrberg, A.A., Gordon, C.R. and Klimley, A.P. (1978). Rapid withdrawal from a sound source by open-ocean sharks. *Journal of the Acoustic Society of America*, 64(5), pp.1289–1297. Doi: 10.1121/1.382114.

Myrberg, A.A. (2001). The acoustical biology of elasmobranchs. *Environmental Biology of Fishes*, 60, pp. 31–45. Doi: 10.1007/978-94-017-3245-1_4.

National Marine Fisheries Service (NMFS). (2018). *Revision to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts*. U.S. Dept. of Commer., NOAA, National Marine Fisheries Service (NMFS). NOAA Technical Memorandum NMFS-OPR-59, 178pp.

Natural England (2010). The Dee Estuary European Marine Site. Natural England and the Countryside Council for Wales advice given under Regulation 33(2) of the Conservation (Natural Habitats &C.) Regulations 1994. []. Available from: http://publications.naturalengland.org.uk/publication/2986296. [Accessed 13-10-21].

Natural England. (2012). Liverpool Bay / Bae Lerpwl Special Protection Area. Conservation Objectives and Standard Data Form. [Online]. Available from: http://publications.naturalengland.org.uk/publication/5089733892898816. [Acccessed 30-09-21].

Natural England (2016). Morecambe Bay and Duddon Estuary SPA Departmental Brief. [Online]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/492891/morecambe-duddon-departmental-brief.pdf

Natural England (2018). Marine Conservation Zones Natural England's advice to Defra on Marine Conservation Zones to be considered for consultation in 2017. Annex 2: Advice on Tranche 3 MCZs with the species feature of conservation importance smelt (Osmerus eperlanus). [Online]. Available from: file:///C:/Users/jackie.hill/Downloads/JP026%20edition%201%20Annex%202%20Advice%20on%20Smelt%20as%20a%20feature%20of%20Regional%20Project%20rMCZs%20published%20advice%20(1).pdf. [Accessed 10-10-21].

Natural England (2019). European Site Conservation Objectives for River Derwent & Bassenthwaite Lake SAC (UK0030032). [Online]. Available from: http://publications.naturalengland.org.uk/publication/6086221126172672. [Accessed 30-09-21]

Natural England, 2021. Natural England's Impact Risk Zones for Sites of Special Scientific Interest. User Guidance v4.0.

Natural England and JNCC., 2012. Joint Natural England and JNCC Interim Advice Note – Presenting information to inform assessment of the potential magnitude and consequences of displacement of seabirds in relation of Offshore Wind farm Developments.

Natural England and JNCC. (2017). Joint SNCB Interim Displacement Advice Note. Advice on how to present assessment information on the extent and potential consequences of seabird displacement from Offshore Wind Farm developments when assessing displacement from offshore wind farms. [Online]. Available from: https://data.jncc.gov.uk/data/9aecb87c-80c5-4cfb-9102-39f0228dcc9a/Joint-SNCB-Interim-Displacement-AdviceNote-2017-web.pdf. [Accessed 13-10-21]

Natural Resource Wales (NRW) (2009). Pen Llŷn a'r Sarnau /Lleyn Peninsula and the Sarnau European Marine Site. Available at: https://naturalresources.wales/media/673816/Pen%20Llyn%20ar%20Sarnau%20%20R33%20Feb%202009.pdf

Natural Resource Wales (NRW) (2016). Proposal to extend and reclassify Ynys Feurig, Cemlyn Bay and The Skerries Special Protection Area and rename it as Anglesey Terns / Morwenoliaid Ynys Môn Species Protection Area. Advice to the Welsh Government. Available at: https://naturalresourceswales.gov.uk/media/681015/revised-departmental-brief-anglesey-terns-spa.pdf

Natural England and Scottish Natural Heritage (SNH). (2016). Solway Firth Proposed Special Protection Area (pSPA) NO. UK9005012). [Online]. Available at: https://www.nature.scot/sites/default/files/2017-12/Marine%20Protected%20Area%20%28Proposed%29%20-%20Site%20selection%20document%20-%20Solway%20Firth.pdf.

Natural England, Welsh Government and Countryside Council for Wales. (2010). The Dee Estuary European Marine Site. [Online]. Available at: https://naturalresources.wales/media/673576/Dee%20Estuary-Reg33-Volume%201-English-091209_1.pdf.

NDA, Geological Disposal: Generic Waste Package Specification, NDA Report No. NDA/RWMD/067, 2012.

NDA, Geological Disposal: Introduction to the RWM Waste Package Specification and Guidance Documentation, WPS/100/04, 2014.

NDA, Geological Disposal: An overview of the RWM Disposability Assessment process, WPS/650/03, 2014.

Neenan S. T. V., White P. R., Leighton T. G., Shaw P. J., (2016), "Modeling vessel noise emissions through the accumulation and propagation of Automatic Identification System data", Proceedings of the Fourth International Conference on the Effects of Noise on Aquatic Life Dublin, Ireland, 10-16 July 2016

Nedwell J R, Parvin S J, Edwards B, Workman R, Brooker A G, Kynoch J E, (2008), "Measurement and interpretation of underwater noise during construction and operation of offshore windfarms in UK waters", COWRIE NOISE-03-2003.

NOAA. (2021). ESA Section 7 Consultation Tools for Marine Mammals on the West Coast. [Online]. Available from: https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/esa-section-7-consultation-tools-marine-mammals-west. [Accessed: 17/09/2021].

Northridge, S., Cargill, A., Coram, A., Mandleber, L., Calderan, S. and Reid, B. (2010). *Entanglement of minke whales in Scottish waters; an investigation into occurrence, causes and mitigation*. Sea Mammal Research Unit. Final Report to Scottish Government CR/2007/49. Available at: http://www.smru.st-andrews.ac.uk/files/2016/08/Entaglement-of-minke-whales-in-Scottish-waters-an-investigation-into-occurrence-causes-and-mitigation.pdf.

Northridge, S.P., Tasker, M.L., Webb, A. and Williams, J.M. (1995). Seasonal distribution and relative abundance of harbour porpoises *Phocoena phocoena* (L.), white-beaked dolphins *Lagenorhynchus albirostris* (Gray) and minke whales *Balaenoptera acutorostrata* (Lacepède) in the waters around the British Isles. *ICES Journal of Marine Science*, 52, pp. 55–66. Doi: 10.1016/1054-3139(95)80015-8.

Nowacek, D.P., Clark, C.W., Mann, D., Miller, P.J.O., Rosenbaum, H.C., Golden, J.S., Jasny, M., Kraska, J. and Southall, B.L. (2015). Marine geophysical surveys and ocean noise: time for coordinated and prudent planning. *Frontiers in Ecology and the Environment*, 13(7), pp. 378–386. Doi: 10.1890/130286.

Ocean Acoustics Library (2021). [Online]. Available at: https://oalib-acoustics.org/.

Ocean Life, Accessed at https://ocean.si.edu/ocean-life/reptiles/sea-turtles

OGP IAGC "An overview of marine seismic operations", (2011), Report No. 448. Accessed http://www.ogp.org.uk/pubs/448.pdf

OSPAR (2009). Overview of the impacts of anthropogenic underwater sound in the marine environment. [Online]. Available at: https://qsr2010.ospar.org/media/assessments/p00441_Noise_background_document.pdf. [Accessed 10-10-21].

Otani, S., Naito, T., Kato, A. and Kawamura, A. (2000). Diving behaviour and swimming speed of a free-ranging harbour porpoise (*Phocoena phocoena*). Marine Mammal Science, 16: 811-814.

Otani, Seiji & Naito, Yasuhiko & Kato, Akiko & Kawamura, Akito. (2006). Diving behavior and swimming speed of a free-ranging harbor porpoise, *Phocoena phocoena*. Marine Mammal Science. 16. 811 - 814. 10.1111/j.1748-7692.2000.tb00973.x.

Owen, E. 2015. Black guillemot (Cepphus grylle) tracking in Orkney, 2013 and 2014. Scottish Natural Heritage Commissioned Report No. 903.

Paxton, A.B., Taylor, J.C., Nowacek, D.P., Dale, J., Cole, E., Voss, C.M. and Peterson, C.H. (2017). Geophysical survey noise disrupted fish use of a temperate reef. *Marine Policy*, 78, pp. 68-73. Doi: 10.1016/j.marpol.2016.12.017.

Payne, J.F., Andrews, C.A., Fancey, L.L., Cook, A.L. and Christian, J.R. (2007). *Pilot study on the effect of geophysical air gun noise on lobster (Homarus americanus)*. Environmental Studies Research Funds Report No. 171. St. John's, NL. 34 p.

Peña, H., Handegard, N.O. and Ona, E. (2013). Feeding herring schools do not react to geophysical airgun surveys. *ICES Journal of Marine Science*, 70(6), pp. 1174-1180. Doi: 10.1093/icesjms/fst079.

Pichegru, L., Nyengera, R., McInnes, A.M. and Pistorius, P. (2017). Avoidance of geophysical survey activities by penguins. *Scientific reports*, 7, 8 pp. Doi: 10.1038/s41598-017-16569-x.

Pierpoint, C. (2008). Harbour porpoise (*Phocoena phocoena*) foraging strategy at a high energy, near-shore site in south-west Wales, UK. *Journal of the Marine Biological Association of the United Kingdom*, 88(6), pp. 1167-1173. Doi: 10.1017/S0025315408000507.

Pinn, E., Mitchell, I., Hawkridge, J. and Macleod, K. (2018). Cetacean abundance and distribution: wide-ranging cetaceans. UK Marine Online Assessment Tool. [Online]. Available at: https://moat.cefas.co.uk/biodiversity-food-webs-and-marine-protected-areas/cetaceans/abundance-and-distribution-of-cetaceans-other-than-coastal-bottlenose-dolphins/. [Accessed: 02/09/2021].

Pirotta, E., Brookes, K.L., Graham, I.M. and Thompson, P.M. (2014). Variation in harbour porpoise activity in response to geophysical survey noise. *Biology Letters*, 10(5), 20131090. Doi: 10.1098/rsbl.2013.1090.

Popper A. N. and Fay, R. R. (1993). Sound Detection and Processing by Fish: Critical Review and Major Research Questions, Brain, Behavior and Evolution. 41:14-38.

Popper, A.N. (2005). A review of hearing by Sturgeon and Lamprey. Report to the U.S. Army Corps of Engineers, Portland District. [Online]. Available at: https://www.researchgate.net/publication/266289438_A_Review_of_Hearing_by_Sturgeon_and_Lamprey.

Popper, A.N. (2012). Fish Hearing and Sensitivity to Acoustic Impacts. Appendix J. Atlantic OCS proposed Geological and Geophysical Activities, Mid-Atlantic and South Atlantic Planning Areas, Draft Programmatic Environmental Impact Statement. OCS EIS/EA BOEM 2012-005. March 2012. 2 vols. [Online]. Available at: http://www.cbd.int.

Popper, A.N., Halvorsen, M.B., Kane, A.S., Miller, D.L., Smith, M.E., Song, J. and Wysocki, L.E. (2007). The effects of high-intensity, low frequency active sonar on rainbow trout. *The Journal of the Acoustical Society of America*, 122(1), pp. 623–635. Doi: 10.1121/1.2735115.

Popper, A.N. and Hastings M.C. (2009). The effects of anthropogenic sources of sound on fishes. *Journal of Fish Biology*, 75(3), pp. 455-489. Doi: 10.1111/j.1095-8649.2009.02319.x.

Popper, A.N. and Hawkins, A.D. (2019). An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes. *Journal of Fish Biology*, 94(5), pp. 692–713. Doi: 10.1111/jfb.13948.

Popper, A.N., Hawkins, A.D., Fay, R.R., Mann, D., Bartol, S., Carlson, T., Coombs, S., Ellison, W.T., Gentry, R., Halvorsen, M.B., Løkkeborg, S., Rogers, P., Southall, B.L., Zeddies, D. and Tavolga, W.N. (2014). *ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*. Cham, Switzerland: Springer and ASA Press.

Popper, A.N., Salmon, M. and Horch, K.W. (2001). Acoustic detection and communication by decapod crustaceans. *Journal of Comparative Physiology A*, 187, pp. 83-89. Doi: 10.1007/s003590100184.

Popper, A.N., Smith, M.E., Cott, P.A., Hanna, B.W., MacGillivray, A.O., Austin, M.E. and Mann D.A. (2005). Effects of exposure to geophysical airgun use on hearing of three fish species. *Journal of the Acoustical Society of America*, 117(6), pp. 3958-3971. Doi: 10.1121/1.1904386.

Porter M. B., “The Bellhop Manual and User’s Guide” 2011. Accessed at http://oalib.hlsresearch.com.

Potter, E.C.E. and Dare, P.J. (2003*). Research on migratory salmonids, eel and freshwater fish stocks and fisheries.* Science series technical report-centre for environment fisheries and aquaculture science.

Prideaux, G. (2016). ‘*Technical Support Information to the CMS Family Guidelines on Environmental Impact Assessments for Marine Noise-generating Activities*’, Convention on Migratory Species of Wild Animals, Bonn.

Quick, N., Arso, M., Cheney, B., Islas, V., Janik, V., Thompson, P.M. and Hammond, P.S. (2014*). The east coast of Scotland bottlenose dolphin population: Improving understanding of ecology outside the Moray Firth SAC*. UK Department of Energy and Climate Change's offshore energy Strategic Environmental Assessment programme. 87 pp.

Reeds, K.A. (2004). *Dermochelys coriacea* Leatherback turtle. In Tyler-Walters H. and Hiscock K. (Eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*. Plymouth: Marine Biological Association of the United Kingdom. [Online]. Available at: https://www.marlin.ac.uk/species/detail/1534

Reichmuth, C., Ghoul, A. and Sills, J.M. (2016). Low-frequency temporary threshold shift not observed in spotted or ringed seals exposed to single air gun impulses. *The Journal of the Acoustical Society of America,* 140(4), 2646. Doi: 10.1121/1.4964470.

Reid, J.B., Evans, P.G.H. and Northridge, S.P. (2003). *Atlas of Cetacean Distribution in north-west European Waters*. Joint Nature Conservation Committee, Peterborough.

Richardson, J.W. (2002). Marine Mammals versus Geophysical and Other Acoustic Surveys: Introduction to the Noise Issues. *Polarforschung*, 72(2/3), pp. 63-67.

Richardson, W.J. (2004). Marine Mammals versus Geophysical and Other Acoustic Surveys: Introduction to the Noise Issues. Polarforschung, 72(2/3), pp.63-67. Richardson, W.J., Greene Jr., C.R., Malme, C.I. and Thompson, D.H. (1995). *Marine Mammals and Noise*. New York: Academic Press. 576 pp.

Richardson, W.J., Greene, C.R., Malme, C.I. and Thomson, D.H. (2013). *Marine mammals and noise*. New York: Academic press.

Ridgway, S.H. and Harrison, R.J. (1981). *Handbook of marine mammals*. New York: Academic Press. 1, pp.1 – 235.

Risch, D., Siebert, U. and Van Parijs, S.M. (2014). Individual calling behaviour and movements of North Atlantic minke whales (*Balaenoptera acutorostrata*). Behaviour 151 (2014) 1335–1360 brill.com/beh.

Ropert-Coudert, Y., Daunt, F., Kato, A., Ryan, P.G., Lewis, S., Kobayashi, K., Mori, Y., Gremillet, D. and Wanless, S. (2009). Underwater wingbeats extend depth and duration of plunge dives in northern gannets *Morus bassanus*. *Journal of Avian Biology,* 40, pp. 380-387.

Ross E., Harris, R.E., Miller, G.W. and Richardson, W.J. (2001). Seal responses to airgun sounds during summer geophysical surveys in the Alaskan Beaufort Sea. *Marine Mammal Science*, 17(4), pp. 795-812.

Ross-Smith, V.H., Robinson, R.A., Banks, A.N., Frayling, T.D., Gibson, C.C. and Clark, J.A. (2014). The Lesser Black-backed Gull *Larus fuscus* in England: how to resolve a conservation conundrum. *Seabird*, 27, pp.41-61.

Rowley, S.J. (2005). *Caretta caretta* Loggerhead turtle. In Tyler-Walters H. and Hiscock K. (Eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*. Plymouth: Marine Biological Association of the United Kingdom. [Online]. Available at: https://www.marlin.ac.uk/species/detail/2094.

RPS Energy. (2011). *Environmental Impact Assessment for 3D Geophysical Survey, Saqqamiut and Prospecting Area, Offshore South Greenland*. Report No. EHE2108. [Online]. Available at: https://naalakkersuisut.gl/~/media/Nanoq/Files/Hearings/2012/Capricorn%20Greenland%20Exploration%201%20ltd/endelig%20eng.pdf.

Russell, D.J.F., Jones, E.L. and Morris, C.D. (2017). Updated Seal Usage Maps: The Estimated at-sea Distribution of Grey and Harbour Seals. *Scottish Marine and Freshwater Science*, 8(25), 30 pp.

Russell, D.J.F. and McConnell, B. (2014). *Seal at-sea distribution, movements and behaviour*. Report to UK Department of Energy and Climate Change (DECC). URN: 14D/085.

Sætre, R. and Ona, E. (1996). Seismiske undersøkelser og skader på fiskeegg og -larver; en vurdering av mulige effekter på bestandsnivå (Geophysical surveys and damage to fish eggs and larvae; an assessment of possible effects at population level) *Havforskningsinstituttet, Fisken og Havet*, 8. 25 pp.

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

Scottish Executive. (2007). *Scottish Marine Renewables: Strategic Environmental Assessment, Environmental Report*. Report prepared for the Scottish Executive by Faber Maunsell and Metoc PLC.

Sea Mammal Research Unit (SMRU). (2021). [Online]. Available at: http://www.smru.st-andrews.ac.uk/.[Accessed 10-10-21].

Sea Watch Foundation. (2012a). Cetaceans of Eastern England. [Online]. Available at: https://seawatchfoundation.org.uk/wp-content/uploads/2012/07/EasternEngland.pdf [Accessed 10-10-21].

Sea Watch Foundation. (2012b). The White Beaked Dolphin Dolphin in UK Waters. [Online]. Available at: https://seawatchfoundation.org.uk/wp-content/uploads/2012/07/White-beaked_Dolphin.pdf

Sea Watch Foundation. (2021). Cetaceans of North-west England and The Isle of Man. [Online]. Available at: https://www.seawatchfoundation.org.uk/wp-content/uploads/2012/07/North-westEngland.pdf. [Accessed 15-10-21.]

Shimada, T., Limpus, C., Jones, R. and Hamann, M. (2017). Aligning habitat use with management zoning to reduce vessel strike of sea turtles. *Ocean and Coastal Management*, 142, pp. 163 – 172. Doi: 10.1016/j.ocecoaman.2017.03.028.

Showler, D.A., Stewart, G.B., Sutherland, W.J. and Pullin, A.S. (2010): What is the impact of public access on the breeding success of ground-nesting and cliff-nesting birds? CEE review 05-010. Centre for Ecology, Evolution and Conservation – School of Biological Sciences, University of East Anglia.

Shrimpton, J.M. (2012). Seawater to freshwater transitions in diadromous fishes. *In Fish physiology Academic Press,* 32, pp. 327-393.

Sims. D.W. (2000). Filter-feeding and cruising swimming speeds of basking sharks compared with optimal models: they filter-feed slower than predicted for their size Journal of Experimental Marine Biology and Ecology, 249(1), 65-76

Sini, M.I., Canning, S.J., Stockin, K.A. and Pierce, G.J. (2005). Bottlenose dolphins around Aberdeen harbour, north-east Scotland: a short study of habitat utilization and the potential Effects of boat traffic. *Journal of the Marine Biological Association*, 85(6), pp. 1547 – 1554.

Sivle, L.D., Vereide, E.H., de Jong, K., Forland, T.N., Dalen, J. and Wehde, H. (2021). Effects of Sound from Geophysical Surveys on Fish Reproduction, the Management Case from Norway. Journal of Marine Science and Engineering, 9(4), 436. Doi: 10.3390/jmse9040436.

Slotte, A., Hansen, K., Dalen, J. and Ona, E. (2004). Acoustic mapping of pelagic fish distribution and abundance in relation to a geophysical shooting area off the Norwegian west coast. Fisheries Research, 67(2), pp. 143–150. Doi: 10.1016/j.fishres.2003.09.046.

Smith, M.E., Kane, A.S. and Popper, A.N. (2004). Acoustical stress and hearing sensitivity in fishes: Does the linear threshold shift hypothesis hold water? Journal of Experimental Biology, 207, pp. 3591–3602.

SNH. (2017). Scottish Marine Wildlife Watching Code. [Online]. Available at: https://www.nature.scot/sites/default/files/2017-06/Publication%202017%20-%20The%20Scottish%20Marine%20Wildlife%20Watching%20Code%20SMWWC%20-%20Part%201%20-%20April%202017%20%28A2263518%29.pdf.

SNH and Natural England. (2010) file:///C:/Users/richard.gibbs/Downloads/solway%20firth%20reg%2033%20(2).pdf

Solan, M., Hauton, C., Godbold, J.A., Wood, C.L., Leighton, T.G. and White, P. (2016). Anthropogenic sources of underwater sound can modify how sediment-dwelling invertebrates mediate ecosystem properties. *Scientific Reports*, 6, 20540. Doi: 10.1038/srep20540.

Solway Firth Partnership. (2011). Tidelines newsletter of the Solway Firth Partnership, winter 2011, issue 35. [Online]. Available at: https://solwayfirthpartnership.co.uk/wp-content/uploads/2018/09/TIDELINES-WINTER-Final-Copy.pdf. [Accessed: 02/09/2021]

Sommer, U. ed., 2012. Plankton ecology: succession in plankton communities. Springer Science & Business Media.

Song, D.A., Mann, P.A., Cott, B.W., Hanna, A.N. and Popper, A.N. (2008). The inner ears of Northern Canadian freshwater fishes following exposure to geophysical air gun sounds. *Journal of the Acoustical Society of America*, 124, pp. 1360–1366. http://doi.org/10.1121/1.2946702. [Online]. Available from: https://www.researchgate.net/publication/23150668_The_inner_ears_of_Northern_Canadian_freshwater_fishes_following_exposure_to_geophysical_air_gun_sounds.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene Jr., C.R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A. and Tyack, P.L. (2007). Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic Mammals,* 33(4), pp. 273-275. Doi: 10.1080/09524622.2008.9753846.

Southall, B.L., Finneran, J.J., Reichmuth, C., Nachtigall, E.P., Kettem, R.D., Bowles, E.A., Ellison, T.W., Nowacek, P.D. and Tyack, L.P. (2019). Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals*, 45(2), pp. 125–232.

Southall, B.L., Rowles, T., Gulland, F., Baird, R.W. and Jepson, P.D. (2013). Final report of the Independent Scientific Review Panel investigating potential contributing factors to a 2008 mass stranding of melon-headed whales (*Peponocephala electra*) in Antsohihy, Madagascar. 75 pp.

Special Committee on Seals (SCOS). (2018). Scientific Advice on Matters Related to the Management of Seal Populations: 2018. Sea Mammal Research Unit. [Online]. Available at: http://www.smru.st-andrews.ac.uk/research-policy/scos/. [Accessed 10-10-21].

Special Committee on Seals (SCOS). (2020) Scientific Advice on Matters Related to the Management of Seal Populations: 2020. [Online]. Available from http://www.smru.st-andrews.ac.uk/files/2021/06/SCOS-2020.pdf. [Accessed 13-10-21].

Speedie, C.D., Johnson, L.A. and Witt, M.J. (2009). Commissioned Report No. 339. Basking Shark Hotspots on the West Coast of Scotland: Key sites, threats and implications for conservation of the species.

Spiga, I., Cheesman, S., Hawkins, A., Perez-Dominguez, R., Roberts, L., Hughes, D., Elliott, M., Nedwell, J. and Bentley, M. (2012) Understanding the Scale and Impacts of Anthropogenic Noise upon Fish and Invertebrates in the Marine Environment. SoundWaves Consortium Technical Review (ME5205).

Stadler JH, Woodbury DP (2009) Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria. Proceedings of Inter-Noise 2009, 38th International Congress and Exposition on Noise Control Engineering, 23-26 August 2009, Ottawa, ON, Canada. Available via » http://www.itre.ncsu.edu/ADC30/10WinterWrkshop_presentation_links.htm. Accessed 28 April 2010.

Stemp, R. (1985). Observations on the effects of geophysical exploration on seabirds. In: Greene GD, Engelhardt FR & Paterson RJ (Eds) *Proceedings of the workshop on effects of explosives use in the marine environment*. Jan 29-31, 1985, Canada: Halifax.

Stone, C. and Tasker, M. (2006). The effects of geophysical airguns on cetaceans in UK waters. *Journal of Cetacean Research and Management*, 8, pp. 255–263.

Stone, C.J., Webb, A., Barton, C., Ratcliffe, N., Reed, T.C., Tasker, M.L., Camphuysen, C.J. and Pienkowski, M.W. 1995. An atlas of seabird distribution in north-west European waters, JNCC, Peterborough, ISBN 1 873701 94 2. [Online]. Available from: https://data.jncc.gov.uk/data/c132752f-827c-41fc-b617-e681db21eaf5/atlas-of-seabird-distribution-north-west-european-waters.pdf. [Accessed 13-10-21].

Swan, J.M., Neff, J.M. and Young, P.C. (1994). Environmental implications of offshore oil and gas development in Australia. The finding of an independent scientific review.

Tappin, D.R., Pearce, B., Fitch, S., Dove, D., Gearey, B., Hill, J.M., Chambers, C., Bates, R., Pinnion, J., Diaz Doce, D., Green, M., Gallyot, J., Georgiou, L., Brutto, D., Marzialetti, S., Hopla, E., Ramsay, E. and Fielding, H. (2011). *The Humber Regional Environmental Characterisation*. British Geological Survey Open Report OR/10/54

ter Hofstede, R.H., Winter, H.V. and Bos, O.G. (2008). *Distribution of fish species for the generic Appropriate Assessment for the construction of offshore wind farms*. IMARES Report C050/08.

Tetley, M.J. and Dolman, S.J. (2013). *Towards a Conservation Strategy for White-beaked Dolphins in the Northeast Atlantic*. Report from the European Cetacean Society's 27th Annual Conference Workshop, The Casa da Baía, Setúbal, Portugal. European Cetacean Society Special Publication Series. 121 pp.

Thaxter, C.B., Wanless, S., Duant, F., Harris, M.P., Benvenuti, S., Watanuki, Y., Cremiller, D. and Hamer, K.C. (2009). Influence of wing loading on the trade-off between pursuit-diving and flight in common guillemots and razorbills. The Journal of Experimental Biology 213:1018 -1025.

Thaxter, C.B., Lascelles, B., Sugar, K., Cook, A.S.C.P., Roos, S., Bolton, M., Langston, R.H.W. and Burton, N.H.K. (2012). Seabird foraging ranges as a preliminary tool for identifying candidate Marine Protected Areas. *Biological Conservation*, 156, pp. 53-61. Doi: 10.1016/j.biocon.2011.12.009.

Thaxter, C.B., Clewley, G., Barber, L., Conway, G.J., Clark, N.A., Emily, S.S., and Burton, N.H.K. (2017). Assessing habitat use of Herring Gulls in the Morecambe Bay SPA using GPS tracking devices. BTO Research Report No. 693.

Theobald P., Lepper P., Robinson S., Hazelwood D., (2009), “Cumulative Noise Exposure Assessment For Marine Mammals Using Sound Exposure Level As A Metric”, UAM Conference Proceedings 2009.

Thompson, D., Sjoberg, M., Bryant, M.E., Lovell, P. and Bjorge, A. (1998). *Behavioural and physiological responses of harbour (Phoca vitulina) and grey (Halichoerus grypus) seals to geophysical surveys*. Report to European Commission of BROMMAD project. No. MAS2 C7940098.

Thompson, P.M., Brookes, K.L., Graham, I.M., Barton, T.R., Needham, K., Bradbury, G. and Merchant, N.D. (2013). Short-term disturbance by a commercial two-dimensional geophysical survey does not lead to long-term displacement of harbour porpoises. *Proceedings of the Royal Society B*, 280(1771), 20132001. Doi: 10.1098/rspb.2013.2001.

Thompson, P.M., Cheney, B., Ingram, S., Stevick, P., Wilson, B. and Hammond, P.S. (Eds) (2011). *Distribution, abundance and population structure of bottlenose dolphins in Scottish Waters*. Scottish Government and Scottish Natural Heritage Funded Report No.354.

Thorstad, E.B., Whoriskey, F., Uglem, I., Moore, A., Rikardsen, A.H. and Finstad, B. (2012). A critical life stage of the Atlantic salmon *Salmo salar*: behaviour and survival during the smolt and initial post-smolt migration. *Journal of Fish Biology*, 81(2), pp. 500 – 542.

Tollit, D.J., Black, A.D., Thompson, P.M., Mackay, A., Corpe, H.M., Wilson, B., Van Parijs, S.M., Grellier, K. and Parlane, S. (1998). Variations in harbour seal *Phoca vitulina* diet and dive-depths in relation to foraging habitat. *Journal of Zoology*, 244(2), pp. 209-222. Doi: 10.1111/j.1469-7998.1998.tb00026.x.

Trippel, E.A. (1998). Egg size and viability and seasonal offspring production of young Atlantic cod. *Transactions of the American Fisheries Society*, 127(3), pp. 39-359.

Turnpenny, A.W.H. and Nedwell, J.R. (1994). *The effects on marine fish, diving mammals and birds of underwater sound generated by geophysical surveys*. Consultancy Report FCR 089/94, Fawley Aquatic Research Laboratories Ltd., 40 pp

Tyack, P.L. (1998). Acoustic communication under the Sea. 163–220. In: Hopp, S.L., Owren, M.J. and Evans, C.S. (Eds.). *Animals Acoustic Communication*. Berlin: Spring-Verlag.

UK Cetacean Stranding Investigation Programme. (2021). [Online]. Available at: http://ukstrandings.org/csip-publications/.

Urick, Robert J. (1983), Principles of Underwater Sound, 3rd Edition. New York. McGraw-Hill.

Valente, J.J., King, S.L. and Wilson, R.R. (2011). Distribution and habitat associations of breeding secretive marsh birds in Louisiana’s Mississippi Alluvial Valley. Wetlands, 31(1), pp.1-10.

Waggit, J.J., Evans, P.G.H., Andrade, J., Banks, A.N., Boisseau, O., Bolton, M., Bradbury, G., Brereton, T., Jan Camphuysen, C., Durinck, J., Felce, T., Fijn, R.C., Garcia-Baron, I., Garthe, S., Geelhoed, S.C.V., Gilles, A., Goodhall, M., Haelters, J., Hamilton, S., Hartney-Mills, L., Hodgins, N., James, K., Jessopp, M., Kavanagh, A.S., Leopold, M. and other authors. (2019). Distribution maps of cetaceans and seabird populations in the North-East Atlantic. *Journal of Applied Ecology*, 57(2), pp. 253–269. Doi: 10.1111/1365-2664.13525.

Waldman, J., Grunwald, C. and Wirgin, I. (2008). Sea lamprey *Petromyzon marinus*: an exception to the rule of homing in anadromous fishes. *Biology letters*, 4(6), pp. 659-662.

Waller J (2000) Synchronised swimmers. BBC Wildlife Magazine, Immediate Media Company, UK

Wanless, S.; Corfield, T.; Harris, M. P.; Buckland, S. T.; Morris, J. A. (1993). Diving behaviour of the shag Phalacrocorax aristotelis (Aves: Pelecaniformes) in relation to water depth and prey size. Journal of Zoology, 231 (1). 11-25.

Wardle, C.S., Carter, T.J., Urquhart, G.G., Johnstone, A.D.F., Ziolkowski, A.M., Hampson, G. and Mackie, D. (2001). Effects of geophysical air guns on marine fish. *Continental Shelf Research,* 21, pp. 1005–1027.

Wenz G. M., (1962), "Acoustic Ambient Noise in the Ocean: Spectra and sources", Journal of the Acoustical Society of America, 34 (12), pp 1936-1956.

Whale and Dolphin Conservation Society (WDCS). (2012). Cardigan Bay Dolphins Discovered In Manx Waters. [Online]. Available from: https://uk.whales.org/2012/01/18/cardigan-bay-dolphins-discovered-in-manx-waters/. [Accessed 13-10-21].

Weir, C.R. (2008). Overt responses of humpback whales (Megaptera novaeangliae), sperm whales (Physeter macrocephalus), and Atlantic spotted dolphins (*Stenella frontalis*) to geophysical exploration off Angola. *Aquatic Mammals*, 34(1), pp. 71-83. Doi: 10.1578/AM.34.1.2008.71.

Welsh Government, Geological Disposal of Higher Activity Radioactive Waste: Working with Communities, January 2019.

Wheeler, A. (1978). *Key to the fishes of Northern Europe*. London: Frederik Warne (Publishers) Ltd.

Wildfowl and Wetlands Trust (WWT) Consulting. (2009). *Distributions of Cetaceans, Seals, Turtles, Sharks and Ocean Sunfish recorded from Aerial Surveys 2001-2008*. Report to the Department of Energy and Climate Change. 32 pp.

Wildlife Trusts. (2021). https://www.wildlifetrusts.org/where_to_see_seal_pups. [Online]. [Accessed: 27/09/2021].

Williams, T. M., Friedl, W. A., Haun, J. E. and Chun, N. K. (1993b). Balancing power and speed in bottlenose dolphins (*Tursiops truncatus*). Symp. Zool. Soc. Lond. 66, 383–394).

Wilson, B., Batty, R.S., Daunt, F. and Carter, C. (2007). *Collision risks between marine renewable energy devices and mammals, fish and diving birds*. Report to the Scottish Executive. Scottish Association for Marine Science, Oban, Scotland.

Wilson, B., Thompson, P.M. and Hammond, P.S. (1997). Habitat use by bottlenose dolphins: seasonal distribution and stratified movement patterns in the Moray Firth, Scotland. *Journal of Applied Ecology*, 34, pp. 1365–1374. Doi: 10.2307/2405254.

Winslade P. (1971). Behavioural and embryological studies on the lesser sand eel *Ammodytes marinus* (Raitt). PhD Thesis. University East Anglia.

Witt, M.J., Hardy, T., Johnson, L., McClellan, C.M., Pikesley, S.K., Ranger, S., Richardson, P.B., Solandt, J.L., Speedie, C., Williams, R. and Godley, B.J. (2012). Basking sharks in the northeast Atlantic: spatio-temporal trends from sightings in UK waters. *Marine Ecology Progress Series*, 459, pp. 121–134. Doi: 10.3354/meps09737.

WOA (2009), World Ocean Atlas dataset available for download at www.nodc.noaa.gov/OC5/WOA09/pr_woa09.html

Woodbury, D.P. and Stadler, J.H., (2008). A proposed method to assess physical injury to fishes from underwater sound produced during pile driving. Bioacoustics, 17(1-3), pp.289-291.

Woodward, I., Thaxter, C.B., Owen, E. and Cook, A.S.C.P. (2019). *Desk-based revision of seabird foraging ranges used for HRA screening.* Report of work carried out by the British Trust for Ornithology on behalf of NIRAS and The Crown Estate. BTO Research Report No. 724.

Xavier, L. (2002). *An introduction to underwater acoustics: principles and applications*. Springer Science and Business Media. 680pp.

Yelverton, J.T., Richmond, D.R., Fletcher, E.R. and Jones, R.K. (1973). Safe distances from underwater explosions for mammals and birds. Report to the Defence Nuclear Agency. National Technical Information Service, US Department of Commerce, 64pp.Zancolli, G., 2018. Assessing lamprey populations in Scottish rivers using eDNA: proof of concept. Scottish Natural Heritage.

Van Beest, F.M., Teilmann, J., Hermannsen, L., Galatius, A., Mikkelsen, L., Sveegaard, S., Balle, J.D., Dietz, R. and Nabe-Nielsen, J. (2018). Fine-scale movement responses of free-ranging harbour porpoises to capture, tagging and short-term noise pulses from a single airgun. *Royal Society open science*, 5(1), p.170110.