Environmental Impact Assessment Report - Volume 2B

Chapter 10
Marine Mammals and Megafauna

ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

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Energy for generations

ORIEL WIND FARM PROJECT

Environmental Impact Assessment Report
Chapter 10: Marine Mammals and Megafauna

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10.1 Introduction

This chapter of the Environmental Impact Assessment Report (EIAR) presents an assessment of the potential impacts of the Oriel Wind Farm Project (hereafter referred to as "the Project") on marine mammals and megafauna. Specifically, this chapter considers the potential impact of the offshore infrastructure (offshore wind farm and offshore cable) of the Project below the High-Water Mark (HWM) during the construction, operational and maintenance, and decommissioning phases.

The assessment presented is informed by the following technical reports:

- Chapter 7: Marine Processes;
- Chapter 9: Fish and Shellfish Ecology;
- Chapter 13: Shipping and Navigation;
- Appendix 10-1: Marine Mammals and Megafauna Technical Report;
- Appendix 10-2: Subsea Noise Technical Report.

This chapter summarises the information contained within appendix 10-1: Marine Mammals and Megafauna Technical Report, which provides a detailed characterisation of the marine mammal and megafauna species ecology within the vicinity of the Project and the wider Irish Sea, based on existing literature and site-specific surveys, and provides information on marine mammal and megafauna species of ecological importance and conservation value. This chapter is also informed by appendix 10-2: Subsea Noise Technical Report, which has been prepared to understand the potential effects of underwater noise emissions associated with the Project.

The details and competencies of the specialist who prepared this chapter can be found in volume 2A, chapter 1: Introduction.

10.2 Purpose of this chapter

The primary purpose of the EIAR chapter is to provide an assessment of the likely direct and indirect significant effects of the Project on marine mammals and megafauna. In particular, this EIAR chapter:

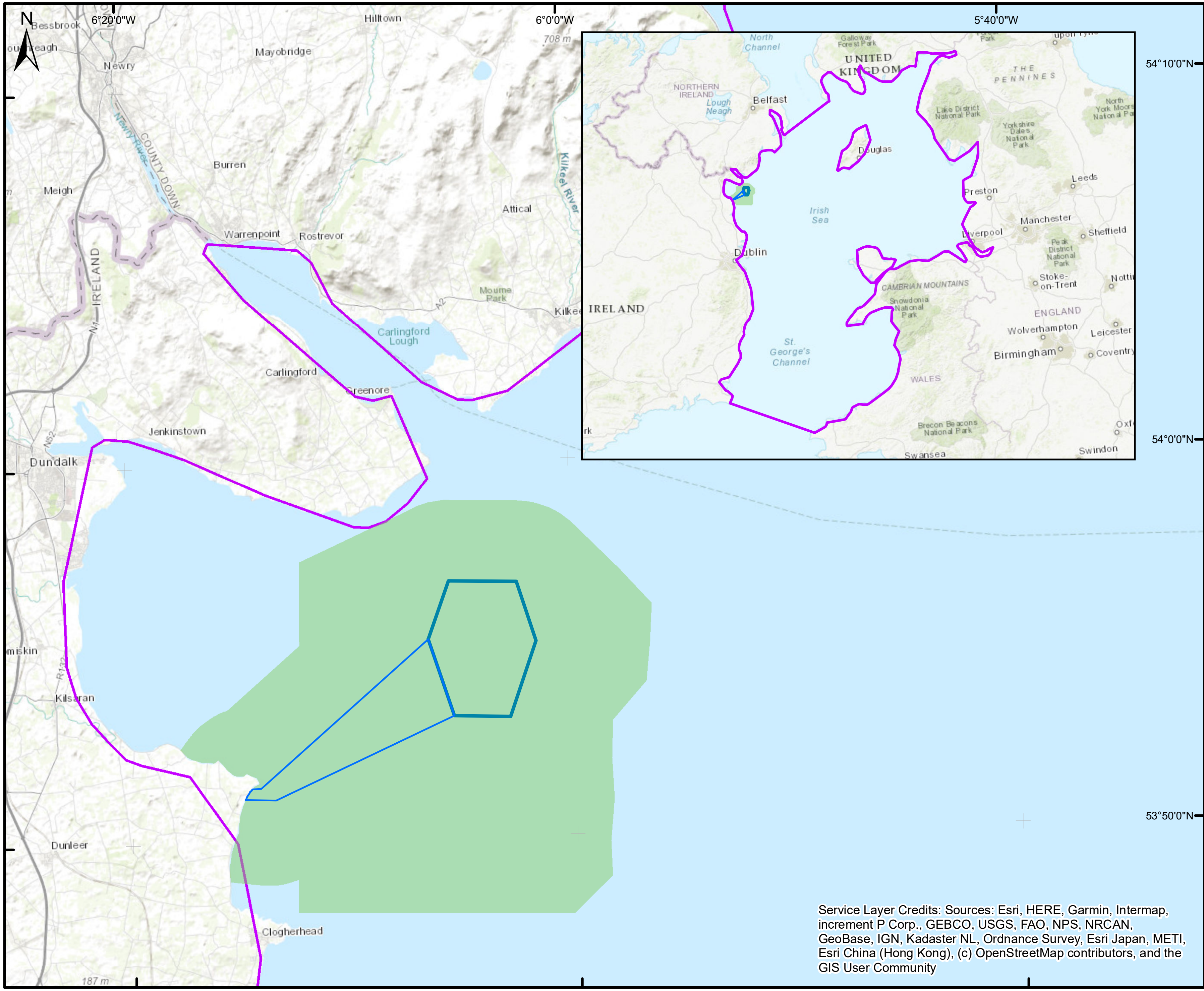
- Presents the existing environmental baseline established from desk studies and site-specific surveys (section 10.7);
- Identifies any assumptions and limitations encountered in compiling the environmental information (section 10.7.4);
- Presents an assessment of the potential likely significant effects on marine mammals and megafauna arising from the Project (section 10.10), based on the information gathered and the analysis and assessments undertaken. An assessment of potential cumulative impacts is provided in section 10.11 and an assessment of transboundary effects is outlined in section 10.12;
- Highlights any necessary monitoring (section 10.10.7) and/or measures (section 10.8.2 and section 10.10.6) to prevent, minimise, reduce or offset the likely significant environmental effects identified in the assessment (section 10.10).

10.3 Study area

For the purposes of the Marine Mammal and Megafauna characterisation, two appropriate study areas were defined (see Figure 10-1):

- **Marine Mammal and Megafauna Study Area (hereafter referred to as the "Marine Megafauna Study Area"):** this is an area of 319.85 km^2 encompassing the offshore wind farm area and offshore cable corridor plus an appropriate buffer of varying extent (as illustrated in Figure 10-1) and is the area within which the site-specific marine mammal surveys were undertaken. The survey area was determined by the offshore wind farm area plus a minimum 4 km buffer (NatureScot, 2023; DCCAE, 2018) and the same area was carried forward for the most recent site-specific surveys in order to maintain consistency; and

- **Regional Marine Mammal and Megafauna Study Area (hereafter referred to as the "Regional Marine Megafauna Study Area"):** marine mammals, basking shark and sea turtles are highly mobile and may range over large distances and therefore to provide a wider context, the desktop review considered their ecology, distribution and abundance within the wider Irish Sea. The Regional Marine Megafauna Study Area also informs the assessment where the Zone of Influence (ZoI) for a given impact (e.g. subsea noise) that may extend beyond the Marine Megafauna Study Area. The Regional Marine Megafauna Study Area has also been used to inform the **Cumulative Marine Mammal and Megafauna Study Area**.

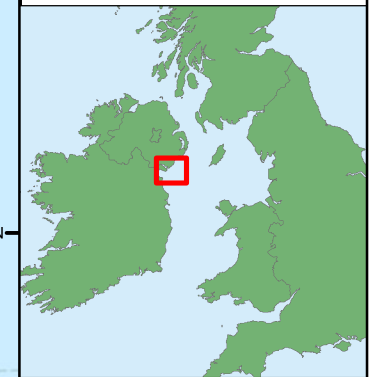


Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Legend

- Offshore Wind Farm Area
- Offshore Cable Corridor
- Marine Mammal and Megafauna Study Area
- Regional Marine Mammal Study Area

Data Sources: Client. atlas.marine.ie



Client

ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

Project

Oriel Wind Farm Project

Title
Figure 10-1
Marine Mammal and Megafauna Study Area and Regional Marine Mammal and Megafauna Study Area

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Scale: 1:250,000 @ A4	**Projection:** ITM (IRENET95)
Date: 07/03/2024	Geographic Co-ordinates: ETRS89

10.4 Policy context

Planning policy on renewable energy infrastructure is presented in volume 2A, chapter 2: Policy and Legislation. This section presents planning policy that specifically relates to marine mammals and megafauna. Planning policy in relation to marine mammals and megafauna, is contained in the Offshore Renewable Energy Development Plan I and II (OREDP) (DECC, 2022) and the National Marine Planning Framework (NMPF) (Department of Housing, Local Government and Heritage (DHLGH, 2021). The policy provisions relevant to marine mammals and megafauna are summarised in Table 10-1 and Table 10-2 below, with other relevant policy provisions set out in Table 10-3.

In February 2023, the 'OREDP II - National Spatial Strategy for the transition to the Enduring Regime' was published in draft and subject to consultation. The draft OREDP II does not define specific provisions similar to OREDP I. The key objectives of OREDP II are:

- *"Assess the resource potential for ORE in Ireland's maritime area*
- *Provide an evidence base to facilitate the future identification of Broad Areas most suitable for the sustainable deployment of ORE in Ireland's maritime area*
- *Identify critical gaps in marine data or knowledge and recommend prioritised actions to close these gaps".*

The OREDP II will provide an evidence base to facilitate the future identification of Broad Areas of Interest most suitable for the sustainable deployment of ORE in Ireland's maritime area, to be assessed in greater detail at regional scale. This assessment will subsequently inform the identification of more refined areas as part of the designation process for Designated Maritime Area Plans (DMAP).

When published, the OREDP II will update the original OREDP published in 2014.

Table 10-1: Summary of OREDP provisions relevant to marine mammals and megafauna.

Summary of OREDP project-level mitigation measures	How and where considered in the EIAR
Marine Mammals	
Physical disturbance: surveys to identify key breeding and foraging sites, nursery areas, haul out (seals), moulting and migration routes; detailed study to examine marine mammal distribution; avoid sensitive sites where possible; where development occurs near to sensitive sites avoid installation during sensitive seasons; programme survey and installation works to reduce potential for noisy or disturbing activities to occur at the same time, and to reduce potential for installation periods to coincide with other developments, to reduce potential for cumulative effects from developments; programme maintenance works to avoid sensitive seasons (e.g. breeding).	Marine mammal and megafauna receptors have been identified through a desktop study and site specific surveys and are discussed in section 10.7. The potential effects of the construction, operational and maintenance and decommissioning phases of the Project have been assessed in section 10.10. An assessment of potential cumulative impacts is provided in section 10.11. The measures included in the Project to prevent and reduce impacts are discussed in section 10.8.2. These include a Marine Megafauna: Vessel Code of Conduct (see volume 2A, appendix 5-5: Marine Megafauna: Vessel Code of Conduct), a Marine Megafauna Mitigation Plan (see volume 2A, appendix 5-4: Marine Megafauna Mitigation Plan) and a Marine Pollution Contingency Plan (see Annex 2 to appendix 5-2: Environmental Management Plan (volume 2A)). Impacts scoped out of the assessment, including Electromagnetic Fields (EMF) on marine mammals and megafauna (except impacts of EMF on basking shark, assessed in section 10.10.5), are discussed in section 10.8.3.
Displacement: surveys to identify key breeding and foraging sites, nursery areas, haul out sites (seals) and migration routes; avoid locating developments on key migration routes or in key breeding and foraging areas; avoid installation during sensitive seasons; programme survey and installation works to reduce potential for noisy or disturbing activities to occur at the same time, and to reduce potential for installation periods to coincide with other developments, to reduce potential for cumulative effects from developments; programme maintenance works to avoid sensitive seasons.	
Noise: implementation of the Code of Practice for the Protection of Marine Mammals during Acoustic Seafloor Surveys in Irish Waters; minimise use of high noise	

Summary of OREDP project-level mitigation measures	How and where considered in the EIAR
emission activities such as impact piling and blasting; avoid installation during sensitive periods; 'soft-starting' piling activities/passive acoustic deterrents; consider using alternatives; use of sound insulation on equipment; use of bubble curtains and other methods (may only be effective in shallow water); investigate options for the use of acoustic deterrents (where suitable); programme developments to reduce potential for cumulative effects; use of marine mammal observers and passive acoustic monitoring to facilitate implementation of exclusion zone during noisy activities; time noisy activities for individual developments to avoid cumulative effect; use of Irish Whale and Dolphin Group (IWDG) recommendations for multibeam survey and cetacean impacts.	
Collision risk: do not site devices in sensitive areas; increase device visibility; enforce speed limits for vessels and establish a code of conduct to avoid disturbance.	
Accidental contamination: design devices to minimise risk of leakage of pollutants, risk assessment and contingency planning; design to reduce risk; avoid shipping routes where collision risk is high; implementation of SOPEP (Shipboard Oil Pollution Emergency Plan).	
Habitat Exclusion: avoid sensitive sites/species; surveys of habitat use by marine mammals.	
Barrier to movement: detailed studies to identify location of key migration corridors and sensitive habitats; detailed study to examine coastal distribution; avoid large installations in migratory corridors; avoid installation of a number of developments on migratory corridors; avoid sensitive areas (breeding, feeding and nursery areas).	
EMF: cable configuration and orientation can reduce field strength; cable burial where possible.	

Table 10-2: Summary of NMPF provisions relevant to marine mammals and megafauna.

Summary of NMPF provision	How and where considered in the EIAR
Biodiversity	
Biodiversity Policy 1: Proposals incorporating features that enhance or facilitate species adaptation or migration, or natural native habitat connectivity will be supported, subject to the outcome of statutory environmental assessment processes and subsequent decision by the competent authority, and where they contribute to the policies and objectives of this NMPF. Proposals that may have significant adverse impacts on species adaptation or migration, or on natural native habitat connectivity must demonstrate that they will, in order of preference and in accordance with legal requirements avoid, minimise, or mitigate significant adverse impacts on species adaptation or migration, or on natural native habitat connectivity.	The potential effects of the construction, operational and maintenance and decommissioning phases of the Project have been assessed in section 10.10. The measures included in the Project to prevent and reduce impacts are discussed in section 10.8.2.
Biodiversity Policy 2: Proposals that protect, maintain, restore and enhance the distribution and net extent of important habitats and distribution of important species will be supported, subject to the outcome of statutory environmental assessment processes and subsequent decision by the competent authority, and where they contribute to the policies and objectives of this NMPF. Proposals must avoid significant reduction in the distribution and net extent of important habitats and other habitats that important species depend on, including avoidance of activity that may result in disturbance or displacement of habitats.	

Summary of NMPF provision	How and where considered in the EIAR
Biodiversity Policy 3: Where marine or coastal natural capital assets are recognised by Government; proposals must seek to enhance marine or coastal natural capital assets where possible; proposals must demonstrate that they will in order of preference, and in accordance with legal requirements: avoid, minimise, or mitigate significant adverse impacts on marine or coastal natural capital assets, or if it is not possible to mitigate significant adverse impacts on marine or coastal natural capital assets proposals must set out the reasons for proceeding.	
Biodiversity Policy 4: Proposals must demonstrate that they will in order of preference and in accordance with legal requirements: avoid, minimise, or mitigate significant disturbance to, or displacement of, highly mobile species.	
Protected Marine Sites	
Protected Marine Sites Policy 1: Proposals must demonstrate that they can be implemented without adverse effects on the integrity of Special Areas of Conservation (SACs) or Special Protection Areas (SPAs). Where adverse effects from proposals remain following mitigation, in line with Habitats Directive Article 6(3), consent for the proposals cannot be granted unless the prerequisites set by Article 6(4) are met.	Protected Marine Sites have been identified through a desktop study and are discussed in section 10.7. The potential effects of the construction, operational and maintenance and decommissioning phases of the Project have been assessed in section 10.10. The measures included in the Project to prevent and reduce impacts are discussed in section 10.8.2. A Natura Impact Statement (NIS) has been prepared for the Project and accompanies the application. The NIS concludes that the Project will not result in adverse effects on the integrity of any SAC or SPA with the implementation of mitigation measures.
Protected Marine Sites Policy 2: Proposals supporting the objectives of protected marine sites should be supported and be informed by appropriate guidance; must demonstrate that they are in accordance with legal requirements, including statutory advice provided by authorities relevant to protected marine sites.	
Protected Marine Sites Policy 3: Proposals that enhance a protected marine site's ability to adapt to climate change, enhancing the resilience of the protected site, should be supported and be informed by appropriate guidance; must demonstrate that they are in accordance with legal requirements, including statutory advice provided by authorities relevant to protected marine sites.	
Protected Marine Sites Policy 4: Until the ecological coherence of the network of protected marine sites is examined and understood, proposals should identify, by review of best available evidence (including consultation with the competent authority with responsibility for designating such areas as required), the features, under consideration at the time the application is made, that may be required to develop and further establish the network. Based upon identified features that may be required to develop and further establish the network, proposals should demonstrate that they will, in order of preference, and in accordance with legal requirements avoid, minimise, or mitigate significant impacts on features that may be required to develop and further establish the network, or if it is not possible to mitigate significant impacts, proposals should set out the reasons for proceeding.	
Underwater Noise	
Underwater Noise Policy 1: Proposals must take account of spatial distribution, temporal extent, and levels of impulsive and/or continuous sound (underwater noise) that may be generated and potential for significant adverse impacts on marine fauna. Where the potential for significant impacts on marine fauna from underwater noise is identified, a Noise Assessment Statement must be prepared by the proposer of development. The findings of the Noise Assessment Statement should demonstrably inform determination(s) related to the activity proposed and the carrying out of the activity itself. The content of the Noise Assessment Statement should be relevant to the particular circumstances and must include:	An assessment of the potential effects of underwater noise during the construction, operational and maintenance and decommissioning phases of the Project have been undertaken and is outlined in section 10.10. The measures included in the Project to prevent and reduce noise impacts are discussed in section 10.8.2. An Acoustic Deterrent Device (ADD) is proposed as mitigation as outlined in section 10.10.6.

Summary of NMPF provision	How and where considered in the EIAR
• Demonstration of compliance with applicable legal requirements, such as necessary assessment of proposals likely to have underwater noise implications, including but not limited to: – Appropriate Assessment (AA); – Environmental Impact Assessment (EIA); – Strategic Environmental Assessment (SEA); – Specific response to 'strict protection' requirements of Article 12 of the Habitats Directive in relation to certain species listed in Annex IV of the Directive; and – Species protected under the Wildlife Acts. • An assessment of the potential impact of the development or use on the affected species in terms of environmental sustainability; • Demonstration that significant adverse impacts on marine fauna resulting from underwater noise will, in order of preference and in accordance with legal requirements be avoided, minimised, mitigated, or if it is not possible to mitigate significant adverse impacts on marine fauna, the reasons for proceeding must be set out.	

Table 10-3: Summary of other policy provisions relevant to marine mammals and megafauna.

Summary of provision	How and where considered in the EIAR
Marine Strategy Framework Directive (MSFD): adopted in July 2008. The overarching goal of the Directive is to achieve 'Good Environmental Status' (GES) by 2020 across Europe's marine environment. To this end, Annex I of the Directive identifies 11 high level qualitative descriptors for determining GES. These include biological diversity, non-indigenous species, elements of marine food webs, contaminants, marine litter and energy (including underwater noise) (European Union, 2008).	The effects of the construction, operational and maintenance, and decommissioning phases of the Project on marine mammals and megafauna, including biodiversity, non-indigenous species, elements of marine food webs, contaminants and underwater noise, have been assessed in section 10.10.
Ireland's National Biodiversity Action Plan 2017-2021: sets out Ireland's vision for biodiversity. Objective number 5 is to 'Conserve and restore biodiversity and ecosystem services in the marine environment'. It lists two targets and eight actions under this objective, including: Progress made towards good ecological and environmental status of marine waters over the lifetime of this plan (Department of Culture, Heritage and the Gaeltacht; DCHG, 2017).	The effects of the construction, operational and maintenance, and decommissioning phases of the Project on marine mammals and megafauna, including biodiversity, have been assessed in section 10.10.
Ireland's Integrated Marine Plan (2012): identifies the marine environment as an area that needs to be protected, managed and developed and as a key component of Ireland's economic recovery and sustainable growth. The second goal of the Integrated Marine Plan is to 'achieve healthy ecosystems that provide monetary and non-monetary goods and services (Inter-Departmental Marine Coordination Group, 2012).	The effects of the construction, operational and maintenance, and decommissioning phases of the Project on marine mammals and megafauna have been assessed in section 10.10.

10.5 Consultation

Table 10-4 summarises the issues identified during consultation activities undertaken to date which are relevant to marine mammals and megafauna, together with how these issues have been considered in the preparation of this EIAR chapter. Chapter 6: Consultation (volume 2A) provides details on the types of consultation activities undertaken for the Project between 2019 and 2024 and the consultees that were contacted.

Table 10-4: Summary of key issues raised during consultation om marine mammals and megafauna.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
October 2019	National Parks and Wildlife Service (NPWS) - written response to request for data.	Provision of baseline data on marine mammals, sea turtles and basking shark.	Detailed baseline characterisation is presented in appendix 10-1: Marine Mammals and Megafauna Technical Report.
October 2019	Cetaceans Strandings Investigation Programme (CSIP) - written response to request for data.	Provision of marine mammal and sea turtle strandings data.	
November 2019	Irish Whale and Dolphin Group (IWDG) - written response to request for data.	Provision of marine mammal data (no information available on sea turtle and basking shark).	
June 2020	NPWS – meeting.	Discussion on 2019/2020 survey methodology including consideration of weather conditions. Discussion of approach to data analyses for density estimates. Presentation of baseline data gathered from site-specific surveys and published records and agreement on study areas. Identification of key marine megafauna receptors. No concerns raised by NPWS with respect to any items discussed. Suggestion to look at evidence for presence of orca around the offshore wind farm area.	Field based and desktop methodology presented in section 10.7. Results of 2019/2020 surveys are presented in section 10.7. Investigated all marine mammals to identify key species (including orca) and further details are provided in appendix 10-1: Marine Mammals and Megafauna Technical Report. Key marine megafauna receptors presented in section 10.7.
February 2021	IWDG - meeting	Discussion on baseline characterisation including agreement on key marine mammal receptors, impacts scoped in and out of assessment and cumulative assessment. Described criteria and output of modelling and noise model used. Discussion of IWDG Best Practice guidance include potential for use of noise abatement methods.	Baseline presented in section 10.7 including key marine mammal receptors; impacts presented in section 10.10 and impacts scoped out are summarised in section 10.8.3. Noise model used has been peer reviewed and validated and presented in 10.10 and set out in full in appendix 10-2: Subsea Noise Technical Report. The measures included in the Project to prevent and reduce noise impacts are discussed in section 10.8.2.
January / February 2023	Members of the public during public consultation	Queries on the potential impacts of the Project on whales, dolphins and seals, including impacts of operational noise.	Baseline presented in section 10.7 including key marine mammal receptors. An assessment of the potential effects of the Project on marine mammals and megafauna is presented in section 10.10. The impacts of operational underwater noise were scoped out of the assessment (see Table 10-13).
September 2023	Department of Agricultural, Environment and Rural Affairs (DAERA) -	Queries on transboundary effects and that they should focus on designated Marine Protected Areas	Baseline characterisation is presented in section 10.7 which lists as a minimum, all SACs within 100 km of the Project for

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
	response to transboundary consultation	(MPAs) and their associated features. Recommendation of the following ranges should be used when screening for either Harbour (*Phoca vitulina*) or Grey seals (*Halichoerus grypus*) and Harbour porpoise (*Phocoena phocoena*): • All SACs within 100 km of the project should be screened for Grey seals; • All SACs within 50 km should be screened for Harbour seals (*Phoca vitulina*); and • All SACs within 100 km should be screened for Harbour porpoise (*Phocoena phocoena*). Murlough SAC (~21 km) should be considered for Harbour Seal, The North Channel SAC (~47 km) for Harbour Porpoise and The Maidens SAC (~120 km) for Grey Seal.	grey seal; all SACs within 50 km of the Project for harbour seal; and all SACs within 100 km of the Project for harbour porpoise. Additional SACs within the Regional Marine Mammal and Megafauna Study Area have been included for completeness, these include: West Wales Marine/Gorllewin Cymru Forol SAC; Lleyn Peninsula and the Sarnau/Pen Llŷn a`r Sarnau SAC; Blackwater Bank SAC; Cardigan Bay/Bae Ceredigion SAC; and Pembrokeshire Marine/Sir Benfro Forol SAC. The Maidens SAC falls outside of the 100 km range of the Project and sits outside the Regional Marine Mammal and Megafauna Study Area, therefore it has not been included.
September 2023	DAERA - response to transboundary consultation	**Marine National Protected Species – Seals** The applicant's attention is drawn to Article 10 of the Wildlife (Northern Ireland) Order 1985 (as amended) under which it is an offence to intentionally or recklessly disturb, capture, injure a Harbour seal or Grey seal.	Baseline characterisation is presented in section 10.7 which includes key marine mammal receptors. An assessment of the potential effects of the Project on marine mammals and megafauna is presented in section 10.10.
September 2023	DAERA - response to transboundary consultation	**UK Marine Policy Statement (2011)** The MPS will facilitate and support the formulation of Marine Plans, ensuring that marine resources are used in a sustainable way in line with the high level marine objectives and thereby: Ensure a sustainable marine environment which promotes healthy, functioning marine ecosystems and protects marine habitats, species and our heritage assets.	An assessment of the potential effects of the Project on marine mammals and megafauna is presented in section 10.10.
September 2023	DAERA - response to transboundary consultation	**The Marine Strategy Regulations 2010** The UK Marine Strategy Regulations 2010 require the UK to take the necessary measures to achieve or maintain Good Environmental Status (GES) through the development of a UK Marine Strategy. The UK Marine Strategy sets out a comprehensive framework for assessing, monitoring and taking action across our seas to achieve the UK's shared vision for 'clean, healthy,	An assessment of the potential effects of the Project on marine mammals and megafauna is presented in section 10.10.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
		safe, productive and biologically diverse ocean and seas'.	
October 2023	Isle of Man - response to transboundary scoping consultation	The scoping response raised the following; how and where are protected marine sites considered; the validity of baseline survey data.	Protected marine sites (i.e. SACs) are considered in this report under section 10.7.1 and their relevant qualifying features discussed in relation to the potential impacts arising from the Project in section 10.10. Protected marine sites have also been assessed in the NIS which has been prepared for the Project and accompanies the application. The Isle of Man Marine Nature Reserves have been considered as part of the desktop study and identification of designated sites (section 10.6.3). Data validity is discussed in section 10.7.4.
November 2023	ABP – pre -application consultation.	Engage with other wind farm developers to inform the cumulative impact assessment.	Other Phase 1 projects along the east coast of Ireland have been considered as part of the CIA presented in section 10.11.

10.6 Methodology to inform the baseline

The methodology to inform the baseline was discussed and agreed in consultation with key stakeholders (see Table 10-4). The approach involved the use of site-specific survey data including boat-based visual surveys and aerial digital surveys collected within the Marine Megafauna Study Area as well as acoustic survey data collected within the offshore wind farm area and offshore cable corridor. Density estimates of recorded species were undertaken for the 2018-2020 site-specific visual surveys. In addition, data were gathered through an extensive literature review of existing data sources. These baseline data have been used to describe the marine mammal, basking shark and sea turtle occurrence, distribution and abundance/density with reference to both the Marine Megafauna Study Area and the Regional Marine Megafauna Study Area. Further detail on the approach is provided below.

10.6.1 Desktop study

Information on marine mammals, basking shark and sea turtles within both the Marine Megafauna Study Area and the Regional Marine Megafauna Study Area was collected through a detailed desktop review of existing studies and datasets. These included published reports on the distribution, occurrence, abundance and densities of marine mammals, basking shark and sea turtles within the Regional Marine Megafauna Study Area. The most recently published available data (e.g. seal haul-out counts) were sought to provide additional context to the baseline characterisation. The data sources used are presented in full within appendix 10-1: Marine Mammals and Megafauna Technical Report.

10.6.2 Site-specific surveys

In order to inform the EIAR, site-specific surveys were undertaken within the Marine Megafauna Study Area, in accordance with the methodology as discussed with NPWS in June 2020 (see Table 10-4 for consultation). A summary of the surveys undertaken to inform the Marine Mammals and Megafauna impact assessment is outlined in Table 10-5 with full details provided in appendix 10-1: Marine Mammals and Megafauna Technical Report.

Table 10-5: Summary of site-specific survey data.

Title	Extent of survey	Overview of survey	Survey contractor	Date	Reference to further information
Oriel Wind Farm 2006 site-specific boat-based surveys	Offshore wind farm area plus buffer (see Figure 10-1).	Three surveys were conducted over a six-month period in 2006 (March/April; May/June; and July/August). 11 transects spaced 2 km apart were surveyed over a two-day period. Surveys were not conducted by dedicated Marine Mammal Observers (MMOs), but incidental marine mammal observations were recorded.	Aquafact Ltd	March to August 2006	Oriel Windfarm Limited (2007)
Oriel Wind Farm 2018 to 2020 site-specific boat-based surveys	Offshore wind farm area plus buffer (see Figure 10-1).	Monthly boat-based surveys were completed from May 2018 to May 2020 (with the exception of February, March and April 2020 due to COVID restrictions). 11 transects spaced 2 km apart were surveyed over a two-day period each month. Surveys for the first three months were not conducted by dedicated MMOs. Surveys from August 2018 onwards were conducted by dedicated MMOs.	Galway Mayo Institute of Technology and IWDG on behalf of Aquafact Ltd	May 2018 to May 2020	Aquafact Ltd. 2019; Aquafact Ltd., 2020; appendix 10-1: Marine Mammals and Megafauna Technical Report.
Oriel Wind Farm 2020 site-specific aerial surveys	Offshore wind farm area plus buffer (see Figure 10-1).	Monthly digital aerial surveys of seabirds and marine mammals and megafauna along the 11 transects surveyed for the boat-based data (see above).	APEM	April 2020 to September 2020	APEM (2020) (see appendix 11-2: Ornithological and Marine Megafauna Aerial Survey Results.
Oriel Wind Farm 2019 to 2020 site-specific Static Acoustic Monitoring (SAM) surveys	Offshore wind farm area and offshore cable corridor (see Figure 10-1).	SAM conducted using self-contained click detectors (C-PODs) at two locations within the wind farm site and two locations within the offshore cable corridor. Duration of deployment differed between locations due to issues with equipment losses.	IWDG	November 2019 to November 2020	O'Brien *et al.* (2020) (see appendix 10-1: Marine Mammals and Megafauna Technical Report)

10.6.3 Identification of designated sites

All designated sites within the Regional Marine Megafauna Study Area and qualifying features that could be affected by the construction, operational and maintenance, and decommissioning of the Project were identified using the three-step process described below:

- Step 1: All designated sites of international, national and local importance within the ZoI were identified using a number of sources. These included Ireland's Marine Atlas interactive map application (http://atlas.marine.ie/), the National Parks and Wildlife Service (NPWS) website, the European Nature Information System (EUNIS) designated site database, and for sites in the UK, the Joint Nature Conservation Committee's (JNCC) website and the Department for Environment, Food and Rural Affairs (Defra) MAGIC interactive map applications (http://magic.defra.gov.uk/).
- Step 2: Information was compiled on the relevant features for each of these sites as follows:

  - The known occurrence of species within the Regional Marine Megafauna Study Area was based on the relevant desktop information and site-specific surveys presented within appendix 10-1: Marine Mammals and Megafauna Technical Report.

- Step 3: Using the above information and expert judgement, sites were included for further consideration if:
  - A designated site directly overlaps with the Regional Marine Megafauna Study Area;
  - Sites and associated qualifying features were located within the potential Zone of Influence (ZoI) for impacts associated with the Project (e.g. potential effect ranges of underwater noise as a result of piling activities during construction; see section 10.10); and
  - Features of a designated site were either recorded as present during recent and historic site-specific surveys within the offshore wind farm area and offshore cable corridor or identified during the desktop study as having the potential to occur within the offshore wind farm area and offshore cable corridor.

10.7 Baseline environment

Sightings and strandings records indicate that twenty-five species of cetacean and two species of pinniped have been recorded in Irish waters (NPWS, 2019; Berrow *et al*., 2010; O'Brien *et al*., 2009)[1]. This high species richness is attributed to the suitability of the physical marine environment (bathymetry, seabed topography, salinity, temperature etc.) and the availability and distribution of prey species in Irish waters. The waters off the west and southwest coasts of Ireland support the greatest diversity and abundance of marine mammals in Irish waters, with further hotspots off the Celtic Deep (to the south of St George's Channel), Dublin Bay and the Isle of Man (NPWS, 2019; Lysaght and Marnell, 2016; Wall *et al.,* 2013).

Cetacean and pinniped distribution is species specific, and not all species are likely to occur in the vicinity of the Project (i.e. within the Marine Megafauna Study Area). Site-specific marine mammal surveys carried out in 2006 and 2018 to 2020 showed that the most common cetacean species within the Marine Megafauna Study Area (Figure 10-1) was harbour porpoise. Marine mammals which were sighted regularly in the site-specific surveys (2018 to 2020) included minke whale *Balaenoptera acutorostrata* and grey seal. Marine mammals which were sighted occasionally during site-specific surveys (2018-2020) included short-beaked common dolphin (hereafter referred to as "common dolphin") *Delphinus delphis* and harbour seal. Whilst bottlenose dolphin *Tursiops truncatus* were not sighted during these surveys, a review of published datasets indicates that bottlenose dolphin may also be occasionally present within the Marine Megafauna Study Area.

Basking shark *Cetorhinus maximus* migrate through the Celtic Sea and Irish Sea during summer months, covering large distances from North Africa to Scotland using both the continental shelf and oceanic habitats in the upper 50-200 m of the water column (Doherty *et al.,* 2017). During site-specific surveys (2018 to 2020), two basking sharks were sighted in the Marine Megafauna Study Area. Tagging studies have also shown that basking shark have migrated through the Marine Megafauna Study Area in previous years (Doherty *et al.,* 2017).

Historical records show that three species of marine turtle are likely to regularly occur in Irish waters, including leatherback (or 'leathery') turtle *Dermochelys coriacea*, loggerhead turtle *Caretta caretta* and Kemp's Ridley turtle *Lepidochelys kempii* (King and Berrow, 2009). Of these species, the leatherback turtle is distributed around the coast of Ireland (including the Irish Sea) and accounts for 80% of all sightings (King and Berrow, 2009). Since 2001, leatherback turtle has been sighted in the Regional Marine Megafauna Study Area in 17 of 18 years (Annual Reports 2001 to 2018, summarised in Penrose and Gander, 2018).

A summary of marine mammal and megafauna baseline within the Marine Megafauna Study Area, in the context of the Regional Marine Megafauna Study Area, is presented in Table 10-6.

[1] Following the sighting of a bowhead whale *Balaena mysticetus* in the Irish Sea in 2017 the total species count for Irish waters has increased from 24 to 25 (IWDG *pers. comm*).

Table 10-6: Summary of marine mammal and megafauna baseline ecology within the Marine Megafauna Study Area in the context of the Regional Marine Megafauna Study Area.

Species	Baseline summary	Conservation importance
Harbour porpoise *Phocoena phocoena*	Widely distributed throughout the western Irish Sea and sighted in every month of site-specific surveys within the offshore wind farm area and buffer (2018-2019). Predominantly distributed in coastal waters and waters of the continental shelf and slope. The ObSERVE aerial surveys suggest that the Irish Sea is an important area year-round, with consistently highest summer abundance in the western Irish Sea and Celtic Sea compared to other areas. Maximum densities from these surveys were 1.046 animals per km^2 (Rogan *et al.,* 2018a). SCANS III aerial surveys for Block O (western Irish Sea) estimated maximum densities of 0.239 animals per km^2 (Hammond *et al.,* 2017). The density in summer 2022 from SCANS IV for Block CS-D (which corresponds to SCANS III Block E) was 0.280 animals per km^2 (Gilles *et al*., 2023). Recent density surface modelling (DSM) was carried out for SCANS-III survey data (Lacey *et al.,* 2022) for the Marine Mammal and Megafauna Study Area. The average density for harbour porpoise was 0.278 animals per km^2. The average density estimate for the Marine Mammal and Megafauna Study Area from Evans and Waggitt (2023) data was 0.224 animals per km^2. Site-specific modelled estimates from recent boat-based surveys provided a monthly average of 0.57 animals km^{-2} and a monthly peak of 1.33 animals km^2. The density range carried forward to the assessment is 0.280 (SCANS-IV Block CS-D; Gilles *et al.,* 2023) to 1.33 animals per km^2 (monthly peak, Oriel site-specific surveys) The total harbour porpoise abundance for the Celtic and Irish Seas (CIS) Management Unit (MU) was estimated as 62,517 animals (CV = 0.13, 95% CI = 48,324 to 80,87) (IAMMWG, 2023).	Harbour porpoise is a qualifying feature of the following SACs: Rockabill to Dalkey Island SAC, 30.5 km to the south of the offshore wind farm area; Lambay Island SAC, located 43.1 km south of the offshore wind farm area; North Channel SAC, 47.8 km to the north of the offshore wind farm area; North Anglesey Marine/ Gogledd Môn Forol SAC, 55.9 km from the offshore wind farm area; Codling Fault Zone SAC, located 63 km south of the offshore wind farm area; West Wales Marine/Gorllewin Cymru Forol SAC 135.9 km southeast from the offshore wind farm area; and Blackwater Bank SAC, located 145.3 km south of the offshore wind farm area.
Bottlenose dolphin *Tursiops truncatus*	Regularly recorded in Irish coastal and offshore waters, and the most frequently sighted cetacean species during ObSERVE surveys in Irish waters, with more than twice as many sightings during winter compared to summer. However, there were very few sightings in the western Irish Sea compared to other regions of the survey. These surveys suggest that the west and southwest of Ireland are likely to be more important in terms of distribution compared to the Irish Sea. Distribution of sightings indicates a preference for waters overlying the continental shelf and deeper ocean waters, but sightings can also occur in enclosed bays and in close proximity to the Irish coast. Cardigan Bay, in the eastern Irish Sea is occupied by a semi-resident population of about 300 animals, likely to venture throughout the Irish Sea, and occur in the offshore wind farm area. However, no bottlenose dolphins were sighted during site-specific surveys in 2006 or 2018-2019 in the Survey Area. Average density recorded by the ObSERVE surveys (2012) for the Irish Sea was estimated as 0.036 animals per km^2 (Rogan *et al.,* 2018b). SCANS III surveys (2016) estimated a density of 0.008 animals per km^2 in the western Irish Sea (Hammond *et al.,* 2017). SCANS IV surveys (2022) estimated a density of 0.235 animals per km^2, which authors noted to be orders of magnitude higher than previous estimates within the same survey block (Gilles *et al*., 2023). The average density for bottlenose dolphin from SCANS-III DSM for the Marine Mammal and Megafauna Study Area (Lacey *et al.,* 2022) was 0.046 animals per km^2. The average density estimate for the Marine Mammal and Megafauna Study Area from Evans and Waggitt (2023) data was 0.0006 animals per km^2. The density range carried forward to the assessment is 0.046 (SCANS-III DSE; Lacey *et al.,* 2022) to 0.235 (SCANS-IV Block CS-D; Gilles *et al.,* 2023). The total bottlenose dolphin abundance for the Irish Sea (IS) MU was estimated as 293 animals (CV = 0.54, 95% CI = 108 to 793) (IAMMWG, 2023), which will be applied to the assessment where	Bottlenose dolphin is the qualifying feature of Cardigan Bay/Bae Ceredigion SAC, which lies 196.4 km east of the offshore wind farm area, and a qualifying feature of the Lleyn Peninsula and the Sarnau/Pen Llŷn a`r Sarnau SAC in northern Cardigan Bay, 139.3 km from the offshore wind farm area.

Species	Baseline summary	Conservation importance
	the density of 0.046 (SCANS III Block E DSM; Lacey *et al.,* 2022) is applied; the IS MU abundance estimate (IAMMWG, 2023) was derived from the original SCANS III sightings data (Hammond *et al.,* 2021).The abundance estimate for the Irish Sea of 8,326 animals (SCANS IV; Gilles *et al.,* 2023) will be applied to the assessment with respect to the SCANS IV density of 0.235 (Gilles *et al.,* 2023); the SCANS IV abundance estimate was derived from SCANS IV sightings data (Gilles *et al.,* 2023).	
Common dolphin *Delphinus delphis*	Commonly inhabits continental shelf waters and occurs along the shelf edge and in deep water. Distribution in Irish waters is primarily to the west and south of Ireland, and in the south of the Irish Sea, however there are occasional records in the western Irish Sea. Whilst ObSERVE and IWDG surveys did not identify any common dolphin in the western Irish Sea, site-specific surveys (2018-2019) did identify common dolphin in the Survey Area during August and September 2018 and January and December 2019, although there were no sightings within the offshore wind farm area and one sighting within the offshore cable corridor. This corroborates IWDG survey sightings which indicate an eastward movement into the Irish Sea, along the south coast during summer months. SCANS II surveys (2012) estimated density in the Irish Sea as 0.008 animals per km^2 (Hammond *et al.,* 2013) however all sightings in this area were from the southern Irish Sea. SCANS IV surveys (2022) estimated a density of 0.027 animals per km^2. The average density for common dolphin from SCANS-III DSE for the Marine Mammal and Megafauna Study Area (Lacey *et al.,* 2022) was 0.033 animals per km^{2,} however no common dolphins were sighted in Irish Sea blocks (Block E and Block F) of SCANS III surveys, and therefore this was not considered a robust estimate of density for the Marine Mammal and Megafauna Study Area. The average density estimate for the Marine Mammal and Megafauna Study Area from Evans and Waggitt (2023) data was 0.00005 animals per km^2. The density carried forward to the assessment is 0.027 (SCANS-IV Block CS-D; Gilles *et al.,* 2023). The total common dolphin abundance for the Celtic and Greater North Seas (CGNS) MU was estimated as 102,656 animals (CV = 0.29, 95% CI = 58,932 – 178,822) (IAMMWG, 2023).	Although not a qualifying interest (QI), common dolphin is commonly observed within the Rockabill to Dalkey Island SAC.
Minke whale *Balaenoptera acutorostrata*	Most frequently sighted mysticete in UK and Irish waters, mostly inhabiting continental shelf waters, usually occurring in depths of less than 200 m and can often be seen close to land. Most abundant off the southwest coast of Ireland and localised patches in the Irish Sea, including the Isle of Man and Dublin Bay. Minke whale exhibit seasonal migrations from polar feeding grounds to warm tropical breeding grounds and are mainly sighted in the Irish Sea in summer months. Numbers in the Irish Sea appear to increase in April to May, peaking in August and tapering in late autumn. Minke whale were sighted during recent site-specific surveys between the months of June and October in the Marine Megafauna Survey Area, although most sightings were outside the offshore wind farm area. ObSERVE surveys (2012) gave a density estimate of 0.014 animals per km^2 in the western Irish Sea (Rogan *et al.,* 2018a). SCANS III surveys (2016) estimated density for the western Irish Sea as 0.017 animals per km^2 (Hammond *et al.,* 2017). SCANS IV surveys (2022) estimated a density 0.0137 animals per km^2 . The average density for minke whale from SCANS-III DSE for the Marine Mammal and Megafauna Study Area (Lacey *et al.,* 2022) was 0.019 animals per km^2. The average density estimate for the Marine Mammal and Megafauna Study Area from Evans and Waggitt (2023) data was 0.00312 animals per km^2. Site-specific modelled estimates from recent boat-based surveys provided a monthly average of 0.04 animals per km^{-2}and a monthly peak of 0.26 animals per km^2.	Although not a QI, minke whale is commonly observed within the Rockabill to Dalkey Island SAC.

Species	Baseline summary	Conservation importance
	The density range carried forward to the assessment is 0.014 (SCANS-IV Block CS-D; Gilles *et al.,* 2023) to 0.26 (Oriel site-specific surveys). The total minke abundance for the CGNS MU was estimated as 20,118 animals (CV = 0.18, 95% CI = 14,061 – 28,786) (IAMMWG, 2023).	
Grey seal *Halichoerus grypus*	Distribution around Ireland is concentrated along the Atlantic seaboard with more isolated regional concentrations on the east coast of Ireland (in the western Irish Sea), with lower pup production here compared to the Atlantic coast. This is most likely due to poor availability of sheltered, undisturbed breeding habitat. Regional concentrations occur off the coast of Wexford, south Dublin Bay, the Skerries, Clogherhead, Dundalk Bay and Carlingford Lough. Lambay Island SAC supports the principal breeding colony of grey seal on the east coast of Ireland. Breeding occurs in late August to December and the annual moult between November to April. The closest haul-out sites to the Project are at the mouth of Carlingford Lough (haul-out located 4.5 km from the offshore wind farm area and 6.5 km from the offshore cable corridor), Clogherhead (haul-out located 13.3 km from the offshore wind farm area and 4.1 km from the offshore cable corridor), and Dundalk Bay (haul-out located 15.5 km from the offshore wind farm area and 14.8 km from the offshore cable corridor) (Morris and Duck, 2019). In 2016, Sea Mammal Research Unit (SMRU) at-sea usage maps estimate a range of mean densities from 0.11 to 0.40 animals per km^2 for the grid cells that overlap the offshore wind farm area. The mean density estimate for the Marine Mammal and Megafauna Study Area, derived from estimates presented in Carter *et al*. (2022), was 0.372 animals per km^2. Site-specific modelled estimates from recent boat-based surveys provided a monthly average of 0.09 animals km^{-2} and a mean monthly peak of 0.21 animals km^{-2}. The total abundance estimate for the Grey Seal Reference Population (GSRP) (Northern Ireland n=2,008; East Ireland, n=1,662; South East Ireland, n=2,211) is 5,882 animals (applying a 25.15% correction based on SCOS, 2021 to counts in SCOS, 2020 and Morris and Duck, 2019).	Grey seal is a QI of Lambay Island SAC which lies 43.1 km south of the offshore wind farm area; qualifying feature of Lleyn Peninsula and the Sarnau/Pen Llŷn a`r Sarnau SAC which lies 139.3 km southeast of the offshore wind farm area; and Pembrokeshire Marine/Sir Benfro Forol SAC which lies ~ 220 km south-southeast of the offshore wind farm area.
Harbour seal *Phoca vitulina*	Areas of particular importance for harbour seal in Irish waters are the southwest of Ireland, southeast of Ireland and the northwest coast of Ireland, with fewer, smaller colonies in the Irish Sea. Aerial surveys undertaken around the coast of Ireland in August/September 2003, 2012, and 2018 indicate that in the Irish Sea, Carlingford Lough (~ 10 km north of the offshore wind farm area) and Lambay Island (~ 43 km south of the offshore wind farm area) are important haul-out sites for harbour seal, in the context of the east coast of Ireland. The closest haul-out sites for harbour seal to the Project are at the mouth of Carlingford Lough (7.9 km from the offshore wind farm area; 10.6 km from the offshore cable corridor), Clogherhead (13.3 km from the offshore wind farm area; 4.1 km from the offshore cable corridor) and Dundalk Bay (15.5 km from the offshore wind farm area; 14.8 km from the offshore cable corridor) (Morris and Duck, 2019). Pups are born in June and July and the annual moult of harbour seal in Ireland occurs from late July through August. SCOS (2018) reports that harbour seal tend to forage within a maximum of 40 or 50 km of their haul-out sites, but most foraging trips tend to be within shorter ranges. SMRU at-sea usage maps (2016) estimated a range of mean densities of 0.24 to 0.43 animals per km^2 in the offshore wind farm area. To the north and west of the offshore wind farm area, a small number of the SMRU grid cells were estimated to have higher predicted mean densities and reach a maximum of 0.61 animals per km^2 with lower values estimated at 0.01 animals per km^2 within the potential Zone of Influence (i.e. for elevations in subsea noise during piling). The mean density estimate for the Marine Mammal and Megafauna	Harbour seal is a QI of the Lambay Island SAC which lies 43.1 km south of the offshore wind farm area and is a qualifying feature of the Murlough SAC, which lies 21.9 km north of the offshore wind farm area.

Species	Baseline summary	Conservation importance
	Study Area, derived from estimates presented in Carter *et al*. (2022), was 0.280 animals per km^2. The total abundance estimate for the Harbour Seal Reference Population (HSRP) (Northern Ireland n=1,405; East Ireland, n=182; South East Ireland, n=48) is 1,635 animals (applying a 72% correction based on SCOS, 2021 to counts in Morris and Duck, 2019).	
Basking shark *Cetorhinus maximus*	Basking shark are the largest fish in Irish waters and migrate through the Celtic Sea and Irish Sea during summer months. Distribution is driven by a range of environmental conditions; surface sightings are typically reported when sea surface temperatures range between 15 and 17.5 °C, where thermal fronts are present and where zooplankton is in greatest abundance. Migration routes cover large distances from the north of Scotland south to North Africa, using both the continental shelf and oceanic habitats in the upper 50-200 m of the water column. Twenty-eight basking shark tagged off Scotland and the Isle of Man in the summer showed an average migration distance of 1,057 km with movements starting in October, with some remaining in the Irish Sea. This research indicates that the Irish Sea, particularly around the Isle of Man, is an important area for overwintering that links foraging grounds in the waters off Ireland to the southern migration destinations. Local basking shark populations are temporary, dynamic groupings of individuals drawn from a much larger population. Low re-sightings numbers meant that reliable estimates for the long-term regional population were not possible, however for one area between the islands of Mull, Coll and Tiree (50 km diameter; 250 km northwest of the offshore wind farm area) a closed-population estimate was generated for six to nine days periods in 2010 of 985 (95% CI = 494 to 1,683) and in 2011 of 201 (95% CI = 143 to 340) (Gore *et al.,* 2016).	Although not a qualifying feature, basking shark during summer months is commonly found in the Lleyn Peninsula and the Sarnau/Pen Llŷn a`r Sarnau SAC and the North Channel SAC which lie 139.3 km southeast and 47.8 km northeast of the offshore wind farm area, respectively.
Leatherback turtle *Dermochelys coriacea*	Leatherback turtle is distributed all around the coast of Ireland and occurs in both the eastern and western Irish Sea. Recent studies have shown that after nesting in the tropics, the majority of north Atlantic leatherbacks head north towards cooler temperate waters. Leatherback turtle are adapted to survive in colder temperate waters and therefore commonly occur in the waters around Britain and Ireland. Distribution is likely to be driven by the distribution of jellyfish and other prey, with peak sightings occurring during summer months. Whilst most sightings records are from near the coast they can also be encountered offshore, and it is likely that offshore areas consist of important foraging grounds for this species. Generating density estimates for this species is difficult, given low numbers. Although not recorded during site-specific surveys, sightings and strandings records (1938 to 2018) from the National Biodiversity Data Centre (NBDC) suggest that this species may occur within the Marine Megafauna Study Area. A density estimate of leatherback turtle in all Irish waters (including the western Irish Sea) was given as 0.06 animals per 100 km^2. This figure was extrapolated to an estimate of 2-3,000 leatherbacks passing through or residing in Irish waters each year, which may be equivalent to 2-5% of the Atlantic population. Aerial surveys conducted in 2003 to 2006 observed 0.25 leatherback turtle per 1,000 km of track flown (Doyle *et al*., 2008).	Although not a qualifying feature, leatherback turtle is commonly found in the West Wales Marine/Gorllewin Cymru Forol SAC and the Lleyn Peninsula and the Sarnau/Pen Llŷn a`r Sarnau SAC, 135.8 km southeast and 139.3 km southeast of the offshore wind farm area, respectively; and often found in the Cardigan Bay/Bae Ceredigion SAC and Pembrokeshire Marine/Sir Benfro Forol SAC, ~ 200 km southeast and 219.5 km southeast of the offshore wind farm area, respectively.

Table 10-7 presents density estimates and population assessments for marine mammals and megafauna in the Marine Megafauna Study Area for use in quantifying the scale of effects as part of the impact assessment. For practical management purposes, the Inter-Agency Marine Mammal Working Group (IAMMWG) has identified Management Units for cetaceans in UK and Irish waters and has provided estimated abundance figures for each (IAMMWG, 2021; 2023). The Marine Megafauna Study Area falls into the Celtic and Irish Seas Management Unit (MU) for harbour porpoise, the Irish Sea MU for bottlenose dolphin and the Celtic and Greater North Sea MU for common dolphin and minke whale (see appendix 10-1:

Marine Mammals and Megafauna Technical Report). Management Units have not been defined for seals in Irish waters and therefore population assessments will be based on the latest abundance estimates for Morris and Duck (2019) east Ireland and south east Ireland regions, alongside the SCOS (2020) Northern Ireland seal management unit. The leatherback turtle population estimate for Irish waters has been informed by an extrapolation of aerial survey counts conducted in 2003 to 2006 (Doyle *et al.,* 2008). No population or density estimates are available for basking shark.

Where possible, species densities have been taken from modelled estimates using the recent site-specific boat-based data. Modelled estimates were available for harbour porpoise and minke whale. For other cetaceans – bottlenose dolphin and common dolphin – density estimates were drawn from the SCANS-III surveys (SCANS-III density surface estimates (DSE); Lacey *et al.* (2022) and/or SCANS-IV surveys (Gilles *et al*., 2023). A range of density values is presented for all cetacean species, other than common dolphin, to represent the variability in density estimates across the region (common dolphin were not sighted in the relevant block in SCANS-III surveys, therefore the recent SCANS-IV estimate has been provided). Densities for grey seal and harbour seal were derived from Carter *et al.* (2022) habitat-based distribution estimates. Density estimates for leatherback turtle were drawn from aerial surveys carried out in 2003 to 2006 (Doyle *et al.,* 2008). The Guidance on Marine Baseline Ecological Assessments and Monitoring Activities for Offshore Renewable Energy Projects (DCCAE, 2018) advises that sightings for sea turtles should be recorded incidentally as part of marine mammal surveys; no reptile-specific survey frequency recommendations are given. As there were no sea turtles sighted as part of the recent site-specific boat-based surveys, the data from Doyle *et al*. (2008) are the only density data available for the Irish Sea.

For all species, the most precautionary estimate of density has been applied to inform the impact assessment.

Table 10-7: Density estimates and population assessments for marine mammals and megafauna in the Marine Megafauna Study Area.

Species	Density estimate for Marine Megafauna Study Area (animals/km^2)	Geographic extent for population assessment (e.g. Management Unit (MU))	Estimated population
Harbour porpoise	0.280[a] – 1.33[b]	Celtic and Irish Sea MU[c]	62,517[c]
Bottlenose dolphin	0.046[d] - 0.235[a]	Irish Sea MU[c]	293[c] *to* 8,326[e]
Common dolphin	0.027[a]	Celtic and Greater North Seas (CGNS) MU[c]	12,262[c]
Minke whale	0.14[a] - 0.26[b]	CGNS MU[c]	20,118[c]
Grey seal	0.372[f]	Minimum population estimate for grey seal across haul-out sites within the East Ireland, South East Ireland and Northern Ireland survey regions (the Grey Seal Reference Population (GSRP))	East Ireland: 1,662[g] South East Ireland: 2,211[g] Northern Ireland: 2,008[h] **GSRP = 5,882**
Harbour seal	0.280[f]	Minimum population estimate for harbour seal across haul-out sites within the East Ireland survey region (the Harbour Seal Reference Population (HSRP))	East Ireland: 182[i] South East Ireland: 48[i] Northern Ireland: 1,405[j] **HSRP = 1,635**
Basking shark	No data	No data	No data
Leatherback turtle	0.06	Irish waters[k]	2,000 to 3,000

[a] SCANS IV Block CS-D (western Irish Sea) data collected summer 2022 (Gilles *et al*., 2023).

[b] Mean monthly maximum density recorded during Oriel Wind Farm Project site-specific boat-based surveys (2018 - 2020).

[c] IAMMWG, 2023. For bottlenose dolphin the IAMMWG, 2023 abundance estimate of 293 animals will only apply where the SCANS-III density surface estimate of 0.046 animals per km^2 is applied.

[d] SCANS-III Block E (western Irish Sea) density surfaces estimates for the offshore wind farm area and offshore cable corridor (Lacey *et al.,* 2022).

[e] Abundance estimate derived from SCANS-IV surveys from Block CS-D and Block CS-E, equating to the area covered by the Irish Sea MU. This abundance estimate will only apply where the SCANS-IV density estimate of 0.235 animals per km^2 is applied.

[f] Mean Carter *et al.* (2022) average densities per km^2 (calculated from 25 km^2 cells) for the Marine Mammal and Megafauna Study Area.

Species	Density estimate for Marine Megafauna Study Area (animals/km^2)	Geographic extent for population assessment (e.g. Management Unit (MU))	Estimated population

[g] Based on grey seal haul-out counts during 2017/18 survey (Morris and Duck, 2019) corrected for the proportion of the population that are estimated to be hauled-out during the survey period (scalar of 0.2515 from SCOS, 2021).

[h] Based on grey seal haul-out counts presented in SCOS (2020) corrected for the proportion of the population that are estimated to be hauled-out during the survey period (scalar of 0.2515 from SCOS, 2021).

[i] Based on harbour seal haul-out counts during 2017/18 survey (Morris and Duck, 2019) corrected for the proportion of the population that are estimated to be hauled-out during the survey period (scalar of 0.72 from Lonergan *et al.,* 2013).

[j] Minimum population estimate presented in SCOS (2021) (corrected for the proportion of the population that are estimated to be hauled-out during the survey period (scalar of 0.72 from Lonergan *et al.,* 2013)).

[k] Doyle *et al.* (2008).

10.7.1 Designated sites

Designated sites identified for marine mammals and megafauna are described in Table 10-8 below.

Table 10-8: Designated sites and relevant qualifying features for marine mammals and megafauna.

Designated Site	Closest distance to offshore wind farm area or offshore cable corridor (km)	Relevant qualifying feature
Murlough SAC (UK0016612)	22.0	Annex II Species • Harbour seal (*Phoca vitulina*) (qualifying feature)
Rockabill to Dalkey Island SAC (003000)	30.6	Annex II Species • Harbour porpoise (*Phocoena phocoena*)
Lambay Island SAC (000204)	43.1	Annex II Species • Grey seal (*Halichoerus grypus*) • Harbour seal (*Phoca vitulina*) • Harbour porpoise (*Phocoena phocoena*)
North Channel SAC (UK0030399)	47.8	Annex II Species • Harbour porpoise (*Phocoena phocoena*)
North Anglesey Marine/Gogledd Môn Forol SAC (UK0030398)	56.0	Annex II Species • Harbour porpoise (*Phocoena phocoena*)
Codling Fault Zone SAC (IE003015)	63.0	Annex II Species • Harbour porpoise (*Phocoena phocoena*)
West Wales Marine/Gorllewin Cymru Forol SAC (UK0030397)	136.0	Annex II Species • Harbour porpoise (*Phocoena phocoena*)
Lleyn Peninsula and the Sarnau/Pen Llŷn a`r Sarnau SAC (UK0013117)	139.3	Annex II Species • Bottlenose dolphin (*Tursiops truncatus*) • Grey seal (*Halichoerus grypus*)
Blackwater Bank SAC (IE002953)	145.3	Annex II Species • Harbour porpoise (*Phocoena phocoena*)
Cardigan Bay/Bae Ceredigion SAC (UK0012712)	196.4	Annex II Species • Bottlenose dolphin (*Tursiops truncatus*) • Grey seal (*Halichoerus grypus*) (qualifying feature)
Pembrokeshire Marine/Sir Benfro Forol SAC (UK0013116)	219.3	Annex II Species • Grey seal (*Halichoerus grypus*)

10.7.2 Important Ecological Features

The important ecological features (IEFs) are those that could be potentially affected by the Project. The importance of ecological features is dependent upon their biodiversity, social, and economic value within a geographic framework of appropriate reference (CIEEM, 2022). IEFs have been identified based on biodiversity importance, recognised through international or national legislation or through local, regional or national conservation plans (e.g. Annex II species under the Habitats Directive, species listed as threatened and/or declining by OSPAR, or Ireland Red List species), and on assessment of value according to the functional role of the species. Table 10-9 presents the criteria applied to determining the ecological value of IEFs within the geographic frame of reference applicable to the Marine Megafauna Study Area. Table 10-10 then presents the value/importance of each ecological receptor based on the criteria outlined in Table 10-9.

Table 10-9: Criteria used to inform the valuation of ecological receptors in the Marine Megafauna Study Area.

Value	Justification
International	Internationally protected species that are listed as a qualifying feature of an internationally protected site (i.e. Annex II protected species designated feature of a European designated site i.e. Natura 2000 site).
National	Internationally protected species (including European Protected Species (EPS)) that are not qualifying features of a candidate or designated European Site but are regularly recorded within the Regional Marine Megafauna Study Area, but in relatively low densities and therefore the area is not considered to be important for the species in an international context. Internationally protected species that are not qualifying features of a European designated site but are recognised as a Biodiversity Action Plan (BAP) priority species either alone or under a grouped action plan and are listed on the local action plan relating to the Regional Marine Megafauna Study Area.
Regional	Internationally protected species that are not qualifying features of a European designated site and are infrequently recorded within the Regional Marine Megafauna Study Area in very low numbers compared to other regions of Ireland.
Local	N/A – There are no criteria given for local value due to the high level of protection under international law for all marine mammal species.

Table 10-10: Marine mammal and megafauna Important Ecological Features (IEFs) and their importance within the Marine Megafauna Study Area.

IEF	Value	Justification
Harbour porpoise	International	Annex II species protected under international legislation and QIs / designated features of Rockabill to Dalkey Island SAC, Lambay Island SAC, North Channel SAC, North Anglesey Marine/Gogledd Môn Forol SAC, Codling Fault Zone SAC, West Wales Marine/Gorllewin Cymru Forol SAC and Blackwater Bank SAC. Regularly sited within the Regional Marine Megafauna Study Area.
Bottlenose dolphin	International	Annex II species protected under international legislation and designated feature of Cardigan Bay/Bae Ceredigion SAC
Common dolphin	National	Internationally protected species *and Ireland Protected Species* regularly sighted in the Regional Marine Megafauna Study Area.
Minke whale	National	Internationally protected species *and Ireland Protected Species* regularly sighted in the Regional Marine Megafauna Study Area.
Grey seal	International	Annex II species protected under international legislation and QIs / designated features of Lambay Island SAC, Lleyn Peninsula and the Sarnau/Pen Llŷn a`r Sarnau SAC and Pembrokeshire Marine/Sir Benfro Forol SAC and is a qualifying feature of Cardigan Bay/Bae Ceredigion SAC. Regularly recorded in the Regional Marine Megafauna Study Area, with large haul-outs at Carlingford Lough, Clogherhead, the Skerries, Dublin Bay and Lambay Island.
Harbour seal	International	Annex II species protected under international legislation and designated feature of Lambay Island SAC and is a qualifying feature of Murlough SAC. Regularly recorded in

IEF	Value	Justification
		the Regional Marine Megafauna Study Area, with large haul-outs at Carlingford Lough, Dundalk Bay, Clogherhead and the Skerries.
Basking shark	National	Internationally protected species/EPS listed on Ireland's Red List of Threatened Species (list No. 11) and UK *BAP Species*. Recorded migrating through Regional Marine Megafauna Study Area on an annual basis.
Leatherback turtle	National	Internationally protected species, listed on Ireland's Red List of Threatened Species (list No. 5) and UK BAP Species, reported regularly (largely stranded) in the Regional Marine Megafauna Study Area.

10.7.3 Future baseline scenario

The European Union (Planning and Development) (Environmental Impact Assessment) Regulations 2018 (hereafter the EIA Regulations 2018) require that "*a description of the relevant aspects of the current state of the environment (baseline scenario) and an outline of the likely evolution thereof without development as far as natural changes from the baseline scenario can be assessed with reasonable effort on the basis of the availability of environmental information and scientific knowledge"* is included within the EIAR.

In the event that the Project is not constructed, an assessment of the future baseline conditions has been carried out and is described within this section.

Marine mammal, basking shark and leatherback turtle populations naturally fluctuate over space and time and therefore changes are likely to be observed over the 40-year lifetime of the Project. Distribution of populations is largely driven by the distribution and abundance of prey species. Many species range over large distances and will therefore exhibit some tolerance to fluctuations in the environment, such as those that may occur as a result of climate change (Hoegh-Guldberg and Bruno, 2010; Poloczanska *et al.,* 2013). Species which naturally have more restricted habitat ranges are likely to be less tolerant and therefore more vulnerable to changes in their environment. For the marine megafauna IEFs in the Regional Marine Megafauna Study Area, species such as grey seal and harbour seal may be sensitive to long term changes, particularly harbour seal, whose natural foraging range is more restricted than that of grey seal (SCOS, 2017).

The impact of anthropogenic-induced climate change has so far been recorded as shifting species distributions, decreased productivity of the oceans, reduced abundance of habitat-forming species, altered food-web dynamics and a greater incidence of disease (Hoegh-Guldberg and Bruno, 2010). Records demonstrate that average global sea surface temperature has risen by 0.72°C between pre-industrial times (1870-1899) and recent years (2005-2014) (Genner *et al.,* 2017). Around the coast of Ireland, sea surface temperatures recorded between 1850 and 2008 showed a mean warming trend of 0.3˚C (i.e. below the global average); however, temperature records suggest that there has been an accelerated rate of warming since 1994 with temperatures rising by 0.6˚C per decade since this time (Nolan *et al.*, 2010). Part of this increase has been attributed to global warming. The warmest sea temperature years on record have been 2005, 2006 and 2007 with particularly strong warming in the southeast of Ireland (Nolan *et al.*, 2010). In UK waters, mean annual sea temperatures have risen by 0.8°C since 1870, and have shown a consistent warming trend from the 1970s onwards (Gattuso *et al.,* 2015). Thus, trends in annual average sea surface temperatures differ spatially, with some areas exhibiting slower warming compared to others (e.g. on average Celtic and Irish Seas have shown a slower increase compared to the North Sea) (UKMMAS, 2017).

Anthropogenic activities in the marine environment can influence the distribution and abundance of marine mammal populations. In the Irish Sea, potential impacts include: injury and mortality due to bycatch from fisheries (particularly for harbour porpoise); removal of prey species by overfishing; direct or indirect effects of contamination (from pollution incidents, sewage discharge, or litter disposal at sea); injury or disturbance from introduced noise into the marine environment (e.g. from shipping, drilling, piling, seismic surveys, military activity, dredging and disposal, aggregate extraction, and Unexploded Ordnance (UXO) detonations); and death or injury due to collision with physical objects (e.g. vessels or renewable energy devices, particularly tidal devices). Species responses to climate change are complex and sensitivities are likely exacerbated by such anthropogenic pressures (in particular, pollution and fishing (Poloczanska *et al.,* 2016)).

SCANS reports presented in 2002, 2006, 2017 and 2023 present an overview of fluctuations in relative abundance of cetacean species between survey years. It is important to note however that changes in abundance in local regions may not necessarily reflect fluctuations in population numbers but may reflect shifts in the distribution of an 'open' population of a species. SCANS abundance and distribution data suggests that harbour porpoise abundance decreased in the Irish Sea from 2005 to 2013, with SCANS II abundance given as 15,230 (CV=0.35) and SCANS III abundance given as 9,376. Abundance derived from SCANS IV survey data for the Irish Sea were more similar to that of SCANS II than SCANS III, at 16,098 suggesting possible recovery in this region. Whilst the overall observed distribution of harbour porpoise in 2016 (SCANS III) was similar to that observed in 2005 (SCANS II) one notable difference is that more sightings were made throughout the English Channel in 2016 than previously, which could be a contributing factor to the reduction of sightings of harbour porpoise in the Irish Sea in 2016 (i.e. a shift in summer distribution).

The results of the SCANS surveys also show a reduction in minke whale abundance in the western Irish Sea from 2005 to 2022, with a SCANS II estimate of 1,070 (CV=0.91), a SCANS III estimate of 603 (CV = 0.62) and a SCANS IV estimate of 477 (CV = 0.63). However, the coefficients of variance for each of these values are high, therefore the difference in observed numbers may be more an indication of sampling error than a reflection of change in abundance. The observed distribution for bottlenose dolphin in 2016 was similar to that observed in 2005 and abundance in the Irish Sea was compatible between years, with the SCANS II survey results providing an estimate of 235 (CV=0.78) and the SCANS III survey providing an estimate of 288 (CV=0.51). Notably, SCANS IV Block E density estimates for bottlenose dolphin (0.2352 animals per km^2) were two orders of magnitude higher than in SCANS III (0.008 animals per km^2) and associated abundance estimates were therefore also notably higher (8,199 (CV=0.353) for Block CS-D in SCANS IV). A notable difference between the SCANS II and III surveys, was the lack of sightings of common dolphin in the Irish Sea in 2016, where in 2005 an abundance estimate of 826 (CV=0.78) was given. Common dolphin was sighted in Block CS-D of SCANS IV, giving a similar abundance estimate to that of SCANS II, of 949 (CV=0.814). Common dolphin is a regular visitor to the Irish Sea (Cronin and Barton, 2014; O'Donnell *et al.,* 2017; Rogan *et al.,* 2018a) and sightings records from ongoing dedicated surveillance efforts in Irish waters (Wall *et al.*, 2013; Cronin and Barton, 2014; O'Donnell *et al.,* 2017; Berrow *et al.,* 2018; Rogan *et al.,* 2018a), including the Irish Sea, provide no evidence of a decline in distribution/range in recent years and therefore the short term trend is considered to be stable (NPWS, 2019).

Ongoing work indicates that both grey seal and harbour seal are at risk of range contraction at the southern end of their range under predicted climate changes in both the lowest and highest warming scenarios presented by the Intergovernmental Panel on Climate Change (IPCC), however these predictions contain considerable uncertainty in part because potential prey re-distributions have not been taken into account (SCOS, 2017).

Grey seal pup production estimates have increased continually since regular surveys began in the 1960s, but the rate of increase has fallen over the past twenty years a (SCOS, 2022). In Northern Ireland between 1995 and 2014 an annual increase of 1.24% in adults and a 4.91% annual increase in pups was reported. Population assessments of the main grey seal breeding colonies in Ireland show that pup production in 2009, 2011 and 2012 were higher in most cases than their 2005 equivalents. Monitoring at SACs with grey seal features also demonstrate this upward trend in population. For example, minimum pup production at Lambay Island, which lies 43.1 km south of the offshore wind farm area and is designated for grey seal, was 58 pups in 2005 and 77 pups between 2009 and 2012 (Culloch *et al.,* 2018). Similarly, whilst a quantitative assessment of trends in the Murlough SAC (designated for harbour seal only) was not possible, a general upwards trend has been reported (1995 to 2014). Pup production acquired during the 2009 to 2012 monitoring programme for the breeding population of grey seal in the Republic of Ireland, in combination with reliable scientific knowledge of historical population among several breeding areas (Ó Cadhla *et al.,* 2008), together provide supporting evidence for a growth in the grey seal breeding population in Ireland since mid-1990s (Ó Cadhla *et al.,* 2013).

In the UK, the overall population of harbour seal since the late 2000s has increased, however there are significant differences in the population dynamic between regions. For example, as reported in SCOS 2008 to 2016, there have been general declines in counts of harbour seal in several regions around Scotland (SCOS, 2017). In Northern Ireland between 1995 and 2014 an annual increase of 0.1% in adults and a 0.88% annual increase in pups was reported (Culloch *et al.,* 2018). In Murlough SAC, which lies 22 km north of the offshore wind farm area and is designated for harbour seal, an annual increase of 2.05% in adults and a 4.41% annual increase in pups was reported (1995 to 2014) (Culloch *et al.,* 2018). Indications are that

Murlough SAC is successfully meeting the objective relating to maintaining a minimum population size of 84 harbour seal. Similarly, surveys of harbour seal at Lambay Island SAC suggest that the population is stable or increasing (NPWS, 2013).

Against the backdrop of anthropogenic activities that may be associated with adverse effects on marine mammals, on the whole, the scientific evidence suggests that populations in the Regional Marine Megafauna Study Area appear to be stable or decreasing for cetacean IEFs, but stable or increasing for pinniped IEFs. It is possible that there will be subtle shifts in distribution in relation to the ongoing effects of climate change, however, based on current population trends, these are likely to be difficult to detect across the Regional Marine Megafauna Study Area.

The global current population trend for basking shark, according to the IUCN red list of threatened species, is decreasing. Accidental catch is the greatest threat to basking shark. Berrow (1994) estimated that 77 to 120 basking shark are taken annually in the bottom set gillnet fishery in the Celtic Sea, and bycatch in the Isle of Man herring fishery is about 10 to 15 fish annually and a further four to five entangled in pot lines. This may represent a substantial proportion of the basking shark population in the Regional Marine Megafauna Study Area (although no population estimates are available for the Irish Sea) and therefore the future baseline scenario suggests a potential decline in the population.

The global current population trend for leatherback turtle, according to the IUCN red list of threatened species, is decreasing. Leatherback turtle in the Irish Sea are likely to be particularly vulnerable to pollution, bycatch and climate change (habitat shifting and alteration; temperature extremes and storms and flooding). Whilst no trend exists for the Irish Sea, records from the UK Cetacean Strandings Investigation Programme (CSIP) show that live sightings reports have generally decreased since 2001, but strandings records (all deceased) are relatively stable across the period 2011 to 2018. Leatherback turtle occurrence in UK waters is largely driven by prey availability and distribution and therefore under predicted climate changes range shifts could occur.

Any changes that may occur during the design life span of the Project have been considered in the context of both greater variability and sustained trends occurring on national and international scales in the marine environment.

10.7.4 Data validity and limitations

The data assumptions and limitations highlighted in appendix 10-1: Marine Mammals and Megafauna Technical Report are typical of difficulties encountered with undertaking field surveys of marine mammals using boat-based methods. Initially (first three months) the 2018-2020 boat-based surveys were conducted using the same observers as used for recording seabirds; this was subsequently amended by introducing dedicated MMOs to reduce the likelihood that marine mammals are missed during the surveys.

Detection probability is also a limiting factor in recording marine mammals with weather conditions playing a significant role in the ability to detect a marine mammal from the observation platform. Identification to species-level can sometimes be difficult, particularly when distinguishing between grey seal and harbour seal at sea. Since there were a number of sightings recorded as ‘seal species’, these unidentified seals were allocated to each species (grey seal *Halichoerus grypus* or harbour seal *Phoca vitulina*), based on the relative proportion that each species contributed to the overall number of identified seals present. In this way, all seal sightings could be used in the data analyses, which is important where the number of sightings in general is relatively low. Site-specific aerial surveys were also conducted in 2020, to provide additional data support to the site-specific vessel surveys (2018-2020). Data were analysed appropriately for each survey method and the most precautionary estimate of density was taken forward for assessment (where sightings were sufficient to do so; see appendix 10-1: Marine Mammal and Megafauna Technical Report).

Guidelines on data validity with regards to marine mammal data lifespan is scarce, however data is typically viewed as valid if within five years. Recent Scottish guidance on marine ornithology baseline suggests data should not be more than 5 years old and there should be at least 2 years of monthly data (Marine Scotland, 2023). Whilst this advice relates directly to marine ornithology, it is typical for marine ornithology and marine mammal surveys to be conducted from the same survey platform (as per Oriel site-specific surveys). In the professional opinion of the author, it is considered that two years of pre-construction surveys to be the minimum requirement for pre-construction surveys, to which the Oriel site-specific surveys (2018-2020) meet.

In relation to the baseline characterisation that underpins this assessment site-specific data gathered 2018-2020 were corroborated by information collated via the detailed desktop review, including the most recent SCANS-IV data (Giles *et al.*, 2023) for cetaceans and recently published seal data (Carter *et al.,* 2022; SCOS, 2021; SCOS, 2020). Therefore, the baseline characterisation for the Marine Mammal and Megafauna Study Area is considered to be fit for purpose for understanding potential impacts and the precaution built into the assessment will capture any potential for data variation.

10.8 Key parameters for assessment

10.8.1 Project design parameters

The project description is provided in volume 2A, chapter 5: Project Description. Table 10-11 outlines the project design parameters that have been used to inform the assessment of potential impacts of the construction, operational and maintenance and decommissioning phases of the Project on marine mammals and megafauna.

Due to the potential for unexpected ground conditions and obstructions, the final route and length of the offshore export cable and offshore inter array cables will be confirmed post consent (design flexibility, see volume 2A, chapter 5: Project Description). For the purposes of the assessment presented in section 10.10, the maximum length of cables (Table 10-11) has been considered to ensure the potential for maximum impact are assessed. Should the final lengths of cables be less than those specified, then the potential for effects will be less than what is outlined in section 10.10. An alternative route within the offshore wind farm area of offshore cable corridor won't change the assessment presented in section 10.10.

Table 10-11: Project design parameters used for the assessment of potential impacts on marine mammals and megafauna.

Potential impact	Phase[1] C	O	D	Project design parameters	Justification
Injury and/or disturbance to marine megafauna from underwater noise during pile-driving	✓	×	×	• 26 monopiles (25 x WTGs and 1 x OSS) of 9.6 m diameter; • Absolute maximum hammer energy of 3,500 kJ; • On average, a maximum of 5 hours piling per pile across all WTG locations (no more than 8 hours at selected locations) with one pile expected to be installed in each 24-hour period; and • Maximum days piling = 26 days.	The spatial extent of noise impacts is driven by key parameters including monopile diameter and hammer size, as well as associated hammer energy required to pile a monopile of this size (see appendix 10-2: Subsea Noise Technical Report). The minimum number of piles within a 24-hour period is likely to lead to the maximum period (number of piling days) over which piling could occur and the maximum within 24 hours would lead to the longest duration on any one day.
Injury and/or disturbance to marine megafauna from elevated underwater noise during routine geophysical surveys	×	✓	×	Routine geophysical surveys of wind turbine foundations, inter-array cables and offshore cable: • Multibeam echosounder (MBES) expected to be the only method of geophysical survey to be employed; • Survey campaigns estimated to occur once every five years for 40-year lifetime of Project; • Surveys to be conducted using one survey vessel; • Duration of 14 days per survey;	First survey campaign expected to occur in year 5, and final campaign in year 35, equating to seven survey campaigns. Assumes daily vessel trip for every day of each 14-day survey window.

Potential impact	Phase[1] C	O	D	Project design parameters	Justification
				• 42-day duration per survey campaign (three surveys per campaign); • 42 vessel round trips per survey campaign; and • Maximum total of 294 survey vessel round trips for lifetime of Project.	
Injury and/or disturbance to marine megafauna from vessels and other construction activities	✓	✓	✓	Vessel types include jack-up barges, tug/anchor handlers, cable installation vessels, scour/cable protection installation vessels, guard vessels, survey vessels, crew transfer vessels (CTVs). *475* vessel round trips during the construction phase, 352 vessel round trips per year during the operational and maintenance phase and 475 vessel round trips during the decommissioning phase. Other construction includes: • Monopile drilling at each location with six days drilling for each monopile = cumulative total of 156 days drilling over construction phase; • Cable trenching for inter-array and offshore cable; and • Cable laying for inter-array and offshore cable. Offshore construction may take place over a period of 15 months. Operational and maintenance phase is 40 years. Decommissioning duration assumed to be similar to that for construction.	Greatest range of vessel types and greatest number of round trips.
Changes in the fish and shellfish community affecting marine megafauna prey resources	✓	✓	✓	Project design parameters as described in chapter 9: Fish and Shellfish Ecology for the following impacts: • Temporary subtidal habitat loss/disturbance; • Injury and/or disturbance to fish from underwater noise during pile driving; • Increased suspended sediment concentrations and associated sediment deposition; • Long-term habitat loss; and • Electromagnetic Fields (EMF) from subsea electrical cabling.	See chapter 9: Fish and Shellfish Ecology.
Electromagnetic Fields (EMF) from subsea electrical cabling may disrupt behaviour of basking shark (*Cetorhinus maximus*)	×	✓	×	Presence of inter-array and offshore cables: • 41 km of 66 kV inter-array cables; • 16 km of 220 kV offshore cable; • Burial depths of between 0.5 m to 3 m; and • Maximum 50% of inter-array cables and maximum 50% of offshore cable may require cable protection. Operational phase of 40 years.	Maximum length of cables and minimum burial depth (greater the depth the more the EMF is attenuated).

1 C = Construction, O = Operation, D = Decommissioning

10.8.2 Measures included in the Project

As part of the project design process, a number of measures have been proposed to reduce the potential for impacts on marine mammals and megafauna (see Table 10-12). These measures include designed-in and management measures (controls). As there is a commitment to implementing these measures, they are considered inherently part of the design of the Project and have therefore been considered in the assessment presented in section 10.10 below (i.e. the determination of magnitude and therefore significance assumes implementation of these measures). These measures are considered standard industry practice for this type of development.

Table 10-12: Measures included in the Project.

Measures included in the Project	Justification
An Environmental Management Plan (EMP) (see volume 2A, appendix 5-2: Environmental Management Plan*)* will be implemented during the construction, operational and maintenance, and decommissioning phases of the Project. The EMP includes Project mitigation/monitoring measures and commitments and a Marine Pollution Contingency Plan (MPCP) which includes key emergency contact details (e.g. Environmental Protection Agency (EPA)). The EMP includes mitigation such as designated areas for refuelling where spillages can be easily contained, storage of chemicals in secure designated areas in line with appropriate regulations and guidelines, double skinning of pipes and takes containing hazardous substances, and storage of these substances in impenetrable bunds. In this manner, accidental release of contaminants from vessels will be strictly controlled, thus providing protection for marine life across all phases of the Project.	Measures will be included to ensure that the potential for release of pollutants from construction, operational and maintenance, and decommissioning plant is minimised.
A Marine Megafauna Mitigation Plan (MMMP) (see volume 2A, appendix 5-4: Marine Megafauna Mitigation Plan*)*will be implemented prior to construction. The MMMP sets out the measures to apply in advance of and during piling activity, including the implementation of a mitigation zone, and monitoring by MMOs and Passive Acoustic Monitoring (PAM).	The implementation of an approved MMMP will mitigate for the risk of physical or permanent auditory injury to marine mammals within a 'mitigation zone'. The mitigation zone is determined considering the potential for instantaneous auditory injury based on the initial hammer strike at 10-15% of the maximum hammer energy (i.e. soft-start hammer energy). The use of an approved MMMP will also minimise the potential for collision risk, or potential injury to, marine mammals and megafauna.
During piling operations, soft starts will be used, following NPWS (2014)[2] guidelines. This will involve the implementation of lower hammer energies (i.e. approximately 10-15% of the maximum hammer energy) at the beginning of the piling sequence before energy input is 'ramped up' (increased) over time to required higher levels (also known as a soft-start).	The soft-start will provide an audible cue to allow marine mammals and megafauna to flee the area before piling at increased hammer energy commences. The soft/slow-start will help to mitigate any potential auditory injury.
The Applicant commits to implementing phased piling alongside other adjacent offshore wind farms in the western Irish Sea as part of a Piling Strategy. This strategy will be prepared post consent and will set out measures for collaboration with other projects to reduce the potential for an in-combination effect. This will include a stepped strategy which follows the mitigation hierarchy - avoid, reduce, mitigate. Consequently, if phased piling is required a collaborative approach will be explored and information presented to demonstrate how a phased piling approach can contribute to the reduction in underwater sound from piling.	To minimise the potential for permanent auditory injury to marine mammals. To minimise the area of habitat affected by underwater noise at any one time.
Geophysical surveys undertaken during the operational and maintenance phase will adopt similar measures as for piling operations, including the implementation of an approved MMMP and Vessel Code of Conduct (see volume 2A, appendix 5-4: Marine Megafauna Mitigation Plan and volume 2A, appendix 5-5: Marine Megafauna: Vessel Code of Conduct). Measures include the use of a mitigation zone around operations, within which MMOs	The implementation of an approved MMMP will mitigate for the risk of physical or permanent auditory injury to marine mammals within a 500 m radial mitigation zone as determined by NPWS guidance (NPWS, 2014)[2]. The soft-start will use a lower-energy output, increasing over a 20-minute period to the maximum data-acquisition energy output to provide an audible cue to allow marine

[2] It is expected that this guidance will be updated in 2024. The final guidance will be included in this measure.

Measures included in the Project	Justification
and PAM will ensure that no marine megafauna are present in the vicinity of the geophysical survey vessel, and the use of a soft-start to survey operation, where possible. It is acknowledged that further consultation with the NPWS and wildlife derogation licences may be required.	mammals and megafauna to flee the area before geophysical surveying commences.
A Vessel Code of Conduct (see volume 2A, appendix 5-5: Marine Megafauna: Vessel Code of Conduct) will be issued to all Project vessel operators, requiring them to: • refrain from approaching animals in the water; • keep vessel speed to a minimum, including near haul-outs; and • avoid abrupt changes in course or speed should marine mammals approach the vessel to bow-ride. The Marine Megafauna: Vessel Code of Conduct will be adhered to at all times.	To minimise the potential for collision risk, or potential injury to, marine mammals and megafauna.
Burial and protection of cables - cables will be buried below the seabed wherever possible, to a minimum burial depth of 0.5 m and a maximum burial depth of 3 m. The appointed contractor will be required prior to the construction phase to submit details on the cable specification and installation methodology. This will include details on the cable laying, including geotechnical data, cable laying techniques and a cable burial risk assessment. Also, in advance of any cable repair, the contractor will be required to submit details on the parameters of the repair or reburial activities and the proposed methodology.	While burial of cables will not reduce the strength of EMF, it does increase the distance between cables and marine mammal and megafauna (and fish and shellfish) receptors, thereby potentially reducing the effect on those receptors.

10.8.3 Impacts scoped out of the assessment

On the basis of the baseline environment and the project description outlined in volume 2A, chapter 5: Project Description, a number of impacts are proposed to be scoped out of the assessment for marine mammals and megafauna. These impacts are outlined, together with a justification for scoping them out, in Table 10-13*.*

Table 10-13: Impacts scoped out of the assessment for marine mammals and megafauna.

Potential impact	Justification
Potential impacts from increased suspended sediment concentrations (SSC) and associated sediment deposition	Whilst increases in SSC as a result of foundation and cable installation activities during the construction phase may affect marine megafauna IEFs through visual impairment, the maximum impact range is not expected to extend beyond a few km from the source (see appendix 7-1: Marine Processes Technical Report), has not been predicted to overlap with any designated sites, nor has the area been identified as important foraging habitat for any IEF. Whilst the ZoI is within the foraging range of harbour seal and grey seal from haul-outs at Carlingford Lough, Dundalk Bay, the Skerries, Clogherhead, Dublin Bay and Lambay Island, there is other suitable habitat available for foraging during temporary periods of increased suspended sediment.
Injury and/or disturbance to marine megafauna from operational underwater noise	The majority of studies investigating the impact of operational offshore wind farms (during the operational and maintenance phase on marine mammals and fish conclude that sounds levels in the order of hundreds of metres distance from the wind turbines would likely be audible, but not at a level sufficient to case injury or behavioural changes (see appendix 10-2: Subsea Noise Technical Report). Norro *et al.* (2011) compared measurements of a range of different foundation methods and turbine ratings in the Belgian part of the North Sea, as well as comparing those to other European waters. The authors found a slight increase in Sound Pressure Level (SPL) compared to the ambient noise measured before the construction of the wind farms. They concluded that even the highest increases found within the dataset (20 to

Potential impact	Justification
	25 dB re 1µ Pa) are likely to be within the natural range of variation in baseline noise and therefore, even with the long-term nature of this impact (lifespan of the wind farm), the operational noise would not cause a significant impact. In addition, evidence presented by Hastie *et al.,* (2015) showed tracked harbour seal moving between operational wind turbines in order to forage. It is predicted therefore that any impact would be highly localised and unlikely to affect marine mammals or megafauna.
Electromagnetic Fields (EMF) from subsea electrical cabling may disrupt behaviour of marine mammals and leatherback turtle	Electromagnetic fields could arise during the operational and maintenance phase from the operation of the 41 km of 66 kV inter-array cables and the 16 km of 220 kV HVAC offshore cable. Electric and magnetic fields occur naturally in the marine environment and are a necessity for many marine animals. Electric fields are produced by the natural movement of charges in seawater and by the movement of charges in the bodies of living organisms. Predators, particularly elasmobranchs, use electric fields as important cues to detect and locate prey species (Crampton, 2019). It is understood that many marine animals may use the earth's magnetic fields for orientation and this can apply to both long distance migrations and local movements (Johnsen and Lohman, 2008). However, the scale to which EMF from subsea cables may interfere with this is likely to be species dependent. For example, electromagnetic field attenuate rapidly with distance and therefore only the most electro- and magneto-sensitive species, such as elasmobranchs are likely to be affected. For marine mammals and sea turtles, any effects of EMF are likely to be very localised – within the immediate vicinity of the cable – and temporary, most likely leading to short-term, reversible behavioural effects. There is limited evidence to suggest that marine mammals and sea turtles may be affected by EMF from subsea cables. For example, migration of the harbour porpoise in and out of the Baltic Sea necessitates several crossings of High-voltage direct current cables in the Skagerrak and western Baltic Sea without any apparent effect on its migration pattern (Walker, 2001). In contrast, there is a more robust body of evidence to suggest that elasmobranchs are likely to be sensitive to EMF. Therefore, although the effects are likely to be very localised, elasmobranchs have been scoped in for the assessment of this impact, whilst marine mammals and sea turtles have been scoped out of further assessment.

10.9 Impact assessment methodology

10.9.1 Overview

The assessment on marine mammals and megafauna has followed the methodology set out in volume 2A, chapter 3: Environmental Impact Assessment Methodology. Specific to the marine mammals and megafauna impact assessment, the following guidance documents have also been considered:

- EPA (2022) Guidelines on the Information to be Contained in Environmental Impact Assessment Reports;
- Guidance for Ecological Impact Assessment in the UK and Ireland. Terrestrial, Freshwater, Coastal and Marine (Chartered Institute of Ecology and Environmental Management (CIEEM), 2022):
  - These guidelines combine the Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater and Coastal, 2nd edition (2016) and the Guidelines for Ecological Impact Assessment in Britain and Ireland: Marine and Coastal (2010).
- Guidance on EIS and NIS Preparation for Offshore Renewable Energy Projects, Department of Communications, Climate Action and Environment (DCCAE, 2017);
- Guidance on Marine Baseline Ecological Assessments and Monitoring Activities for Offshore Renewable Energy Projects Parts 1 and 2 (DCCAE, 2018);
- Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Judd, 2012); and
- Guidance to Manage the Risk to Marine Mammals from Man-made Sound Sources in Irish Waters (NPWS, 2014).

10.9.2 Impact assessment criteria

Determining the significance of effects is a process that involves defining the magnitude of the impacts and the sensitivity of the receptors. This section describes the criteria applied in this chapter to assign values to the magnitude of potential impacts and the sensitivity of the marine mammal and megafauna receptors. The terms used to define magnitude and sensitivity are based on those which are described in further detail in volume 2A, chapter 3: EIA Methodology.

Magnitude of impact quantifies the amount of change arising from an activity that could lead to alteration in the environment (e.g. piling could lead to an elevation in underwater sound) and the associated outcome or effect on sensitive ecological receptors. The assessment describes the spatial extent over which impacts and effects could occur arising from a particular activity (e.g. area of effect and associated number of animals in a population affected), how long animals are exposed to an activity that could cause an effect in the context of the life-history of a species (i.e. the duration), the frequency of the exposure that could lead to a change (i.e. continuous or intermittent) and whether or not the resultant change in either the receiving environment or features exposed is reversible.

The criteria for defining impact magnitude in this chapter are outlined in Table 10-14 below.

Table 10-14: Definition of terms relating to the magnitude of an impact.

Magnitude of impact	Definition
High	The impact could lead to large scale changes to behaviour and distribution, that are extensive in the context of the relevant geographic frame of reference (area/proportion of MU). The duration and frequency of the impact overlap with a sufficient number of reproductive cycles to alter the population trajectory. The effect, which may be either reversible or irreversible in individuals, would be of sufficient severity to affect the long-term viability of the relevant population over a generational scale. (Adverse)
	Long-term benefits to many individuals within the population (e.g. long-term improvement of key habitats) such that there is an increase in the relevant population trajectory over a generational scale. (Beneficial)
Medium	The impact could lead to large scale changes to behaviour and distribution, that are extensive in the context of the relevant geographic frame of reference (area/proportion of MU). The duration and frequency of the impact are sufficient to overlap with at least one reproductive cycle. The effect, which may be either reversible or irreversible in individuals could result in some population-level effects, but not a level that would alter the relevant population trajectory over a generational scale. (Adverse)
	Life-time benefits to some individuals although not enough to affect the relevant population trajectory over a generational scale. (Beneficial)
Low	The impact could lead to changes to behaviour and distribution in individuals, but which are relatively small in the context of the relevant geographic frame of reference (area/proportion of MU). The duration and frequency of the impact are such that there would be minimal disruption to reproductive cycles. Whilst there may be effects at an individual level which may be either reversible or irreversible, these would not be at a scale that would lead to any measurable population-level effects (Adverse)
	Minor benefit, or positive addition to individuals over a localised scale. (Beneficial)
Negligible	The impact could lead to very minor changes in behaviour and distribution of individuals within the impacted area but not at a level that would be measurable. Effects are likely to be reversible and highly unlikely to result in any population-level effects. (Adverse)
	Very minor benefit, or positive addition to individuals but not at a level that would be measurable. (Beneficial)

The sensitivity of marine mammal qualifying features has been defined by an assessment of the ability of a receptor to adapt to a given impact, its resilience to that impact and its ability to recover back to pre-impact conditions. Resilience is the ability to withstand a perturbation or disturbance by resisting damage. Recoverability is the ability of the same species to return to a state close to that which existed before the activity or event which caused change. It is dependent on the ability of the individuals to recover following cessation of the activity that causes the impact.

Information on these aspects of sensitivity of the marine mammal IEFs to given impacts has been informed by the best available evidence from scientific research on marine mammals and megafauna (studies on captive animals as well as observations from field studies). In particular, evidence from field studies of marine mammals during the construction and operation of offshore wind farms (and analogous activities such oil and gas surveys) has been used to inform this impact assessment. The review of adaptability, resilience and recoverability of marine mammal and megafauna IEFs have been combined with the assessed status (i.e. the level of designation/importance) of the affected receptor as defined in section 10.7.2 and as presented in Table 10-10. The criteria for defining receptor sensitivity in this chapter are outlined in Table 10-15 below.

Table 10-15: Definition of terms relating to the sensitivity of the receptor.

Sensitivity	Definition
High	Resilience: Limited resilience to the effect either in the short or long-term; effect will cause a change in ecological functioning Adaptability: Limited ability or unable to adapt behaviour to sustain ecological functioning Resilience: Limited resilience to the effect either in the short or long-term; effect will cause a change in ecological functioning Recoverability: Limited or no ability for the animal to recover from the effect even after cessation of the impact *A receptor is of high sensitivity where adverse effects on multiple key ecological functions (e.g. feeding, breeding, nursing) could occur with limited resilience and limited potential for recovery such that reproduction and survival of individuals would be affected*.
Medium	Resilience: Some resilience to the effect with some impairment of ecological functioning which may affect reproductive success but unlikely to affect survival of individuals. Adaptability: Ability to adapt behaviour to a level where ecological functioning can be sustained to allow individual survival. Recoverability: Ability for the animal to recover from the effect although recovery may be slow. *A receptor is of medium sensitivity where adverse effects on one or more key ecological functions (e.g. feeding, breeding, nursing) could be sustained beyond the duration of the impact (some resilience to the effect) but not at a level that would affect individual survival although reproductive success may be affected until the individual has recovered (ability to recover).*
Low	Resilience: Resilient to the effect with minor impairment of ecological functioning but unlikely to affect reproduction and survival rates of individuals. Adaptability: Ability to adapt behaviour such that ecological function can be maintained. Recoverability: Animal is able to return to previous behavioural states/activities once the impact has ceased within a short timeframe (days, weeks). *Low sensitivity is such that adverse effects on ecological functions (e.g. feeding, breeding, nursing) are likely to be very short term and would not affect reproductive success or individual survival.*
Negligible	Very little or no effect on the ecological functioning of individuals.

The significance of the effect upon marine mammals and megafauna is determined by correlating the magnitude of the impact and the sensitivity of the receptor. The particular method employed for this assessment is presented in Table 10-16. Where a range of significance of effect is presented in Table 10-16, the final assessment for each effect is based on calculated assessment and professional judgement.

For the purposes of this assessment, any effects with a significance level of slight or less have been concluded to be not significant in terms of the EIA Regulations.

Table 10-16: Matrix used for the assessment of the significance of the effect.

Sensitivity of receptor	Magnitude of impact: Negligible	Low	Medium	High
Negligible	Imperceptible	Imperceptible or slight	Imperceptible or slight	Slight
Low	Imperceptible or slight	Imperceptible or slight	Slight	Slight or moderate
Medium	Imperceptible or slight	Slight	Moderate	Moderate or major
High	Slight	Slight or moderate	Moderate or major	Major or Profound

10.9.3 Identification of Designated sites

Where Natura 2000 sites (i.e. internationally designated sites) are considered, this chapter summarises the assessments made on the qualifying features of internationally designated sites as described within section 10.7.1 of this chapter (with the assessment on the site itself deferred to the Natura Impact Statement (NIS) which accompanies the application.

With respect to nationally and locally designated sites, where these sites fall within the boundaries of an internationally designated site and where notified QIs of the Natura site are also features of interest of the nationally designated sites (e.g. Natural Heritage Areas (NHAs) which underpin a Natura site), only the international site has been taken forward for assessment. This is because potential effects on the integrity and conservation status of the nationally designated site are assumed to be inherent within the assessment of the internationally designated site (i.e. a separate assessment for the national site is not undertaken). However, where a nationally designated site falls outside the boundaries of an international site, but within the Marine Megafauna Study Area, an assessment of the impacts on the overall site is made in this chapter using the EIA methodology.

10.10 Assessment of significance

The potential impacts arising from the construction, operational and maintenance and decommissioning phases of the Project are listed in Table 10-11 along with the project design parameters against which each impact has been assessed.

A description of the potential effect on marine mammals and megafauna caused by each identified impact is given below.

10.10.1 Injury and/or disturbance to marine megafauna from underwater noise during pile-driving

Marine mammals, particularly cetaceans, are capable of generating and detecting sound (Au *et al.,* 1974; Bailey *et al.,* 2010) and are dependent on sound for many aspects of their lives (i.e. prey-identification; predator avoidance; communication and navigation). Increases in anthropogenic noise may consequently lead to a potential effect within the marine environment (Parsons *et al.,* 2008; Bailey *et al.,* 2010). Elasmobranchs (i.e. such as basking shark) detect sound using inner ear end organs; they do not have a swim bladder or any other air-filled cavity, therefore they can only sense sound as pressure through their lateral line system (McFarlane *et al.,* 2008). They do use hearing to detect prey, however this is less true of basking shark as a filter-feeding shark. The hearing bandwidth for elasmobranchs is from ~20 Hz up to 1 kHz, however no species-specific data is available for basking shark. At present, sea turtles are known to sense low frequency sound; the effective range of hearing of these species is within low frequencies (100 to 500 Hz) (Popper *et al.,* 2014). However, little is known about the extent of noise exposure from anthropogenic sources in their natural habitats, or the potential impacts of increased anthropogenic noise exposure on sea turtle biology (Samuel *et al.,* 2005). Sea turtles likely use sound for navigation, locating prey, avoiding predators, and environmental awareness. Sea turtle ear morphology lends itself to the reception of low frequency sounds, and research shows they are most sensitive to frequencies below 1,000 Hz (Bartol *et al.*, 1999; Bartol and Ketten 2006; Ridgway *et al.,* 1969 in Piniak *et al.,* 2012).

Pile-driving during the construction phase has the potential to result in elevated levels of subsea noise that are detectable by marine mammals and megafauna above background levels and could result in injurious or behavioural effects on IEFs. A detailed underwater noise modelling assessment has been carried out to investigate the potential for injurious and behavioural effects on IEFs as a result of piling (impulsive sounds), using the latest criteria (appendix 10-2: Subsea Noise Technical Report), which is drawn upon in the assessment presented below.

Summary of Subsea Noise Modelling: Injury

Injury thresholds for marine mammals

Auditory injury in marine mammals can occur as either a Permanent Threshold Shift (PTS), where there is no hearing recovery in the animal, or as a Temporary Threshold Shift (TTS), where an animal can recover from the tissue damage. Irish guidance recommends that the risk of TTS is included as potential injury as this could have negative effects on the ability of animals to use natural sounds, including communication, navigation, and prey location, and could lead to consequences for an animal's fitness (NPWS, 2014). The most likely response of an animal exposed to noise levels that could induce TTS is, however, to flee the ensonified area. It is therefore considered that there is also a behavioural response (disturbance) that overlaps with potential injury ranges, and animals exposed to noise levels that have the potential to induce TTS are likely to actively avoid hearing damage by moving away from the area.

For marine mammals, injury thresholds are based on both linear (i.e. un-weighted) peak sound pressure levels (SPL_{pk}) and marine mammal hearing-weighted cumulative Sound Exposure Level (SEL_{cum}). The SEL_{cum} takes account of the cumulative sound received by an animal within the ensonified area over the entire piling sequence and is weighted by marine mammal hearing groups based on similarities in known or expected hearing capabilities (Southall *et al.,* 2007*).* Marine mammal hearing groups are described in the latest guidance (Southall *et al*., 2019) as follows:

- **Low frequency (LF) cetaceans** (i.e. marine mammal species such as baleen whales with an estimated functional hearing range between 7 Hz and 35 kHz); minke whale is the IEF in the LF cetacean group;
- **High frequency (HF) cetaceans** (i.e. marine mammal species such as dolphins, toothed whales, beaked whales and bottlenose whales with an estimated functional hearing range between 150 Hz and 160 kHz); bottlenose dolphin and common dolphin are the IEFs in the HF cetacean group;
- **Very high frequency (VHF) cetaceans** (i.e. marine mammal species such as true porpoises, Kogia, river dolphins and cephalorhynchid with an estimated functional hearing range between 275 Hz and 160 kHz); harbour porpoise is the IEF in the VHF cetacean group;
- **Phocid pinnipeds in water (PW)** (i.e. true seals with an estimated functional hearing range between 50 Hz and 86 kHz); grey seal and harbour seal are the IEFs in the PW group.

The dual criteria (SPL_{pk} and SEL_{cum}) approach was employed in the subsea noise assessment to assess the potential for auditory injury (PTS and TTS) to occur in marine mammals (appendix 10-2: Subsea Noise Technical Report). Firstly, injury ranges were predicted based on exposure to SPL_{pk} from a single hammer strike at different levels (soft start initiation, soft start, ramp up, low energy and full energy). The peak injury thresholds were used to determine potential ranges for instantaneous injury to each species from a single hammer strike to a monopile. Secondly, injury ranges were predicted based on a marine mammal being exposed to impulsive noise from multiple hammer strikes over a prolonged period; the assumption being that a marine mammal exposed to lower noise levels over a prolonged period could experience auditory injury.

The parameters modelled were based on the maximum hammer energy being achieved (3,500 kJ) and the maximum duration of piling at any one location (one pile installed within a 24-hour period) (see Table 10-11).

Note that it is unlikely that the maximum hammer energy would be achieved at all piling locations so this assumption is considered to be very conservative (i.e. on average across all locations, the hammer energies are more likely to reach a maximum of 2,500 kJ). On average, the maximum duration of piling across the wind farm is five hours for a single monopile.

A summary of the parameters modelled in the subsea noise assessment is provided in Table 10-17, noting that measures included in the Project in the form of soft start and ramp up will be implemented as part of the Project, as described previously in Table 10-12.

Table 10-17: Design parameters modelled for a single monopile.

Pile type	Locations	Threshold	Parameter modelled	
			Parameter	Description
Monopile	East and west of the offshore wind farm area	Weighted SEL_{cum} Ramp up during single pile installation (maximum 5 hours duration)	Initiation Soft start Ramp up Standard operation Full power	1 min @ 525 kJ 20 min @ 525 kJ 9 min @ 525 to 2,500 kJ 150 min @ 2,500 kJ 120 min @ 3,500 kJ
		Unweighted SPL_{pk} Ramp up during single pile installation (maximum 5 hours duration)	Initiation Soft start Ramp up Standard operation Full power	1 min @ 525 kJ 20 min @ 525 kJ 9 min @ 525 to 2,500 kJ 150 min @ 2,500 kJ 120 min @ 3,500 kJ

To carry out exposure calculations (SEL_{cum} metric) the noise modelling assessment made a simplistic assumption that an animal would be exposed over a 24-hour period and that there would be no breaks in activity during this time. It was assumed that an animal would swim away from the noise source at the onset of activity at a constant rate and subsequently, conservative species-specific swim speeds were incorporated into the model (see Table 10-18).

Table 10-18: Swim speeds assumed for exposure modelling.

Species	Hearing group	Swim speed (m/s)	Source reference
Harbour porpoise	VHF	1.5	Otani *et al.*, 2000
Harbour seal	PW	1.8	Thompson, 2015
Grey seal	PW	1.8	Thompson, 2015
Minke whale	LF	2.3	Boisseau *et al.*, 2021
Bottlenose dolphin	HF	1.52	Bailey and Thompson, 2010
Common dolphin	HF	1.52	Bailey and Thompson, 2010

The subsea noise model adopted a number of conservative assumptions that results in a precautionary assessment (appendix 10-2: Subsea Noise Technical Report). These are summarised below:

- The modelling assumed the maximum hammer energy would be reached at all locations, whereas this is unlikely to be the case, based on examples from other offshore wind farms (e.g. Beatrice Offshore Wind Farm), where the mean actual hammer energy averages were considerably lower than the worst case assessed in the Environmental Statement and only six out of 86 asset locations reached maximum hammer energy (Beatrice, 2018);

- The soft start procedure simulated does not allow for short pauses in piling (e.g. for realignment) and therefore the modelled SEL_{cum} is likely to be an overestimate since, in reality, these pauses will reduce the noise exposure that animals experience whilst fleeing;

- Due to a combination of factors (e.g. dispersion of the waveform, multiple reflections from sea surface and seafloor, and molecular absorption of high frequency energy), impulsive sounds are likely to transition into non-impulsive sounds at distance from the sound source with empirical evidence suggesting such shifts in impulsivity could occur markedly within 10 km from the sound source (Hastie *et al.,* 2019). Since the precise range at which this transition occurs is unknown, noise models still adopt the impulsive thresholds at all ranges which is likely to lead to an overestimate of effect ranges at larger distances (tens of kilometres) from the sound source; and

- The model overestimates the noise exposure an animal receives since it does not account for any time that marine mammals spend at the surface and the reduced sound levels near the surface.

Species-specific TTS thresholds developed by NMFS (2018), and those previously presented by Southall *et al.* (2007), define a TTS onset as the exposure required to produce 6 dB of TTS, from either direct measurements or extrapolation of available data. There is currently, however, extremely limited data on impulsive noise TTS onset in marine mammals upon which these thresholds are based (Southall *et al.,* 2019). It has been necessary to determine exposure functions for TTS in order to estimate the levels at which the onset of PTS could occur (as experiments inducing PTS in animals are considered unethical) and predicted exposures of 40 dB of TTS are considered to result in PTS onset (Southall *et al.,* 2007). For the purposes of developing these thresholds, TTS was considered to be "the minimum threshold shift clearly larger than any day-to-day or session-to-session variation in a subject's normal hearing ability", and which "is typically the minimum amount of threshold shift that can be differentiated in most experimental conditions" (Southall *et al.,* 2007). Thus, using a threshold for the onset of TTS would typically result in overestimates of potential ranges at which ecologically significant effects could occur. Coupled with the precautionary assumptions in the model, particularly with respect to the SEL_{cum} metric, this means that estimates of TTS are likely to be unrealistic and therefore should be interpreted with caution. Injury (PTS and TTS) criteria (assessment thresholds) are presented in Table 10-20 below.

Injury thresholds for basking shark and sea turtle

In basking shark and sea turtles, injury is assessed as 'mortality and mortal injury' (immediate or delayed death) or 'impairment' (recoverable injury). As described for marine mammals previously, injury thresholds were based on unweighted SPL_{pk} and SEL_{cum} metrics. A dual criteria approach was used to assess the potential for 'mortality and mortal injury' and 'impairment'. Injury ranges (in metres) were determined using these criteria, except for where insufficient data existed to determine a quantitative guideline value. In these cases the risk was categorised in relative terms as "high", "moderate" or "low" at three distances from the source: "near" (i.e. in the tens of metres), "intermediate" (i.e. in the hundreds of metres) or "far" (i.e. in the thousands of metres) (Table 10-23). As with marine mammals, the SPL_{pk} criterion was used to determine potential ranges for instantaneous injury from a single hammer strike (monopile) and the SEL_{cum} criterion was used to determine injury ranges predicted based on an animal being exposed to impulsive noise from multiple hammer strikes over a prolonged period.

Similarly, the noise modelling assessment made a simplistic assumption that an animal would be exposed over a 24-hour period and that there would be no breaks in activity during this time. It was assumed that an animal would swim away from the noise source at the onset of activity at a constant rate and subsequently, conservative species-specific swim speeds were incorporated into the model (see Table 10-19).

Table 10-19: Swim speeds assumed for exposure modelling.

Species	Hearing group	Swim speed (m/s)	Source reference
Basking shark	Group 1 fish	1.0	Sims, 2000
All other fish groups	All fish groups	0.5	Popper *et al.,* 2014

Summary of Subsea Noise Modelling: Disturbance

Disturbance thresholds for marine mammals

Beyond the zone of injury, noise levels are such that they no longer result in physical injury but can result in disturbance to marine mammal behaviour. A marine mammal's response to disturbance will depend on the individual and the context; previous experience and acclimatisation will affect whether an individual exhibits an aversive response to noise, particularly in a historically noisy area. Typically, a threshold approach has been adopted in offshore wind farm assessments in the UK to quantify the scale of the effects. For example, the United States (US) National Marine Fisheries Service (NMFS) (NMFS, 2005) define strong disturbance in all marine mammals as Level B harassment and for impulsive noise suggests a threshold of 160 dB re 1 μPa (root mean square (rms)). This threshold meets the criteria defined by JNCC (2010) as a 'non-trivial' (i.e. significant) disturbance and is equivalent to the Southall *et al*. (2007) severity score of five or more on the behavioural response scale. Beyond this threshold the behavioural responses are likely to become less severe (e.g. minor changes in speed, direction and/or dive profile, modification of vocal behaviour and minor changes in respiratory rate (Southall *et al*., 2007)). The NMFS guidelines suggest a precautionary level of 140 dB re 1 µPa (rms) to indicate the onset of low-level marine mammal disturbance effects for all mammal groups for impulsive sound (NMFS, 2005), although this is not considered likely to lead to a 'significant' disturbance response.

More recently, to illustrate the variation in behavioural responses of marine mammals, Graham *et al*. (2017) used empirical evidence collected during piling at the Beatrice Offshore Wind Farm (Moray Firth, Scotland) to demonstrate that the probability of occurrence of harbour porpoise (measured as porpoise positive minutes) increased exponentially moving further away from the source. The study showed a 100% probability of disturbance at an (un-weighted) SEL of 180 dB re 1 µPa^{2}s, 50% at 155 dB re 1 µPa^{2}s and dropping to approximately 0% at an SEL of 120 dB re 1 µPa^{2}s. Importantly, Graham *et al*. (2019) demonstrated that the response of harbour porpoise to piling diminished over the piling phase such that, for a given received noise level or at a given distance from the source, there were more detections of animals at the last piling location compared to the first piling location. The dose response thresholds tie in with the NMFS (2005) criteria since a mild behavioural response is suggested to occur at a threshold of 140 dB re 1 µPa (rms) which is the equivalent of 130 dB 1 µPa^{2}s where a small response (c. 10% of animals) would occur according to the dose response. Dose response is an accepted approach to understanding the behavioural effects from piling and has been applied at other UK offshore wind farms (for example Seagreen (Seagreen Wind Energy Ltd, 2012)) and Hornsea Project Three (GoBe, 2018).

Similarly, a telemetry study undertaken by Russell *et al*. (2016) investigating the behaviour of tagged harbour seal during pile driving at the Lincs Offshore Wind Farm in the Wash found that there was a proportional response at different received noise levels. Dividing the study area into a 5 km x 5 km grid, the authors modelled SEL_{ss} levels and matched these to corresponding densities of harbour seal in the same grids during non-piling versus piling periods to show change in usage. The study found that there was a significant decrease in usage (abundance) during piling at predicted received SEL levels of between 142 dB and 151 dB re 1 µPa^{2}s. More recent work undertaken by Whyte *et al.* (2020) to develop dose-response relationships between changes in harbour seal density and predicted received noise levels during piling at the Lincs offshore wind farm in the southern North Sea. The study found significant changes in seal density at 145 dB re 1 µPa^{2}s and above. Below 145 dB re 1 µPa^{2}s there was no significant change in seal density detected, therefore received noise levels of below 145 dB re 1 µPa^{2}s have not been reported on (Whyte *et al.,* 2020). By applying these criteria (see Table 10-21) the magnitude of effect can be quantified with respect to the spatial extent of disturbance, and subsequently the number of animals potentially disturbed. There is, however, a note of caution associated with this approach. Southall *et al*. (2021) highlights that the challenges for developing a comprehensive set of empirically derived criteria for such a diverse group of animals are significant. Extensive data gaps have been identified (e.g. measurements of the effects of elevated noise on baleen whales) which mean that extrapolation from other species has been necessary. Sounds that disturb one species may, however, be irrelevant or inaudible to other species since there are broad differences in hearing across the frequency spectrum for different marine mammal hearing groups. Variance in responses even within a species are well documented to be context and sound-type specific (Ellison *et al*., 2012). In addition, the potential interacting and additive effects of multiple stressors (e.g., reduction in prey, noise and disturbance; contamination, etc.) are likely to influence the severity of responses (Lacy *et al*., 2017).

For these reasons, neither a threshold approach nor a dose-response function was provided in the original guidance (Southall *et al*., 2007) and subsequently the recent recommendations by Southall *et al*. (2021) also steer away from a single overarching approach. Instead, Southall *et al*. (2021) proposes a framework for developing probabilistic response functions for future studies. The paper suggests different contexts for characterising marine mammal responses with distinctions made by sound sources (i.e. pile driving, active sonar, seismic surveys and continuous/industrial noise). Three parallel categories have been proposed within which a severity score from an acute (discrete) exposure can be allocated:

- Survival – defence, resting, social interactions and navigation;
- Reproduction – mating and parenting behaviours; and
- Foraging – search, pursuit, capture and consumption.

Even where studies have been able to assign responses to these categories based on acute exposure there is still limited understanding of how longer term (chronic) exposure could translate into population-level effects. To explore this, Southall *et al*. (2021) reported observations from long term whale watching studies and suggested that there were differences in the ability of marine mammals to compensate for long term disturbance which related to their breeding strategy. Mysticetes are capital breeders - accumulating energy in their feeding grounds and transferring this to calves in their breeding ground – and their ability to compensate for chronic exposure to noise will depend on a range of ecological factors. Such factors include the relative importance of the disturbed area and prey availability within their wider home range, individual exposure history, and the presence of concurrent disturbances in other areas of their range. Animals may be able to compensate for short-term disturbances by feeding in other areas, for example, which would reduce the risk of longer-term population consequences. Christiansen and Lusseau (2015) studied the effect of whale watching on minke whale in Faxafloi Bay, Iceland and found no significant long-term effects on vital rates although years with low sandeel density led to increased exposure to whale watching as whales were forced to move into disturbed areas to forage. Odontocetes, however, may be more vulnerable to whale watching compared to mysticetes due to their more localised, and often, coastal home ranges. Bejder *et al*. (2006) documented a decrease in local abundance of bottlenose dolphin which was associated with an increase in whale watching in a tourist area compared to a control area.

The marine mammals considered in this assessment vary biologically and therefore have different ecological requirements that may affect their sensitivity to disturbance. This point is illustrated by the differences between the two seal species identified as key biological receptors in the baseline. Grey seal are capital breeders (foraging to build up stored fat reserves for lactation) and often make long foraging trips from haul-outs. In contrast, harbour seal are income breeders (feeding throughout the pupping season) and make shorter foraging trips from haul-outs.

In summary, Southall *et al.* (2021) clearly highlights the caveats associated with simple, one-size-fits-all, threshold approaches that could lead to errors in disturbance assessments. Recognising this inherent uncertainty in the quantification of effects the assessment has adopted a precautionary approach at all stages of assessment including:

- Conservative assumptions in the marine mammal baseline (e.g. use of seasonal density peaks) (Table 10-7); and
- Conservative assumptions for the project parameters (Table 10-11); and
- Conservative assumptions in the subsea noise modelling (as set out in appendix 10-2: Subsea Noise Technical Report and summarised above).

Relevant assumptions have been described throughout this chapter and demonstrate that such layering of conservatism is likely to lead to a very precautionary assessment.

A dose response curve was applied to this assessment to determine the number of animals that may potentially respond behaviourally to received noise levels during piling. Unweighted SEL_{ss} contours were plotted in 5 dB isopleths in decreasing increments from 180 dB to 120 dB re.1 $\mu Pa^2 s$ using the highest modelled received noise level for 4% reducing to 0.5% Conversion Factor (CF) and 1% constant CF.

To adopt the most precautionary approach, the dose response contours were plotted in Geographical Information System (GIS) for all modelled locations and the location selected for assessment was the one whereby the contours covered the greatest spatial area. The areas within each 5 dB isopleth were calculated from the spatial GIS map and a proportional expected response, derived from the dose response curve for each isopleth area, was used to calculate the number of animals potentially disturbed. These numbers were subsequently summed across all isopleths to estimate the total number of animals disturbed during piling. The number of animals predicted to respond was based on species specific densities as agreed with statutory consultees (Table 10-7).

For harbour porpoise the dose-response curve was applied from the first location modelled as shown by Graham *et al*. (2017) where the probability of response approaches zero at c. 120 dB SEL_{SS}. In the absence of species-specific data for other cetacean species the same dose response curve was assumed to apply to all cetacean IEFs in this assessment (Figure 10-2:).

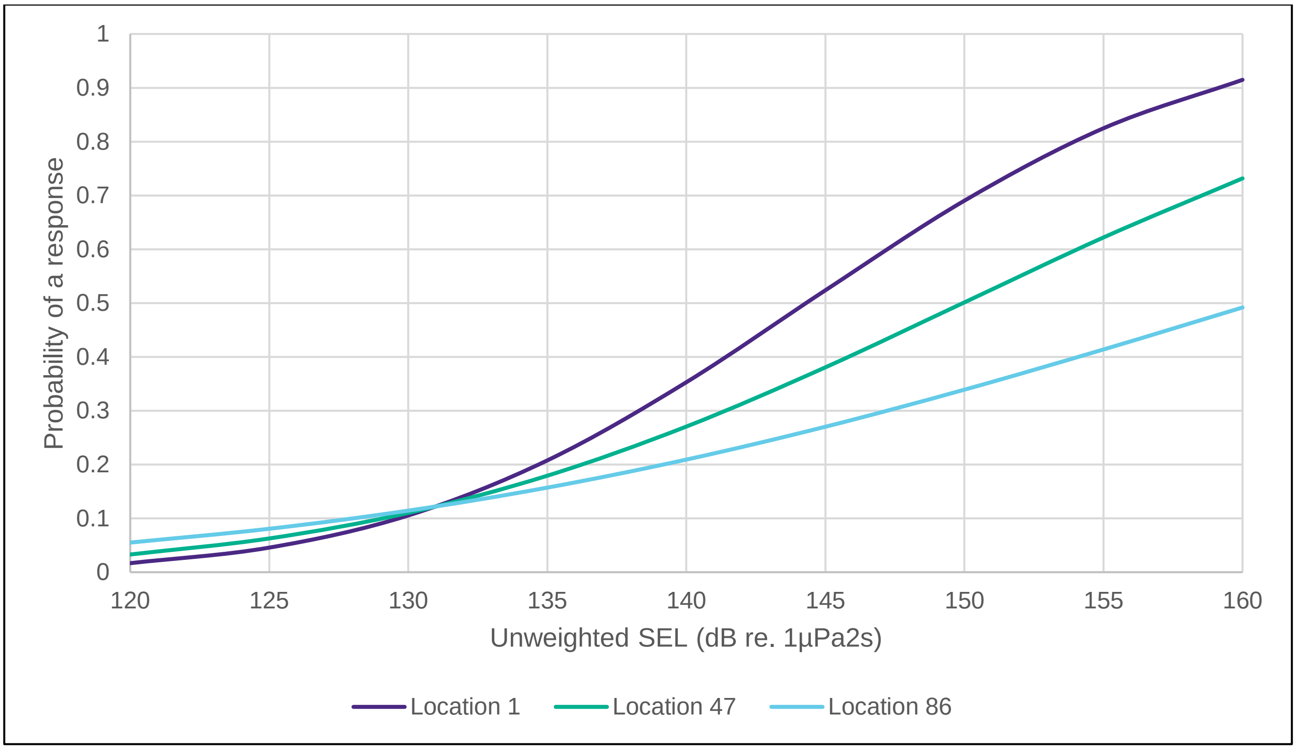


Figure 10-2: The probability of a harbour porpoise response (24h) in relation to the partial contribution of unweighted received single-pulse SEL for the first location piled (purple line), the middle location (green line) and the final location piled (blue line). Harbour porpoise occurrence was considered to have responded to piling when the proportional decrease in occurrence exceeded a threshold of 0.5. (Reproduced with permission from Graham *et al.,* 2019).

For harbour seal and grey seal, subsea noise modelling was undertaken using a dose-response approach with SEL single-strike (SEL_{ss}) contours modelled in 5 dB increments with each isopleth linked to a probability of disturbance as derived from Whyte *et al.* (2020) (Figure 10-3). This approach was recently applied to Awel y Môr Offshore Wind Farm, after consultation with Natural Resource Wales (RWE, 2022b). It has been assumed that all seals are displaced at sound exposure levels above 180 dB re 1 µPa2s. This is a conservative assumption since there were no data presented in the study at this level. Furthermore, it is important to note that there is a percentage decrease anomaly in response to either 170 - 175 or 175 – 180 dB re 1 µPa2s. This (undetermined) anomaly likely occurred due to the small number of spatial cells included in the analyses for these categories (n = 2 and 3 respectively, compared to a minimum of 5 spatial cells at other SELs). The harbour seal curve has been applied to grey seal disturbance also, as no corresponding data for grey seal are available, and it is considered to be an appropriate proxy for grey seal given both species are within the same hearing group (PW). Disturbance criteria (assessment thresholds) are presented in Table 10-21 below.

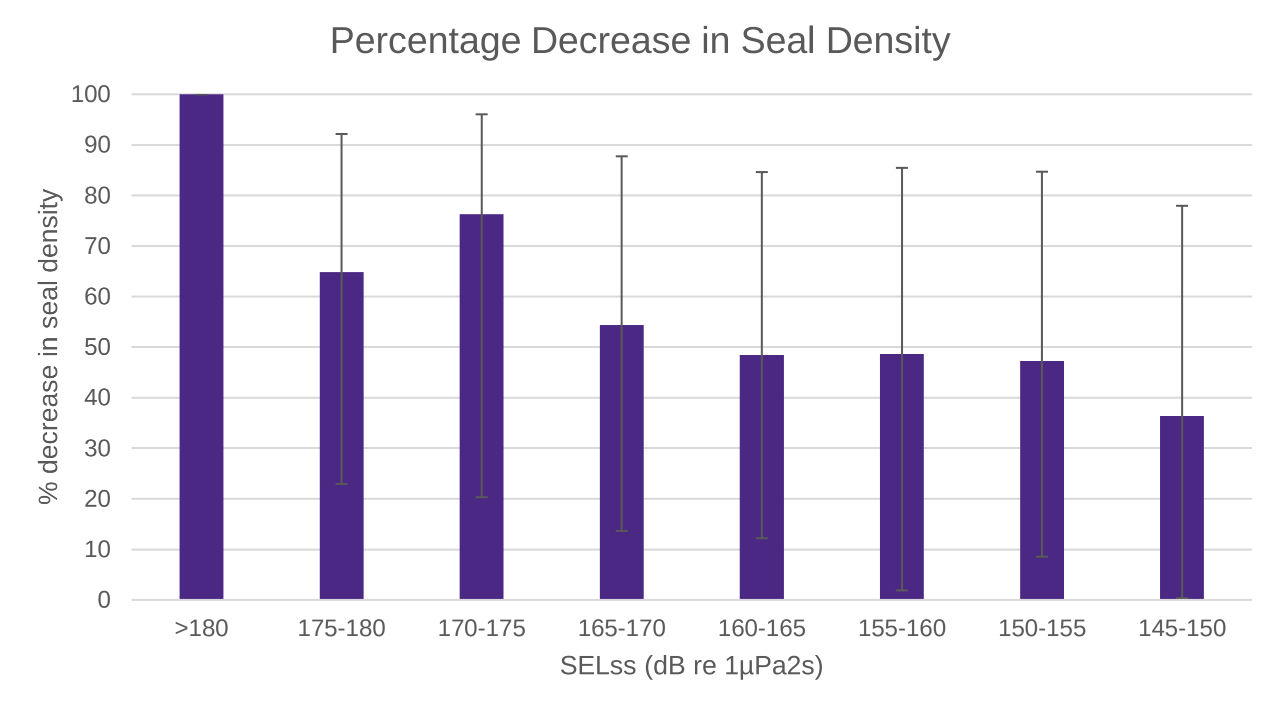


Figure 10-3: Percentage decrease in seal density as a function of estimated Sound Exposure Level (SEL) (showing upper and lower 95% Confidence Intervals (CI) as error bars). (Reproduced with permission from Whyte et al., 2020).

Disturbance thresholds for basking shark and sea turtle

Adult basking shark and sea turtles not in the immediate vicinity of the noise generating activity are generally thought to be able to vacate the area and avoid physical injury, resulting in behavioural effects (disturbance). Behavioural effects in response to construction related underwater noise include a wide variety of responses including startle responses (also known as C-turn responses), strong avoidance behaviour, changes in swimming or schooling behaviour or changes of position in the water column.

The approach taken to determine disturbance to basking shark and sea turtle was based on disturbance criteria in Popper *et al.,* (2014). The risk of behavioural effects is categorised in relative terms as “high”, “moderate” or “low” at three distances from the source: “near” (i.e. in the tens of metres), “intermediate” (i.e. in the hundreds of metres) or “far” (i.e. in the thousands of metres). These criteria for disturbance due to sound are qualitative rather than quantitative, and as such a source of noise of a particular type (e.g. piling) would result in the same predicted impact, no matter the level of noise produced or the propagation characteristics. As such, noise modelling also employed criteria set out in Washington State Department of Transport (WSDOT, 2011) which adopts an un-weighted sound pressure level of 150 dB re 1 µPa (rms) as the criterion for onset of behavioural effects, based on work by Hastings (2002).

Summary of thresholds

A summary of the criteria (acoustic thresholds) for onset of injury and disturbance used in the marine mammal noise assessment is provided below in Table 10-20 and Table 10-21. A summary of the criteria (acoustic thresholds) for onset of injury and disturbance used in the basking shark and sea turtle noise assessment is provided below in Table 10-22 and Table 10-23

Table 10-20: Summary of injury (PTS and TTS) onset acoustic thresholds for impulsive noise (NMFS, 2018).

Hearing Group	Injury	
	PTS	TTS
Low frequency (LF) cetaceans (minke whale)	219 dB re 1 µPa (SPL_{pk})	213 dB re 1 µPa (SPL_{pk})

Hearing Group	Injury	
	PTS	TTS
	183 dB re 1 µPa²s (SEL_{cum})	168 dB re 1 µPa²s (SEL_{cum})
High frequency (HF) cetaceans (bottlenose dolphin and common dolphin)	230 dB re 1 µPa (SPL_{pk})	224 dB re 1 µPa (SPL_{pk})
	185 dB re 1 µPa²s (SEL_{cum})	170 dB re 1 µPa²s (SEL_{cum})
Very high frequency (VHF) cetaceans (harbour porpoise)	202 dB re 1 µPa (SPL_{pk})	196 dB re 1 µPa (SPL_{pk})
	155 dB re 1 µPa²s (SEL_{cum})	140 dB re 1 µPa²s (SEL_{cum})
Phocid pinnipeds in water (PW) (grey seal and harbour seal)	218 dB re 1 µPa (SPL_{pk})	212 dB re 1 µPa (SPL_{pk})
	185 dB re 1 µPa²s (SEL_{cum})	170 dB re 1 µPa²s (SEL_{cum})

Table 10-21: Disturbance Criteria for Marine Mammals Used in this Study (NMFS, 2005).

Hearing Group	Non-Impulsive Threshold	Impulsive Threshold (other than piling)	Impulsive Threshold (piling)
Mild disturbance (all marine mammals)	-	140 dB re 1µ Pa (rms)	Based on SEL 5 dB contours
Strong disturbance (all marine mammals)	120 dB re 1µ Pa (rms)	160 dB re 1µ Pa (rms)	Based on SEL 5 dB contours

Table 10-22: Criteria for onset of injury to fish due to impulsive piling (Popper et al., 2014).

Type of animal (species)	Parameter	Mortality and potential mortal injury	Recoverable injury
Fish: no swim bladder (particle motion detection) (basking shark)	SEL, dB re 1 µPa²s	> 219	>216
	Peak, dB re 1 µPa	> 213	>213
Sea turtle (leatherback turtle)	SEL, dB re 1 µPa²s	210	(*Near*) High (*Intermediate*) Low (*Far*) Low
	Peak, dB re 1 µPa	> 207	

Table 10-23: Criteria for onset of behavioural effects in fish for impulsive and non-impulsive sound (Popper et al., 2014).

Type of animal (species)	Relative risk of behavioural effects	
	Impulsive piling	Non-impulsive sound
Fish: no swim bladder (particle motion detection) (basking shark)	(*Near*) High (*Intermediate*) Moderate (*Far*) Low	(*Near*) Moderate (*Intermediate*) Moderate (*Far*) Low
Sea turtle (leatherback turtle)	(*Near*) High (*Intermediate*) Moderate (*Far*) Low	(*Near*) High (*Intermediate*) Moderate (*Far*) Low

Summary of interim population consequences of disturbance (iPCoD) modelling

To understand the potential for long-term population level effects on marine mammal species resulting from piling activities only at the Project, population modelling using the iPCoD model was undertaken.

There is limited understanding of how behavioural disturbance and auditory injury affect survival and reproduction in individual marine mammals and consequently how this translates into effects at the population level. The iPCoD model was developed using a process of expert elicitation to determine how physiological and behavioural changes affect individual vital rates (i.e. the components of individual fitness that affect the probability of survival, production of offspring, growth rate and offspring survival).

Expert elicitation is a widely accepted process in conservation science whereby the opinions of many experts are combined when there is an urgent need for decisions to be made but a lack of empirical data with which to inform them. In the case of iPCoD, the marine mammal experts were asked for their opinion on how changes in hearing resulting from PTS and behavioural disturbance (equivalent to a score of 5* or higher on the ‘behavioural severity scale’ described by Southall *et al.* (2007)) associated with offshore renewable energy developments affect calf and juvenile survival and the probability of giving birth (Harwood *et al.,* 2014). Experts were asked to estimate values for two parameters which determine the shape of the relationships between the number of days of disturbance experienced by an individual and its vital rates, thus providing parameter values for functions that form part of the iPCoD models (Harwood *et al.,* 2014). The relationship between disturbance and survival/reproduction assumes that individual animals would have a limited ability to alter their activity budget to compensate for a reduction in e.g. time spent feeding (Houston *et al.,* 2012; King *et al.,* 2015). The individual's ability to provision/care for young, evade predation or resist disease would likely be affected, and it is expected that effects would be reflected in changes to vital rates. It is important to note, however, that this relationship is highly simplified (Harwood *et al.,* 2014), and an individual’s response to disturbance will depend on factors including the context of the disturbance, the individual's existing condition and its exposure history (Ellison *et al.,* 2012). The iPCoD framework applies simulated changes in vital rates to infer the number of animals that may be affected by disturbance as a means to iteratively project the size of the population.

The iPCoD model simulates the mean population difference over time for an impacted versus an unimpacted population to provide comparison of the type of changes that could occur resulting from natural environmental variation, demographic stochasticity and human-induced disturbance. It can be assumed that disturbance occurs only on the day (24 hours) that piling takes place (Graham *et al.,* 2019; Brandt *et al.,* 2011). However, residual disturbance has conservatively been set at one day, meaning that the model assumes that disturbance occurs on the day of piling and persists for a period of 24 hours after piling has ceased. The results are summarised in relation to the forecasted population size over time with forecasts made at certain timepoints (e.g. two, six, 13, 19 and 25 years) after piling commences. In addition, the model calculates the median ratio of the unimpacted to the impacted population size at these timepoints. A caveat of the iPCoD framework, however, is that the models do not account for density dependence and therefore the forecasts may be unrealistic as they assume that vital rates in the population will not alter as a result of density-dependent factors (e.g. competition).

Alternative approaches to assessing the iPCoD include (i) matrix models, which allow for an assessment of a population, with and without disturbance (e.g. Caswell *et al.,* 2001) and (ii) data-driven, state-dependent behavioural approaches in lieu of expert elicitation (e.g. McHuron *et al.,* 2017). Nonetheless, uncertainties in the iPCoD framework have been offset as far as possible by adopting a precautionary approach at all stages of the assessment from the project design parameters, conservatism in the underwater sound model and adoption of precautionary estimates to represent the densities of key species. Thus, the results from the iPCoD modelling undertaken for the Project is considered to be inherently cautious and should be interpreted as such.

Population modelling using iPCoD was carried out for the following species:

- Harbour porpoise;
- Bottlenose dolphin;
- Minke whale;
- Grey seal; and
- Harbour seal.

The population models were developed using the relevant reference populations (Table 10-7) and using published demographic parameters (see appendix 10-3: Marine Mammal Population Modelling Report (IPCoD)). For bottlenose dolphin, two different quantitative approaches were used to estimate numbers of animals affected and both values subsequently fed into the iPCoD model (the SCANS-III surface density estimate was compared against the Irish Sea MU population as recommended by IAMMWG (2023); and the SCANS-IV density estimate for Block CS-D was compared against the summed total for the two SCANS-IV blocks that combine to cover the Irish Sea region).

The expert elicitation required to inform the transfer functions that are integral to the iPCoD modelling process has not yet considered short-beaked common dolphin. As a consequence, the iPCoD framework does not currently facilitate population modelling for this species, and has therefore not been included.

Construction phase

Magnitude of impact

The installation of foundations within the offshore wind farm area may lead to injury and/or disturbance to marine mammals and megafauna from underwater noise during pile driving. The noise assessment considered the installation of 9.6 m diameter monopiles with a hammer energy of 3,500 kJ. The piling parameters and resulting source sound levels for monopiles are described above and set out in Table 10-17.

Injury

The subsea noise modelling assessment showed that the injury ranges were larger for piling activities modelled in the east of the offshore wind farm area than the west, with a couple of exceptions where, due to differences in bathymetry, the ranges were similar to those in the west of the offshore wind farm area (see appendix 10-2: Subsea Noise Technical Report). As such only outputs for the east of the offshore wind farm area (as the maximum effect ranges) have been presented here.

Marine Mammal IEFs

Including soft start and ramp up as a measure included in the Project, the greatest predicted range for PTS (using the SPL_{pk} metric) was for harbour porpoise - a VHF cetacean - with PTS potentially occurring out to 236 m (Table 10-24). For comparison, at the west location the maximum range over which PTS could occur was estimated as 219 m for harbour porpoise, suggesting that the risk of PTS varies from location to location, with 236 m anticipated as the maximum across all locations (Table 1-18 in appendix 10-2: Subsea Noise Technical Report).

The greatest range for PTS (using the SEL_{cum} metric) was predicted for minke whale - a LF cetacean - with PTS occurring out to 394 m (Table 10-25). The PTS threshold using the SEL_{cum} metric was exceeded at 168 m for harbour porpoise and 19 m for pinnipeds but not exceeded for bottlenose dolphin and common dolphin, both HF cetaceans (Table 1-17 in appendix 10-2: Subsea Noise Technical Report).

To reduce risk of injury in all marine mammals, and for the purposes of developing the MMMP (see volume 2A, appendix 5-4: Marine Megafauna Mitigation Plan) a mitigation zone (over which the pre-piling watch should take place) was defined. Based on the dual metric (SPL_{pk} and SEL_{cum}) noise modelling for the mitigation zone has been defined as a minimum of 394 m (i.e. this was the maximum predicted injury range across all marine mammals and both metrics).

The greatest range for TTS, using the SPL_{pk} metric, was predicted for harbour porpoise as a VHF cetacean. TTS in harbour porpoise could occur during piling out to a maximum range of 344 m (Table 10-24). The greatest range for TTS, using the SEL_{cum} metric, was predicted for minke whale, as an LF cetacean. TTS in minke whale could occur during piling out to a maximum range of 8,060 m (Table 10-25). As described previously (see *Injury Thresholds for Marine Mammals*), TTS ranges are considered unrealistic due to the thresholds applied and the levels of conservatism built into the model and are therefore an overestimation of the magnitude of the impacts.

For comparison, ranges have also been presented for a scenario without measures included in the Project (i.e. without soft-start initiation (‘first strike’)) to demonstrate the effectiveness of including these designed in mitigation measures to reduce both the PTS and TTS injury ranges (Table 10-25).

Table 10-24: Summary of peak pressure injury ranges for marine mammals due to impact piling of 9.6 m diameter monopiles at the east of the offshore wind farm area (N/E = threshold not exceeded). Note that with engineering mitigation in place (Table 10-12) the ranges of effect are only relevant for the hammer initiation (‘Soft Start – First Strike; 525 kJ); Max Energy ranges have been presented for comparison only.

Hearing group (species)	Threshold (Unweighted Peak)	Range (m)	
		Soft Start - First Strike	Max Energy
LF	PTS - 219 dB re 1 µPa (pk)	81	168
	TTS - 213 dB re 1 µPa (pk)	118	245
HF	PTS - 230 dB re 1 µPa (pk)	41	84
	TTS - 224 dB re 1 µPa (pk)	59	123
VHF	PTS - 202 dB re 1 µPa (pk)	236	489
	TTS - 196 dB re 1 µPa (pk)	344	713
PW	PTS - 218 dB re 1 µPa (pk)	86	179
	TTS - 212 dB re 1 µPa (pk)	126	261
	TTS - 226 dB re 1 µPa (pk)	52	108

Table 10-25: Summary of the SEL_{cum} injury ranges for marine mammals due to piling of single monopile at the east of the offshore wind farm area (N/E = threshold not exceeded). Ranges are shown for the unmitigated and mitigated (initiation + soft start + ramp up).

Species / Group	Threshold (Weighted SEL_{cum})	Range (m)
LF	PTS - 183 dB re 1 µPa^{2}s	394
	TTS - 168 dB re 1 µPa^{2}s	8,060
HF	PTS - 185 dB re 1 µPa^{2}s	N/E
	TTS - 170 dB re 1 µPa^{2}s	12
VHF	PTS - 155 dB re 1 µPa^{2}s	168
	TTS - 140 dB re 1 µPa^{2}s	5,980
PW	PTS - 185 dB re 1 µPa^{2}s	19
	TTS - 170 dB re 1 µPa^{2}s	1,330

The maximum numbers of marine mammals potentially affected within the modelled ranges for PTS and TTS are presented in Table 10-26 (SPL_{pk}) and Table 10-27 (SEL_{cum}) and are estimated using the most up to date species-specific density estimates (Table 10-7). Estimates of abundance within associated Management Units have been used to present these values as a proportion of the population (Table 10-7). For all assessed marine mammal IEFs, less than a single individual is likely to experience PTS or TTS as a result of soft start initiation of impact piling based on the SPL_{pk} thresholds for the species (see Table 10-20). Similarly, predictions of the number of animals within the ensonified area that could lead to the onset of PTS using the SEL_{cum} threshold found that for all species less than one animal would be affected (see Table 10-27), other than bottlenose dolphin and common dolphin, where the threshold for PTS was not exceeded. The ranges of effect predicted for TTS using the SEL_{cum} threshold suggest that up to 150 harbour porpoise and up to 54 minke whale may be within the ensonified area (Table 10-27). These numbers represent very small proportions of the MU populations (i.e. up to 0.239 % for harbour porpoise and 0.264 % for minke whale). Note also, for minke whale in particular, there is strong seasonality and some months in which minke whale may not be within the Marine Megafauna Study Area, thus the numbers presented are representative of the maximum densities occurring during the seasonal peak. Considering a precautionary approach using the peak densities, the magnitude of the impact of TTS (which is reversible) is not anticipated to lead to any population level effects.

To reduce the risk of permanent and temporary auditory injury, measures included in the Project will be implemented as part of a MMMP (see volume 2A, appendix 5-4: Marine Megafauna Mitigation Plan). This will include recording of marine mammal activity (visually and using PAM) over a pre-defined mitigation zone based on the maximum range over which PTS is predicted to occur, in this case a minimum of 236 m (Table 10-24). In addition to the measures included in the Project (see Table 10-12), an ADD which has been shown to be effective in deterring marine mammals from proximity to piling which may result in injury (McGarry *et al.,* 2017; Gordon *et al.,* 2019) will be implemented as part of the MMMP, subject to discussion with stakeholders. The use of an ADD is considered as mitigation and discussed later in this section (and section 10.10.6).

Table 10-26: Number of animals potentially affected by PTS (auditory injury) and TTS arising from soft start initiation for piling at a single monopile at the east of the offshore wind farm area based on peak pressure injury ranges (N/E = threshold not exceeded).

Species	Threshold (Unweighted Peak)	Density estimate (animals/km^2)	MU population	Range (m)	Area of sea within zone of injury (km^2)	Number animals within zone of injury	Proportion of MU population (%)
Harbour porpoise	PTS - 202 dB re 1 µPa (pk)	0.280 - 1.330	62,517	236	0.17	< 1	7.85×10^{-5} - 0.0004
	TTS - 196 dB re 1 µPa (pk)			344	0.37	< 1	0.0002 - 0.0008
Bottlenose dolphin	PTS - 230 dB re 1 µPa (pk)	0.046 - 0.235*	293 8,326*	41	0.005	< 1	8.29×10^{-5} 1.49×10^{-5}
	TTS - 224 dB re 1 µPa (pk)			59	0.01	< 1	0.0002 3.09×10^{-5}
Common dolphin	PTS - 230 dB re 1 µPa (pk)	0.027	102,656	41	0.005	< 1	1.39×10^{-7}
	TTS – 224 dB re 1 µPa (pk)			59	0.01	< 1	2.88×10^{-7}
Minke whale	PTS – 219 dB re 1 µPa (pk)	0.014 – 0.260	20,118	81	0.02	< 1	1.43×10^{-6} - 2.66×10^{-5}
	TTS - 213 dB re 1 µPa (pk)			118	0.04	< 1	3.04×10^{-6} - 5.65×10^{-5}
Grey seal	PTS - 218 dB re 1 µPa (pk)	0.372	5,882	86	0.02	< 1	0.0001
	TTS - 212 dB re 1 µPa (pk)			126	0.05	< 1	0.0003
Harbour seal	PTS - 218 dB re 1 µPa (pk)	0.280	1,635	86	0.02	< 1	0.0004
	TTS - 212 dB re 1 µPa (pk)			126	0.05	< 1	0.0009

* Density generated using SCANS-IV data has been compared against a reference population estimated by summing the abundance within the Irish Sea SCANS-IV blocks

Table 10-27: Number of animals potentially affected by PTS (auditory injury) and TTS arising from impact piling at a single monopile location at the east of the offshore wind farm area based on SEL injury ranges (including soft start) (N/E = threshold not exceeded).

Species	Threshold (Weighted) SEL_{cum}	Project measure	Density estimate (animals/km^2)	MU population	Range (m)	Area of sea within zone of injury (km^2)	Number animals within zone of injury	Proportion of MU population (%)
Harbour porpoise	PTS – 155 dB re 1 μPa^2s	Soft start	0.280 - 1.330	62,517	168	0.09	< 1	3.97 x 10^{-5} - 0.0002
	TTS - 140 dB re 1 μPa^2s				5,980	112.29	32 - 150	0.050 - 0.239
Bottlenose dolphin	PTS - 185 dB re 1 μPa^2s	Soft start	0.046 - 0.235*	293 8,326*	*N/E*	N/A	N/A	N/A
	TTS - 170 dB re 1 μPa^2s				12	0.0005	< 1	7.10 x10^{-6} 1.28 x10^{-6}*
Common dolphin	PTS - 185 dB re 1 μPa^2s	Soft start	0.027	102,656	*N/E*	N/A	N/A	N/A
	TTS - 170 dB re 1 μPa^2s				12	0.0005	< 1	1.19 x10^{-8}
Minke whale	PTS - 183 dB re 1 μPa^2s	Soft start	0.014 – 0.260	20,118	394	0.49	< 1	3.39 x 10^{-5} - 0.0006
	TTS - 168 dB re 1 μPa^2s				8,060	203.99	3 - 54	0.014 - 0.264
Grey seal	PTS - 185 dB re 1 μPa^2s	Soft start	0.372	*5,882*	19	0.001	< 1	6.3 x 10^{-6}
	TTS - 170 dB re 1 μPa^2s				1,330	5.55	2	0.031
Harbour seal	PTS - 185 dB re 1 μPa^2s	Soft start	0.280	*1,635*	19	0.001	< 1	1.94 x 10^{-5}
	TTS - 170 dB re 1 μPa^2s				1,330	5.55	2	0.095

* Density generated using SCANS-IV data has been compared against a reference population estimated by summing the abundance within the Irish Sea SCANS-IV blocks

The impact of injury on marine mammal receptors is predicted to be of local spatial extent, medium-term duration (i.e. maximum duration of piling phase), intermittent (i.e. elevations in subsea noise occur intermittently over the piling phase) and permanent (PTS)/ temporary (TTS). It is predicted that the impact will affect the receptor directly. The assessment shows that over the ensonified area, only small numbers of animals of all species are likely to occur within the injury zones. These numbers are relatively small in the context of the relevant geographic frames of reference, and would not be at a scale that would lead to any measurable population-level effects. In addition, with measures in place including soft start and an MMMP, the magnitude is therefore, considered to be low for PTS as the range of effect falls within the distance which can be managed via the MMMP and medium for TTS (as the range of effect may extend beyond the distance which can be managed by the MMMP).

Basking Shark and Leatherback Turtle IEFs

With implementation of the measures included in the Project (i.e. soft start) (Table 10-12), the impact ranges for mortality and recoverable injury, based on the SPL_{pk} metric, are predicted as 172 m for leatherback turtle and 118 m for basking shark (Table 10-28). The ranges predicted for mortality and recoverable injury using the SEL_{cum} metric were considerably smaller compared to the SPL_{pk} metric. Mortality and recoverable injury could occur to a maximum range of 17 m for sea turtles, whereas the threshold for mortality and recoverability for basking shark was not exceeded (Table 10-28). The criterion for assessing recoverable injury in sea turtles is qualitative rather than quantitative. The noise modelling assessed that at near distances (tens of metres) the risk of recoverable injury is high, but at both intermediate (hundreds of metres) and far distances (thousands of metres), the risk of recoverable injury was low (Table 10-23).

TTS is a temporary reduction in hearing sensitivity caused by exposure to intense sound. Normal hearing ability returns following cessation of the noise causing TTS, though this period is variable. When experiencing TTS, basking shark and leatherback turtle may have decreased fitness due to a reduced ability to communicate, detect predators or prey, and/or assess their environment. The effects of TTS in basking shark and sea turtle may occur out to maximum ranges of 770 m and 17 m respectively (Table 10-29).

Table 10-28: Summary of the peak pressure injury ranges for fish and sea turtles due to installation of one monopile at the east of the offshore wind farm area (N/E = threshold not exceeded).

Class (relevant species)	Response	Threshold (SPL_{pk}, dB re 1 µPa)	Range (m)	
			First Strike	Max
Basking shark (no swim bladder; particle motion detection)	Mortality and recoverable injury (SPL_{pk})	213	118	245
Sea turtles	Mortality	207	172	357

Table 10-29: Summary of the SEL_{cum} injury ranges for fish and sea turtles due to piling at the east of the offshore wind farm area. Ranges presented are for cumulative exposure for installation of a single monopile. Assessment is based on ranges predicted considering implementation of soft start.

Class (relevant species)	Response	Threshold (SEL, dB re 1 µPa^{2}s)	Range (m)
Basking shark (no swim bladder; particle motion detection)	Mortality	219	N/E
	Recoverable injury	216	N/E
	TTS	186	770
Sea turtles	Mortality	210	17

Density estimates for sea turtle are very low in the Marine Megafauna Study Area (0.06 animals per km^2, Table 10-7). As such, regardless of metric, less than one individual has the potential to be within the ensonified area for injury. Taking a precautionary approach, one individual would represent < 0.05 % of the population (Table 10-7). For basking shark, it has not been possible to estimate the number of animals potentially affected by piling activities, given the absence of density and abundance estimates for this species in the Regional Marine Megafauna Study Area. However, based on encounter rates during recent site-specific surveys (maximum 0.006 animals per km^2, see appendix 10-1: Marine Mammals and Megafauna Technical Report), it is predicted that the risk of encountering an animal within the ensonified area is very small. With a MMMP in place (Table 10-12), piling would be delayed if a basking shark or sea turtle were sighted within the injury zone thereby reducing the risk further.

The impact of injury on basking shark and leatherback turtle is predicted to be of local spatial extent, medium-term duration, intermittent and permanent (mortality or injury)/temporary (TTS). It is predicted that the impact will affect the receptor directly. Measures included in the Project, including soft start and implementation of the MMMP, will reduce the risk of injury occurring on basking shark and leatherback turtle. In addition, the risks are likely to be very small due to the low number of animals passing through the Marine Megafauna Study Area and therefore entering the zones of influence. The magnitude is therefore considered to be negligible for both PTS and TTS.

Disturbance

<u>Marine Mammal IEFs</u>

Disturbance ranges for all marine mammal species are shown in Figure 10-4 and Figure 10-5 (SEL_{ss} metric), for the installation of monopiles at the east of the offshore wind farm area, as the largest spatial extent.

The number of animals predicted to experience potential disturbance as a result of piling at the east of the wind farm (largest spatial extent) are set out in Table 10-30. Predicted number of animals are based on the most up to date species-specific density estimates (Table 10-7) and represent the maximum numbers that may be affected.

Based on a dose-response approach (derived from Graham *et al. (*2017), the most conservative estimate of disturbance predicted that between 153 and 725 harbour porpoise have the potential to be disturbed by piling, representing 0.245 to 1.160% of the MU population. However, this represents the maximum number across the entire range of disturbance responses (from slight changes in behaviour, such as changes in swimming speed or direction, through to displacement). Of this, up to 64 harbour porpoise are predicted to experience strong disturbance (above 160 dB re 1µ Pa (rms)) representing 0.101% of the MU population, whilst up to 2,111 are predicted to experience mild disturbance (140 – 160 dB re 1µ Pa (rms)) representing 3.376% of the MU population (Table 10-30).

Disturbance is expected to affect fewer bottlenose dolphin, common dolphin and minke whale during piling, however the bottlenose dolphin population estimates (n=293, from IAMMWG, 2023; and n=8,326, derived from Gilles *et al.,* 2023) are significantly smaller than the relevant harbour porpoise population (n=62,517). Therefore disturbance, based on a dose-response approach (derived from Graham *et al.,* 2017) of up to 129 animals, represents 1.549% of the SCANS-IV abundance estimate; or disturbance of up to 26 animals, based on the SCANS-III DSE of 0.046 animals per km^2 represents 8.63% of the Irish Sea MU (see Table 10-30).

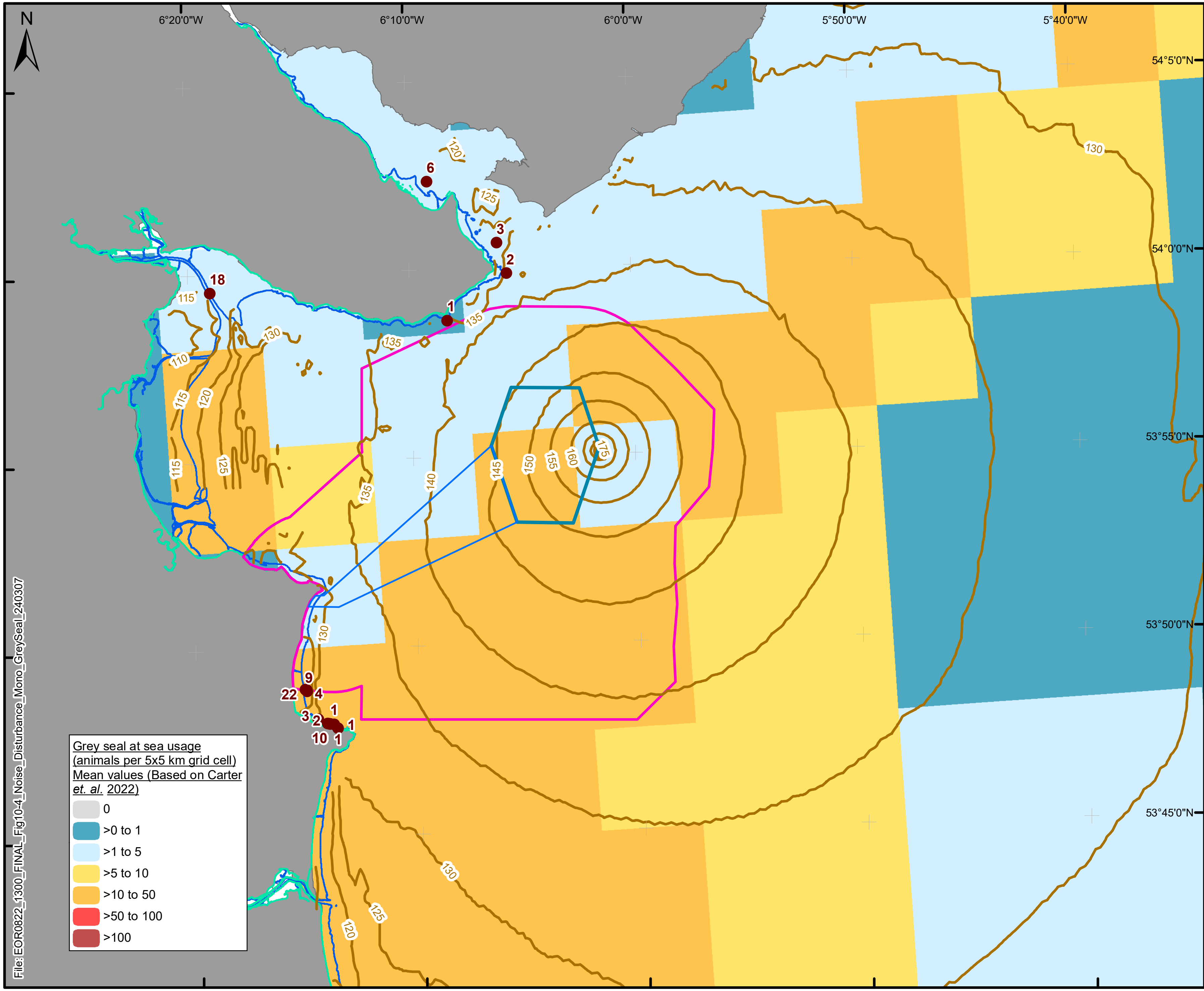
Based on a dose-response approach (derived from Whyte *et al.,* 2020) up to 21 grey seal have the potential to be disturbed by piling, representing up to 0.357% of the GSRP. Up to 16 harbour seal have the potential to be disturbed by piling, representing up to 0.979% of the HSRP (dose-response derived from Whyte *et al.,* 2020) (Table 10-30). Of these, up to 18 grey seal and 14 harbour seal have the potential to experience strong disturbance (above 160 dB re 1µ Pa (rms)) representing up to 0.300% and 0.812% of the GSRP and HSRP, respectively. Up to 33 grey seal, and 25 harbour seal have the potential to experience mild disturbance (140 – 160 dB re 1µ Pa (rms)) representing up to 0.551% and 1.491% of the GSRP and HSRP, respectively (see Table 10-30).

Mild disturbance for seals has previously been considered theoretically to occur over a larger area than strong disturbance, and therefore has the potential to affect larger numbers of each species. However, Whyte *et al.* (2020) showed for harbour seal, that beyond 25 km (below 145 dB re 1µ Pa (rms)) from the piling noise source, no significant changes in seal density were detected. Therefore, modelling has predicted that the range of effect in which strong and mild disturbance could occur is not likely to extend to haul-out sites in the vicinity of the offshore wind farm area for either grey seal (Figure 10-4) or harbour seal (Figure 10-5), regardless of whether piling occurs at the east or the west of the Project. Animals originating from these haul-out sites still have the potential to overlap with these contours but are not expected to experience severe behavioural effects. Barrier effects as a result of installation of monopiles however, could either prevent seals from travelling to forage from haul-out sites, or force seals (particularly harbour seal) to travel greater distances than is usual.

Table 10-30: Number of animals predicted to be disturbed within unweighted SEL_{ss} noise contours as a result of impact piling of monopiles at the east of the offshore wind farm area. Also shows number of animals predicted to be disturbed, calculated within unweighted SEL_{ss} noise contours, that equate to strong and mild disturbance thresholds under NMFS (2005).

Species	Density estimate (animals/km²)		MU population		All disturbance responses (5 dB contours (SEL_{ss}); Russel *et al.*, 2017)				Strong disturbance (equivalent to ≥ 160 dB re 1µ Pa (rms); NMFS, 2005)				Mild disturbance (equivalent to 140 – 160 dB re 1µ Pa (rms); NMFS, 2005			
					Number of animals		Proportion of MU population (%)		Number of animals		Proportion of MU population (%)		Number of animals		Proportion of MU population (%)	
	Average	Maximum			Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum	Average	Maximum
Harbour porpoise	0.280	1.330	62,517		153	725	0.245	1.160	14	64	0.021	0.101	445	2,111	0.711	3.376
Bottlenose dolphin	0.046	0.235*	293	8,326*	26	129	8.63%	1.549	3	12	0.751	0.134	74	374	25.133	4.482
Common dolphin	0.027	-	102,656		15	-	0.015	-	2	-	0.001	-	21	-	0.020	-
Minke whale	0.014	0.260	20,118		8	142	0.040	0.706	< 1	13	0.003	0.061	22	79	0.108	0.389
Grey seal	0.372	-	5,882		21	-	0.357	-	18	-	0.300	-	33	-	0.551	-
Harbour seal	0.280	-	1,635		16	-	0.979	-	14	-	0.812	-	25	-	1.491	-

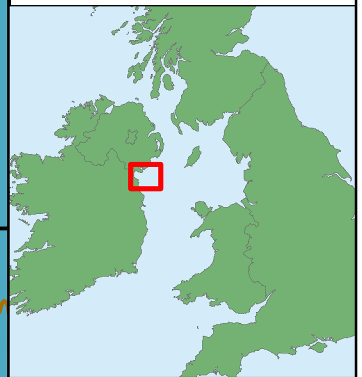
* Density generated using SCANS-IV data has been compared against a reference population estimated by summing the abundance within the Irish Sea SCANS-IV blocks



Legend

- Offshore Wind Farm Area
- Offshore Cable Corridor
- 2017/18 Grey Seal Individuals (number per haul out location)
- Noise Contour (dB re 1μ Pa (SELss))
- Marine Mammal and Megafauna Study Area
- Mean High Water
- Mean Low Water

Data Sources: Client. Marine Scotland



Client

ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

Project

Oriel Wind Farm Project

Title **Figure 10-4**
Marine mammal disturbance ranges (SELss) for monopiles at the east modelled locations overlaid on grey seal at-sea usage (animals per 5x5 km grid cell) and grey seal sightings at haul outs

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Issue Details

Drawn By: NG	**Project No.** EOR0822 (MDR1520B)
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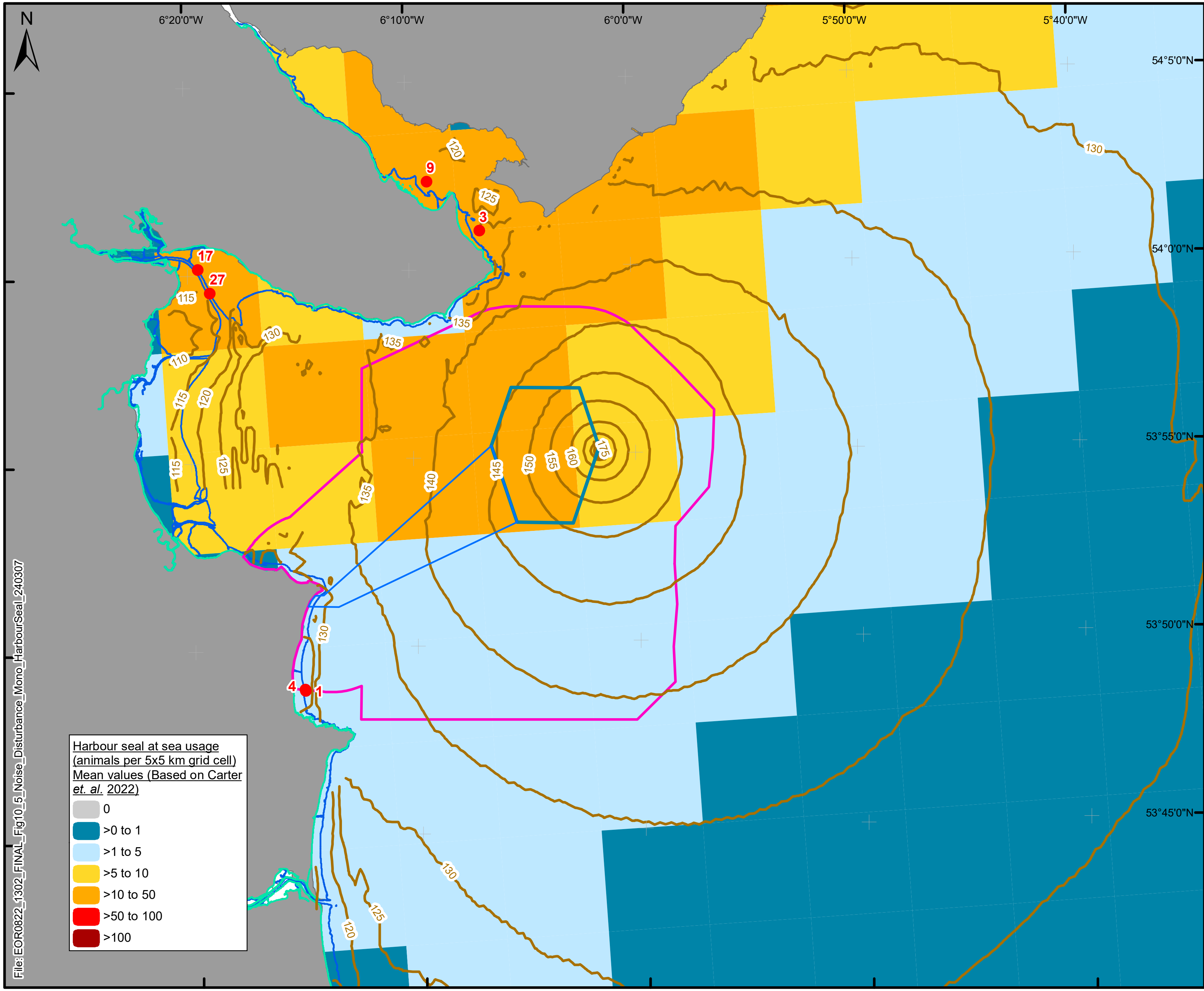
Approved By: AOS	
Scale: 1:250,000 @ A4	**Projection:** ITM (IRENET95) Geographic Co-ordinates: ETRS89
Date: 07/03/2024	



Legend

- Offshore Wind Farm Area
- Offshore Cable Corridor
- 2017/18 Harbour Seal Individuals (number per haul out location)
- Noise Contour (dB re 1µ Pa (SELss))
- Marine Mammal and Megafauna Study Area
- Mean High Water
- Mean Low Water

Data Sources: Client. Marine Scotland

Client

ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

Project

Oriel Wind Farm Project

Title Figure 10-5

Marine mammal disturbance ranges (SELss) for monopiles at the east modelled locations overlaid on harbour seal at-sea usage (animals per 5x5 km grid cell) and harbour seal sightings at haul-outs

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Issue Details

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Population modelling was carried out to investigate the potential for underwater noise associated with the installation of monopiles to affect the population trajectory over time for harbour porpoise, bottlenose dolphin, minke whale grey seal and harbour seal.

Results of the iPCoD modelling for harbour porpoise against the CIS MU showed that the median ratio of the impacted population to the unimpacted population at both 6 and 25 years was 1.0000, with 10 fewer animals at time point 3 (0.0156% of the CIS MU) and seven fewer animals at time point 26 (0.011% of the CIS MU). This means there is no significant difference between the population trajectories for an unimpacted population and impacted population (see Figure 10-6).

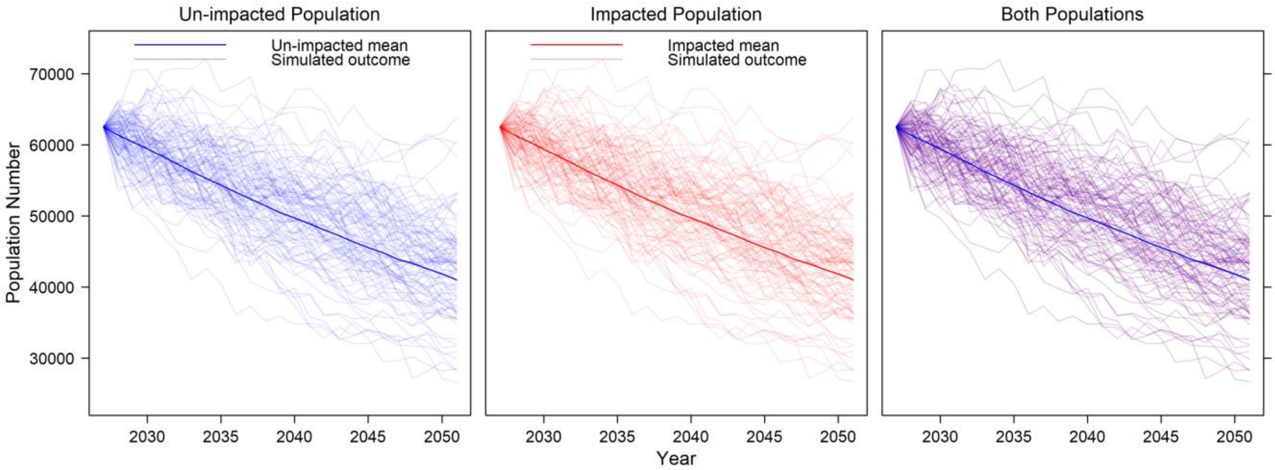

Figure 10-6: Mean simulated population trajectories of harbour porpoise for the impacted vs un-impacted population over a 25-year simulation.

Results of the iPCoD modelling for the SCANS III DSM density estimate for bottlenose dolphin compared against the IAMMWG (223) population estimate showed that the median ratio of the impacted population to the unimpacted population at both 6 and 25 years was 1.0000, with two fewer animals at time points 3 and 26 (0.682% of the population estimate) (see Figure 10-7). For the SCANS IV Block CS-D density estimate compared against the SCANS IV population estimate for the Irish Sea, results also showed that the median ratio of the impacted population to the unimpacted population at both 6 and 25 years was 1.0000. There were four fewer animals at time point three (0.048% of the population estimate) and three fewer animals at time point 26 (0.048% of the population estimate) This means there is no significant difference between the population trajectories for an unimpacted population and impacted population (see Figure 10-8).

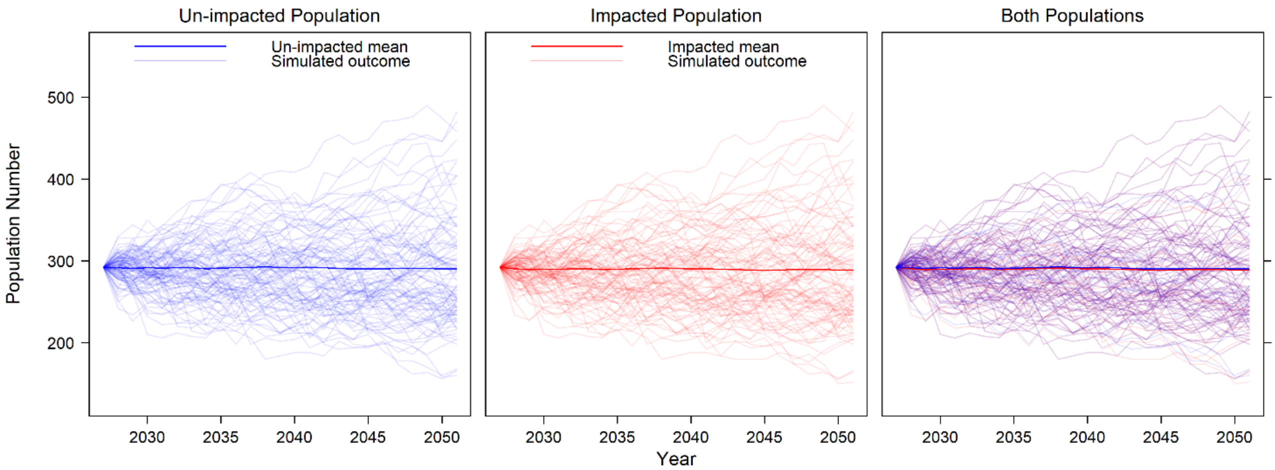

Figure 10-7: Mean simulated population trajectories of bottlenose dolphin for the impacted vs un-impacted population over a 25-year simulation (SCANS-III abundance and Irish Sea MU).

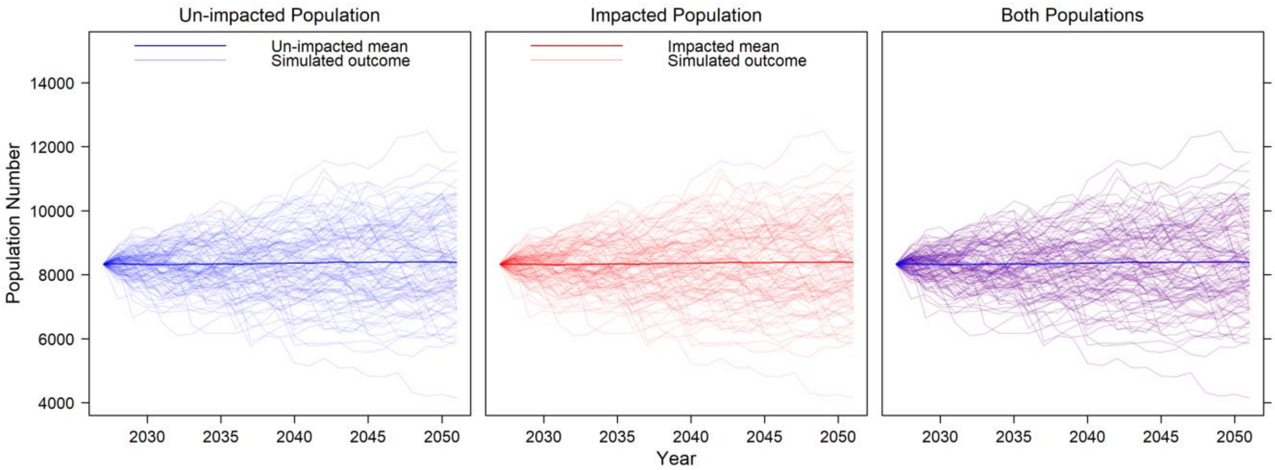

Figure 10-8: Mean simulated population trajectories of bottlenose dolphin for the impacted vs un-impacted population over a 25 year simulation (SCANS-IV abundance and combined SCANS-IV blocks within the Irish Sea).

Results of the iPCoD modelling for minke whale against the CGNS MU, grey seal against the GSRP and harbour seal against the HSRP showed negligible difference in the growth trajectory of all three species between the un-impacted populations and impacted populations and projected population values were the same at all timepoints. Both the median and the mean counterfactual was 1 through the 25-year simulation for all three species, which means there is no difference between the population trajectories for an unimpacted population and impacted population for all three species (see Figure 10-9; Figure 10-10; and Figure 10-11).

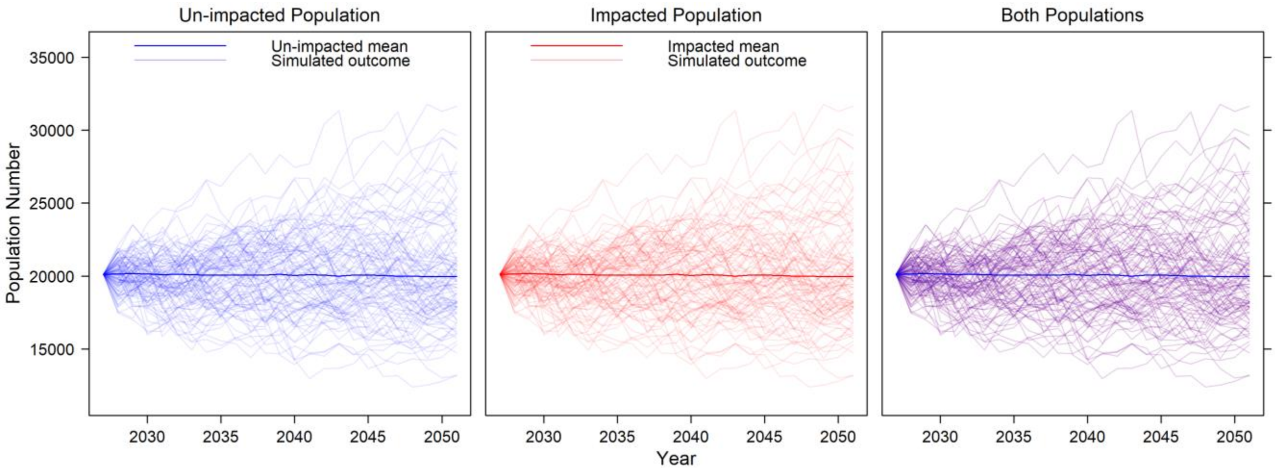

Figure 10-9: Mean simulated population trajectories of minke whale for the impacted vs un-impacted population over a 25-year simulation.

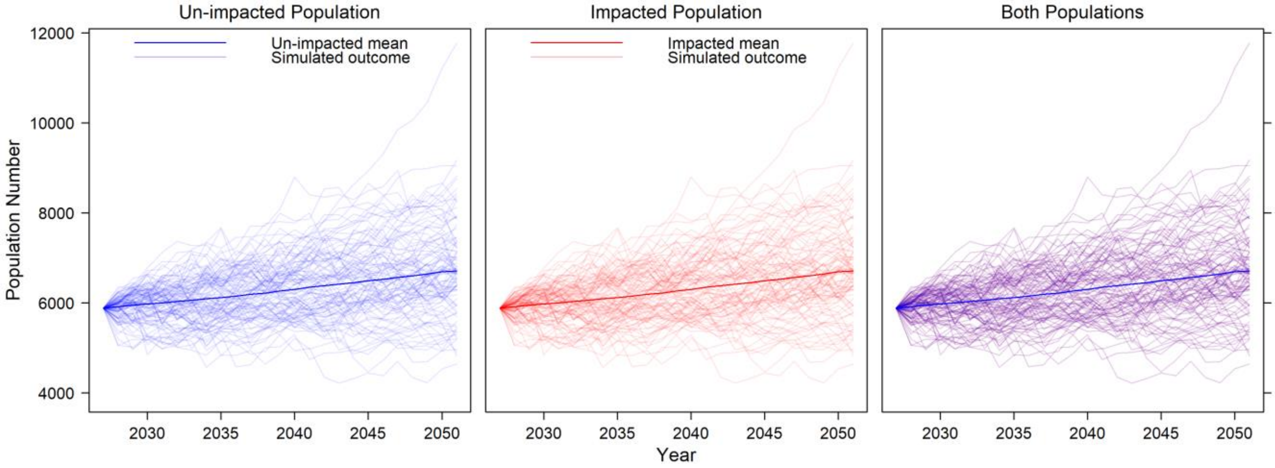

Figure 10-10: Mean simulated population trajectories of grey seal for the impacted vs un-impacted population over a 25 year simulation.

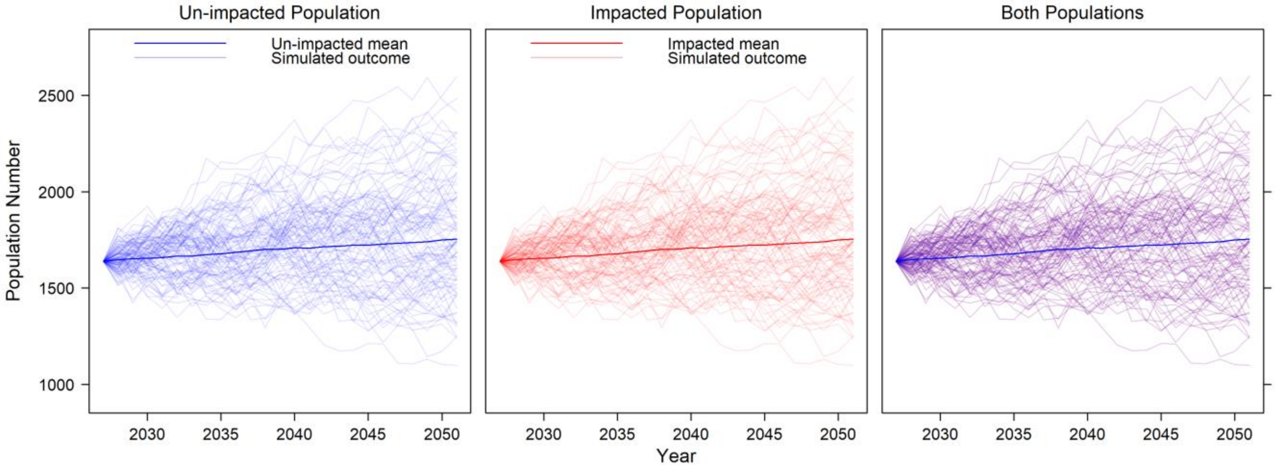

Figure 10-11: Mean simulated population trajectories of harbour seal for the impacted vs un-impacted population over a 25-year simulation.

In summary, modelling results for all species demonstrated that there may be a small reduction in population size for the impacted populations, however these changes would not be enough to significantly affect population trajectories over a generational scale (i.e. small changes in the simulated trajectories fall within the expected range of natural variation) (detailed in appendix 10-3: Marine Mammal Population Modelling Report (IPCoD)).

The impact of disturbance on marine mammals is predicted to be of regional spatial extent, as it extends beyond the boundaries of the offshore wind farm area, medium-term duration, intermittent, and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude of the impact could lead to changes to behaviour and distribution in individuals, but not at a scale that would lead to any measurable population-level effects; any shifts would be relatively small in the context of the relevant geographic frames of reference. The impact would occur during piling only, which comprises a small fraction of the construction period; the duration and frequency of the impact are such that there would be minimal disruption to reproductive cycles. The magnitude is therefore, considered to be low.

<u>Basking Shark and Leatherback Turtle IEFs</u>

Noise modelling outputs show that noise attenuation is rapid with distance from foundation location. The results also indicate that, based on a behavioural response occurring at levels in excess of 150 dB re 1 µPa (rms) (as the criterion for onset of behavioural effects; Hastings, 2002) basking shark and leatherback turtle may exhibit behavioural responses within 3-4 km of the source. These results broadly align with qualitative thresholds for behavioural effects on basking shark and leatherback turtle, as set out in Table 10-23, with moderate risk of behavioural effects in the range of 100s to 1,000s of metres from the piling activity, depending on the species. Basking shark (as an elasmobranch with no swim bladder) and leatherback turtle are likely to be at moderate risk of behavioural effects in the range of tens and hundreds of metres from the piling activity, but low risk in the range of thousands of metres.

The impact of disturbance on basking shark and leatherback turtle (IEFs of national value) is predicted to be of local spatial extent, medium-term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude of the impact could lead to changes to behaviour and distribution in individuals, but unlikely to be at a scale that would lead to any measurable population-level effects. The impact would occur during piling only, which comprises a small fraction of the construction period. Whilst it is not possible to calculate likely numbers of animals within the disturbance range, due to the qualitative nature of the criteria, based on the likely low number of animals passing through the area for the duration of the construction activities, the magnitude for basking shark and leatherback turtle is considered to be low.

Sensitivity of the receptor

Injury

Harbour Porpoise IEF

Studies of auditory injury in relation to a typical piling sequence have suggested that hearing impairment as a result of exposure to piling noise is likely to occur where the source frequencies overlap the range of peak sensitivity for the receptor species rather than across the whole frequency hearing spectrum (Kastelein *et al*., 2013). Kastelein *et al*. (2013) demonstrated experimentally that for simulated piling noise (broadband spectrum), harbour porpoise's hearing around 125 kHz (the key frequency for echolocation) was not affected. Instead, a measurable threshold shift in hearing was induced at frequencies of 4 to 8 kHz, although the magnitude of the hearing shift was relatively small (2.3 to 3.6 dB at 4 to 8 kHz) due to the lower received SELs at these frequencies. This was due to most of the energy from the simulated piling occurring in lower frequencies (Kastelein *et al*., 2013).

In addition to the frequency characteristics of the source, the duty cycle of fatiguing sounds is also likely to affect the magnitude of a hearing shift. Kastelein *et al*. (2014) suggests that hearing may recover to some extent during inter-pulse intervals. Similarly, Finneran *et al*. (2015) highlights that whilst a threshold shift can accumulate across multiple exposures, the resulting shift (in this study TTS) will be less than the shift from a single, continuous exposure with the same total SEL. Again, this suggests that the ranges predicted by the subsea noise model using the SEL_{cum} metric are likely to be overestimates.

For the purposes of assessing sensitivity to injury, there is a distinction between PTS and TTS. PTS is a permanent and irreversible hearing impairment and therefore it is expected that harbour porpoise is sensitive to this effect as the loss of hearing would affect key life functions (e.g. communication, predator detection, foraging, mating and maternal fitness) and could lead to a change in an animal's health (if chronic) or vital rates (if acute) (Erbe *et al*., 2018). Relating a potential loss in hearing to a biologically significant response is challenging due to a paucity of empirical data, however a potential consequence of a disruption in key life functions is that the health of impacted animals would deteriorate and potentially lead to reduced birth rate in females and mortality of individuals (Costa, 2012). Since PTS is irreversible, harbour porpoise is assessed as having limited resilience, limited ability to adapt behaviour to sustain ecological functioning, and limited ability to recover from the effect in the short and long term, given the potential for the impact to result in a change in both reproduction and survival rate, and international value. The sensitivity of harbour porpoise to PTS is therefore considered to be high.

TTS is a temporary and reversible hearing impairment and therefore it is anticipated that any animals experiencing this shift in hearing would recover after they are no longer exposed to elevated noise levels (i.e. they may have moved beyond the injury zone or piling has ceased). The implication of animals experiencing TTS, leading to potential displacement, is not fully understood, but it is likely that aversive responses to anthropogenic noise could temporarily affect life functions as described for PTS. However, due to the reversible nature of TTS, this is less likely to lead to acute effects and will largely depend on recoverability. The degree and speed of hearing recovery will depend on the characteristics of the sound the animal is exposed to, and on the degree of shift in hearing experienced. A study measuring recovery rates of harbour porpoise following exposure to sound source of 75 db re 1 μPa (SEL) over 120 minutes found that recovery to the pre-exposure threshold was estimated to be complete within 48 minutes following exposure (the higher the hearing threshold shift, the longer the recovery) (SEAMARCO, 2011). Scientific understanding of this is limited to the results of controlled exposure studies on small numbers of captive animals (reviewed in Finneran *et al*., 2015). Extrapolating these results to how animals may respond in the natural environment should be treated with caution as it is not possible to exactly replicate natural environmental conditions, and the small number of test subjects would not account for intraspecific differences (i.e. differences between individuals) or interspecific differences (i.e. extrapolating to other species) in response. Since TTS is reversible, harbour porpoise are assessed having high resilience to the effect with minor impairment of ecological functioning, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability, and international value. The sensitivity of harbour porpoise to TTS is therefore considered to be low.

<u>Minke Whale IEF</u>

Although very little is known about minke whale hearing, it is likely that they rely on low frequency hearing. They do not echolocate but likely use sound for communication. Due to this uncertainty and given that any effects will be irreversible (i.e. as noted for harbour porpoise above), minke whale are assessed as having limited resilience, limited ability to adapt behaviour to sustain ecological functioning, and limited ability to recover from the effect in the short and long term, given the potential for the impact to result in a change in both reproduction and survival rates, and international value. Minke whale are assessed as having a high sensitivity to PTS.

Whilst there are no available species-specific recovery rates for minke whale to TTS, there is no evidence to suggest that recovery will be significantly different to harbour porpoise recovery rates. In addition, minke whale exhibit a temporal distribution, with most sightings in continental shelf waters occurring between May and September. SCANS III surveys were carried out during summer months, and therefore density values, and subsequent predicted numbers to be affected for minke whale will be overly conservative for piling activities occurring during winter months. Given that minke whale would be able to tolerate the effect without any impact on reproduction or survival rates and would be able to return to previous behavioural states or activities once the impacts had ceased, minke whale are assessed as having high resilience to the effect with minor impairment of ecological functioning, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability, and national value. The sensitivity of minke whale to TTS has been assessed as low.

<u>Dolphin Species IEFs</u>

Individual dolphins experiencing PTS would suffer a biological effect that could impact on animals' health and vital rates (Erbe *et al*., 2018). As described for harbour porpoise (above) there are frequency-specific differences in the onset and growth of a noise-induced threshold shift in relation to the characteristics of the noise source and hearing sensitivity of the receiving species. For example, exposure of two captive bottlenose dolphin to an impulsive noise source between 3 and 80 kHz found that there was increased susceptibility to auditory fatigue between frequencies of 10 to 30 kHz (Finneran, 2013). The SEL_{cum} threshold incorporates hearing sensitivities of marine mammals and the magnitude of effects were considerably smaller compared to the very high frequency (e.g. harbour porpoise) and low frequency (e.g. minke whale) species, highlighting that high frequency species are less sensitive to the frequency components of the piling noise signal. However, given that effects are irreversible (i.e. as noted for harbour porpoise above) and in light of how important sound is for echolocation, foraging and communication in small toothed cetaceans, common dolphin and bottlenose dolphin are of high vulnerability, low recoverability and international/ national value. Bottlenose dolphin and common dolphin have been assessed as having a high sensitivity to PTS.

Again, whilst there are no available species-specific recovery rates for high frequency cetaceans to TTS, there is no evidence to suggest that recovery will be significantly different to harbour porpoise recovery rates therefore animals can recover their hearing after they are no longer exposed to elevated noise levels (i.e. they may have moved beyond the injury zone or piling has ceased). Given that both common dolphin and bottlenose dolphin would be able to tolerate the effect without any impact on reproduction or survival rates, and would be able to return to previous behavioural states or activities once the impacts had ceased, these species are assessed as having limited resilience, limited ability to adapt behaviour to sustain ecological functioning, and limited ability to recover from the effect in the short and long term, given the potential for the impact to result in a change in both reproduction and survival rates, and international/national value. The sensitivity of common dolphin and bottlenose dolphin to TTS has therefore been assessed as low.

Seal Species IEFs

Seals are less dependent on hearing for foraging than cetacean species, but may rely on sound for communication and predator avoidance (e.g. Deecke *et al*., 2002). Hastie *et al.* (2015) reported that, based on calculations of SEL of tagged harbour seal during the construction of the Lincs offshore wind farm (Greater Wash, UK), at least half of the tagged seals would have received sound levels from pile driving that exceeded auditory injury thresholds for pinnipeds (PTS). However, population estimates indicated that the relevant population trend is increasing and therefore, although there are many other ecological factors that will influence the population health, this indicated that predicted levels of PTS did not affect sufficient numbers of individuals, by a sufficient amount, to cause a decrease in the population trajectory (Hastie *et al.,* 2015). Hastie *et al.* (2015) however, noted that due to paucity of data on effects of sound on seal hearing, the exposure criteria used are intentionally conservative and therefore predicted numbers of individuals likely to be affected by PTS would also have been highly conservative. However, despite the uncertainty in the ecological effects of PTS on seals, seals rely on hearing much less than cetaceans and therefore would exhibit some tolerance (i.e. the effect is unlikely to cause a change in either reproduction or survival rates). In addition, it has been proposed that seals may be able to self-mitigate (i.e. reduce their hearing sensitivity in the presence of loud sounds in order to reduce their perceived SPL) (Kastelein *et al.,* 2018b). Seals are therefore considered to be of medium vulnerability, low recoverability and international value. Although this evidence suggests a lower sensitivity of pinnipeds to PTS, based on uncertainties a precautionary approach has been taken and the sensitivity of grey seal and harbour seal to PTS has therefore been assessed as high.

A study measuring recovery rates of harbour seal following exposure to a sound source of 193 dB re 1 μPa^{2}s (SEL_{cum}) over 360 minutes found that recovery from TTS to the pre-exposure baseline was estimated to be complete within 72 minutes following exposure (Kastelein *et al.,* 2018b). These results are similar to recovery rates found in SEAMARCO (2011), which showed that for small TTS values, recovery in seals was very fast (around 30 mins); the higher the hearing threshold shift, the longer the recovery. Therefore, in most cases, reduced hearing for such a short time probably has little effect on the total foraging period of a seal. If hearing is impaired for longer periods (hours or days) the impact is likely to be ecologically significant (SEAMARCO, 2011). The results indicate that harbour seal (and therefore grey seal, using harbour seal as a proxy) are less vulnerable to TTS than harbour porpoise for the noise bands tested. In addition, it is expected that animals would move beyond the injury range prior to the onset of TTS. Given that both grey seal and harbour seal are likely to be able to tolerate the effect without any impact on both reproduction and survival rates and would be able to return to previous behavioural states or activities once the impacts had ceased, seals are assessed as having limited resilience, limited ability to adapt behaviour to sustain ecological functioning, and limited ability to recover from the effect in the short and long term, given the potential for the impact to result in a change in both reproduction and survival rates, and international value. The sensitivity of grey seal and harbour seal to TTS has been assessed as low.

Cetacean and Pinniped Summary

In summary, for PTS, in all cetaceans (nationally or internationally important IEFs), based on their reliance on hearing for survival, the sensitivity has been assessed as having limited resilience, limited ability to adapt behaviour to sustain ecological functioning, limited ability to recover from the effect in the short and long term, given the potential for the impact to result in a change in both reproduction and survival rates. All cetaceans are national or international value. The sensitivity of cetaceans to PTS is therefore, considered to be high.

Despite the uncertainty in the ecological effects of PTS, seals rely on hearing much less than cetaceans and therefore would exhibit some tolerance to the effect. Therefore, seals are assessed as having some resilience to the effect, an ability to adapt behaviour to a level where ecological functioning can be sustained to allow individual survival, and an ability for the animal to recover from the effect. Seals are assessed as international value. However, as a precautionary measure the sensitivity of seals to PTS is considered to be high.

In all marine mammal species, based on recovery rates, and the likely ability of all receptors to tolerate the effect of TTS without any impact on reproduction or survival rates, all species are ssessed as having high resilience to the effect with minor impairment of ecological functioning, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability, All cetaceans are national to international value. The sensitivity to TTS has therefore, conservatively, been assessed as low.

Basking Shark and Leatherback Turtle IEFs

Basking shark and leatherback turtle are known to migrate through the Regional Marine Megafauna Study Area during summer months and therefore have the potential to be within the range of noise impacts as a result of piling.

The MarLIN sensitivity review for basking shark highlighted that there is no direct evidence of sounds causing basking shark mortality or stress, but the behaviour of other sharks is known to be altered by sound (MarLIN, 2019). It is anticipated that high levels of anthropogenic noise could cause TTS and (more likely) barotrauma in basking shark as a result of impulsive energy produced in activities such as pile driving (Halvorsen *et al.,* in Casper *et al.,* 2012). Noise impacts as a result of piling have the potential to cause tissue damage and could be lethal to sea turtles, including leatherback turtle (Nelms *et al.,* 2016). Startle responses observed in sharks and sea turtles, such as increased swim speeds and altered dive durations, may also lead to physical damage and mortality as a result of decompression sickness and strandings (Gordon *et al*., 2003; Wright *et al*., 2007; Mann *et al*., 2010; Jepson *et al*., 2013). Although both species use sound for predator avoidance (Chapuis *et al.,* 2019; Piniak *et al.,* 2016), reliance on hearing for survival and reproduction is expected to be lower than in cetaceans and therefore animals would exhibit some tolerance (i.e. the effect is unlikely to cause a change in either reproduction or survival rates). Basking shark and leatherback turtle are deemed to be of medium resilience, low adaptability and low recoverability, and national value; the sensitivity of these species to PTS has therefore been assessed, conservatively, as high.

Whilst recovery rates from impairment (recoverable injury) for basking shark and leatherback turtle are unknown, it is expected that individuals of both species would move beyond the injury range prior to the onset of impairment. Given that both species are likely to be able to tolerate the effect without any impact on reproduction or survival rates and would be able to return to previous behavioural states or activities once the impacts had ceased, basking shark and leatherback turtle are assessed as having medium resilience, high adaptability and high recoverability, and national value. The sensitivity of basking shark and leatherback turtle to recoverable injury has therefore been assessed as low.

Disturbance

Studies have shown that acoustic disturbance from seismic survey activities may lead to the interruption of normal behaviours (such as feeding or breeding) and avoidance, leading to displacement from the area and exclusion from critical habitats (Goold, 2009; Weller *et al*., 2002; Castellote *et al*., 2010, 2012). Noise may also cause stress which in turn can lead to a depressed immune function and reduced reproductive success (Anderson *et al.,* 2011; DeSoto *et al.,* 2013).

Harbour Porpoise IEF

For the project design parameters (installation of monopiles), whilst the ranges for disturbance for all marine mammals are equal, densities within the Regional Marine Megafauna Study Area vary significantly between species. Harbour porpoise, as a species, is particularly vulnerable to disturbance, as individual harbour porpoise needs to forage frequently due to their high metabolic rate. The variance in behavioural responses to increased subsea noise is well documented and is context specific with factors such as the activity state of the receiving animal, nature and novelty of the sound (i.e. previous exposure history), and spatial relation between sound source and receiving animal being important in determining the likelihood of a behavioural response and therefore their sensitivity (Ellison *et al.*, 2012). A recent study on piling at the Beatrice Offshore Wind Farm suggests that harbour porpoise may adapt to increased noise disturbance over the course of the piling phase, thereby showing a degree of tolerance and behavioural adaptation (Graham *et al.,* 2019; see Figure 10-2:).

A recent article by Southall *et al.* (2021) introduces a behavioural response severity spectrum, building on earlier work presented in Southall *et al.* (2007) and the expanding literature in this area. Southall *et al.* (2021) illustrates the progressive severity of possible responses within three response categories: survival (e.g. resting, navigation, defence), feeding (e.g. search, consumption, energetics), and reproduction (e.g. mating, parenting). For example, at the most severe end of the spectrum (scored 7 to 9), where sensitivity is highest, displacement could occur resulting in movement of animals to areas with an increased risk of predation and/or with sub-optimal feeding grounds. A failure of vocal mechanisms to compensate for noise and interruption of key reproductive behaviour including mating and socialising could occur. In these instances, there would likely be a reduction in an individual's fitness leading to potential breeding failure and impact on survival rates. Acknowledging the limitations of the single step-threshold approach for strong disturbance and mild disturbance (i.e. Does not account for inter-, or intra-specific variance or context-based variance), harbour porpoise within the area modelled as 'strong disturbance' would be most sensitive to behavioural effects and therefore may have a response score of 7 or above according to Southall *et al.* (2021). At the lower end of the behavioural response spectrum the potential severity of effects reduces and whilst there may be some detectable responses that could result in effects on the short-term health of animals, these are less likely to impact on an animals' survival rate. For example, mild disturbance could lead to effects such as changes in swimming speed and direction, minor disruptions in communication, interruptions in foraging, or disruption of parental attendance/nursing behaviour (Southall *et al.*, 2021).

Although harbour porpoise may be able to avoid the disturbed area and forage elsewhere, there may be a potential effect on reproductive success of some individuals. As mentioned previously, it is anticipated that there would be some adaptability to the elevated noise levels from piling and therefore survival rates are not likely to be affected. Due to the uncertainties associated with the effects of behavioural disturbance on vital rates, harbour porpoise is deemed to be of medium resilience, high adaptability and high recoverability, and international value. Therefore, the sensitivity of harbour porpoise to disturbance has, conservatively, been assessed as medium for both strong and mild disturbance noting that for the latter the sensitivity is likely to be lower.

<u>Other Cetaceans IEFs</u>

Common dolphin, minke whale and bottlenose dolphin are not thought to be as vulnerable to disturbance as harbour porpoise, as foraging requirements are less frequent. Common dolphin and minke whale, in particular, are wide-ranging and viable high-quality foraging habitat exists outside of the Marine Megafauna Study Area. In addition the occurrence of minke whale within the study area was very seasonal, with animals observed during late summer/early autumn only. Bottlenose dolphin likely to be foraging in the area form part of the Irish Sea MU, which is far smaller, and therefore any effect on the individual is more likely to have an impact at the population level.

There is scant information regarding the specific sensitivities of these species to disturbance from piling noise. The Southall *et al*. (2021) severity spectrum applies across all marine mammals and therefore it is expected that, as described for harbour porpoise, strong disturbance could result in displacement whilst mild disturbance would result in other, less severe behavioural responses.

Common dolphin, minke whale and bottlenose dolphin could tolerate the effects of disturbance and whilst there may some impacts on reproduction in the area of 'strong disturbance' there is not likely to be an impact on survival rates with some tolerance built up over the course of the piling. It is anticipated that animals would return to previous activities once the impact had ceased. Common dolphin and minke whale are deemed to be of medium resilience, high adaptability and high recoverability, and national value. Bottlenose dolphin are deemed to be of medium resilience, high adaptability and high recoverability, and international value. The sensitivity of all three receptors to disturbance has therefore been assessed as medium.

<u>Seal Species IEFs</u>

Strong disturbance could result in displacement of seals from an area. Mild disturbance constitutes only slight changes in behaviour, such as changes in swimming speed or direction, and is unlikely to result in population-level effects. Although there is likely to be alternative foraging sites for both harbour seal and grey seal, barrier effects as a result of installation of monopiles could either prevent seals from travelling to forage from haul-out sites (Figure 10-4 and Figure 10-5) or force seals (particularly harbour seal) to travel greater distances than is usual.

As can be seen by SMRU at-sea usage maps for harbour seal (Figure 10-5), the offshore wind farm area appears to overlap with an area of relatively high usage for harbour seal within the Marine Megafauna Study Area, which is likely to consist of important foraging grounds for seals originating from haul-out sites at the mouth of Carlingford Lough, Dundalk bay and Clogherhead. Harbour seal may be disturbed/displaced within their usual foraging habitat during periods of piling. This could have a particular impact during lactating periods (June to August), when female harbour seal spend much of their time in the water with their pups, and foraging is more restricted than during other periods (Thompson and Härkönen, 2008). Consequences could include reduced fecundity, reduced fitness, and reduced reproductive success. Although harbour seal may be able to avoid the disturbed area and forage elsewhere, there will be an energetic cost to having to move greater distances to find food, and therefore there may be a potential effect on reproductive success of some individuals. Harbour seal is deemed to be of medium resilience, high adaptability and high recoverability, and international value. The sensitivity of harbour seal to disturbance has therefore been assessed as medium.

As can be seen in Figure 10-4, grey seal appear to have a wider at-sea usage within the Marine Megafauna Study Area, and based on their likely foraging ranges (up to 100 km from a haul-out site) may be better adapted than harbour seal to seeking alternative foraging habitat; although notably there will still be an energetic cost of having to move greater distances to find food. Strong disturbance will be temporary, and behaviour is expected to resume to baseline levels outside of the periods of piling. It is expected that grey seal will exhibit some tolerance to disturbance and the effect is unlikely to cause a change in either reproduction or survival rates. Grey seal is deemed to be of medium resilience, high adaptability and high recoverability, and international value. The sensitivity of grey seal to disturbance has therefore been assessed as medium.

<u>Basking Shark and Leatherback Turtle IEFs</u>

A number of studies have examined the behavioural effects of the sound pressure component of impulsive noise (including piling operations and seismic airgun surveys) on fish species. Mueller-Blenkle *et al*. (2010) reported an observable behavioural response at 140 to 161 dB re 1 µPa SPL_{pk} for cod and 144 to 156 dB re 1 µPa SPL_{pk} for sole. Pearson *et al*. (1992) observed a startle or “C-turn response” at peak pressure levels beginning around 200 dB re 1 µPa, although this was less common with the larger fish. McCauley *et al*. (2000) reported a general fish behavioural response to move to the bottom of the cage during periods of high level exposure (greater than rms levels of around 156 to 161 dB re 1 µPa; approximately equivalent to SPL_{pk} levels of around 168 to 173 dB re 1 µPa). Noise modelling results (appendix 10-2: Subsea Noise Technical Report) show that the installation of monopiles (project design parameter (spatial)) at the east of the offshore wind farm area would result in noise levels of 140 dB re µ1 Pa occurring up to 10 km from the sound source. Therefore, based on the information presented in Mueller-Blenkle *et al*. (2010), Pearson *et al*. (1992) and McCauley *et al*. (2000), beyond a range of 10 km, there is a low risk of the above behavioural effects being exhibited by basking shark. The above studies align with the criteria for onset of behavioural effects for fish and sea turtle which states that at ‘far’ distances from the sound source (thousands of metres) there is likely a low risk of onset of behavioural effects from impulsive piling and at ‘intermediate’ distances there is likely a moderate risk of onset of behavioural effects from impulsive piling (Table 10-23). Very limited data exists on sea turtle behavioural responses to noise, therefore the data presented for fish has been used as a proxy.

Basking shark and leatherback turtle are known to migrate through the Regional Marine Megafauna Study Area during summer months and therefore this is considered to be the most sensitive time of year. Piling activities are, however, unlikely to result in barrier effects to migration for these receptors; as stated above disturbance ranges will likely constitute a small area in the context of the wider available habitat in the Irish Sea. Whilst basking shark may opportunistically feed during their migratory movements in summer months, there is no published information to suggest that particular areas within the Regional Marine Megafauna Study Area are important foraging grounds where basking shark may aggregate to feed. In addition, as filter feeders, basking shark do not rely on sound to locate ‘struggling’ prey as with other non-filter feeding shark species (e.g. blue shark or porbeagle) (MarLIN, 2019), therefore any noise impacts are unlikely to impact on the fitness of basking shark at the individual or population level. Manx waters, northeast of the Marine Megafauna Study Area, may constitute important mating habitat for basking shark (Bloomfield and Solandt, 2008; Howe, 2018) however disturbance ranges do not extend this far, and therefore reproduction is unlikely to be affected by piling in the offshore wind farm area. Beaches of the UK and Ireland do not host nesting grounds for leatherback turtle and therefore their sensitivity to disturbance in this respect will be low. Offshore waters of the Irish Sea could potentially host important feeding grounds for sea turtles (NPWS, 2019), but as stated previously, the area disturbed during piling will likely constitute a very small proportion of available habitat in the context of the wider region. It is expected that both basking shark and leatherback turtle could tolerate the effects of disturbance without any impact on reproduction and survival rates and would return to previous activities once the impact had ceased. Basking shark and leatherback turtle are deemed to be of high resilience, high adaptability and high recoverability, and national value. The sensitivity of basking shark and leatherback turtle to disturbance has therefore been assessed as low.

Significance of the effect

Overall, the significance of the effect of injury and/or disturbance to marine megafauna from underwater noise during piling is presented in Table 10-31. All variants of the impact are predicted to be of **imperceptible or slight adverse significance**, which is not significant in EIA terms.

Table 10-31: Significance of the effect to IEFs as a result of injury and/or disturbance from underwater noise during pile-driving including measures included in the Project (soft start and MMMP).

IEF	Injury							Disturbance			
	Magnitude		Sensitivity		Significance of the effect		Significant / Not significant	Magnitude	Sensitivity	Significance of the effect	Significant / Not significant
	PTS	TTS / Recoverable injury	PTS	TTS / Recoverable injury	PTS	TTS / Recoverable injury					
Harbour porpoise	Low	Medium	High	Low	**Slight adverse**	**Slight adverse**	**Not significant**	Low	Medium	**Slight adverse**	**Not significant**
Bottlenose dolphin	Low	Medium	High	Low	**Slight adverse**	**Slight adverse**	**Not significant**	Low	Medium	**Slight adverse**	**Not significant**
Common dolphin	Low	Medium	High	Low	**Slight adverse**	**Slight adverse**	**Not significant**	Low	Medium	**Slight adverse**	**Not significant**
Minke whale	Low	Medium	High	Low	**Slight adverse**	**Slight adverse**	**Not significant**	Low	Medium	**Slight adverse**	**Not significant**
Grey seal	Low	Medium	High	Low	**Slight adverse**	**Slight adverse**	**Not significant**	Low	Medium	**Slight adverse**	**Not significant**
Harbour seal	Low	Medium	High	Low	**Slight adverse**	**Slight adverse**	**Not significant**	Low	Medium	**Slight adverse**	**Not significant**
Basking shark	Negligible	Negligible	High	Low	**Slight adverse**	**Slight adverse**	**Not significant**	Low	Low	**Imperceptible**	**Not significant**
Leatherback turtle	Negligible	Negligible	High	Low	**Slight adverse**	**Slight adverse**	**Not significant**	Low	Low	**Imperceptible**	**Not significant**

Mitigation and residual effect

A number of measures have been included in the Project and are described in Table 10-12, including a soft start to piling and the implementation of an MMMP. The significance of the effect associated with implementation of these measures has been described in the preceding text.

Mitigation will also be applied by use of an ADD. Originally developed for use in aquaculture, ADDs have been commonly used in marine mammal mitigation at UK offshore wind farms to deter animals from injury zones prior to the start of piling and the JNCC (2010) draft guidance for piling mitigation recommends their use, particularly in respect of periods of low visibility or at night to allow 24 hour working. With a number of research projects on ADDs commissioned via the Offshore Renewables Joint Industry Programme (ORJIP), the use of ADDs for mitigation at offshore wind farms has gained momentum. Indeed, for the Beatrice Offshore Wind Farm, the use of ADDs was accepted by the regulators (Marine Scotland) as the only mitigation tool to be applied pre-piling as it was thought to be more effective at reducing the potential for injury to marine mammals compared to standard mitigation (MMOs and PAM) which have limitations with respect to effective detection over distance (Parsons *et al*., 2009; Wright and Cosentino, 2015).

There are a number of different ADDs on the market with different sound source characteristics (see McGarry *et al*., 2020) and a suitable device will be selected based on the key species requiring mitigation for the Project. The selected device will typically be deployed from the piling vessel and activated for a pre-determined duration to allow animals sufficient time to move away from the sound source whilst also minimising the additional noise introduced into the marine environment. The type of ADD and approach to mitigation (including activation time and procedure) will be discussed and agreed with relevant stakeholders prior to construction.

Noise modelling was carried out for the SEL_{cum} metric to determine the potential efficacy of using this device to deter marine mammals from the injury zone (see appendix 10-2: Subsea Noise Technical Report). The modelled scenario included the activation of an ADD for a period of 15 minutes prior to initiation of piling and was compared to the scenario with the implementation of the measures included in the Project (designed-in and management measures) only (i.e. initiation + soft start + ramp up) to determine whether deployment of an ADD was of potential benefit to reducing the risk of injury to marine mammals (Table 10-32). There is no evidence for the effectiveness of ADDs as a tool to deter basking shark and sea turtle and therefore this was not considered in the modelling approach for these species.

Table 10-32: Project design parameters modelled for a single monopile.

Pile type	Locations	Threshold	Parameter modelled	
			Parameter	Description
Monopile	East and west of the offshore wind farm area	Weighted SEL_{cum} Ramp up during single pile installation (maximum 5 hours duration)	Initiation Soft start Ramp up Standard operation Full power	1 min @ 525 kJ 20 min @ 525 kJ 9 min @ 525 to 2,500 kJ 150 min @ 2,500 kJ 120 min @ 3,500 kJ
		Unweighted SPL_{pk} Ramp up during single pile installation (maximum 5 hours duration)	Initiation Soft start Ramp up Standard operation Full power	1 min @ 525 kJ 20 min @ 525 kJ 9 min @ 525 to 2,500 kJ 150 min @ 2,500 kJ 120 min @ 3,500 kJ

The results suggest that the use of an ADD will further reduce the risk of injury occurring in marine mammal receptors. For example, based on the SEL_{cum} metric, with an ADD deployed and activated the thresholds for PTS are not exceeded in any species as animals would flee beyond the injury zones prior to the start of piling (Table 10-40 and Table 10-41). Over a duration of 15 minutes activation and based on a conservative swim speed of 1.5 m/s (Otani *et al.,* 2000) a marine mammal would be able to move a distance of 1,350 m. Several studies provide empirical evidence for deterrence over these distances particularly for harbour porpoise (e.g. Dahne *et al.,* 2017; Geelhoed *et al.,* 2017; Brandt *et al.,* 2012) and seal species (e.g. Gordon *et al.,* 2019; Gordon *et al.,* 2015; ABPmer, 2014). It is therefore anticipated that animals would be beyond the maximum injury zone predicted using the SPL_{pk} metric at soft start initiation (i.e. up to 236 m). Several studies provide evidence that ADDs deter different marine mammals over several hundreds of metres or indeed up to several kilometres from the source in a small number of cases (reviewed in McGarry *et al*., 2020). In particular, minke whale, in which modelled SEL_{cum} injury ranges were greatest (Table 10-33) have been shown to make directed movements and increase their net swim speed at distances of greater than one kilometre from an ADD (Boisseau *et al.,* 2021).

The use of an ADD will also reduce the risk of TTS occurring in marine mammals. With an ADD deployed the range at which the SEL_{cum} threshold for TTS will be reduced to 5,980 m for minke whale, 4,620 m for harbour porpoise and for high frequency cetaceans and pinnipeds the TTS thresholds would not be exceeded (Table 10-33 and Table 10-34). As discussed previously, for TTS these ranges are likely to be unrealistic overestimates, however, the subsea noise modelling does illustrate that the use of an ADD can be used to reduce the risk of a temporary auditory impairment.

Table 10-33: Summary of the SEL_{cum} injury ranges for marine mammals due to piling of single monopile at the east of the offshore wind farm area with measures included in the Project and mitigation (ADD) (N/E = threshold not exceeded).

Species / Group	Threshold (Weighted SEL_{cum})	Range (m)	
		Measures included in the Project	Measures included in the Project + mitigation (ADD)
LF	PTS – 183 dB re 1 µPa²s	394	N/E
	TTS – 168 dB re 1 µPa²s	8,060	5,980
HF	PTS – 185 dB re 1 µPa²s	N/E	N/E
	TTS – 170 dB re 1 µPa²s	12	N/E
VHF	PTS – 155 dB re 1 µPa²s	168	N/E
	TTS – 140 dB re 1 µPa²s	5,980	4,620
PW	PTS – 185 dB re 1 µPa²s	19	N/E
	TTS – 170 dB re 1 µPa²s	1,330	N/E

Magnitude of impact

Since deployment of an ADD means that the PTS threshold would not be exceeded there would be no animals potentially exposed to noise levels that could cause PTS. Thus, the magnitude of the impact due to PTS is considered to be negligible.

Similarly, TTS would not be experienced in common dolphin or bottlenose dolphin (as high frequency cetaceans), nor in the pinnipeds harbour seal and grey seal. The number of animals affected by TTS would be reduced for harbour porpoise and minke whale with the use of an ADD. With an ADD activated, between 19 and 90 harbour porpoise may be exposed to noise levels that induce TTS compared to 32 – 149 without the use of an ADD (Table 10-34). Between 2 and 30 minke whale may experience TTS with an ADD activated compared to 3 – 54 without an ADD (Table 10-34). The magnitude of the impact of TTS for high frequency cetaceans and pinnipeds would be negligible, whilst for very high frequency cetaceans and low frequency cetaceans the residual magnitude is, conservatively, assessed as medium.

Sensitivity of the receptor

The sensitivity of a species to PTS, however, remains as described previously and therefore for all marine mammals, sensitivity to PTS has been assessed as high vulnerability (cetaceans) / medium vulnerability (pinnipeds), low recoverability and international value. The sensitivity is therefore considered to be high. Similarly, sensitivity to TTS is as described previously and has been assessed as deemed to be of medium vulnerability, high recoverability and national to international value. The sensitivity to TTS has therefore, conservatively, been assessed as low.

Table 10-34: Number of animals potentially affected by PTS (auditory injury) and TTS arising from impact piling at the east of the offshore wind farm area based on SEL injury ranges (soft start and soft start + mitigation (ADD)) (N/E = threshold not exceeded).

Species	Threshold (Weighted) SEL_{cum}	Measures applied	Density estimate (animals/km²)	MU population	Range (m)	Area of sea within zone of injury (km²)	Number animals within zone of injury	Proportion of MU population (%)
Harbour porpoise	PTS – 155 dB re 1 µPa²s	Soft start	0.280 – 1.330	62,517	168	0.09	< 1	3.97×10^{-5} – 0.0002
	TTS – 140 dB re 1 µPa²s				5,980	112.29	32 – 150	0.050 – 0.239
	PTS – 155 dB re 1 µPa²s	Soft start + ADD			N/E	N/A	N/A	N/A
	TTS – 140 dB re 1 µPa²s				4,620	67.02	19 – 90	0.030 – 0.143
Bottlenose dolphin	PTS – 185 dB re 1 µPa²s	Soft start	0.046 0.235*	293 8,326*	*N/E*	N/A	N/A	N/A
	TTS – 170 dB re 1 µPa²s				12	0.0005	< 1	7.10×10^{-6} 1.28×10^{-6}
	PTS – 185 dB re 1 µPa²s	Soft start + ADD			*N/E*	N/A	N/A	N/A
	TTS – 170 dB re 1 µPa²s				*N/E*	N/A	N/A	N/A
Common dolphin	PTS – 185 dB re 1 µPa²s	Soft start	0.027	102,656	*N/E*	N/A	N/A	N/A
	TTS – 170 dB re 1 µPa²s				12	0.0005	< 1	1.199×10^{-8}
	PTS – 185 dB re 1 µPa²s	Soft start + ADD			*N/E*	N/A	N/A	N/A
	TTS – 170 dB re 1 µPa²s				*N/E*	N/A	N/A	N/A
Minke whale	PTS – 183 dB re 1 µPa²s	Soft start	0.014 – 0.26	20,118	394	0.49	< 1	3.39×10^{-5} – 0.0006
	TTS – 168 dB re 1 µPa²s				8,060	203.99	3– 54	0.014 – 0.264
	PTS – 183 dB re 1 µPa²s	Soft start + ADD			*N/E*	N/A	N/A	N/A
	TTS – 168 dB re 1 µPa²s				5,980	112.34	2 – 30	0.008 – 0.145
Grey seal	PTS – 185 dB re 1 µPa²s	Soft start	0.327	5,882	19	0.001	< 1	6.30×10^{-6}
	TTS – 170 dB re 1 µPa²s				1,330	5.55	2	0.031
	PTS – 185 dB re 1 µPa²s	Soft start + ADD			*N/E*	N/A	N/A	N/A
	TTS – 170 dB re 1 µPa²s				*N/E*	N/A	N/A	N/A
Harbour seal	PTS – 185 dB re 1 µPa²s	Soft start	0.280	1,635	19	0.001	< 1	1.24×10^{-5}
	TTS – 170 dB re 1 µPa²s				1,330	5.55	2	0.095
	PTS – 185 dB re 1 µPa²s	Soft start + ADD			*N/E*	N/A	N/A	N/A
	TTS – 170 dB re 1 µPa²s				*N/E*	N/A	N/A	N/A

* Density generated using SCANS-IV data has been compared against a reference population estimated by summing the abundance within the Irish Sea SCANS-IV blocks

Significance of the residual effect

With an ADD activated prior to soft start the residual magnitude of the impact of subsea noise from piling leading to PTS is considered to be negligible and the sensitivity of marine mammal IEFs is considered to be high. The significance of the effect of PTS is therefore assessed as **slight adverse significance**, which is not significant in EIA terms (Table 10-35).

With an ADD activated prior to soft start the magnitude of the impact of TTS for high frequency cetaceans and pinnipeds would be negligible, whilst for very high frequency cetaceans and low frequency cetaceans the residual magnitude is, conservatively, assessed as medium. The sensitivity of all marine mammals IEFs is considered to be low. The significance of the effect of TTS is therefore assessed as **imperceptible adverse significance** (bottlenose dolphin, common dolphin, harbour seal and grey seal) or **slight adverse significance** (harbour porpoise and minke whale), which is not significant in EIA terms (Table 10-39).

With an ADD activated prior to soft start there is no change to the significance of disturbance from piling on marine mammals. For the ADD itself, the magnitude of disturbance is assessed as low and the sensitivity of all marine mammals is considered to be low. The significance of the effect of disturbance resulting from the ADD is therefore **imperceptible adverse significance** and not significant in EIA terms (Table 10-39).

Impact of use of ADD on Marine Mammals

It is also important to highlight the potential magnitude of effect and sensitivity of marine mammals to the ADD itself. Whilst ADDs deployed for such short durations are unlikely to lead to injury there may be some trade-off with an increase in disturbance during the period of activation. Depending on the device employed, ADDs may elicit a strong behavioural response and lead to displacement over potentially large ranges (up to a kilometre or more) for periods of time longer than the activation of the device itself. For example, a Lofitech ADD deployed for 15 minutes pre-piling led to a minimum return time of two hours within 1 km of the deployment location (Thompson *et al*., 2020). Whilst this is useful for reducing the risk of injury to marine mammals (because animals may stay out of the injury zone for sufficient lengths of time) there needs to be a balance to ensure that ADD do not lead to significant additional disturbance themselves. This can be achieved by optimising both ADD source signals and deployment schedules (Thompson *et al.*, 2020). Since the effect of ADDs on marine mammals is likely to be a short-term disturbance response over a relatively localised area (within a maximum of few kilometres) and animals are likely to quickly recover to baseline levels (within a few hours) the magnitude of disturbance is considered to be low for all species and all marine mammals IEFs are considered to be of low vulnerability, high recoverability and international value.

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Table 10-35: Significance of the effect to IEFs as a result of injury and/or disturbance from underwater noise during pile-driving with measures included in the Project (MMMP and soft start) plus an ADD.

IEF	Injury							Disturbance			
	Magnitude		Sensitivity		Significance of the effect		Significant / Not significant	Magnitude	Sensitivity	Significance of the effect	Significant / Not significant
	PTS	TTS / Recoverable injury	PTS	TTS / Recoverable injury	PTS	TTS / Recoverable injury					
Harbour porpoise	Negligible	Medium	High	Low	Slight adverse	Slight adverse	Not significant	Low	Medium	Slight adverse	Not significant
Bottlenose dolphin	Negligible	Negligible	High	Low	Slight adverse	Imperceptible	Not significant	Low	Medium	Slight adverse	Not significant
Common dolphin	Negligible	Negligible	High	Low	Slight adverse	Imperceptible	Not significant	Low	Medium	Slight adverse	Not significant
Minke whale	Negligible	Medium	High	Low	Slight adverse	Slight adverse	Not significant	Low	Medium	Slight adverse	Not significant
Grey seal	Negligible	Negligible	High	Low	Slight adverse	Imperceptible	Not significant	Low	Medium	Slight adverse	Not significant
Harbour seal	Negligible	Negligible	High	Low	Slight adverse	Imperceptible	Not significant	Low	Medium	Slight adverse	Not significant
Basking shark	Negligible	Negligible	High	Low	Slight adverse	Imperceptible	Not significant	Low	Low	Imperceptible	Not significant
Leatherback turtle	Negligible	Negligible	High	Low	Slight adverse	Imperceptible	Not significant	Low	Low	Imperceptible	Not significant

10.10.2 Injury and/or disturbance to marine megafauna from elevated underwater noise during routine geophysical surveys

Routine geophysical surveys are planned to allow inspection of offshore infrastructure foundations, inter-array cables and offshore cable corridor during the operational and maintenance phase, and these have the potential to cause direct or indirect effects (including injury or disturbance) on marine mammal IEFs. An underwater noise modelling assessment has been carried out to investigate the potential for injurious and behavioural effects on marine mammals as a result of geophysical surveys using the latest criteria (appendix 10-2: Subsea Noise Technical Report), which is drawn upon in the assessment below. Noise modelling has been undertaken only for MBES surveying methods and did not consider non-impulsive sources to be a key potential impact for basking shark and sea turtles, which were subsequently screened out.

Underwater noise modelling for geophysical surveys has been undertaken based upon the likely parameters of the equipment expected to be employed. Here, the Kongsberg EM710 MBES unit has been modelled operating at 105 kHz, 231 dB re 1μPa re 1 m (rms) (see Table 10-36 below), although this equipment can typically work at a range of signal frequencies, depending on the distance to the seabed and the required resolution. For sonar-like sources the signal is highly directional, acting like a beam, and is emitted in pulses. Sonar-based sources are considered as continuous (non-impulsive) because they generally comprise a single (or multiple discrete) frequency as opposed to a broadband signal with high kurtosis, high peak pressures and rapid rise times (see appendix 10-2: Subsea Noise Technical Report, wherein a full description of the source sound levels for geophysical survey activities is provided).

Table 10-36: Typical Sonar like survey equipment parameters used in assessment.

Survey Type	Unit	Frequency (kHz)	Source Level (dB re 1μPa) (rms)	Pulse Rate (s^{-1})	Pulse Width (ms)	Beam Width	Swathe Beamwidth
MBES	Kongsberg EM710	105	231	30	0.2	2°	140°

Operational and maintenance phase

Magnitude of impact

Injury

Potential impacts of routine geophysical surveys will depend on the characteristic of the source, survey design, frequency bands and water depth. Sonar-like sources have very strong directivity which effectively means that there is only potential for injury when a marine mammal is directly underneath the sound source. Once the animal moves outside of the main beam, there is no potential for injury. This section provides estimated ranges for injury of marine mammals during the operational and maintenance phase of the Project.

With respect to the spatial range within which there is a potential of PTS occurring to marine mammals as a result of routine geophysical surveys, PTS has the potential to occur out to a maximum of 227 m for harbour porpoise (Table 10-37). For dolphin species PTS is expected to occur out to a maximum of 124 m, for minke whale out to 12 m, and pinniped species out to 34 m, from the sound source. TTS has the potential to occur out to a maximum of 449 m (harbour porpoise). For dolphin species, TTS is expected to occur out to a maximum of 172 m, for minke whale out to 107 m, and pinniped species out to 123 m, from the sound source.

Table 10-37: PTS and TTS onset thresholds and potential impact ranges for marine mammal species during non-impulsive MBES geophysical surveys, based on comparison to Southall *et al.* (2019) SEL thresholds.

Species	Hearing group (NMFS, 2018)	SEL threshold (dB re 1 $\mu Pa^2 s$)	Impact range (m)
Minke whale	LF	PTS – 199	12
		TTS – 179	107
Bottlenose dolphin	HF	PTS – 198	124
		TTS – 178	172
Common dolphin	HF	PTS – 198	124
		TTS – 178	172
Harbour porpoise	VHF	PTS – 173	227
		TTS – 153	449
Harbour seal	PW	PTS – 201	34
		TTS – 181	123
Grey seal	PW	PTS – 201	34
		TTS – 181	123

The number of marine mammals with the potential to be injured, within the modelled ranges for PTS and TTS presented in Table 10-37 were estimated using the most up to date species-specific density estimates (Table 10-7). Due to low predicted injury ranges, for all marine mammal species, it is predicted that there is the potential for no more than one animal to experience PTS or TTS as a result of routine geophysical surveys. The geophysical surveys are considered to be short term, as inspection of inter-array cables and offshore cable will be undertaken across a survey campaign duration of up to 14 days per survey (i.e. one 14-day survey window for inspection of inter-array cables; one 14-day survey window for inspection of offshore cable), up to a maximum of once every five years over the 40-year lifetime of the Project. Similarly, inspection of offshore wind turbine foundations will be conducted up to a maximum of every five years during the Project lifespan, and each survey campaign will last up to 14 days. If all survey campaigns were to be carried out consecutively, this would represent a maximum of 42 days of geophysical surveying every five years, however actual surveying is not expected to occur for the entire survey window, as time has been included here to account for weather and technical downtime.

Mitigation for injury during surveys using geophysical survey equipment deployed from a conventional vessel will involve the use of MMOs and PAM to ensure that the risk of injury over the defined mitigation zone is reduced in line with NPWS guidance (NPWS, 2014). A soft start will be applied where possible. The largest injury range was predicted as 449 m (TTS, for harbour porpoise) and it is considered that standard industry measures will be effective at reducing the risk of injury over this distance. Full details of measures and associated procedures are presented in the MMMP that accompanies this EIAR (volume 2A, appendix 5-4: Marine Megafauna Mitigation Plan).

Overall, with the above measures applied, the magnitude of the impact of routine geophysical surveys is predicted to be of very limited spatial extent, medium-term duration (i.e. maximum duration of geophysical survey) and intermittent. Whilst the impact itself would occur during the operational and maintenance phase only, the effect of PTS should it occur, would be permanent. The effect of TTS and the impact itself (i.e. during the geophysical surveys) is reversible. It is predicted that the impact will affect the receptor directly. The impact could lead to PTS and/or TTS in a small number of animals but this would not be at a scale that would lead to any measurable population-level effects. The magnitude for PTS and TTS is, therefore, considered to be low.

Disturbance

The estimated maximum range for onset of disturbance is based on underwater noise levels being greater than the 120 dB re 1 μPa (rms) threshold applicable for all marine mammals (Table 10-21). The disturbance range as a result of geophysical site-investigation surveys will be higher than those presented for PTS, so the predicted range of disturbance, beyond which no animals are expected to experience disturbance, is approximately 1,410 m (see appendix 10-2: Subsea Noise Technical Report). However, considering the high degree of variation between studies relating to the onset of behavioural effects due to non-impulsive sound, it is recommended that any predicted disturbance ranges are viewed as probabilistic, and potentially over-precautionary.

For those animals which may be disturbed, there is likely to be a proportional response, and not all animals will be disturbed to the same extent. Similarly, the life history of an individual, and the context of the reception of sound, will also influence the likelihood of an individual to exhibit an aversive response. It should also be highlighted that these impacts will not be continuous over the operational and maintenance phase, and that routine geophysical surveys will instead be carried out over a period of days within any given survey window. Therefore, given the limited quantitative information available any simplified calculation is likely to produce an overestimation of the number of animals potentially disturbed, particularly given the intermittent and highly directional nature of sound from sonar-based survey methods (like MBES). Nonetheless, an estimate of the number of animals for each species that have the potential to be disturbed by elevated underwater noise during routine geophysical surveys are presented in Table 10-38, based on density estimates presented in Table 10-7.

Table 10-38: Number of animals potentially affected by disturbance arising from geophysical site investigation surveys.

Species	Hearing group (NMFS, 2018)	Estimated density (animals per km^2)	Number animals within zone of disturbance	Percentage of population (%)
Harbour porpoise	VHF	0.280 – 1.330	2 - 9	0.003 - 0.013
Bottlenose dolphin	HF	0.008 0.036*	< 1	0.098 0.018
Common dolphin	HF	0.008	2	0.0016
Minke whale	LF	0.014 – 0.260	<1	0.0004
Grey seal	PW	0.372	3	0.039
Harbour seal	PW	0.280	2	0.107

* Density generated using SCANS-IV data has been compared against a reference population estimated by summing the abundance within the Irish Sea SCANS-IV blocks

However, all geophysical surveys will be very short duration (up to several months), activities are likely to be intermittent, and animals are expected to recover quickly after cessation of the survey activities. The magnitude of the impact could result in a minor alteration to the distribution of marine mammals.

The impact of geophysical surveys leading to behavioural effects is predicted to be of local spatial extent, short term duration, intermittent and the effect of disturbance is of high reversibility (with animals returning to baseline levels soon after surveys have ceased). It is predicted that the impact will affect the receptor directly. The impact could lead to changes to behaviour and distribution in a small number of individuals but this would not be at a scale that would lead to any measurable population-level effects. The magnitude is therefore considered to be low.

Sensitivity of receptor

Injury

The maximum range for injury from geophysical surveys (specifically MBES) was predicted to be 227 m for PTS (harbour porpoise) and 449 m for TTS (harbour porpoise). Ruppel *et al*. (2022) categorised marine acoustic sources into four tiers according to their potential to injure marine mammals, with categories determined by physical criteria about the sound source: source level, transmission frequency, directionality, beamwidth, and pulse repetition rate. Those sources in Tier Four were considered unlikely to result in a loss of individuals and included most high-resolution geophysical sources, including MBES. This study also suggested that surveys deploying multiple, simultaneous, non-impulsive *de minimis* sources are unlikely to result in loss of marine mammals.

Although there is some evidence for short-term behavioural responses of marine mammals to underwater noise from geophysical surveys, sonar-based methods such as MBES pose a reduced risk of injury to auditory systems in comparison to seismic sources (Lurton and DeRuiter, 2011). For MBES operating in mid-range and full ocean depth, there is a potential to cause injury to some cetacean species at very close proximity, however in shallower waters such as those in which the Project is located, the frequency range within which MBES systems operate falls outside the hearing threshold of cetaceans and attenuates more quickly than lower frequencies operated at a lower power. It is therefore considered unlikely that geophysical survey equipment could cause injury (JNCC, Natural England and CCW, 2010).

For PTS, marine mammals are assessed as having limited resilience, limited ability to adapt behaviour to sustain ecological functioning, and limited ability to recover from the effect in the short and long term, given the potential for the impact to result in a change in both reproduction and survival rates, and international value. The sensitivity of the receptor to PTS from elevated underwater sound during geophysical surveys is therefore considered to be high.

For TTS, marine mammals are assessed as having some resilience, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability, and international value. The sensitivity of the receptor to TTS from elevated underwater sound during geophysical surveys is therefore considered to be medium.

Disturbance

The transmission frequencies of many commercial sonar systems (approximately 12 to 1800 kHz) overlap with the hearing and vocal ranges of many species (Richardson *et al*., 1995), and whilst many are high frequency sonar systems with peak frequencies well above marine mammal hearing ranges, it is possible that relatively high levels of sound are also produced as sidebands at lower frequencies (Hayes and Gough, 1992), which may elicit behavioural responses in marine mammals. However, in the context of exposure to sonar-like sound sources, such as MBES, marine mammals may show subtle behavioural responses. Factors such as species, behavioural context, location, and prey availability may also be as important or more important than the acoustic signals themselves (Ruppel *et al*., 2022), and Kates Varghese *et al*. (2020) showed that MBES surveys may be affect vocalisation rate, but neither displacement nor changes in foraging were observed.

MacGillivray *et al*. (2014) compared sound level above hearing threshold as a function of horizontal distance for seven acoustic sources including MBES, Side Scane Sonar (SSS), Sub-bottom Profiler (SBP) and Ultra-high Resolution Seismic (UHRS). Weighting sounds according to hearing sensitivity allows assessment of relative risks associated with exposure and whilst this analysis was not specifically focussed on the potential for behavioural responses, it allowed comparison of modelled acoustic sources. For all species, modelled sensation levels (i.e. potential for disturbance) were lowest for the high frequency sources (e.g. SSS and MBES) which operate at the upper limits of the audible spectrum. Modelling indicated that odontocetes (such as harbour porpoise, bottlenose dolphin and common dolphin) were most likely to hear sounds from mid frequency sources (fishery, communication, and hydrographic systems), mysticetes (such as minke whale) from low frequency sources (SBP and airguns), and pinnipeds from both mid and low frequency sources.

Studies have largely focused on the effects of multi-array seismic surveys on marine mammals, and therefore evidence for behavioural responses to sonar-like sources (e.g. MBES, SSS, SBPs) is less widely available. Multi-array impulsive sound sources are broadband in character (i.e. produce sound across a wide range of frequencies), unlike sonar-like sources which typically produce more tonal sound either at a discrete frequency or a range of discrete frequencies. However, findings from studies of multi-array impulsive sources may be useful in supporting predictions of behavioural responses of marine mammals to geophysical survey sources in general (including MBES), given the overlap of parameters that typically characterise sound sources (i.e. transmission frequency; source level; pulse duration) (see MacGillivray *et al*., 2014; Ruppel *et al*., 2022).

Whilst evidence on the behavioural responses of marine mammals to MBES is limited, an Independent Scientific Review Panel deemed a 12 kHz MBES to be the most plausible trigger for an extreme behavioural response in melon-headed whale *Peponocephala electra*, which resulted in a 2008 mass stranding in a shallow lagoon in Madagascar, an area where such open-ocean species would not be expected to occur (Southall *et al*., 2013). Whilst an unequivocal cause and effect relationship between MBES and the strandings cannot be concluded, the study highlights that intermittent, repeated sounds of this nature could present a salient and potential aversive stimulus, which suggests that potential for such behavioural responses (or indirect injury) from MBES should be considered in environmental assessments (Southall *et al*., 2013).

Hastie *et al*. (2014) carried out behavioural response tests to two sonar systems (200 kHz and 375 kHz systems) on grey seal at the SMRU seal holding facility. Results showed that both systems had significant effects on seal behaviour. Grey seal spent significantly more time hauled out during the 200 kHz sonar operation and although animals remained swimming during operation of the 375 kHz sonar, they were distributed further from the sonar.

Aside from displacement or avoidance, other behavioural responses have been demonstrated (Wright and Cosentino, 2015). Responses to seismic surveys have included cessation of singing (Melcón *et al*., 2012) and alteration of dive and respiration patterns, which may lead to energetic burdens on the animals (Gordon *et al*., 2003). In some cases, behavioural responses may lead to greater effects than expected, such as strandings (Cox *et al*., 2006; Tyack *et al*., 2006) or interruptions to migration (Heide-Jørgensen *et al*., 2013). However, such responses are highly context-dependent and variable, depending on factors such as the activity of the animal at the time (Robertson *et al*., 2013), prior experience to exposure (Andersen *et al*., 2012), extent or type of disturbance (Melcón *et al*., 2012), environment in which they inhabit (Heide-Jørgensen *et al*., 2013) and the type of survey (as discussed by Ruppel *et al*., 2022).

It is expected that, to some extent, marine mammals will be able to adapt their behaviour to reduce effects associated with elevated levels of underwater noise during geophysical surveys. Marine mammals are assessed as having high resilience to the effect with minor impairment of ecological functioning, have an ability to adapt behaviour such that ecological function can be maintained, high recoverability, and international value. The sensitivity of the receptor to disturbance from elevated underwater sound during geophysical surveys is therefore considered to be medium.

Significance of effect

Overall, the magnitude of the impact of PTS is deemed to be low and the sensitivity of the receptor is considered to be high. There would be no change to the international value of these species. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Overall, the magnitude of the impact of TTS is deemed to be low and the sensitivity of the receptor is considered to be medium. There would be no change to the international value of these species. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms

Overall, the magnitude of the impact of disturbance is deemed to be low and the sensitivity of the receptor is considered to be medium. There would be no change to the international value of these species. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

10.10.3 Injury and/or disturbance to marine megafauna from vessel and other construction activities

Increased vessel movement during the construction, operational and maintenance, and decommissioning phases has the potential to result in a range of impacts on marine mammals, basking shark and leatherback turtle, including:

- Injury or death due to collision with vessels;
- Avoidance behaviour or displacement; and
- Masking of vocalisations or changes in vocalisation rate.

Other construction activities, such as pile drilling, have the potential to result in elevated levels of subsea noise that are detectable by marine mammals and megafauna above background levels and could result in injurious or behavioural effects on IEFs.

Construction phase

Magnitude of impact

The installation of Project infrastructure within the offshore wind farm area and offshore cable corridor may lead to injury and/or disturbance to marine megafauna from vessel activities. The project design includes for a maximum 475 vessel round trips during the offshore construction phase (15 months), with vessel types including jack-up barges, tug/anchor handlers, cable installation vessels, scour/cable protection installation vessels, guard vessels, survey vessels, and CTVs. Source sound data for vessels likely to utilised are set out in Table 10-39.

The main drivers influencing the magnitude of the impact are vessel type, speed and ambient noise levels (Wilson *et al.,* 2007). Baseline levels of vessel traffic in the Marine Megafauna Study Area are likely to be relatively high. A total of 28 vessels were recorded within a 5 nm buffer of the offshore wind farm area and offshore cable corridor over the month of January 2019 (1 to 3 vessels per day), with 78 vessels recorded over the month of July 2019 (one to six vessels per day), based on AIS data, and comprising of cargo vessels, fishing vessels, service vessels, tankers, recreational vessels and other vessels (see appendix 13-1: Navigation Risk Assessment). Vessel traffic was recorded transiting to/from Clogherhead, Dundalk Harbour and Carlingford Lough. It is highly likely that a proportion of the Project vessels will be stationary or slow moving throughout construction activities for significant periods of time. A vessel traffic validation exercise undertaken in 2022 found no significant differences in vessel traffic volumes or patterns between 2019 and 2022 (see appendix 13-1: Navigation Risk Assessment).

Other construction activities with the potential to generate underwater noise, and therefore injury and/or disturbance to marine mammal IEFs, include pile drilling, cable trenching and cable laying. Pile drilling may be required at each pile location following pile driving. As outlined in Table 10-11, the project design parameter assumes up to six days drilling per pile for monopiles, which equates to up to 156 days of drilling over the entire construction phase. The potential impact ranges for drilled piling are expected to be small (or not exceeded) for all marine megafauna, due to the low broadband SEL levels expected from these operations, at 160 dB re 1 μPa^{2}s. As outlined in Table 1-26 in appendix 10-2: Subsea Noise Technical Report, the impact ranges for both cable trenching and cable laying are considered to be smaller than that of the vessels which will be used to carry out these activities, therefore the impact ranges for vessels have been assessed as a proxy. Noise impacts as a result of cable trenching and laying are therefore not considered further in this assessment.

Table 10-39: Vessels involved in the construction, operational and maintenance and decommissioning phases of the Project.

Vessel type	Descriptions / assumptions	Data Source	Sound source pressure level at 1 m		
			RMS, dB re 1 μPa	Peak, dB re 1 μPa	SEL(24h), dB re 1 μPa^{2}s
Sand wave clearance	‘Gerardus Mercator’ trailer hopper suction dredger using DP as proxy	Wyatt (2008)	180	183	229
Boulder clearance	Back-hoe dredger used as proxy	Nedwell *et al.* (2008)	163	166	212
Main Installation Vessels (Jack-up Barge/DP vessel)	‘Gerardus Mercator’ trailer hopper suction dredger using DP as proxy	Wyatt (2008)	180	183	229
Jack up rig	Jack up rig	Evans (1996)	163	166	212
Tug/Anchor Handlers	Tug used as proxy	Richardson (1995)	172	175	221
Cable Installation Vessels	‘Gerardus Mercator’ trailer hopper suction dredger using DP as proxy	Wyatt (2008)	180	183	229
Rock Placement Vessels	‘Gerardus Mercator’ trailer hopper suction dredger using DP as proxy	Wyatt (2008)	180	183	229

Vessel type	Descriptions / assumptions	Data Source	Sound source pressure level at 1 m		
			RMS, dB re 1 µPa	Peak, dB re 1 µPa	SEL(24h), dB re 1 µPa²s
Guard Vessels	Tug used as proxy	Richardson (1995)	172	175	221
Survey Vessels	Offshore support vessel used as proxy	McCauley (1998)	179	182	228
Crew Transfer Vessels	Offshore support vessel used as proxy	McCauley (1998)	179	182	228
Scour / Cable Protection / Seabed Preparation / Installation Vessels	Offshore support vessel used as proxy	McCauley (1998)	179	182	228

A detailed underwater noise modelling assessment has been carried out to investigate the potential for injurious and behavioural effects on IEFs (appendix 10-2: Subsea Noise Technical Report) as a result of increased vessel noise (non-impulsive sound), and pile drilling, using the latest criteria, and is used to inform the assessment presented below.

Injury

Injury to all marine megafauna receptors could manifest in the form of injury through collision with vessels or auditory injury (PTS and/or TTS) as a result of increased noise from vessels or pile drilling.

Auditory injury

To assess potential auditory injury from vessel noise and pile drilling on marine mammal IEFs, noise modelling was carried out using the dual criteria approach of SPL_{pk} and SEL_{cum} metrics in order to estimate the ranges over which PTS and TTS could occur. For basking shark and sea turtle, the SEL_{cum} metric was applied to assess estimated ranges for recoverable injury (exposure for 48 hours) and TTS (exposure for 12 hours). Source noise levels were based on worst-case assumptions (see appendix 10-2: Subsea Noise Technical Report). Table 10-40 sets out the predicted ranges for PTS and TTS for marine mammals, basking shark and sea turtle, based on the SEL_{cum} metric (maximum predicted ranges). The exposure metrics for different marine mammal flee speeds were employed, as applied in the assessment of Injury and/or disturbance from underwater noise during pile-driving.

The noise modelling assessment showed that, for all marine mammal groups, and based on the more precautionary ranges modelled (i.e. SEL_{cum}), the threshold for PTS was not exceeded for pile drilling. The threshold for PTS for vessel movements was only exceeded for harbour porpoise, where PTS could occur out to a maximum of < 15 m for five types of vessel (see Table 10-40). For basking shark and leatherback turtle recoverable injury could occur out to a maximum of 20 m for vessels but was not exceeded for pile drilling. In respect of TTS, the greatest effect ranges were predicted for harbour porpoise from noise associated with vessels such as survey vessels, CTVs and seabed preparation vessels (1,670 m); basking shark and leatherback turtle may be affected out to 79 m from noise associated with these vessels (Table 10-40). The thresholds for PTS and TTS for both grey seal and harbour seal are not predicted to be exceeded. Fish may be affected by TTS as a result of pile drilling out to a maximum of 15 m.

Table 10-40: Estimated PTS and TTS ranges for marine mammals, basking shark and leatherback turtle during construction (based on SELcum metric).

Source/Vessel	Range (m)									
	Low frequency cetacean		High frequency cetacean		Very high frequency cetacean		Phocid pinniped in water		Basking shark and leatherback turtle	
	PTS	TTS	PTS	TTS	PTS	TTS	PTS	TTS	Recoverable Injury	TTS
Sand wave clearance	N/E	N/E	N/E	N/E	<15	566	N/E	N/E	20	71

Source/Vessel	Range (m)									
	Low frequency cetacean		High frequency cetacean		Very high frequency cetacean		Phocid pinniped in water		Basking shark and leatherback turtle	
Boulder clearance	N/E	N/E	N/E	N/E	N/E	< 15	N/E	N/E	N/E	N/E
Installation vessel, construction vessel (DP)	N/E	N/E	N/E	N/E	<15	566	N/E	N/E	20	71
Jack up rig	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E	N/E
Tug/anchor handlers	N/E	N/E	N/E	N/E	N/E	282	N/E	N/E	< 10	31
Rock placement vessel and cable installation vessels	N/E	N/E	N/E	N/E	<15	566	N/E	N/E	20	71
Guard vessels	N/E	N/E	N/E	N/E	N/E	282	N/E	N/E	< 10	31
Survey vessel and support vessels	N/E	N/E	N/E	N/E	<15	1,670	N/E	N/E	19	79
Crew transfer vessel	N/E	N/E	N/E	N/E	<15	1,670	N/E	N/E	19	79
Scour / Cable Protection / Seabed Preparation / Installation Vessels	N/E	N/E	N/E	N/E	<15	1,670	N/E	N/E	19	79
Pile drilling	N/E	N/E	N/E	N/E	N/E	40	N/E	N/E	N/E	< 15

The number of animals potentially affected by PTS or TTS as a result of vessel noise and pile drilling has been calculated based on the most up to date species-specific density estimates (Table 10-7). There is the potential for up to 12 harbour porpoise to experience TTS at any one time as a result of vessel noise, which equates to < 0.01 % of the MU. No other marine mammal species is predicted to experience TTS. In addition, since TTS is a recoverable injury the impact of elevated noise from vessels leading to injury is predicted to be reversible. Whist the numbers of animals likely to be affected at any one time are extremely low, the offshore construction phase is expected to last for 15 months.

For basking shark, density estimates are not available, however based on the almost negligible range of effect, less than one individual is expected to experience PTS or TTS. Similarly, less than one leatherback turtle is predicted to experience PTS or TTS from vessel noise or pile drilling.

As such the magnitude for auditory injury (PTS and TTS) to all marine megafauna as a result of vessels involved in the construction phase and pile drilling is deemed to be of local spatial extent, medium term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. Whilst the thresholds for PTS and TTS are not exceeded for some species, the magnitude is conservatively, considered to be low for all species.

Collision

There are different potential outcomes of vessel collision; both fatal and non-fatal injuries have been documented (Laist *et al.,* 2001; Vanderlaan and Taggart, 2007; Cates *et al.,* 2017). Fatal collisions can be seen via carcasses washing up on beaches (Laist *et al.,* 2001; Peltier *et al.,* 2019); carcasses caught on vessel bows (Laist *et al.,* 2001; Peltier *et al.,* 2019); and floating carcasses which have strong evidence of ship strike, such as propeller cuts, significant bruising, oedema, internal bleeding radiating from a specific impact site, fractures and ship paint marks (Jensen and Silber, 2003; Douglas *et al*., 2008). Fatalities from ship strikes, however, often go unreported (Authier *et al.,* 2014). For non-fatal injuries, there is evidence of animals which have survived ship strikes with no discernible injury: animals which survive with non-fatal injuries from propellers have been widely documented (Wells *et al.,* 2008; Luksenburg, 2014).

Guidance provided by NOAA has defined serious injury to marine mammals as '*any injury that will likely result in mortality*' (NMFS, 2005). NMFS clarified its definition of 'serious injury' (SI) in 2012 and stated their interpretation of the regulatory definition of serious injury as any injury that is 'more likely than not' to result in mortality, or any injury that presents a greater than 50% chance of death to the marine mammal (NMFS,

2012) (Helker *et al.,* 2017). This definition was also applied to basking shark and sea turtles. Non-serious injury is likely to result in short-term impacts and may also have long-term effects on health and lifespan.

Vessel traffic associated with the Project has the potential to lead to an increase in vessel movements within the Marine Megafauna Study Area. This increase in vessel movement could lead to an increase in interactions between marine mammals and other megafauna and vessels during offshore construction. Vessels travelling at 7 m/s or faster are those most likely to cause death or serious injury (as per the NMFS definition) to marine mammals, basking shark and sea turtles (Laist *et al.,* 2001; Wilson *et al.,* 2007). With the exception of CTVs, vessels involved in the construction phase are likely to be travelling considerably slower than this, and all vessels will be required to follow a Vessel Code of Conduct (see volume 2A, appendix 5-5: Marine Megafauna: Vessel Code of Conduct) to minimise interaction with marine mammals (Table 10-12). In addition, the noise emissions from vessels involved in the construction phase are likely to deter animals from the potential zone of impact.

As such the magnitude for collision risk as a result of vessels involved in the construction phase for all marine megafauna receptors is deemed to be of local spatial extent, medium term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be negligible.

Disturbance

Increased vessel noise, resulting in avoidance behaviour, displacement or masking of vocalisations is likely to occur only where increased noise from vessel movements associated with the construction phase are greater than the background ambient noise level. As stated above, there are existing levels of vessel traffic within the Marine Megafauna Study Area, and therefore ambient noise levels are expected to be relatively high. Disturbance may also arise as a result of pile drilling following piling activity. Disturbance ranges for vessels and for pile drilling, along with predicted number of animals to be disturbed are set out in Table 10-41.

<u>Marine mammal IEFs</u>

The conservative assumption has been made that all marine mammal species will react to increases in vessel movement to the same extent. In reality, the distance over which effects will occur will vary according to the species and the ambient noise levels; hearing ability, vertical space use and behavioural response differences between species are likely to affect the distance over which effects occur.

Noise modelling was carried out to estimate maximum ranges for the onset of disturbance in marine mammals (appendix 10-2: Subsea Noise Technical Report), based on exceeding the 120 dB re 1 µPa (rms) threshold applicable for all marine mammals, noting that this threshold is for 'mild disturbance' and therefore is not likely to result in displacement of animals. Survey and support vessels; CTVs; and scour/cable protection, seabed preparation, and installation vessels result in the greatest modelled disturbance out to 8.5 km (~ 227 km^2) for all marine mammal species (Table 10-41). At the lower end of the scale, boulder clearance vessels were predicted to result in disturbance ranges out to 755 m (Table 10-41). Pile drilling activities were predicted to result in disturbance out to 1,083 m (Table 10-41).

The number of marine mammals with the potential to be disturbed by vessels and pile drilling are presented in Table 10-41, based on the most up to date species-specific density estimates (Table 10-7), noting that there is likely to be a proportionate disturbance response of animals within the modelled contours (i.e. not all animals will be disturbed to the same extent) (Graham *et al.,* 2017). As stated previously, the life history of an individual and the context will also influence the likelihood of an individual to exhibit an aversive response to noise.

Harbour porpoise is likely to be the most sensitive species to disturbance from vessel traffic with potentially larger numbers (up to 302 animals) affected compared other species. However, even over the largest disturbance ranges only a small proportion (up to 0.48%) of the harbour porpoise population would be affected at any one time. The proportions of the populations of marine mammals affected by mild disturbance from vessel activity varied between species and was a reflection of the size of the MU population against which the affected numbers were compared. For example up to 54 bottlenose dolphin potentially disturbed represents up to 0.64% of the SCANS-III abundance estimate for the Irish Sea (the IS MU), and up to 11 bottlenose dolphin potentially disturbed represents up to 3.56% of the SCANS-IV abundance estimate for the Irish Sea. Similarly for harbour seal, 64 animals disturbed represents 3.88% of the relevant MU population, and for grey seal 85 animals disturbed represents 1.43% of the relevant MU population.

The impact is predicted to be of local spatial extent, medium term duration, intermittent, and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude of the impact could lead to measurable changes to behaviour in individuals but is unlikely to directly result in displacement, and therefore in the context of the relevant geographic frames of reference, would not be at a scale that would lead to any measurable population-level effects. The magnitude is therefore, considered to be low for all marine mammal species.

Basking Shark and Leatherback Turtle IEFs

Disturbance in ‘fish’ (basking shark and leatherback turtle) from non-impulsive sound is categorised in relative terms as “high”, “moderate” or “low” at three distances from the source: “near” (i.e. in the tens of metres), “intermediate” (i.e. in the hundreds of metres) or “far” (i.e. in the thousands of metres). For basking shark, the onset of behavioural effects is likely to be moderate in the range of tens and hundreds of metres, and low in the range of thousands of metres. For leatherback turtle, the onset of behavioural effects is likely to be high in the range of tens of metres, moderate in the range of hundreds of metres and low in the range of thousands of metres. Due to the likely low numbers of basking shark and leatherback turtle present within the Marine Megafauna Study Area, numbers of animals disturbed are expected to be low.

The impact is predicted to be of local spatial extent, medium term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. Whilst it is not possible to calculate likely numbers of animals within the disturbance range, due to the qualitative nature of the criteria, based on the likely low number of animals passing through the area for the duration of the construction activities, it is considered unlikely that the impact of disturbance would be at a scale that could lead to any measurable population-level effects. The magnitude for basking shark and leatherback turtle is considered to be low.

Table 10-41: Number of animals with the potential to be disturbed by construction vessels and pile drilling within estimated disturbance ranges for marine mammals (continuous sources).

Source	Range (km)	Area (km^2)	Estimated number of marine mammals with the potential to be disturbed													
			Harbour porpoise		Bottlenose dolphin				Common dolphin		Minke whale		Grey seal		Harbour seal	
			Number of animals	Proportion of MU population (%)	Number of animals		Proportion of MU population (%)		Number of animals	Proportion of MU population (%)	Number of animals	Proportion of MU population (%)	Number animals	Proportion of MU population (%)	Number animals	Proportion of MU population (%)
Sand wave clearance; Installation vessel, construction vessel (DP); rock placement vessel and cable installation vessels	3.6 km	40.69	12 - 55	0.018 – 0.086	2	10*	0.63	0.11	12	0.010	< 1 - 11	0.002 – 0.05	15	0.257	12	0.696
Boulder clearance	755 m	1.79	< 1 - 3	0.001 – 0.003	< 1	< 1*	0.03	0.005	< 1	0.0004	< 1	0.0001 – 0.002	< 1	0.011	< 1	0.031
Jack up rig	< 20 m	< 0.001	*Negligible*													
Tug/anchor handlers; guard vessels	3.4 km	36.3	11 - 49	0.016 – 0.077	2	9*	0.57	0.10	10	0.009	< 1 - 10	0.002 – 0.046	14	0.229	11	0.621
Survey vessel and support vessels; CTVs; Scour / Cable Protection / Seabed Preparation / Installation Vessels	8.5 km	226.86	64 - 302	0.102 – 0.483	11	54*	3.56	0.64	62	0.060	4 - 59	0.157 - 0.29	85	1.434	64	3.885
Pile drilling	1.083 km	3.68	2 - 5	0.002 – 0.008	< 1	< 1*	0.057	0.01	2	0.0009	< 1	0.0003 - 0.005	2	0.023	2	0.063

* Density generated using SCANS-IV data has been compared against a reference population estimated by summing the abundance within the Irish Sea SCANS-IV blocks

Sensitivity of the receptor

Injury (auditory injury and collision risk)

The sensitivity of marine megafauna receptors to auditory injury has been assessed as part of the previous impact and is not reiterated here. Both PTS and TTS ranges as a result of vessels and pile drilling involved in the construction phase (non-impulsive sound) (Table 10-40) are far lower than that for piling (impulsive sound) (Table 10-24 and Table 10-25). The sensitivity of all marine megafauna receptors to PTS has therefore been assessed as high, and to TTS has been assessed as medium.

There can be consequences to a lack of response to disturbance for all marine megafauna IEFs; behavioural habituation can result in decreased wariness of vessel traffic, which has the potential to result in an increased collision risk (Cates *et al.,* 2017). Vessel strikes are known to be a cause of mortality in marine mammals (Carrillo and Ritter*,* 2010), but it is possible that mortality from vessel strikes is under-recorded (Van Waerebeek *et al.*, 2007). Laist *et al.* (2001) reported that collisions between vessels and large whales tended to lead to death, but non-lethal collision has also been reported by Van Waerbeek *et al.,* (2007). Therefore, collisions between vessels and cetaceans are not necessarily lethal on all occasions. Collision risk for seals is less understood than for cetaceans, however trauma ascribed to collisions with vessels has been identified in a small proportion of both live stranded (Goldstein *et al.*, 1999) and dead stranded seals in the USA (Swails, 2005). In these studies, however, less than 2% of all necropsied seal deaths were identified as resulting from vessel collisions. A study by Onoufriou *et al.,* (2016) in the Moray Firth, Scotland showed that seals do not necessarily occupy the same areas as vessels during trips between haul-outs and foraging sites but that seals tended to remain beyond 20 m from vessels (only three instances over 2,241 days of seal activity resulted in passes at less than 20 m).

For basking shark, propeller and boat strikes may result in serious injury, particularly in summer months when animals are feeding at the surface; however, there are few reported incidents of injury from collision; anecdotal evidence of collisions with basking shark were reported on two occasions by marine tourism boats in the Clyde Sea but the extent of any injuries suffered was unknown (Speedie *et al.,* 2009). Leatherback turtle are also vulnerable to vessel strike when surfacing to breathe. Boat strikes account for a significant proportion of sea turtle mortalities in nearshore turtle habitats worldwide. For example, 2.5% of green turtle found dead on beaches in Hawaii between 1982 and 2003 were attributed to boat strike (Chaloupka *et al.*, 2008). Boat strikes were also identified as the cause of mortality for leatherback turtle off the coast of Gabon (Deem *et al.* 2006). Denkinger *et al*., (2013) looked at records of live green turtle surveyed in the Galapagos and found that up that 20% of injuries were likely to be from collisions with boats.

With the exception of CTVs, vessels involved in the construction phase are likely to be travelling considerably slower than 7 m/s and all vessels will be following the Code of Conduct set out in the MMMP in order to reduce the risk of collision. It is considered that there is a high likelihood of avoidance from both increased vessel noise and collision risk, with a high potential for recovery (assuming no strikes occur).

Although the risk of injury from construction traffic is relatively low, the consequences of collision risk could be fatal. All marine megafauna receptors would have limited tolerance to a collision risk, and the effect of the impact could cause a change in both reproduction and survival of individuals, and receptors would have limited ability for the animal to recover from the effect. All marine megafauna are assessed as having limited resilience, limited ability to adapt behaviour to sustain ecological functioning, and low recoverability. Receptors are of international/national value. As such the sensitivity of all marine megafauna receptors to collision has been assessed as high.

Disturbance

Marine mammal IEFs

Disturbance levels for marine mammal receptors will be dependent on individual hearing ranges and background noise levels within the vicinity. Sensitivity to vessel noise is most likely related to the marine mammal activity at the time of disturbance (IWC, 2006, Senior *et al*., 2008). For example, resting dolphins are likely to avoid vessels, foraging dolphins will ignore them, and socialising dolphins may approach vessels (Richardson *et al*., 1995).

Marine mammals can both be attracted to, and disturbed by, vessels. Harbour porpoise are particularly sensitive to high frequency noise and are more likely to avoid vessels; Heinanen and Skov (2015) identified that the occurrence of harbour porpoise declines significantly when the number of vessels in a 5 km^2 area exceeds 80 in one day. Other species such as common dolphin is regularly sighted near vessels and may also approach vessels (e.g. bow-riding). However, dolphins are also known to show aversive behaviours to vessel presence, including increased swimming speed, avoidance, increased group cohesion and longer dive duration (Miller *et al.,* 2008). Reactions of marine mammals to vessel noise are often linked to changes in the engine and propeller speed (Richardson *et al.*, 1995); Watkins (1986) reported avoidance behaviour in baleen whales from loud or rapidly changing noise sources, particularly where a boat approached an animal. Disturbance is likely to be greater in dolphins and porpoises with presence of smaller fast-moving vessels as they are more sensitive to high frequency noise, and baleen whales, such as minke whale, are likely to be more sensitive to slower moving vessels emitting lower frequency noise. Pirotta *et al.* (2015) found that transit of vessels in the Moray Firth resulted in a reduction (by almost half) of the likelihood of recording bottlenose dolphin prey capture buzzes. They also suggest that vessel presence, not just vessel noise, resulted in disturbance. There is, however, evidence of habituation to boat traffic and therefore a slight increase from the existing levels of traffic in the vicinity of the Project may not result in high levels of disturbance. For example, Lusseau *et al.* (2011) (Scottish Natural Heritage (SNH) commissioned report) undertook a modelling study which predicted that increased vessel movements associated with offshore wind development in the Moray Firth did not have a negative effect on the local population of bottlenose dolphin, although it did note that foraging may be disrupted by disturbance from vessels.

Harbour porpoise are distributed widely throughout the Irish Sea and therefore it can be assumed (since they have a requirement to feed regularly) that there is suitable foraging habitat across their range. Therefore, localised disturbance within the Marine Megafauna Study Area is unlikely to lead to any population-level effects on this species. Similarly, common dolphin and minke whale are both wide-ranging species and viable high-quality foraging habitat exists outside of the Marine Megafauna Study Area. Bottlenose dolphin likely to be foraging in the offshore wind farm area form part of the Irish Sea MU, which is relatively small, however, the core distribution for this species is in the eastern Irish Sea (Cardigan Bay) and around the west coast of Ireland.

Seals are particularly sensitive to disturbances in regions where vessel traffic overlaps with productive coastal waters (Robards *et al*., 2016). Richardson (2012) reported avoidance behaviour or alert reactions in harbour seal when vessels approach within 100 m of a haul-out (Richardson, 2012). When disturbed, seals that are hauled-out typically flush into the water which could be detrimental during pupping season (e.g. Terhune and Almon, 1983; Johnson and Acevedo-Gutiérrez, 2007). The presence of vessels in foraging grounds could result in reduced foraging success, particularly in harbour seal given reduced foraging ranges (~ 50 km from haul-outs) when compared to grey seal (~ 150 km from haul-outs) (SCOS, 2017). However, seals can be curious and have been recorded approaching tour boats that regularly visit an area and may habituate to sounds from tour vessels (Bonner, 1982). The closest haul-out to the offshore wind farm area for both grey seal and harbour seal is 4.5 km to the north at Carlingford Lough, and 10 km to the south at Clogherhead. Vessels could transit to and from the offshore wind farm area from an Irish Sea port or from further afield. Given the proximity of these haul-outs to existing vessel routes (see appendix 13-1: Navigation Risk Assessment), disturbance at haul-out sites is unlikely to be increased by the construction phase of the Project.

Given the existing levels of traffic in the Marine Megafauna Study Area, the additional vessels associated with the Project are unlikely to increase the risk of disturbance to any marine mammal species. It is expected that marine mammals could tolerate the effects of disturbance without any impact on reproduction and survival rates and would return to previous activities once the impact had ceased. All marine mammals are assessed as having high resilience to the effect with minor impairment of ecological functioning, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability. All marine mammals are of international/national value. The sensitivity of all marine mammal receptors to disturbance has therefore been assessed as low.

<u>Basking Shark and Leatherback Turtle IEFs</u>

Basking shark and leatherback turtle are known to migrate through the Regional Marine Megafauna Study Area during summer months and therefore this is considered to be the most sensitive time of year. Vessel movements involved in the construction phase, however, are unlikely to result in barrier effects to migration for these receptors as disturbance ranges will likely constitute a small area in the context of the wider available habitat in the Irish Sea.

Evidence shows that basking shark do not tend to respond to the presence of surface craft (Speedie *et al.,* 2009); scientists conducting satellite tagging exercises typically are able to place tags on basking shark from within one metre of the individual (Sims *et al.,* 2005). In addition, it is known that most basking shark killed in harpoon fisheries were shot at very close range, with basking shark showing little or no indication of evasive action (Maxwell, 1952). Bloomfield and Solandt (2008) however reported that when disturbed by boats, basking shark were seen to dive and move away from the area, however it is unknown whether this is caused by the noise, visual presence or a combination of the two. A study carried out in southwest England (Wilson 2000, *in* Speedie *et al.,* 2009) identified that engine noise has some limited effect on shark behaviour, as does the angle of approach, but beyond that the effects were inconclusive. The Manx waters, 80 km northeast of the Marine Megafauna Study Area, may constitute important mating habitat for basking shark (Bloomfield and Solandt, 2008; Howe, 2018) however disturbance ranges will not extend this far, and therefore reproduction is unlikely to be affected by vessel movements involved in the construction phase.

Whilst little published data exists on the behavioural response of sea turtles to vessels, responses are expected to consist of changes in swimming speed or direction, and diving behaviour, however, similar to marine mammals, direct displacement from the Marine Megafauna Study Area is unlikely. Beaches of the UK and Ireland do not host nesting grounds for leatherback turtle and therefore their sensitivity to disturbance in this respect will be low. Offshore waters of the Irish Sea could potentially host important feeding grounds for sea turtles (NPWS, 2019), but the area of likely disturbance as a result of vessel movements in the construction phase will likely constitute a very small proportion of available habitat in the context of the wider region.

Given existing levels of traffic, vessels involved in the construction phase are unlikely to increase the risk of disturbance and therefore it is expected that basking shark and leatherback turtle could tolerate the effects of disturbance without any impact on reproduction and survival rates and would return to previous activities once the impact had ceased. Basking shark and leatherback turtle are assessed as having high resilience to the effect with minor impairment of ecological functioning, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability. Both species are of national value. The sensitivity of basking shark and leatherback turtle to disturbance has therefore been assessed as low.

Significance of the effect

Injury

Overall, the magnitude of the impact of PTS is deemed to be low and the sensitivity of the receptor is considered to be high. There would be no change to the international value of these species. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Overall, the magnitude of the impact of TTS is deemed to be low and the sensitivity of the receptor is considered to be medium. There would be no change to the international value of these species. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms

Overall, the magnitude of the collision risk impact is deemed to be negligible and the sensitivity of all marine megafauna receptors is considered to be high. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Disturbance

Overall, the magnitude of the impact is deemed to be low and the sensitivity of all marine megafauna receptors is considered to be low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

Operational and maintenance phase

Magnitude of impact

Operational and maintenance activities may lead to injury and/or disturbance to marine megafauna from vessel activities. The design includes for a maximum of 352 vessel round trips per year over the Project lifetime (see Table 10-39).

An overview of the potential for auditory injury and/or disturbance and injury from collisions with vessel to marine megafauna as a result of Project vessels is given above for the construction phase and is not reiterated here.

Vessel types which will be required during the operational and maintenance phase include jack-up vessels, CTVs and survey vessels (Table 10-39) and therefore the size and noise outputs from these vessels will result in a similar maximum adverse spatial parameter as the construction phase.

The magnitude of the impact of the operational and maintenance phase, for both auditory injury and disturbance for all marine megafauna receptors, is therefore not expected to be greater than that assessed for the construction phase. Similarly, the magnitude of the impact of the operational and maintenance phase, for injury from vessel collisions for all marine megafauna receptors not expected to be greater than that assessed for the construction phase.

The impact is predicted to be of local spatial extent, long term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The likelihood of a vessel strike occurring is considered to be very low due to avoidance behaviour, particularly where vessels follow defined routes. The magnitude is therefore, considered to be low (for both auditory injury and disturbance from vessel noise) and negligible (collision risk), for all marine megafauna receptors.

Sensitivity of the receptor

The sensitivity of the receptors during the operational and maintenance phase is not expected to differ from the sensitivity of the receptors during the construction phase. Therefore, for all marine megafauna receptors, the sensitivity to PTS is deemed to be high, the sensitivity to TTS is deemed to be medium, and the sensitivity to injury from vessel collisions is deemed to be high.

Significance of the effect

Injury

Overall, the magnitude of the impact of PTS is deemed to be low and the sensitivity of the receptor is considered to be high. There would be no change to the international value of these species. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Overall, the magnitude of the impact of TTS is deemed to be low and the sensitivity of the receptor is considered to be medium. There would be no change to the international value of these species. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Overall, the magnitude of the collision risk impact is deemed to be negligible and the sensitivity of all marine megafauna receptors is considered to be high. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Disturbance

Overall, the magnitude of the impact is deemed to be low and the sensitivity of marine megafauna receptors is considered to be low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

Decommissioning phase

The effects of decommissioning activities are expected to be the same or similar to the effects from construction.

Injury

Overall, the magnitude of the impact of PTS is deemed to be low and the sensitivity of the receptor is considered to be high. There would be no change to the international value of these species. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Overall, the magnitude of the impact of TTS is deemed to be low and the sensitivity of the receptor is considered to be medium. There would be no change to the international value of these species. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Overall, the magnitude of the collision risk impact is deemed to be negligible and the sensitivity of all marine megafauna receptors is considered to be high. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Disturbance

The significance of effect is therefore **imperceptible adverse significance**, which is not significant in EIA terms.

10.10.4 Changes in the fish and shellfish community affecting marine megafauna prey resources

Potential effects on the fish assemblages during the construction, operational and maintenance and decommissioning phases of the Project, as identified in chapter 9: Fish and Shellfish Ecology, may have indirect effects on marine mammal and basking shark receptors. Leatherback turtle primarily feed on jellyfish, for which there is unlikely to be a receptor-impact pathway for the Project-related activities, and therefore leatherback turtle as a receptor will not be taken forward into this assessment.

The key prey species for marine mammals include a number of clupeids (e.g. herring), gadoids (e.g. cod, whiting), salmon, flatfish and sandeels. Basking shark largely feed on zooplankton. The Fish and Shellfish Ecology assesment identified whitefish (including haddock and cod) and shellfish (including crab, lobster) as important commercial fisheries in the Fish and Shellfish Ecology Study Area. The area was also identified as an important spawning and nursery ground for a number of whitefish species and a recovery ground for cod. High abundances of cod and plaice eggs recorded from the northwest Irish Sea and in particular due east of Dundalk Bay were identified (Roden and Ludgate, 2003). The area is also known as a spawning ground for whiting and herring. Other prey species for marine mammals found in the Fish and Shellfish Ecology Study Area include Atlantic salmon, pollack, mackerel, haddock and European eel.

Construction phase

Potential construction phase impacts on fish and shellfish receptors include temporary subtidal habitat loss/disturbance, injury and/or disturbance to fish from underwater noise during pile driving and increased suspended sediment concentrations and associated sediment deposition (chapter 9: Fish and Shellfish Ecology).

Magnitude of impact

Temporary habitat loss could potentially affect spawning, nursery or feeding grounds of fish and shellfish receptors, with demersal fish and shellfish, and demersal spawning species the most vulnerable. The project design parameter assessed in chapter 9: Fish and Shellfish Ecology includes for 709,500 m^2 of temporary habitat loss/disturbance during the construction phase, which equates to 1.3% of the offshore wind farm area and offshore cable corridor, therefore representing a very small proportion of the Project site. Due to the localised nature of the effects and the small proportion of the Fish and Shellfish Ecology Study Area affected, temporary loss of habitat was considered unlikely to diminish ecosystem functions for fish and shellfish species, and therefore the overall significance of the effect was deemed to be slight adverse (not significant in EIA terms).

Injury and/or disturbance to fish from underwater noise during pile driving could adversely affect fish and shellfish receptors as a result of mortality, impairment or behavioural effects. The project design parameter assessed in chapter 9: Fish and Shellfish Ecology is the same as assessed here for Marine Mammals and Megafauna (installation of monopiles via impact/percussive piling with an average maximum hammer energy of 2,500 kJ and absolute maximum hammer energy of 3,500 kJ). Subsea noise modelling showed that mortality or recoverable injury ranges could extend out to a maximum distance of 217 m from the source, as a result of installation of monopiles (SPL_{pk} metric) and TTS could occur out to a maximum distance of 1,750 m and 770 m for sea turtle and basking shark respectively, as a result of installation of monopiles (SPL_{cum} metric). The potential risk of onset of behavioural effects in fish from installation of piles was based on qualitative criteria set out by Popper *et al.* (2014) and categorises risk of effects in relative terms as “high”, “moderate” or “low” at three distances from the source: “near” (i.e. tens of metres), “intermediate” (i.e. hundreds of metres) or “far” (i.e. thousands of metres). The fish and shellfish assessment reported that proposed piling activities will unlikely result in mortality, but some recoverable injury is possible within 1 km of the piling works (in the most precautionary scenario), particularly for salmonids, scombridae, gadoids and eels, herring, sprat and shads. Behavioural responses were reported to be more likely for gadoids and eels, herring, sprat and shads within hundreds to thousands of metres from the piling source. The overall significance of the effect was deemed to be slight adverse.

An increase in suspended sediment concentrations (SSC) may lead to short term avoidance of affected areas by sensitive fish and shellfish species, although many species are considered to be tolerant of turbid environments and regularly experience changes in SSC due to natural variability in the Irish Sea. The project design parameter assessed in chapter 9: Fish and Shellfish Ecology assumed all wind turbine and offshore substation foundations will be installed by drilling 9.6 m diameter piles and installation of inter-array cables through ploughing/jetting. Fish and shellfish species that are likely to be affected by sediment deposition are those that feed or spawn on or near the seabed. Adult fish species are less susceptible to physiological effects from increases in SSC than juveniles. Modelling of SSC associated with the foundation installation showed low levels of suspended sediments with peaks of 100 mg/l extending beyond the offshore wind farm area. The average suspended sediment concentration beyond the immediate vicinity of the offshore wind farm area are generally less than 30 mg/l with most of the sediment plume envelope having a suspended sediment concentration of less than 10 mg/l. Sediment deposition is predicted to be indiscernible from the background due to the limited quantity of material released, with the exception of directly at the drill site where cuttings fall to the seabed. Based on the low levels of increase in SSC, the localised nature of the impact, and the tolerance of fish and shellfish receptors, the overall significance of the effect was deemed to be imperceptible.

Therefore, the impact for all marine megafauna receptors is predicted to be of local spatial extent, short-term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor indirectly. The magnitude is therefore, considered to be low.

Sensitivity of the receptor

Marine mammals exploit a suite of different prey items and can travel great distances to forage. It is likely that the effects described for fish and shellfish (chapter 9: Fish and Shellfish Ecology) will occur over a similar, or lesser, extent and duration as those for marine mammals. For example, avoidance behaviour of fish during the construction phase will lead to displacement over potentially smaller ranges than those given for most marine mammals. In addition, as prey moves out of the areas of potential impact, so marine mammals are likely to follow in order to exploit these resources.

The fish and shellfish communities found within the Fish and Shellfish Ecology Study Area were characteristic of the fish and shellfish assemblages in the wider western Irish Sea (see appendix 9-1: Fish and Shellfish Ecology Technical Report). Therefore, whilst the offshore wind farm area is located within and close to spawning and nursery grounds (e.g. herring spawning ground) and could potentially be adversely affected by impacts such as temporary habitat loss, underwater noise, and increased SSC, due to the highly mobile nature of marine mammals it is likely that these animals will be able to exploit similar resources elsewhere. Although there could be an energetic cost, particularly to harbour porpoise, grey seal and harbour seal if animals have to travel further to alternative foraging grounds, the impacts are expected to be short-term in nature. It is expected that all marine mammal receptors would be able to tolerate the effect without any impact on reproduction and survival rates and would be able to return to previous activities once the impact had ceased. All marine mammals are assessed as high resilience to the effect with minor impairment of ecological functioning, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability. All marine mammal receptors are of international/national value. Therefore, the sensitivity of all marine mammal receptors is considered to be low.

Basking shark are likely to only be opportunistically feeding in the Marine Megafauna Study Area and will not be reliant on this area as an important feeding ground (see appendix 10-1: Marine Mammals and Megafauna Technical Report). Similarly, the Marine Megafauna Study Area has not been identified as an important foraging area for leatherback turtle in the context of the available habitat in the wider Irish Sea. It is expected that there will be little or no effect on the behaviour of basking shark and leatherback turtle and therefore both receptors are deemed to assessed as having high resilience to the effect with minor impairment of ecological functioning, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability. Both species are of national value. The sensitivity of basking shark and leatherback turtle has been assessed as negligible.

Significance of the effect

Overall, the magnitude of the impact is deemed to be low and the sensitivity of the receptors is considered to be negligible to low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

Operational and maintenance phase

Potential operational and maintenance phase impacts on fish and shellfish receptors include temporary subtidal habitat loss/disturbance, increased suspended sediment concentrations and associated sediment deposition, long-term subtidal habitat loss and EMF from subsea electrical cabling (see chapter 9: Fish and Shellfish Ecology).

Magnitude of impact

Temporary subtidal habitat loss/disturbance could occur as a result of component replacement activities and cable repair/reburial activities. The project design parameter assessed in chapter 9: Fish and Shellfish Ecology is for 387,000 m^2 of temporary habitat loss/disturbance during the operational and maintenance phase, equating to 0.06% of the offshore wind farm area and offshore cable corridor combined, with only a small proportion of the total habitat loss/disturbance likely to be occurring at any one time over the 40-year operational phase of the Project. The Fish and Shellfish Ecology impact assessment considered that the magnitude of the impact and the sensitivity of the receptors would be similar to that assessed for the construction phase, and therefore the overall significance of the effect was deemed to be imperceptible adverse.

Increased SSC could occur as a result of repair or reburial of the inter-array and offshore cables. The project design parameter assessed in chapter 9: Fish and Shellfish Ecology assumed seven inter-array cable repair, seven reburial events and three offshore cable repair and three reburial events over the Project lifetime, using similar methods as those for cable installation activities (i.e. trenching/jetting). The Fish and Shellfish Ecology impact assessment considered that any suspended sediments and associated deposition will be of the same magnitude, or lower as for construction, with the sensitivity of the receptors similar to that assessed for the construction phase. The overall significance of the effect was therefore deemed to be imperceptible adverse.

Long-term subtidal habitat loss (for the duration of the 40-year operational and maintenance phase) will occur under all foundation structures, associated scour protection and any required cable protection, and may result in impacts on fish and shellfish receptors. The Project design parameters assessed in chapter 9: Fish and Shellfish Ecology assumed a maximum of 332,060 m^2 of long-term habitat loss, equating to 0.4% of the offshore wind farm area and offshore cable corridor combined. Fish and shellfish species that are reliant upon the presence of suitable sediment/habitat for their survival are considered to be more vulnerable to change. The fish species most vulnerable to habitat loss include sandeel which are demersal spawning species (i.e. eggs are laid on the seabed), as these have specific habitat requirements for spawning (i.e. sandy sediments). However, the proportion of habitat affected within the offshore wind farm area and offshore cable corridor is small and this area is smaller still in the context of the known sandeel habitats and the potential sandeel habitats in the wider western Irish Sea Fish and Shellfish Ecology Study Area. The Fish and Shellfish Ecology impact assessment therefore considered the overall significance of effect to be imperceptible or slight adverse.

Localised EMF may result from the presence and operation of inter-array and offshore cables which could potentially affect the sensory mechanisms of some species of fish and shellfish, particularly electrosensitive species (including elasmobranchs) and migratory fish species (CMACS, 2003). Species for which there is evidence of a response to electrical (E) and/or magnetic (B) fields include elasmobranchs (sharks, skates and rays), river lamprey, sea lamprey, European eel, plaice and Atlantic salmon (Gill *et al*., 2005, CSA, 2019). It can be inferred that the life functions supported by an electric sense may include detection of prey, predators or conspecifics to assist with feeding, predator avoidance, and social or reproductive behaviours. Life functions supported by a magnetic sense may include orientation, homing, and navigation to assist with long or short-range migrations or movements (Gill *et al*., 2005; Normandeau *et al*., 2011). Based on the localised nature of the impact (centimetres from the cables), the rapid decay of EMF and the ability of receptors to detect and therefore avoid EMF, the Fish and Shellfish Ecology assessment concluded the overall significance of the effect to be slight adverse.

Therefore, for temporary habitat loss and increased SSC the impact for all marine mammal receptors and basking shark is predicted to be of local spatial extent, short term duration, intermittent and high reversibility. For long-term habitat loss and EMF, the impact for all marine mammal receptors and basking shark is predicted to be of local spatial extent, long term duration, continuous and low reversibility. It is predicted that the impact will affect the receptor indirectly. The magnitude is considered to be low for both short-term and long-term impacts.

Sensitivity of the receptor

The sensitivity of the receptors during the operational and maintenance phase are not expected to significantly differ from the construction phase despite the potential for long-term loss of fish and shellfish habitat or EMF. This is due to the very small scale and localised nature of the impact. It is expected that all marine mammal receptors would be able to tolerate the effect without any impact on reproduction and survival rates, and therefore the sensitivity of all marine mammal receptors is considered to be low. It is expected that there will be little or no effect on the behaviour of basking shark. Basking shark are deemed to be of low vulnerability, high recoverability and national value. The sensitivity of basking shark has been assessed as negligible.

Significance of the effect

Overall, the magnitude of the impact is deemed to be low and the sensitivities of the receptors are considered to be negligible to low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

Decommissioning phase

The effects of decommissioning activities are expected to be the same or similar to the effects from construction. The significance of effect is therefore **imperceptible adverse**, which is not significant in EIA terms.

10.10.5 Electromagnetic Fields (EMF) from subsea electrical cabling may disrupt behaviour of basking shark

Operational and maintenance phase

During transmission of electricity along the inter-array and offshore cables, localised and low frequency EMF are emitted. Basking shark are known to be magneto-sensitive and therefore EMF could affect sensory mechanisms and lead to effects on large-scale movement, scale orientation, feeding or mate finding.

Magnitude of impact

The presence and operation of inter-array and offshore cables within the offshore wind farm area and offshore cable corridor may lead to a localised EMF over the 40-year operational phase of the Project.

Electromagnetic fields comprise both the electric (E) fields, measured in volts per metre (V/m), and the magnetic (B) fields, measured in tesla (T). Background measurements of the magnetic field are approximately 50 μT in the North Sea, and the naturally occurring electric field in the North Sea is approximately 25 μV/m (Tasker *et al*., 2010). Measurements in the Irish Sea are unlikely to differ significantly. It is common practice to block the direct electrical field (E) using conductive sheathing, meaning that the EMFs that are emitted into the marine environment are the magnetic field (B) and the resultant induced electrical field (iE). Cable burial and concrete mattressing may also be useful in reducing the magnitude of the impacts, although noting that the emitted magnetic fields may still be at a level that could be detectable by certain marine organisms (Gill *et al.,* 2009).

The strength of the magnetic field (and consequently, iE fields) decreases rapidly horizontally and vertically with distance from source (review by Nyqvist *et al.,* 2020). A recent study conducted by CSA (2019), corroborates this, finding that inter-array and offshore cables buried between depths of one to two metres reduces the magnetic field at the seabed surface four-fold. For cables that are unburied and instead protected by thick concrete mattresses or rock berms, the field levels were found to be similar.

The orientation of the cable in relation to the Earth's geomagnetic field and the distance between buried cables can influence the change in magnetic field. For example (Table 10-42), cables that run roughly parallel to the Earth's geomagnetic field in some locations may cause an increase in the intensity of the magnetic field whereas cables running perpendicular to the Earth's geomagnetic field will cause a decrease in magnetic field below ambient levels (Normandeau *et al*., 2011).

Table 10-42: Average magnetic fields (μT) generated for AC export cables at horizontal distances from the cable (assuming cable burial to a depth of 1 m; source: modified from Normandeau et al., 2011).

Distance above seabed (m)	Horizontal Distance (m) from cable		
	0 m	4 m	10 m
0	7.85	1.47	0.22
5	0.35	0.29	0.14
10	0.13	0.12	0.08

A variety of design and installation factors affect EMF levels in the vicinity of the cable, these include current flow, distance between cables, cable orientation relative to the earth's magnetic field (direct current (DC) only), cable insulation, number of conductors, configuration of cable and burial depth. The Project design includes a singular offshore cable and therefore in the intertidal zone and shallower subtidal zone only one cable will be laid. In addition, cables are designed with a protective sheathing to reduce magnetic and electric fields. Cables will be buried to a depth of between 0.5 m and 3 m and cable protection will be used when cable burial is not possible.

The impact is predicted to be of local spatial extent (i.e. restricted to within the offshore wind farm area and offshore cable corridor), long-term duration (i.e. the lifetime of the Project), continuous and irreversible (during the lifetime of the Project; recoverability is possible following completion of decommissioning). It is predicted that the impact has the potential to affect basking shark directly. The magnitude is therefore, considered to be low.

Sensitivity of the receptor

Elasmobranchs use their perception of magnetic and electric fields for orientation and prey detection (Lozano-Minguez *et al.,* 2011; Tricas T and Gill AB, 2011; Wilson *et al.,* 2010; Snyder and Kaise, 2008) and are therefore sensitive to electro- or magnetic fields. According to Bailey *et al.,* (2014) EMFs have the potential to affect the movements and navigation of marine animals, including basking shark.

The sensitivity of a species to EMFs emitted by cables depends on the water depth that it generally inhabits, such that species that are known to inhabit relatively shallow water and those that feed near the bottom may be more exposed to EMF than species found in the pelagic zone in deeper water (e.g. basking shark). The electrosensory mechanisms of elasmobranchs may be sensitive to small electric fields around subsea cables, with animals responding with changes in orientation and behaviour (Kajiura and Fitzgerald, 2009).

There is less evidence for a response of elasmobranchs to external magnetic fields. Research suggests that the magnetic impact of subsea cables is unlikely to affect many magnetically sensitive species to any great extent and would likely be perceived only as a variation to the Earth's natural field (Normandeau *et al*., 2011); magnetic fields are likely to be attenuated to some extent by the cable sheath and seabed and therefore the ambient magnetic fields in the vicinity of the cable are likely to be altered only slightly. In addition, magneto-sensitive species are unlikely to respond to magnetic fields from AC cables because the rate of change of the field (polarity reversal) would be too rapid for a behavioural response to occur (Normandeau *et al*., 2011).

Whilst studies have suggested that chronic exposure to electromagnetic radiation could impact nervous, cardiovascular, reproductive and immune systems of marine species (Reifolo *et al.,* 2016), this is not considered to be a risk to basking shark given their temporary occurrence in the offshore wind farm area (see appendix 10-1: Marine Mammals and Megafauna Technical Report).

It is expected that basking shark could tolerate the effects of EMF without any impact on reproduction and survival rates and therefore basking shark has been assessed as having high resilience to the effect with minor impairment of ecological functioning, has an ability to adapt behaviour such that ecological function can be maintained, and high recoverability. Basking shark is of national value. The sensitivity of basking shark to EMF has therefore been assessed as low.

Significance of the effect

Overall, the magnitude of the impact is deemed to be low and the sensitivity of the receptor is considered to be low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

10.10.6 Mitigation and residual effects

Measures included in the Project are outlined in section 10.8.2 for all activities.

Mitigation using an ADD is proposed to minimise impacts arising from injury to marine megafauna from underwater noise during pile-driving by deterring animals to move beyond the predicted injury zone as outlined in section 10.10.6 In order to minimise noise disturbance from the Project, a Piling Strategy will be implemented, alongside an MMMP which sets out a final project design prior to construction as well as options for potential management measures that may be implemented to ensure any effects are reduced to an acceptable level, such as phased piling.

With the implementation of the measures included in the Project (section 10.8.2), the residual effects are as outlined in the assessment provided in section 10.10.1. With an ADD activated prior to soft start (see section 10.10.1), it is concluded that the residual significance of the effect of PTS and TTS on marine mammal IEFs is assessed as **slight adverse significance** and **imperceptible to slight adverse significance** respectively, which is not significant in EIA terms.

It is noted that the significance of the effect from the ADD itself on disturbance from piling is assessed as **imperceptible adverse significance** and not significant in EIA terms.

10.10.7 Future monitoring

No marine mammals and megafauna monitoring to test the predictions made within the impact assessment is considered necessary.

10.11 Cumulative Impact Assessment

10.11.1 Methodology

The Cumulative Impact Assessment (CIA) takes into account the impact associated with the Project together with other projects. The projects selected as relevant to the CIA presented within this chapter are based upon the results of a screening exercise (see volume 2A, appendix 3-1: CIA Screening Annex). Each project has been considered on a case-by-case basis for screening in or out of this chapter's assessment based upon data confidence, effect-receptor pathways and the spatial/temporal scales involved.

The approach to assessment examines the cumulative effects of the Project alongside the following projects if they fall within the ZoI for Marine Mammals (further details on the ZoI are provided in volume 2A, appendix 3-1: CIA Screening Annex):

- Other projects with consent but not yet constructed/construction not completed;
- Other projects in a consent application process but not yet determined (including planning applications, foreshore lease/licence applications, Dumping at Sea Permit applications, etc.);

- Other projects currently operational that were not operational when baseline data were collected, and/or those that are operational but have an ongoing impact; and
- Projects, which satisfy the definition of 'relevant maritime usage' under the Maritime Area Planning Act (2021) (i.e. wind farm projects designated as 'Relevant Projects' or 'Phase 1 Projects') including Arklow Bank II, Bray and Kish banks, North Irish Sea Array, Codling Wind Park (I and II).

The specific projects screened into this CIA are outlined in Table 10-43 and Figure 10-12.

Collaboration with the other Phase 1 projects has informed the CIA. This included discussions amongst the project teams on the approach and methodologies regarding alignment of sensitivities and magnitudes where possible. Also the projects commit to implementing phased piling alongside other adjacent offshore wind farms in the western Irish Sea as part of a Piling Strategy should construction programmes overlap.

Cumulative population modelling for the Phase 1 projects in the Irish Sea has been completed and no significant impacts to any marine mammals from disturbance from piling at the five projects is predicted. This information will also be used to inform the piling strategy.

Table 10-43: List of other projects considered within the CIA.

Project	Status	Distance from offshore wind farm area (km)	Distance from offshore cable corridor (km)	Description of Project	Dates of construction (if applicable)	Dates of operation (if applicable)	Overlap with the Project
Offshore Wind Farms							
North Irish Sea Array (NISA)	Maritime Area Consent	16.2	18.1	EIA Scoping Report (2021) refers to the construction of an offshore wind farm of up to 500 MW, consisting of 36 turbines with a maximum height of 320 m and rotor diameter of up to 290 m. Offshore substation platforms may be required.[3]	Unknown	Unknown (Design life minimum 35 years)	Potential for overlap with construction and operational and maintenance phases of the Project and therefore potential for physical or temporal overlap.
Dublin Array	Maritime Area Consent	61.2	57	EIA Scoping report (2020) refers to the construction of Bray and Kish offshore wind farm of up to 900 MW, consisting of up to 61 turbines with a max. height of 308 m and rotor diameter of up to 285 m and up to three offshore substation platforms.[4]	Unknown	Unknown (Design life minimum 35 years)	Potential for construction and operation phases to overlap with the Project. Potential for cumulative effect associated with underwater noise emissions (i.e. greater area of regional habitat affected).
Codling Wind Park	Maritime Area Consent	61.4	57.2	EIA Scoping report (2020) refers to the construction of an offshore wind farm of up to 1500 MW, consisting of up to 140 turbines with a maximum height of 320 m and rotor diameter of up to 288 m. The project will also contain up to five offshore substation platforms.[5]	Unknown	Unknown (Design life minimum 35 years)	Potential for overlap with construction and operational and maintenance phases of the Project and therefore potential for physical or conceptual overlap.
Arklow Bank Wind Park	Maritime Area Consent	107.1	104.7	EIA Scoping Report (2023): The project will include between 37 and	Unknown	Unknown (Design life minimum 35 years)	Potential for construction and operation phases to overlap with

[3] Project website https://northirishseaarray.ie/: states that wind farm will consist of 35 to 46 turbines.

[4] Project website: https://dublinarray.com/project-information/key-facts/: states between 39 and 50 turbines (total project capacity 824 MW) individual tip heights between approx. 270 m and 310 m.

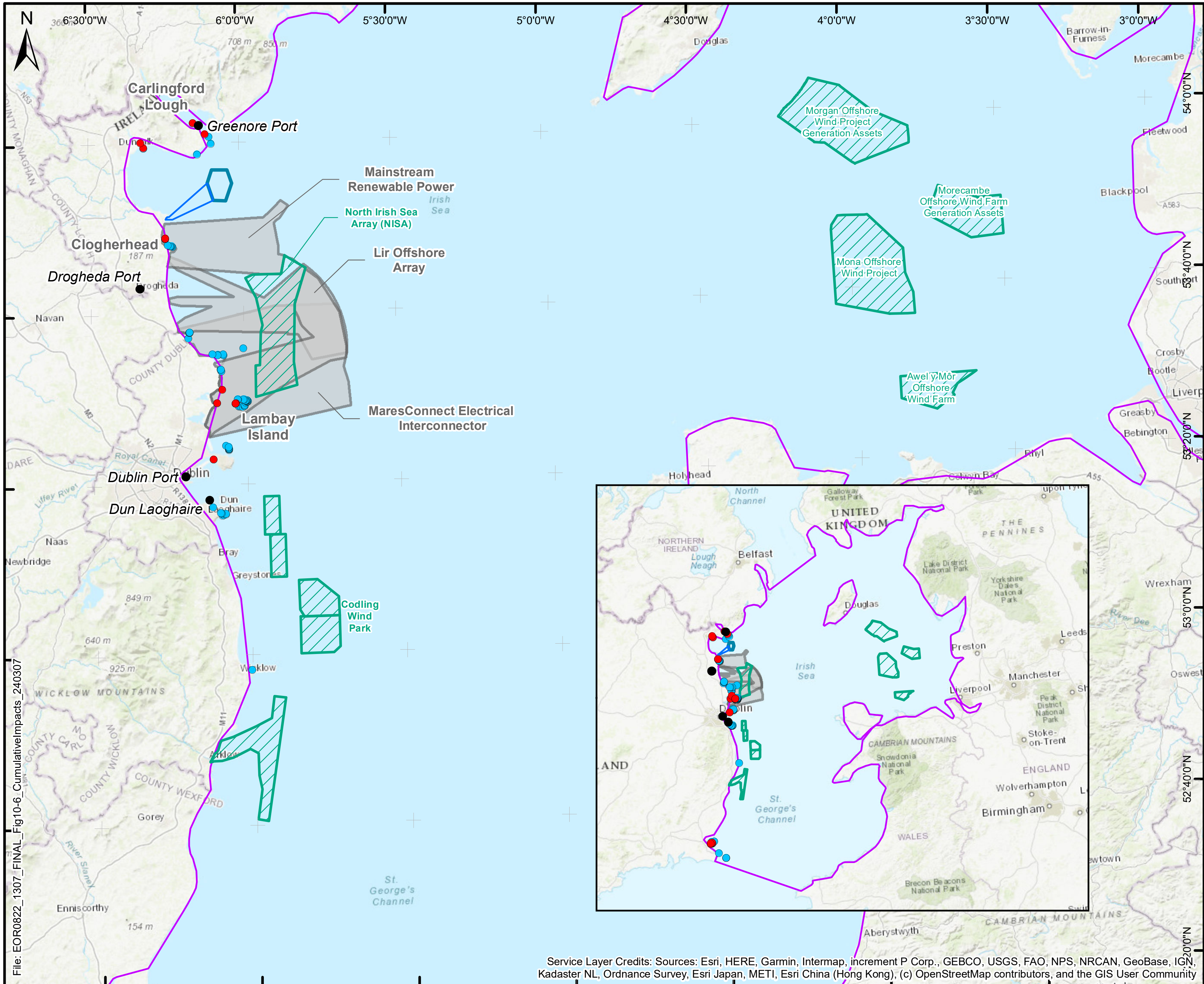
[5] Project website: https://codlingwindpark.ie/the-project/: states max energy output 1300 MW, 100 turbines, turbine tip height max 320 m.

Project	Status	Distance from offshore wind farm area (km)	Distance from offshore cable corridor (km)	Description of Project	Dates of construction (if applicable)	Dates of operation (if applicable)	Overlap with the Project
				56 turbines ad up to two Offshore Substation Platforms (OSP) and foundation substructures. The area in which the proposed wind turbines, inter-array cables and OSP(s) will be located on Arklow Bank covers an area of seabed approximately 64km^2.[6]			the Project. Potential for cumulative effect associated with underwater noise emissions (i.e. greater area of regional habitat affected).
Morgan Offshore Wind Project: Generation Assets	Planning	119	119	Offshore Wind Farm (1.5 GW capacity) in English waters. Scoping report indicates up to 107 turbines and up to eight offshore substations. Application not yet submitted.	Unknown	Unknown	Potential for overlap with construction and operational phases of the Project and therefore potential for physical or conceptual overlap.
Mona Offshore Wind Project	Planning	127	131	Offshore Wind Farm (1.5 GW capacity) in Welsh and English waters. Scoping report indicates up to 107 turbines and up to eight offshore substations. Application not yet submitted.	Unknown	Unknown	Potential for overlap with construction and operational and maintenance phases of the Project and therefore potential for physical or conceptual overlap.
Awel y Môr Offshore Wind Farm	Planning	142	145	Offshore Wind Farm (500 MW capacity) in Welsh waters. Application submitted but not awarded.	01/01/2026 - 31/12/2029	01/01/2030 – 31/12/2055	Potential for overlap with construction and operational activities of the Project to overlap with construction and operational activities of Awel y Môr Offshore Wind Farm.
Morecambe Offshore Windfarm:	Planning	155	155	Offshore Wind Farm (Maximum 960 MW capacity) in English waters. Scoping report indicates up to 40 turbines and up to two	Unknown	Unknown	Potential for overlap with construction and operation phases of the Project and therefore

[6] Project website https://www.sserenewables.com/: states between 36 and 60 turbines (up to 800MW) along with one to two OSS and foundation substructures, a network of inter-array cabling and two offshore export cables.

Project	Status	Distance from offshore wind farm area (km)	Distance from offshore cable corridor (km)	Description of Project	Dates of construction (if applicable)	Dates of operation (if applicable)	Overlap with the Project
Generation Assets				offshore substations. Application not yet submitted.			potential for physical or conceptual overlap.
Site investigations							
Mainstream Renewable Power Ltd.	Planning	15	18.1	Foreshore Licence application for site investigation works off County Dublin. Surveys include Geophysical, Geotechnical, Metocean and Ecological site investigations.	N/A	Unknown (subject to award of licence).	Potential for construction phase of the Project to overlap with surveys and site investigation activities for other projects. Potential for in-combination effect of subsea noise emissions (i.e. greater area of regional habitat affected). Other site investigation surveys screened out due to large distances from Project (i.e. all other site investigation surveys are 45 km or greater from Project) and since effects are likely to be very localised and short term there is considered to be no physical or conceptual effect-receptor pathway.
Lir Offshore Array	Planning	4.2	0.8	Foreshore Licence application for site investigation works off County Dublin. Surveys include Geophysical, Geotechnical, Metocean and Ecological site investigations.	N/A	Unknown (subject to award of licence)	
MaresConnect Electrical Interconnector	Planning	24.6	23.4	Site investigation surveys for the proposed MaresConnect electrical interconnector between RoI and Wales.	N/A	Unknown (subject to award of licence)	
26 additional site investigation surveys located between 45.3 km and 287 km from the Project							For the impact of injury and/or disturbance to marine mammal species from vessel activities there is the potential for overlap with construction and operational phases of the Project and therefore potential for physical or conceptual overlap. For the impact of injury and/or disturbance to marine mammals from elevated underwater noise during geophysical surveys there

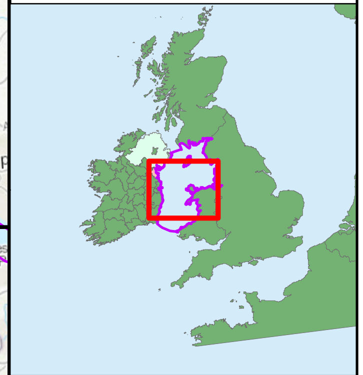
Project	Status	Distance from offshore wind farm area (km)	Distance from offshore cable corridor (km)	Description of Project	Dates of construction (if applicable)	Dates of operation (if applicable)	Overlap with the Project
							is considered to be no potential for overlap due to distance from the Project (> 45 km).



Legend

- Offshore Wind Farm Area
- Offshore Cable Corridor
- Cumulative Marine Mammal and Megafauna Study Area
- Wind Farm Application Area
- Harbour Seal haul-out
- Grey Seal haul-out
- Site Investigation Surveys

Data Sources: Client, ICES, SNH
gov.ie (Dept of Housing, Local Government and Heritage)



Client

ORIEL WINDFARM
OFFSHORE RENEWABLE ENERGY

Project

Oriel Wind Farm Project

Title

Figure 10-12 Other projects screened into the cumulative impact assessment

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Issue Details

Drawn By:	NG	Project No.	EOR0822 (MDR1520B)
Checked By:	NG	File Ref:	
Approved By:	AOS		EOR0822_MAM_E_1307_FINAL
Scale:	1:1,100,000 @ A4	Projection:	ITM (IRENET95) Geographic Co-ordinates: ETRS89
Date:	07/03/2024		

NOTE:
1. This drawing is the property of RPS Group Ltd. It is a confidential document and must not be copied, used, or its contents divulged without prior written consent.
2. All levels are referred to Ordnance Datum, Malin Head.
3. Ordnance Survey Ireland Licence EN 0005019 ©Copyright Government of Ireland.

Table 10-44 presents the relevant project design parameters from Table 10-11 which are used to assess the potential cumulative impacts of the Project with the other projects identified in Table 10-43 (where information is available).

Impacts have been carried forward for assessment where there is potential for an effect to occur from the Project alone over a scale that could impact cumulatively with other projects within the Regional Marine Megafauna Study Area. Therefore, three impacts are assessed here: 1) injury/ disturbance to marine megafauna from underwater noise during pile-driving; 2) injury/ disturbance to marine megafauna from elevated noise during routine geophysical surveys; and 3) injury/disturbance to marine megafauna from vessel activities. Effects on marine mammals and megafauna arising from the impact of changes in the fish and shellfish community and EMF from subsea electrical cabling (basking shark) are considered to be localised to within the offshore wind farm area and offshore cable corridor and unlikely to lead to cumulative effects with other projects.

Table 10-44: Project design parameters considered for the assessment of potential impacts on marine mammals and megafauna.

Potential impact	Phase			Project design parameters	Justification
	C	O	D		
Injury and/or disturbance to marine megafauna from underwater noise during pile-driving.	✓	✗	✗	Design parameters as described for the Project (Table 10-11) assessed cumulatively with the following other projects: **Offshore wind farms** • Dublin Array – piling of up to 61 foundations; • NISA - piling of up to 36 foundations. • Arklow Bank Wind Park (Phase 2) – piling of up to 62 foundations; • Codling Wind Park – piling of up to 140 foundations; • Awel y Môr Offshore Wind Farm – piling of up to 50 foundations; • Mona Offshore Wind Project – piling of up to 115 foundations; • Morgan Offshore Wind Project Generation Assets: – piling of up to 115 foundations; and • Morecambe Offshore Windfarm Generation Assets – piling of up to 42 foundations.	Maximum potential for cumulative effects from underwater noise from construction operations within the Regional Marine Megafauna Study Area.
Injury and/or disturbance to marine megafauna from elevated underwater noise during routine geophysical surveys.	✗	✓	✗	Design parameters as described for the Project (Table 10-11) assessed cumulatively with the following other projects: **Offshore wind farms** • NISA - piling of up to 46 foundations. **Site investigation surveys** • Mainstream Renewable Power Ltd. – site investigation surveys; • Lir Offshore Array Ltd. – site investigation surveys; and • MaresConnect Electrical Interconnector – site investigation surveys.	Maximum potential for cumulative effects of underwater noise from routine survey operations within the Regional Marine Mammal and Megafauna Study Area. Site investigation surveys more than 45 km from the Project have been screened out as having no potential for cumulative effects.
Injury and/or disturbance to marine megafauna from vessel activities.	✓	✓	✓	Design parameters as described for the Project (Table 10-11) assessed cumulatively with the following other projects: **Offshore wind farms** • Dublin Array – vessel traffic during all phases; • NISA - vessel traffic during all phases;	Maximum potential for cumulative effects from vessel activity associated with construction and maintenance works within the Regional

Potential impact	Phase C	O	D	Project design parameters	Justification
				• Arklow Bank Wind Park (Phase 2) – vessel traffic during all phases; • Codling Wind Park – vessel traffic during all phases; and • Awel y Môr Offshore Wind Farm – vessel traffic during all phases. • Mona Offshore Wind Project – vessel traffic during all phases; • Morgan Offshore Wind Project Generation Assets: – vessel traffic during all phases; and • Morecambe Offshore Windfarm – vessel traffic during all phases. **Site investigation surveys** • Mainstream Renewable Power Ltd. – site investigation surveys; • Lir Offshore Array Ltd. – site investigation surveys; and • MaresConnect Electrical Interconnector – site investigation surveys. • Up to 26 additional site investigation surveys ranging from 45.3 km and 287 km from the Project that have the potential to overlap temporally.	Marine Megafauna Study Area.

10.11.2 Assessment of significance

A description of the significance of cumulative effects upon marine mammal and megafauna receptors arising from each identified impact is given below.

Injury and/or disturbance to marine megafauna from underwater noise during piling-driving / drilling

Construction phase

Magnitude of impact

The installation of foundations within the offshore wind farm area, together with the projects identified in Table 10-44, may lead to either spatial effects (where piling phases overlap) and/or temporal effects (a longer duration of piling compared to the Project alone). Other projects screened into the assessment within the Regional Marine Megafauna Study Area include the following offshore wind farms: Dublin Array, Arklow Bank Wind Park (Phase two), NISA and Codling Wind Park, Awel y Môr Offshore Wind Farm, Mona Offshore Wind Project, Morgan Offshore Wind Project Generation Assets and Morecambe Offshore Windfarm Generation Assets.

The maximum predicted injury ranges for the Project are presented below in Table 10-45, along with project parameters and predicted injury ranges for those projects where quantitative information is available.

Table 10-45: Piling parameters and injury ranges for the Project and screened-in projects located in the eastern Irish Sea (with the implementation of measures included in projects).

Project	Reference	Distance from Oriel Wind Farm Project (km)	Scenario	Maximum PTS range (km)		Maximum TTS range (km)	
				SPL_{pk} metric	SEL_{cum} metric	SPL_{pk} metric	SEL_{cum} metric
Oriel Wind Farm Project	Section 10.8.1	-	3,500 kJ 5 – 8 hrs per pile 26 monopiles	0.236	0.168	0.344	5.98
Morgan Offshore Windfarm Generation Assets	Morgan Offshore Wind Ltd. (2023)	119.5	5,500 kJ 9.5 hrs per pile 70 piles	0.99	5.47	TTS ranges not presented	
Mona Offshore Wind Farm	Mona Offshore Wind Ltd. (2023)	127.0	5,500 kJ 9.5 hrs per pile 70 monopiles	0.96	5.36	TTS ranges not presented	
Awel y Môr Offshore Wind Farm	RWE (2022a)	142.4	5,000 kJ 3.2 hours per pile 50 monopiles	0.64	10	1.5	30
Morecambe Offshore Windfarm Generation Assets	Morecambe Offshore Windfarm Ltd (2023)	151.3	5,000 kJ 4.5 hours per pile 42 monopiles	0.66	4.4	1.6	24

For projects where quantitative information is available (Morgan Offshore Wind Project Generation Assets, Mona Offshore Wind Project, Awel y Môr Offshore Wind Farm and Morecambe Offshore Windfarm Generation Assets) ranges presented for PTS are up to 0.99 km for the SPL_{pk} metric and up to 5.47 km for the SEL_{cum} metric. TTS ranges presented are up to 1.6 km for the SPL_{pk} metric and up to 30 km for the SEL_{cum} metric. Assuming that projects adopt standard industry measures to mitigate the risk of PTS there is no potential for a cumulative effect of PTS. TTS to some extent will also be mitigated through the adoption of standard industry measures, but even with the possibility of a residual effect, TTS is reversible. In addition, projects in the eastern Irish Sea are located more than 119 km from the Project and therefore there is considered to be no potential for overlap of injury ranges.

For projects in the western Irish Sea (Dublin Array, Arklow Bank Wind Park (Phase 2), NISA and Codling Wind Park), no quantitative information on PTS or TTS ranges is available. It is considered that PTS ranges and TTS ranges would be in the same order of magnitude, or less than those presented in Table 10-45. Whilst there is greater potential for overlap of injury ranges with projects located in the western Irish Sea, the closest project is located approximately 16 km away (NISA). Therefore, assuming that all projects screened in to the cumulative assessment adopt standard industry measures to mitigate the risk of PTS it is considered that there is no potential for cumulative effects for injury from elevated underwater noise during piling. The focus of cumulative effects is therefore on the potential for disturbance of marine mammals. The modelled disturbance contours for piling at the east of the Project are set out in Figure 10-4 and Figure 10-5 and the numbers of animals potentially affected by disturbance as a result of piling at the Project are set out in Table 10-30.

Injury to marine mammal species is considered unlikely to lead to cumulative effects as the effect ranges are considered to be very localised and, with mitigation in place, are unlikely to lead to potential effects.

There is the potential for a cumulative effect of disturbance from piling at the Project with other projects in the Regional Marine Mammal and Megafauna Study Area (see Table 10-46), including Awel y Môr Offshore Wind Farm, Mona Offshore Wind Project, Morgan Offshore Wind Project Generation Assets, Morecambe

Offshore Wind Project Generation Assets, Dublin Array, Arklow Bank Wind Park (Phase 2), NISA and Codling Wind Park.

For cumulative projects where detailed information is available, piling is expected to take place for up to 201 days for piling of monopiles at Awel y Môr Offshore Wind Farm (over the 1-year piling phase in 2028); 35 days for piling of monopiles at both Mona Offshore Wind Project and Morgan Offshore Wind Project Generation Assets (over the respective 2-year construction phases in 2027 and 2028); and 42 days for piling of monopiles at Morecambe Offshore Wind Project Generation Assets (over the 2-year piling phase in 2027 and 2028). These timelines are, however, indicative and may be subject to change. Piling at each of these projects will occur as a discrete stage within the overall construction phase and therefore the periods of piling may not coincide.

It has been assumed that construction phases for the other phase 1 offshore wind farm projects could overlap temporally with the construction phase of the Project, with potential for piling operations to coincide.

The maximum predicted disturbance ranges for the Project are presented below in Table 10-46, along with disturbance ranges for those projects where quantitative information is available. The Awel y Môr Offshore Wind Farm did not consider effects on harbour seal, as this species was scoped out. Given that the cumulative assessment for piling is provided on species-by-species basis, harbour seal will not be considered further for this Project. There were no estimates available for the number of animals likely to be affected during piling for Dublin Array, Arklow Bank Wind Park (Phase 2), NISA or Codling Wind Park, and therefore a quantitative cumulative assessment was not possible for these projects.

Table 10-46: Maximum number of animals with the potential to be disturbed (applying a dose-response disturbance approach) as a result of piling at Oriel Wind Farm Project and cumulative projects located in the eastern Irish Sea (projects for which quantitative information is available).

Project	Reference	Distance from Oriel Wind Farm Project (km)	Animals with the potential to be disturbed											
			Harbour porpoise		Bottlenose dolphin		Common dolphin		Minke whale		Grey seal		Harbour seal	
			Number animals	Proportion of MU	Number animals	Proportion of MU	Number animals	Proportion of MU	Number animals	Proportion of MU	Number animals	Proportion of MU	Number animals	Proportion of MU
Oriel Wind Farm Project	Section 10.10	-	725	1.160%	26 (SCANS III) 129 (SCANS IV)	8.63% 1.549%	15	0.015%	142	0.706%	21	0.357%	16	0.979%
Morgan Offshore Windfarm Generation Assets	Morgan Offshore Wind Ltd. (2023)	119.49	1,370	2.19%	16	5.28%	100	0.10%	96	0.48%	48	0.08 – 0.35%	< 1	0.005%
Mona Offshore Wind Farm	Mona Offshore Wind Ltd. (2023)	127.04	587	0.94%	17	5.69%	109	0.11%	105	0.52%	92	0.15 – 0.68%	< 1	0.03%
Awel y Môr Offshore Wind Farm	RWE (2022)	142.37	275	0.44%	23	7.9%	17	0.02%	36	0.18%	81	1.60%	Species not assessed	
Morecambe Offshore Windfarm Generation Assets	Morecambe Offshore Windfarm Ltd (2023)	151.25	1,279	2.0%	< 1	0.000017 %	< 1	0.000001 3%	2	0.0089%	11	0.098 – 0.99%	3	0.19%

For those projects where quantitative information is available (projects in the eastern Irish Sea), the numbers of animals predicted to be affected by individual projects represent relatively small proportions of respective MUs (Table 10-46). If piling were to coincide at these projects there is potential for a larger area of available habitat within the wider Irish Sea to be affected at any one time. However, these projects are located more than 119 km from the Project (Table 10-46). Strong and mild disturbance contours (160 dB re 1µ Pa (rms) and 140 dB re 1µ Pa (rms), respectively) modelled for the Project are predicted to extend to ~3.2 km and ~17 km from the Project, respectively (see Figure 10-4 and Figure 10-5). Therefore, the likelihood for overlap of either strong or mild disturbance contours of the Project with those from projects where noise modelling has been undertaken (projects in the eastern Irish Sea) is negligible.

The remaining projects considered are located between 16 and 107 km from the Project, in the western Irish Sea. Whilst quantitative information is not available for these projects, the proximity to the Project of the closer projects means there is potential for a larger number of marine mammals to be at any one time. Assuming similar disturbance ranges for those modelled for the Project, there is potential for overlap of mild disturbance contours with proximal projects (e.g. NISA at approximately 16 km distance). As previously described (see section 10.10.1) at this lower end of the behavioural response spectrum animals are unlikely to be displaced from their habitat; behavioural responses are expected to be less severe (such as changes in swimming speed or direction) and are unlikely to result in population-level effects. Temporally, the duration of disturbance within the western Irish Sea would be greatest where piling occurs sequentially at these wind farms. As described previously (section 10.10.1), piling represents only a fraction of the overall construction phase of the Project with a total of 208 hours over 26 days of piling over the 15-month offshore construction period (i.e. piling occurs for ~7.5% of the total construction period).

The impact of piling at four offshore wind farms in the western Irish Sea (in addition to the Project) and four offshore wind farms in the eastern Irish Sea may lead to potential cumulative behavioural effects on sensitive marine mammal species. The maximum adverse spatial scenario would be where piling occurs concurrently at all nine project sites (recognising the unlikelihood of this occurring), whilst the maximum adverse temporal scenario would be where piling occurs sequentially. All project sites are, however, located beyond the distances within which there would likely be overlap of strong disturbance contours during piling at these project sites (i.e. closest offshore wind farm is approximately 16 km from the Project). Whilst the potential cumulative effect is predicted to be of regional spatial extent and medium term, and the impact will affect the receptor directly, the effect of behavioural disturbance is of high reversibility (with animals returning to baseline levels within hours/days after piling have ceased). Disturbance would occur as a series of short-term, intermittent events and there is evidence from the published literature to suggest that recoverability would be rapid following cessation of piling. The impact could result in some measurable changes to individuals that are disturbed (i.e. interruption of feeding or breeding and/or displacement to alternative area) but there are no long-term population-level consequences of disturbance anticipated.

As previously highlighted, if piling were to coincide at these wind farms there is potential for greater number of individuals to be affected at any one time, leading to a greater maximum spatial scenario. Whilst the Project is expected to contribute low levels of disturbance to any cumulative effect, in order to minimise the level of disturbance in the Irish Sea, a Piling Strategy will be implemented, alongside an MMMP (see Table 10-12 which sets out a final project design prior to construction as well as options for potential management measures that may be implemented to ensure any effects are reduced to an acceptable level, such as phased piling.

As stated in section 10.10.1, population modelling was carried out for the Project alone for harbour porpoise, bottlenose dolphin, minke whale, grey seal and harbour seal. Modelling results for all species demonstrated that there may be negligible reductions in population sizes for the impacted populations. Such small changes would not be enough to significantly affect population trajectories over a generational scale and would fall within the expected range of natural variation.

The impact is predicted to be of local/regional spatial extent, medium term duration, intermittent, and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude of the impact could result in a small but measurable alteration to the distribution of marine mammals but only during piling, which comprises a small fraction of the overall construction periods for these projects. In addition, the small proportion of the relevant reference populations affected at any one time is likely to be small, and would not be at a scale that would lead to any measurable population-level effects. The magnitude is therefore, considered to be low.

Sensitivity of receptor

The species likely to be affected include harbour porpoise, bottlenose dolphin, common dolphin, minke whale, grey seal, harbour seal and leatherback turtle. Most species will range widely throughout the Irish Sea and therefore will readily move between areas to exploit prey resources.

Potentially the most vulnerable species is the harbour seal, which has a greater degree of site-fidelity within the Regional Marine Megafauna Study Area compared to the other species and ranges relatively short distances from haul-out sites on foraging trips. Key haul-outs for harbour seal on the east coast of Ireland are largely restricted to Dundalk Bay, Strangford Lough and Wexford Harbour (Baines, 1997) although there are small numbers recorded in the Dublin area, mainly on the north Dublin islands and coast and on Dalkey Island to the south of Dublin Bay (Cronin *et al.,* 2004). Therefore, harbour seal are most likely to be affected cumulatively during piling at both the Project and at Dublin Array, although in the latter case only small numbers of animals may be affected. Results of a behavioural study on tagged seals during the construction of a wind farm in the Greater Wash, UK, showed that seals were not excluded from the wind farm during the overall construction phase but that there were reduced levels of activity up to 25 km from piling sites (Russell *et al.,* 2016). Displacement ranged from between 4.7 km up to 40.5 km from the piling source, but seals recovered quickly and returned to the wind farm site within two hours of cessation of piling (Russell *et al.*, 2016). A population model developed by Thompson *et al.* (2013) looking at the effect of strong disturbance (displacement) on the harbour seal within the Moray Firth during cumulative piling at two offshore wind farms suggests that even where a large proportion of the population may be affected (43.2%), recovery would be likely within a generational scale. As described above, Dublin Array is located approximately 60 km from the Project and therefore there is unlikely to be any spatial overlap in disturbance effects. Harbour seal tend to forage within close proximity to haul-outs (40 to 50 km; see Table 10-6) and therefore would be unlikely to be affected by concurrent piling at the two wind farms in a single foraging trip.

Grey seal also show site-fidelity to haul-outs within the Regional Marine Megafauna Study Area, although the foraging range for this species is greater compared to harbour seal, with individuals typically travelling distances of up to 100 km to feeding grounds. The key haul-outs for grey seal on the east coast of Ireland are at Wexford Harbour, Clogherhead, Dundalk Bay and Carlingford Lough. Lambay Island SAC, 43.1 km south of the offshore wind farm area, supports the principal breeding colony of grey seal on the east coast of Ireland. The sensitivity of grey seal to piling is expected to be similar to that described above for harbour seal with reduced levels of activity within the area of disturbance. Due to the distances travelled it is possible that an individual may be affected at more than one project during cumulative piling.

Harbour porpoise is the most frequently recorded of the marine mammals and megafauna within the Irish Sea and also during site-specific surveys at the Project (Table 10-7) and at Dublin Array (Saorgus Energy Ltd., 2012). Therefore, this is the species most likely to be encountered within the wind farm areas during piling and where cumulative effects could lead to potential larger numbers of animals disturbed or displaced compared to piling at the Project alone. Harbour porpoise has a relatively high metabolic rate which makes this species potentially vulnerable to disturbance if individuals are unable to obtain sufficient levels of prey intake. This may be more of an issue cumulatively, where potentially multiple areas may be affected at any one time or if the same individual is disturbed over a longer period (e.g. if it is exposed sequentially at all three wind farms). However, as described previously (section 10.10), harbour porpoise range widely and exploit a suite of prey resources throughout their range. The wind farm areas considered in this CIA are not highlighted as being of specific importance for harbour porpoise in the context of the Regional Marine Megafauna Study Area and therefore it is assumed that individuals can move to other areas as alternative habitats. Even in the event that animals are displaced into less-optimal habitat, the duration of effect is likely to be limited to the pile-driving activity only, with recovery occurring rapidly following cessation of the piling (see section 10.10). An Agent Based Model (ABM) developed to look at the effect of cumulative piling at offshore wind farms in the North Sea on harbour porpoise provides evidence to suggest that, even where multiple wind farms are piling together, there would be no long-term population effect on this species (Nabe-Neilson *et al.*, 2018).

For other marine mammal species and sea turtles, the sensitivity is considered to be lower than that described for harbour seal and harbour porpoise above. This is because all these species are wide ranging and therefore avoidance of the disturbed area only represents a small proportion of their available habitat. In addition, the densities of bottlenose dolphin, common dolphin, minke whale, grey seal and leatherback turtle are low within the western Irish Sea (see appendix 10-1: Marine Mammals and Megafauna Technical Report) suggesting that only small numbers may be present within the disturbed areas during piling.

Harbour seal, grey seal and harbour porpoise are assessed as having moderate resilience, have some ability to adapt behaviour such that ecological function can be maintained, and high recoverability. These receptors are of international/national value. Cumulatively, harbour seal and grey seal may be more sensitive if a larger area of habitat near key haul-outs is ensonified during piling. For harbour porpoise, this species may be more sensitive from the cumulative piling scenario if disturbance displaces animals into sub-optimal habitat and reduces potential foraging time, particularly if the same individuals are potentially affected by piling at all considered wind farms. Based on the ecology and distribution of these three species, it is considered likely that they would have the ability to adapt behaviour such that, whilst reproduction rates of some individuals may be affected, it is unlikely that survival rates would be affected and all three receptors are able to return to previous behavioural states/activities once the impact has ceased. The sensitivities of these receptors are, therefore, cautiously considered to be medium.

Bottlenose dolphin, common dolphin, minke whale and leatherback turtle are assessed as having high resilience to the effect with minor impairment of ecological functioning, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability. These receptors are of international/national value. Due to the potentially small numbers affected and the ability of receptors to avoid small areas of disturbance in the context of their wider available habitat, it is considered unlikely that these species will be more sensitive to the cumulative effects of piling compared to piling at the Project alone. These species are therefore likely to tolerate the effect without any impact on reproduction and survival rates and are able to return to previous behavioural states/activities once the impact has ceased. The sensitivities of the receptors are therefore, considered to be low.

Significance of effect

For harbour seal, grey seal, bottlenose dolphin and harbour porpoise, overall, the magnitude of the impact is deemed to be low and the sensitivities of the receptors are considered to be medium. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

For common dolphin, minke whale and leatherback turtle, overall, the magnitude of the impact is deemed to be low and the sensitivities of the receptors are considered to be low. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Basking shark was not assessed in other projects as a key receptor and therefore has not been included in the cumulative assessment with the Project.

Injury and/or disturbance to marine megafauna from elevated underwater noise during geophysical surveys

Operational and maintenance phase

Magnitude of impact

Geophysical surveys associated with routine inspection of the Project offshore infrastructure, together with geophysical and site investigation surveys associated with projects identified in Table 10-44, may increase the potential for auditory injury or disturbance to marine mammals and megafauna. Surveying operations will commence in year five and will have a five-year periodicity. Other projects screened into the assessment within the Regional Marine Megafauna Study Area include Mainstream Renewable Power site investigation surveys, Lir Offshore Array site investigation surveys, MaresConnect site investigation surveys and routine geophysical surveys at NISA.

The potential for marine mammal receptors to experience auditory injury as a result of underwater noise due to geophysical surveys associated with the Project would be expected to occur only within the vicinity of operational geophysical survey equipment: up to 227 m for PTS for harbour porpoise, and up to 449 m for harbour porpoise for TTS. The risk of both PTS and TTS is expected to be reduced further by the implementation of measures discussed in Table 10-12. The potential for marine mammal receptors to experience disturbance as a result of underwater noise due to geophysical surveys associated with the Project would be expected to occur at greater distances (out to 1,410 m) than for injury.

Quantitative information on injury and disturbance ranges for site investigation surveys at Mainstream Renewable Power, Lir Offshore Array and MaresConnect is available in respective Foreshore Licence applications. Although the equipment to be employed for geophysical site investigation surveys of the Project assets is expected to be restricted to MBES methods only, a range of geophysical survey equipment for other cumulative projects has been assessed, employing multiple equipment types with a range of operational parameters. For Mainstream Renewable Power, injury and disturbance ranges are predicted to be similar to those for the Project (up to 200 m for harbour porpoise for PTS, and up to 2,000 m for harbour porpoise for both TTS and disturbance). For MaresConnect, the results of noise modelling demonstrated that for harbour porpoise in particular, the onset of PTS is predicted to arise from between 17 m and 23 m from the source and potential behavioural effects are predicted to occur within 2.4 km and 2.5 km. The same level of information is not available for the Lir project but ranges are expected to be similar to those presented for the other two projects. Quantitative information is not available for NISA but it is expected that injury and disturbance ranges would be of a similar magnitude to the Project. It is expected that injury ranges for all cumulative projects would be further reduced by the implementation of measures, and therefore the potential for cumulative impacts would be further reduced.

Routine geophysical surveying of the offshore assets of the Project is planned to occur every five years, commencing in year five, and survey campaigns are expected to be a maximum total duration of 42 days (assuming three consecutive 14-day surveys, see Table 10-11. There is therefore potential for temporal overlap with the other site investigation surveys included in Table 10-44. However, there is expected to be a low probability that these would coincide temporally given the low frequency and short duration of survey campaigns for the Project.

As a conservative approach it is assumed as a worst-case scenario that up to two geophysical site investigation surveys could overlap with the Project geophysical surveys at any one point. There are limitations on the number of survey vessels that could carry out such surveys at any one time and therefore it is highly unlikely that all surveys associated with projects set out in Table 10-44 would overlap temporally.

Sonar-like geophysical survey systems have very strong directivity which effectively means that there is only potential for injury when a marine mammal is directly underneath the sound source or directly within the swathe. Once the animal moves outside of the main beam, there is significantly reduced potential for injury. The closest site investigation survey to the Project is Mainstream Renewable Power (0.8 km to the south of the Project) and the closest wind farm project with the potential for geophysical surveys to be undertaken during its operational and maintenance phase is NISA (16.2 km to the south of the Project). In the unlikely event that surveys were to overlap temporally between the Project and NISA, the distance between these projects is significantly greater than the maximum spatial range over which injury or disturbance associated with geophysical survey methods is likely to occur.

As such the magnitude for injury and/or disturbance from elevated underwater noise during geophysical surveys for all marine megafauna receptors is deemed to be of local spatial extent, short-term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be low.

Sensitivity of receptor

The species with the potential to be affected by injury and/or disturbance from elevated underwater noise during geophysical surveys for projects described in Table 10-44 are those identified as key sensitive receptors for the Project alone. These include harbour porpoise, bottlenose dolphin, common dolphin, minke whale, grey seal and harbour seal. Basking shark and sea turtles were not assessed in other projects as a key receptor and therefore have not been included in the cumulative assessment with the Project.

Marine mammals are assessed as having limited resilience, limited ability to adapt behaviour to sustain ecological functioning, and limited ability to recover from the effect in the short and long term, given the potential for the impact to result in a change in both reproduction and survival rate, and international value. The sensitivity of the receptor to PTS from elevated underwater sound during geophysical surveys is therefore, considered to be high.

Marine mammals are assessed as having some resilience, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability, and international value. The sensitivity of the receptor to TTS from elevated underwater sound during geophysical surveys is therefore, considered to be medium.

Marine mammals are assessed as having some resilience, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability, and international value. The sensitivity of the receptor to disturbance from elevated underwater sound during surveys is therefore considered to be medium.

Significance of effect

Taking into account the low probability for temporal overlap of geophysical surveys for the Project and those projects described in Table 10-44, and the distance between the Project and other projects being sufficiently great so as to preclude a direct effect of injury and/or disturbance from elevated underwater noise during respective geophysical surveys, overall, the magnitude of the impact is deemed to be low and the sensitivities of the receptors are considered to be medium to high. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

Injury and/or disturbance to marine megafauna from vessel activities

Construction phase

Magnitude of impact

Vessel traffic associated with the construction of the Project, together with vessel traffic associated with the projects identified in Table 10-44, may increase the potential for injury (vessel noise or collision risk) and/or disturbance (vessel noise) to marine mammals and megafauna. Other projects screened into the assessment within the Cumulative Marine Mammal and Megafauna Study Area include: Dublin Array, Arklow Bank Wind Park (Phase 2), NISA, Codling Wind Park, Awel y Môr Offshore Wind Farm, Mona Offshore Wind Project, Morgan Offshore Wind Project Generation Assets, Morecambe Offshore Windfarm Generation Assets, the Setanta Wind Park, North East Wind, Lir Offshore Array, Banba, and MaresConnect site investigations (Table 10-44).

The types of vessels involved in construction activities at the Dublin Array, Arklow Bank Wind Park (Phase 2), NISA and Codling Wind Park, Awel y Môr, Mona Offshore Wind Project, Morgan Offshore Wind Project Generation Assets, and Morecambe Offshore Windfarm Generation Assets are anticipated to be similar to those identified for construction of the Project, such as jack-up vessels, tug/anchor handers, cable installation vessels, scour/cable protection installation vessel, guard vessels, survey vessels and crew transfer vessels. The number of return trips for vessels involved in construction activities at the Project is provided in Table 10-11. Vessels travelling to/from the Project would originate at an Irish Sea or Celtic Sea port, such as suitable ports located in Great Britain, and would follow existing shipping routes when in transit.

This assessment considered injury resulting from both vessel noise and collision risk due to the uplift in traffic associated with projects screened in to the cumulative assessment. The assessment for the Project alone (see section 10.10.3) both PTS and TTS were not exceeded for high frequency cetaceans, or for seals. For harbour porpoise the PTS range was very small (< 15 m for all vessel types and sound sources). For TTS the maximum range was 1.67 km (for survey and support vessels, crew transfer vessels (CTV), and scour/cable protection/seabed preparation/installation vessels (see Table 10-39).

For offshore wind projects in the western Irish Sea, no publicly available information on which to base quantitative assessment was identified for NISA, Dublin Array, Codling Wind Park or Arklow Bank Wind Park (Phase 2). The Awel y Môr assessment summarised that in the context of 57 vessels per day recorded within the study area, at the busiest time of year, the introduction of vessels during the construction of the wind farm would not be a novel impact for marine mammals present in the area. Whilst quantitative information is not available for other projects screened into the cumulative assessment it is expected that predicted ranges would be similar to those reported for the Project.

Quantitative information was available for offshore wind projects in the eastern Irish Sea. The Awel y Môr assessment summarised that in the context of 57 vessels per day recorded within the study area, at the busiest time of year, the introduction of vessels during the construction of the wind farm would not be a novel impact for marine mammals present in the area. The Mona Offshore Wind Project identified a maximum of 80 vessels on site at any one time, a maximum of 2,004 return trips per year and maximum disturbance ranges of 22 km. The Morgan Offshore Wind Project Generation Assets identified a maximum of 63 vessels on site at any one time, and a maximum of 1,878 return trips per year, and maximum disturbance ranges of

22 km. Both projects concluded that a slight increase from the existing levels of traffic in the vicinity of the respective project areas may not result in high levels of disturbance. The Morecambe Offshore Windfarm Generation Assets anticipated up to 30 vessels on site at any one time, with 150 return trips for delivery of main components and installation over the construction phase, and 2,778 return trips per year for support vessels. Disturbance ranges were not modelled, but assessment for all species was based on a disturbance impact range of 2 km (based upon studies by Brandt *et al*. 2018 and Benhemma-Le Gall *et al*. (2021).

The number of vessels associated with geotechnical and geophysical site investigation surveys in the Irish Sea is anticipated to be small (one or two per project) and typically the duration of surveys will be relatively short (weeks to a few months). There are up to 26 site investigation surveys identified in the screening area for marine mammals. Surveys typically occur over short durations (typically up to 2 months) and therefore as a conservative approach it is assumed as a worst-case scenario that up to two surveys (in addition) could overlap with the Project geophysical surveys (associated with routine inspection of the Project offshore assets) at any one point. There are limitations on the number of survey vessels that could carry out such surveys at one time and therefore it is highly unlikely that all would overlap temporally.

As such, the magnitude for auditory injury to all marine mammals as a result of cumulative vessel activity is deemed to be of local spatial extent, medium term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be low.

As described above (section 10.10), injury to marine mammals and megafauna is more likely to arise from vessels travelling in excess of 7 m/s (Wilson *et al.,* 2007) or 14 knots (Laist *et al.,* 2001), however, vessels involved in the construction or survey of each project are likely to be travelling considerably slower than this, and therefore collision risk is expected to be lower than that posed by commercial shipping activity. Vessel traffic associated with offshore wind farm construction and site investigation surveys will be localised to within the project areas and will likely follow existing shipping lanes to/from port. Therefore, even with a cumulative increase in vessel traffic, the type of vessels involved and transit routes is unlikely to impose a greater risk to marine mammals and megafauna. As such the magnitude for collision risk as a result of vessels involved in the construction phase for all marine megafauna receptors is deemed to be of local spatial extent, medium term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be negligible.

Disturbance from vessel noise may also result in a cumulative effect on sensitive receptors. As described for the Project alone (section 10.10), there is potential for a fleeing response (based on the TTS threshold) to occur over very localised ranges depending on the vessel (up to maximum of 1,670 m across all vessel types and species groups). Behavioural effects could occur over greater ranges as a result of vessel noise, and the use of the conservative NMFS threshold of 120 dB re 1 μPa (rms) led to predicted ranges of disturbance from construction vessels at the Project between 755 m and 8.5 km depending on vessel type. The increase in number of vessels associated with the other projects screened into this assessment is anticipated to be relatively small in context of the existing levels of vessel activity in the area (from shipping, fishing and recreational traffic) and the magnitude of the impact would be largely localised to within project sites.

Awel y Môr Offshore Wind Farm, Mona Offshore Wind Project, Morgan Offshore Wind Project Generation Assets, Morecambe Offshore Windfarm Generation Assets, Dublin Array, Arklow Bank Wind Park (Phase 2), Statkraft, NISA, Codling Wind Park are located considerable distances from the Project and therefore there is unlikely to be any spatial overlap in the vessel activity at these project sites. Site investigation surveys at Mainstream Renewable Power and Lir Offshore Array would be carried out in close proximity to the offshore wind farm area, however, these surveys would only lead to a very small uplift in vessel numbers (e.g. up to two vessels per survey).

In terms of disturbance, the impact could result in a small but measurable alteration to the distribution of marine mammals and megafauna but, due to the localised nature of the impact in each of the cumulative project areas, reduction in reproductive success of affected animals is considered unlikely. The impact is predicted to be of local spatial extent, medium term duration, intermittent and high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude is therefore, considered to be low.

Injury (collision risk and auditory injury) and disturbance would occur as a series of short-term, intermittent events. Implementation of a Code of Conduct for vessel operators, particularly in proximity to seal haul-outs, would reduce the risk of injury from collision with construction vessels. A suite of different marine mammal species are common to all project areas considered in this assessment, and therefore may be sensitive to cumulative behavioural effects from vessels. However, given the existing baseline levels of vessel activity in the area, it is anticipated that animals would be tolerant to small increases and would recover rapidly following cessation of the activity.

Sensitivity of receptor

The species likely to be affected are those identified as key sensitive receptors for the Project and at least one other wind farm, and include: harbour porpoise, bottlenose dolphin, common dolphin, minke whale, grey seal, harbour seal and leatherback turtle.

There are interspecific differences in the potential sensitivity of cetaceans to vessels (collision risk and disturbance) with some species actively avoiding vessels, whilst other are attracted towards them (see section 10.10). Harbour porpoise was highlighted as being particularly sensitive to vessel noise and avoidance is likely (Heinanen and Skov, 2015). Similarly, bottlenose dolphin reduce their activity in response to both the presence of vessels and the noise arising from vessel movements (Pirotta *et al.,* 2015). However, the link between vessel movements and reduced marine mammal activity is not straight forward to establish due to intrinsic factors that may also contribute to a variance in distribution and abundance (e.g. changes in prey distribution and natural seasonal fluctuations). A six-year monitoring programme undertaken off the coast of County Mayo, in an area identified as being important for cetaceans, showed that vessel activity associated with the construction of a gas pipeline may lead to a decrease in the presence common dolphin but that such effects would be short-lived as the broad seasonal patterns in abundance of this species remain unchanged (Culloch *et al.*, 2016). In addition, despite the known sensitivity of harbour porpoise to vessel noise (i.e. active avoidance of vessels; Hermannsen *et al*., 2015, Dyndo *et al*., 2015), there was no detectable decrease in the numbers of harbour porpoise associated with an increase in vessel activity during pipeline construction (Culloch *et al.,* 2016). For species that actively avoid vessels it is anticipated that the risk of injury from collision would be low.

The sensitivity of seals to vessel traffic was described previously (section 10.10) and highlighted that the presence of boats near seal haul-outs could lead to disruption of foraging and potentially reduced pupping success. Key harbour seal and grey seal haul-outs nearest the Project were identified as 4.5 km north at Carlingford Lough, 10 km south at Clogherhead and 43.1 km south at Lambay Island (Figure 10-12). Harbour seal and grey seal at sea within the vicinity of the haul-outs on the east coast of Ireland are likely to be exposed to existing high levels of vessel activity to/from busy ports in the area (e.g. Dublin, Dun Laoghaire, and Greenore Harbour; Figure 10-12). Both collision risk and disturbance are anticipated to be higher in the vicinity of haul-out sites, particularly for young seals that have no previous experience of vessel traffic. Vessels associated with the Project will follow a Code of Conduct which includes, *inter alia*, limiting the speed of vessels near haul-outs, avoiding sudden changes in direction, and refraining from approaching animals in the water (see volume 2A, appendix 5-5: Marine Megafauna: Vessel Code of Conduct).

On the east coast of Ireland, and within the vicinity of the other projects screened into this assessment, there are small numbers of harbour seal recorded in the Dublin area, mainly on the north Dublin islands and coast and on Dalkey Island to the south of Dublin Bay (Cronin *et al.,* 2004). With small foraging ranges, harbour seal may be sensitive to a cumulative increase in vessel activity near key haul-outs. The offshore wind farm area is 43.1 km from Lambay Island SAC, designated for harbour porpoise, grey seal but also a small population of harbour seal, therefore it is likely that grey seal and harbour seal from this SAC may venture to the north and may potentially occur in the vicinity of the Project as well as moving to other project areas. With greater foraging ranges, grey seal, in particular, may be sensitive to an uplift in vessel activity as they move between haul-outs and key foraging areas on the east coast of Ireland. As described above, however, seals in these areas (near busy ports) are already exposed to existing levels of baseline vessel activity and therefore are likely to be tolerant to small uplifts in vessel traffic.

Within the vicinity of the other projects screened into this assessment, density of leatherback turtle is likely very low and foraging is wide-ranging, therefore leatherback turtle are unlikely to be sensitive to a cumulative uplift in vessel activity. The beaches of Ireland and the UK do not host nesting grounds for leatherback turtle and therefore their sensitivity to vessel activity in this respect will be low. Offshore waters of the Irish Sea could potentially host important feeding grounds for sea turtles (NPWS, 2019), but the predicted areas of impact from the Project and the other projects considered in this assessment will likely constitute a very small proportion of available habitat in the context of the wider region.

Due to the small and localised nature of the uplift in vessel activity compared to baseline levels, it is considered unlikely that marine mammal and megafauna species will be more sensitive to the cumulative effects of injury or disturbance compared to the Project alone.

In terms of injury from vessel traffic (auditory injury and collision risk) it is assumed that vessels will follow a Code of Conduct for vessel operators, therefore reducing the risk (see volume 2A, appendix 5-5: Marine Megafauna: Vessel Code of Conduct). However, although the risk of injury from construction traffic is relatively low, the consequences of collision risk, in particular, could be fatal. All marine megafauna receptors would have limited tolerance to a collision risk, and the effect of the impact could cause a change in both reproduction and survival of individuals, and receptors would have limited ability for the animal to recover from the effect. All marine megafauna have therefore been assessed as having limited resilience, limited ability to adapt behaviour to sustain ecological functioning, and limited ability to recover from the effect. All marine megafauna receptors are of international/national value. As such the sensitivity of all marine megafauna receptors to injury has been assessed as high.

In terms of disturbance from vessel traffic, the marine mammal and megafauna receptors are likely to tolerate the effect without any impact on reproduction and survival rates and are able to return to previous behavioural states/activities once the impact has ceased. All marine megafauna species have therefore been assessed as having high resilience to the effect with minor impairment of ecological functioning, have an ability to adapt behaviour such that ecological function can be maintained, and high recoverability. All marine megafauna receptors are of international/national value The sensitivities of the receptors are therefore, considered to be low.

Significance of effect

For collision risk, overall, the magnitude of the impact is deemed to be negligible and the sensitivities of the receptors are considered to be high. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

For auditory injury, overall the magnitude of the impact is deemed to be low and the sensitivity of all marine megafauna receptors is considered to be low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

For disturbance, overall, the magnitude of the impact is deemed to be low and the sensitivities of the receptors are considered to be low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

Operational and maintenance phase

Magnitude of impact

Vessel traffic associated with the operational and maintenance phase of the Project, together with vessel traffic associated with the projects identified in Table 10-44, may increase the potential for injury and/or disturbance to marine mammals and megafauna. Other projects screened into the assessment within the Cumulative Marine Mammal and Megafauna Study Area include Dublin Array, Arklow Bank Wind Park (Phase 2), NISA, Codling Wind Park, Awel y Môr Offshore Wind Farm, Mona Offshore Wind Project, Morgan Offshore Wind Project Generation Assets, Morecambe Offshore Windfarm Generation Assets, the Setanta Wind Park, North East Wind, Lir Offshore Array, Banba, and MaresConnect site investigations (Table 10-44).

The magnitude of the impact is not expected to differ from that presented for the construction phase. The magnitude of the impact for all receptors is therefore considered to be low for auditory injury and disturbance and negligible for collision risk.

Sensitivity of the receptor

The sensitivity of the receptors during the operational and maintenance phase is not expected to differ from that presented for the construction phase. The sensitivity of the impact for all receptors is therefore considered to be low for auditory injury and disturbance and high for collision risk.

Significance of the effect

For collision risk, overall, the magnitude of the impact is deemed to be negligible and the sensitivities of the receptors are considered to be high. The effect will, therefore, be of **slight adverse significance**, which is not significant in EIA terms.

For auditory injury, overall the magnitude of the impact is deemed to be low and the sensitivity of all marine megafauna receptors is considered to be low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

For disturbance, overall, the magnitude of the impact is deemed to be low and the sensitivities of the receptors are considered to be low. The effect will, therefore, be of **imperceptible adverse significance**, which is not significant in EIA terms.

Decommissioning phase

The effects of decommissioning activities are expected to be the same or similar to the effects from construction.

10.12 Transboundary effects

The Regional Marine Mammal and Megafauna Study Area covers the Irish Sea and therefore extends to the coastlines of Northern Ireland, Scotland, England and Wales. This area was defined to assess the likely significant effects which may extend beyond the Marine Megafauna Study Area (e.g. subsea noise) and also to account for marine mammals, basking shark and sea turtles, which are highly mobile and may range over large distances. These impacts are examined in section 10.10 and as no significant effects are predicted, there is no potential for significant transboundary effects with regard to marine mammals and megafauna from the Project upon the interests of the UK and other EEA States.

10.13 Interactions

A description of the likely interactions arising from the Project on marine mammals and megafauna is provided in volume 2C, chapter 32: Interactions.

10.14 Summary of impacts, mitigation measures and residual effects

This chapter has presented the results of the assessment of potential impacts of the Project on marine mammals and megafauna, covering all impacts seaward of the HWM during the construction, operational and maintenance, and decommissioning phases. Detailed technical information underpinning the impact assessments presented within this chapter is contained within appendix 10-1: Marine Mammals and Megafauna Technical Report and appendix 10-2: Subsea Noise Technical Report.

Characterisation of the baseline environment was undertaken following site-specific surveys and a desk-based literature review. Receptors which were identified to be present within the Marine Megafauna Study Area and include harbour porpoise, bottlenose dolphin, common dolphin, minke whale, harbour seal, grey seal, basking shark and leatherback turtle.

Table 10-47 presents a summary of the potential impacts, mitigation measures and residual effects in respect to marine mammals and megafauna. Table 10-48 presents a summary of the potential cumulative impacts, mitigation measures and residual effects.

The impacts assessed include:

- Injury and/or disturbance to marine megafauna from underwater noise during pile-driving;
- Injury and/or disturbance to marine megafauna from elevated underwater noise during routine geophysical surveys;

- Injury and/or disturbance to marine megafauna from vessels and other construction activities;
- Changes in the fish and shellfish community affecting marine megafauna prey resources;
- Electromagnetic Fields from subsea electrical cabling may disrupt behaviour of basking shark (Cetorhinus maximus).

Throughout the construction, operational and maintenance and decommissioning phases, all impacts were found to be of either imperceptible or slight adverse significance on marine mammal and megafauna receptors within the Marine Megafauna Study Area and Regional Marine Megafauna Study Area (i.e. not significant in EIA terms).

The cumulative impacts assessed include:

- Injury/disturbance from underwater noise during pile driving (construction phase);
- Injury/disturbance from elevated underwater noise during routine geophysical surveys (operational and maintenance phase); and
- Injury/disturbance from vessel activity (all phases).

Impacts were not predicted to have any significant effects on marine mammal, basking shark or leatherback turtle populations.

No potential transboundary impacts have been identified in regard to the effects of the Project.

Table 10-47: Summary of potential environment effects, mitigation and monitoring. The ranges presented reflect the magnitude/sensitivities with respect to different species.

Description of impact		Phase C	Phase O	Phase D	Measures included in Project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Injury and/or disturbance to marine megafauna from underwater noise during pile-driving	Injury	✓	✗	✗	MMMP (implementation of a soft-start, and MMOs / PAM Operators); Piling Strategy	C: Low to medium	C: Low to high	C: Imperceptible or slight adverse	None	Imperceptible or slight adverse	None
	Disturbance	✓	✗	✗	Piling Strategy	C: Low	C: Low to medium	C: Imperceptible or slight adverse	None	Imperceptible or slight adverse	None
	Injury	✓	✗	✗	MMMP (implementation of a soft-start, and MMOs / PAM Operators); Piling Strategy	C: Negligible to medium	C: Low to high	C: Imperceptible or slight adverse	ADD	Imperceptible or slight adverse	None
Injury and/or disturbance to marine megafauna from elevated underwater noise during geophysical surveys	Injury	✗	✓	✗	MMMP (implementation of a soft-start (where possible), and MMOs / PAM Operators)	O: Low	O: Medium to High	O: Slight adverse	None	Slight adverse	None
	Disturbance	✗	✓	✗	N/A	O: Low	O: Medium	O: Slight adverse	None	Slight adverse	None
Injury and/or disturbance to marine megafauna from vessel and other construction activities	Auditory injury	✓	✓	✓	N/A	C: Low O: Low D: Low	C: Medium to High O: Medium to High D: Medium to High	C: Slight adverse O: Slight adverse D: Slight adverse	None	Slight adverse	None
	Collision risk	✓	✓	✓	Vessel Code of Conduct	C: Negligible O: Negligible D: Negligible	C: High O: High D: High	C: Slight adverse O: Slight adverse D: Slight adverse	None	Slight adverse	None
	Disturbance	✓	✓	✓	N/A	C: Low O: Low D: Low	C: Low O: Low D: Low	C: Imperceptible O: Imperceptible D: Imperceptible	None	Imperceptible	None

Description of impact	Phase C	Phase O	Phase D	Measures included in Project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Changes in the fish and shellfish community affecting marine megafauna prey resources	✓	✓	✓	N/A	C: Low O: Low D: Low	C: Negligible or low O: Negligible or low D: Negligible or low	C: Imperceptible O: Imperceptible D: Imperceptible	None	Imperceptible	None
Electromagnetic Fields (EMF) from subsea electrical cabling may disrupt behaviour of basking shark (*Cetorhinus maximus*)	✗	✓	✗	N/A	O: Low	O: Low	O: Imperceptible	None	Imperceptible	None

Table 10-48: Summary of potential cumulative environment effects, mitigation and monitoring.

Description of impact		Phase C	Phase O	Phase D	Measures included in the Project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Injury and/or disturbance to marine megafauna from underwater noise during pile-driving	Injury	✓	✗	✗	MMMP (implementation of a soft-start, and MMOs/PAM Operators)	C: Negligible to low	C: Low to high	C: Imperceptible or slight adverse	ADD deployment	Imperceptible or slight adverse	None
	Disturbance	✓	✗	✗	N/A	C: Low	C: Low - medium	C: Imperceptible or slight adverse	None	Imperceptible or slight adverse	None
Injury and/or disturbance to marine megafauna from elevated underwater noise during geophysical surveys	Injury	✗	✓	✗	MMMP (implementation of a soft-start, and MMOs/PAM Operators)	O: Low	O: Medium - High	O: Slight adverse	None	Slight adverse	None
	Disturbance	✗	✓	✗	N/A	O: Low	O: Medium	O: Slight adverse	None	Slight adverse	None

Description of impact		Phase C	O	D	Measures included in the Project	Magnitude of impact	Sensitivity of receptor	Significance of effect	Additional measures	Residual effect	Proposed monitoring
Injury and/or disturbance to marine megafauna from vessel activities	Auditory injury	✓	✓	✓	N/A	C: Low O: Low D: Low	C: Low O: Low D: Low	C: Imperceptible or slight adverse O: Imperceptible or slight adverse D: Imperceptible or slight adverse	None	Imperceptible or slight adverse	None
	Collision risk	✓	✓	✓	Vessel Code of Conduct	C: Negligible O: Negligible D: Negligible	C: High O: High D: High	C: Slight adverse O: Slight adverse D: Slight adverse	None	Slight adverse	None
	Disturbance	✓	✓	✓	N/A	C: Low O: Low D: Low	C: Low O: High D: Low	C: Imperceptible or slight adverse O: Imperceptible or slight adverse D: Imperceptible or slight adverse	None	Imperceptible or slight adverse	None

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