Environmental Impact Assessment Report
Volume 1, Chapter 8: Underwater Noise

MarramWind Offshore Wind Farm

December 2025

MarramWind

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Checked by:	WSP UK Limited
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Contents

8. Underwater Noise

8.1 Introduction

8.1.1.1 This Chapter presents a summary of the underwater noise modelling undertaken to support the Environmental Impact Assessment (EIA) Report for the Project. It provides the technical foundation for assessing underwater noise-related effects on ecological and socio-economic receptors as detailed in other chapters of the EIA Report. The modelling outputs inform assessments of: benthic, epibenthic and intertidal ecology; marine mammals; fish ecology; commercial fisheries; and socio-economics, and are supported by embedded environmental measures within the project design. As a technical chapter, it does not assess likely significant effects directly but provides essential data and context for those assessments.

8.1.1.2 This underwater noise chapter of the EIA Report includes:

- the legislation, planning policy, guidance and other documentation that has informed the assessment (**Section 8.2: Relevant legislative and policy context**);
- the outcome of consultation and engagement that has been undertaken to date, including how matters relating to underwater noise have been addressed (**Section 8.3: Consultation and engagement**);
- the scope of the assessment for underwater noise (**Section 8.4: Scope of the assessment)**;
- the overall environmental baseline (**Section 8.5: Baseline conditions**);
- the basis for the EIA Report (**Section 8.6: Basis for the EIA Report**);
- methodology for underwater noise modelling (**Section 8.7: Methodology for underwater noise**);
- the results of the underwater noise modelling (**Section 8.8: Results of underwater noise assessment**);
- a reference list is provided (**Section 8.9: References**); and
- a glossary of terms, abbreviations and units is provided (**Section 8.10: Glossary and abbreviations**).

8.1.1.3 The underwater noise assessment informs the assessments of the following chapters:

- **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**: The introduction of sound energy to the marine environment has the potential to affect invertebrate species (shellfish). The information from this Chapter will be used to inform the benthic, epibenthic and intertidal ecology assessment.
- **Chapter 11: Marine Mammals**: The introduction of sound energy to the marine environment has the potential to affect cetaceans and seals. The information from this Chapter will be used to inform the marine mammals assessment.
- **Chapter 13: Fish Ecology**: The introduction of sound energy to the marine environment has the potential to affect fishes, particularly those sensitive to sound and those with swim bladders. The information from this Chapter will be used to inform the fish ecology assessment.

- **Chapter 14: Commercial Fisheries**: The introduction of sound energy to the marine environment has the potential to affect commercial fish species and their fisheries. The information from this Chapter will be used to inform commercial fisheries assessment.
- **Chapter 30: Socio-economics**: The introduction of sound energy to the marine environment has the potential to affect recreational receptors, such as those fishing, sailing, motor-cruising, kite-surfing, surfing, windsurfing, and sea- or surf-kayaking or canoeing. The information from this Chapter will be used to inform the socio-economics assessment.

8.1.1.4 This Chapter is also supported by the following appendices in **Volume 3**:

- **Volume 3, Appendix 8.1: Underwater Noise Modelling Assessment**.

8.2 Relevant legislative and policy context and technical guidance

8.2.1 Legislative and policy context

8.2.1.1 This Section identifies the relevant legislation and policy context that has informed the scope of the underwater noise assessment. Further information on policies relevant to the EIA and their status is set out in **Chapter 2: Legislative and Policy Context**, which provides an overview of the relevant legislative and policy context for the Project. **Chapter 2** is supported by **Volume 3, Appendix 2.1: Planning Policy Framework**, which provides a detailed summary of international, national, marine and local planning policies of relevance to the EIA. Individual policies of specific relevance to this assessment and associated appendices have been taken into account.

8.2.1.2 This summary provides a foundation for understanding the legislative and policy context that has informed the underwater noise modelling presented in this Chapter. These modelling outputs support the assessment and mitigation of impacts on receptors as carried out in the relevant chapters outlined in **paragraph 8.1.1.3**.

8.2.1.3 The legislation and international agreements relevant to underwater noise includes:

- Marine Environment (Amendment) (EU Exit) Regulations 2018;
- Marine Strategy Regulations 2010;
- Marine and Coastal Access Act 2009;
- Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008, establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive (MSFD)) – Descriptor 11: Energy including underwater noise
- Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR) 1992; and
- International Regulations for the Prevention of Collisions at Sea (COLREGS) (International Maritime Organisation (IMO), 1972/1977).

8.2.1.4 The policy relevant to underwater noise includes:

- Policy paper: Reducing marine noise (Department for Environment Food and Rural Affairs (DEFRA), 2025):

- JNCC, Natural England and Cefas position on the use of quieter piling methods and noise abatement systems when installing offshore wind turbine foundations (JNCC, Natural England and Cefas 2025);
- Draft Updated Sectoral Marine Plan 2025 (Scottish Government, 2025);
- Policy paper: Marine environment: unexploded ordnance clearance Joint Position Statement (Department for Energy Security and Net Zero (DESNZ), 2025);
- National Planning Framework 4 (NPF4) 2023 (Scottish Government, 2023a);
- Powering up Britain (DESNZ, 2023a);
- National Policy Statement (NPS) EN-3 2023 National Policy Statement for Renewable Energy Infrastructure (DESNZ, 2023b);
- A revised draft NPS EN-3 was published in April 2025, but the EN-3 2023 noted above remains in-force at the time of writing;
- Sectoral Marine Plan for Offshore Wind 2020 (Scottish Government, 2020); and
- Scottish National Marine Plan 2015 (Scottish Government, 2015).

8.2.2 Relevant technical guidance

8.2.2.1 Other information and technical guidance relevant to the assessment undertaken for underwater noise include:

- Marine mammal noise exposure criteria: Updated scientific recommendations for residual hearing effects (Southall *et al.,* 2019);
- Underwater acoustics – Terminology (International Organisation for Standardisation (ISO), 2017); and
- Sound exposure guidelines for Fishes and Sea Turtles (Popper *et* al., 2014).

8.3 Consultation and engagement

8.3.1 Overview

8.3.1.1 This Section describes the consultation and stakeholder engagement undertaken on the Project in relation to underwater noise. This includes early engagement, the outcome of and response to the Scoping Opinions (Scottish Government, 2023b; Aberdeenshire Council, 2023) in relation to the underwater noise assessment, non-statutory consultation, and the findings of the Project's Statutory Consultation. An overview of engagement undertaken for the Project as a whole can be found in Section 5.5 of **Chapter 5: Approach to the EIA**.

8.3.1.2 The feedback received has informed the modelling methodology and scope presented in this Chapter, which in turn supports impact assessments in other chapters of the EIA Report.

8.3.2 Key issues

8.3.2.1 A summary of the key issues raised during statutory and non-statutory consultation, specific to underwater noise, is outlined below in **Table 8.1.** These issues have been considered in the development of the underwater noise modelling and the presentation of results in this Chapter, which underpin assessments elsewhere in the EIA Report.

Table 8.1 Stakeholder issues responses – underwater noise

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
Marine Directorate – Licensing Operations Team (MD-LOT) and Marine Directorate – Science, Evidence, Data and Digital (MD-SEDD)	N/A	29 September 2022 and 30 September 2022 Offshore EIA Scoping Workshop and follow-up written questions.	The Project team submitted the following written questions to MD-LOT and MD-SEDD after the workshop: • Do the regulators agree with the proposed study area, data sources, receptor groups and impact pathways, and overall approach to the assessment including the approach to underwater noise modelling? • Are there any data sources that should be considered that were not noted in the workshop (i.e. as reported upon in this Chapter)? • Can MD-LOT advise on what point in time the Cumulative Effects Assessment (CEA) should start, e.g. forward from MarramWind or from the first offshore wind project in Scotland or some other time?	MD-LOT and MD-SEDD confirmed to the Project team that they (NatureScot and Royal Society for Protection of Birds) would respond to these questions in the advisory response to be provided during the Scoping Report consultation process. These questions are, therefore, answered in the below rows of this table.
MD-LOT	301	12 May 2025 MD-LOT Scoping Opinion (Scottish Government, 2023b).	*"5.4.1 The Scottish Ministers welcome the Developer's proposal to scope in the effects of UXO clearance and the effects of underwater noise during the construction and decommissioning phases of the Proposed Development. Given the uncertainty around the effects associated with the anchoring systems and cabling of floating WTGs, the Scottish Ministers advise further engagement and discussion with Marine Scotland and NatureScot before the submission of the EIA Report."*	**Volume 3, Appendix 8.1** provides the modelling results that underpin receptor-specific assessments. These results were shared with MD-LOT and NatureScot as part of ongoing engagement in 2025 to inform the wider EIA.
NatureScot	521	12 May 2025 MD-LOT Scoping Opinion Appendix	"*Underwater noise and vibration*	

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
		1: Consultation Responses and Advice (Scottish Government, 2023b).	*We support scoping in the effect of underwater noise during construction and decommissioning phases, and the effects of UXO clearance.* *We support scoping in the effects of underwater noise during the operation and maintenance phase. These effects arising from floating wind turbine generators, their anchoring systems and cabling are not well understood at present. This will require further discussion and agreement with Marine Scotland and NatureScot."*	
MD-LOT	302	12 May 2025 MD-LOT Scoping Opinion (Scottish Government, 2023b).	*"5.4.2* *Regarding the impulsive underwater noise assessment as noted in section 5.3.12 of the Scoping Report, the Scottish Ministers advise that this assessment includes vibration (particle motion) for fish and shellfish, which is supported by the SFF. In line with NatureScot's advice, the Scottish Ministers would expect to see, if appropriate to the study area, sandeel, cod, and herring eggs as part of the assessment. In addition, the Scottish Ministers highlight the representation from Dee DSFB noting the potential for[m] marine renewables to have an impact on salmon through underwater noise."*	The Project provided a position statement to MD-LOT on 19 January 2024 acknowledging that the issue of particle motion sensitivity in many fish species is recognised and of concern to the wider research community. While recent research papers (e.g. Popper and Hawkins, 2018, 'The importance of particle motion to fishes and invertebrates') make clear that the detection of the particle motion component of some species (including salmon) is important, there remains a lack of data both in respect of predictions of the particle motion level as a consequence of a noise source such as piling, and a lack of knowledge of the sensitivity of a fish, or a wider category of fish, to a particle motion value. In short, it is insufficient to simply recognise that a species is sensitive to particle motion, we must know how sensitive. Currently, this is absent from the knowledge-base, and
NatureScot	522	12 May 2025 MD-LOT Scoping Opinion Appendix 1: Consultation Responses and Advice (Scottish Government, 2023b).	*"We note that Section 5.3.12 (Underwater noise and vibration) states that impulsive underwater noise will be assessed for relevant fish (and marine mammal) species. We advise that this should also include vibration (particle motion) for fish and shellfish. Sensitive fish species have not been specified but we would expect to see sandeel, cod and herring eggs if appropriate to the study area."*	

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
				therefore there is no practical way to assess the impact of impulsive underwater noise on any species of fish. Popper and Hawkins (2019) acknowledges this, stating that "*since there is an immediate need for updated criteria and guidelines on potential effects of anthropogenic sound on fishes, we recommend, as do our colleagues in Sweden (Andersson et al., 2017), that the criteria proposed by Popper et al. (2014) should be used*". Therefore, the use of sound pressure as a proxy for these species remains the best available science for this study and is our intended approach for undertaking the assessment. Any recommendations for the assessment of particle motion, or new articles in the literature that the stakeholder may have seen in relation to this, would be well received. MD-LOT responded on 20 February 2024 stating "*MD-LOT has reviewed MarramWind's position statements in response to the Scoping Opinion and notes the update provided by MarramWind. As noted above, the information provided here should be detailed and included within MarramWind's EIA report.*"

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
				The modelling results presented in this Chapter inform the assessment of noise on fish receptors in **Chapter 13: Fish Ecology**.
MD-LOT	303	12 May 2025 MD-LOT Scoping Opinion (Scottish Government, 2023b).	*"5.4.3* *Regarding the marine mammal assessment detailed in section 5.6.6 of the Scoping Report, the Scottish Ministers advise in line with the NatureScot representation of the importance that noise from all sources is included when conducting the assessment."*	The underwater noise modelling presented in **Volume 3, Appendix 8.1** includes predictions for the following listed noise sources. These outputs support impact assessments in **Chapter 11: Marine Mammals** and **Chapter 13: Fish Ecology**: • piling of driven piles; • piling of driven pile anchors; • other noisy activities, including cable laying, dredging and drilling; • operational wind turbine generator noise; • cable snapping; and • unexploded ordnance clearance. Sound level predictions are summarised in **Section 8.88.8** and the significance of effect on marine mammals is considered in **Chapter 11: Marine Mammals**. The Applicant provided a position statement to MD-LOT on 19 January 2024 stating geophysical survey impacts to be assessed through other relevant licensing and is considered stand alone, not in the EIA Report. MD-LOT
NatureScot	487	12 May 2025 MD-LOT Scoping Opinion Appendix 1: Consultation Responses and Advice (Scottish Government, 2023b).	*"Little detail is provided on the underwater noise entry in Table 5.6.11, but it is important to ensure that noise from all sources are included, not just piling – e.g. geophysical surveys, UXO, vessel movement, rock placement, trenching, etc plus operational noise."*	

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
				responded on 20 February 2024 stating "*MD-LOT has reviewed MarramWind's position statements in response to the Scoping Opinion and notes the approaches noted by MarramWind*." Therefore, geophysical surveys are not assessed further in the EIA Report.
MD-LOT	304	12 May 2025 MD-LOT Scoping Opinion (Scottish Government, 2023b).	*"5.4.4 The Scottish Ministers are content with the study area proposed in section 5.3.7 of the Scoping Report and agree that the study area should be reviewed and amended concerning the impact pathways as identified through the EIA assessment."*	The spatial extent of the underwater noise modelling has been used to define the zones of influence (ZOIs) of those receptors for which underwater noise presents an impact pathway. Study areas are described in the respective receptor chapters: • **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**; • **Chapter 11: Marine Mammals**; • **Chapter 13: Fish Ecology**; • **Chapter 14: Commercial Fisheries**; and • **Chapter 30: Socio-Economics**
MD-LOT	305a	12 May 2025 MD-LOT Scoping Opinion (Scottish Government, 2023b).	*"5.4.5 The Scottish Ministers are content with the technical guidance confirmed in Table 5.3.2 of the Scoping Report but recommend that the additional data sources highlighted by NatureScot are used to inform the EIA Report."*	**Section 8.2.2** provides the technical guidance used to inform this Chapter. As recommended by NatureScot, **Volume 3, Appendix 8.1** refers to the work on the Hywind project, and references studies of offshore floating wind farms, including but not limited to those by Tougaard *et al*. (2020) and Risch *et al*. (2023).
NatureScot	543	12 May 2025 MD-LOT Scoping Opinion Appendix	*"We agree that the relevant legislation and policy (Table 5.1.1), technical guidance (Table 5.1.2) and data sources (Table 5.1.4) have been identified. However we*	

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
		1: Consultation Responses and Advice (Scottish Government, 2023b).	*advise that Tougaard et al, 2020 is a paper for consideration rather being agreed technical guidance.”*	The legislation and policy relevant to underwater noise is provided in **Section 8.2.1**.
NatureScot	544	12 May 2025 MD-LOT Scoping Opinion Appendix 1: Consultation Responses and Advice (Scottish Government, 2023b).	*“We also recommend that the applicant refers to any information on the noise characteristics of operational floating wind turbines emerging from Hywind and Kincardine floating offshore wind farms, or from projects located in other countries. It is likely that any comparison would be qualitative, but an understanding of the likely characteristics and/or the variability in operational noise emissions would be useful for MarramWind.”*	
MD-LOT	305b	12 May 2025 MD-LOT Scoping Opinion (Scottish Government, 2023b).	*“5.4.6 Section 6.1.1 within Appendix 4A of the Scoping Report confirms there is the potential for significant effects arising from the Proposed Development on the interests of EEA States and as such transboundary effects may arise. However, in line with the NatureScot representation, there are unlikely to be any transboundary underwater noise and vibration impacts associated with the Proposed Development. Therefore, the Scottish Ministers disagree with the Developer’s proposal to scope in underwater noise and vibration transboundary effects and recommend this is scoped out of the EIA Report.”*	Transboundary effects of underwater noise have, therefore, been scoped out and are not considered in this EIA.
NatureScot	547	12 May 2025 MD-LOT Scoping Opinion Appendix 1: Consultation Responses and Advice (Scottish	*“We advise that there are unlikely to be any transboundary impacts.”*	

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
		Government, 2023b).		
Dee District Salmon Fishery Board	405	12 May 2025 MD-LOT Scoping Opinion Appendix 1: Consultation Responses and Advice (Scottish Government, 2023b).	*"In January 2022, the Scottish Government released its Wild Salmon Strategy which gave a clear message that there is sadly now unequivocal evidence that populations of Atlantic Salmon are at crisis point. The Strategy calls on government agencies, as well as the private sector, to prioritise the protection and recovery of Scotland's wild Atlantic salmon populations.* *One of the key pressures identified in the strategy is marine development, with marine renewables highlights as having the potential to impact salmon through noise, water quality and effects on electromagnetic fields (EMFs) used by salmon for migration."*	The Scottish Government's Wild Salmon Strategy is one of the sources informing **Chapter 13: Fish Ecology**. The methodology for the assessment of underwater noise impacts on salmon (and other fish species) is outlined in **Section 8.7.38.7** and the impact assessment is presented in **Chapter 13: Fish Ecology**.
NatureScot	481	12 May 2025 MD-LOT Scoping Opinion Appendix 1: Consultation Responses and Advice (Scottish Government, 2023b).	*"We do not advise using the EDR of 26km for UXO clearance, or 15km for piling as these are not site-specific and should be considered on a case-by-case basis. Instead, we would expect to see underwater noise modelled in order to better understand the distance at which noise may impact marine mammals. For geophysical surveys, however, we recommend using a 5km EDR as a precautionary approach, as recommended in JNCC's guidance on noise management in SACs (ref).* *Ref: JNCC, 2020.*	**Volume 3, Appendix 8.1** includes predictions for noise from unexploded ordnance (UXO) clearance, the results of which are summarised in **Section 8.8.2**. These inform the impact assessment on marine mammals (**Chapter 11: Marine Mammals**). An effective deterrence range of 26km has not been used in the assessment. The Applicant provided a position statement to MD-LOT on 19 January 2024 stating geophysical survey impacts to be assessed through other relevant licensing and is considered stand alone, not in the EIA Report. MD-LOT responded on 20 February 2024 stating "*MD-LOT has reviewed MarramWind's*

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
				position statements in response to the Scoping Opinion and notes the approaches noted by MarramWind." Therefore, geophysical surveys are not assessed further in the EIA Report.
NatureScot	542	12 May 2025 MD-LOT Scoping Opinion Appendix 1: Consultation Responses and Advice (Scottish Government, 2023b).	*"We are content with the study area as proposed in Section 5.3.7, which is based on the sensitivities of the relevant receptors (marine mammals, fish and shellfish, commercial fisheries, infrastructure and other marine users). We agree that the study area should be reviewed and amended in relation to the impact pathways as identified through the EIA assessment."*	The spatial extent of the underwater noise modelling has been used to define the ZOIs of those receptors for which underwater noise presents an impact pathway. Study areas are described in the respective receptor chapters: • **Chapter 10: Benthic, Epibenthic and Intertidal Ecology**; • **Chapter 11: Marine Mammals**; • **Chapter 13: Fish Ecology**; • **Chapter 14: Commercial Fisheries**; and • **Chapter 30: Socio-economics**.
NatureScot	546	12 May 2025 MD-LOT Scoping Opinion Appendix 1: Consultation Responses and Advice (Scottish Government, 2023b).	*"We are broadly content with the impacts that are to be scoped in/out of assessment, and have offered comments, where appropriate, in Appendices B (marine mammals) and E (fish and shellfish) of this letter."*	Acknowledged. Comments relating to the scoping in of underwater noise impacts on marine mammals and fishes are addressed elsewhere in this table.
NatureScot	548	12 May 2025 MD-LOT Scoping Opinion Appendix 1: Consultation	*"We are generally content with the approach to assessment as described in Sections 5.3.13-15... With regards to fish, we highlight that impact ranges can vary dramatically based on the model and parameters being*	**Volume 3, Appendix 8.1** uses both a static / stationary and fleeing animal model for fishes. It discusses the

Stakeholder	Stakeholder issue ID	Date, document, forum	Stakeholder comment	How is this addressed in the EIA Report
		Responses and Advice (Scottish Government, 2023b).	*used (e.g. static vs fleeing animal response). We recommend that the assessment is supported by a review of fish responses to piling, particularly examining the effect of different fleeing speeds."*	evidence for fish behavioural responses and published fleeing speeds.
NatureScot	549	12 May 2025 MD-LOT Scoping Opinion Appendix 1: Consultation Responses and Advice (Scottish Government, 2023b).	*"We are content with the proposed approach to cumulative assessment described in Sections 5.3.22-23."*	Assessment of cumulative effects can be found in **Chapter 33: Cumulative Effects Assessment**. Underwater noise modelling has been carried out to support the assessment of impacts on marine mammals and fishes.
NatureScot		18 March 2024, Scoping consultation follow-up questions email from NatureScot.	*"Advice with regard to vibration (particle motion) for fish and shellfish:* *The following paper will be of use: "Particle motion: the missing link in underwater acoustic ecology"* (Nedelec *et al.*, 2016). *This is the most recent paper on this topic that we are aware of: "Best Practice Guide for Underwater Particle Motion Measurement for Biological Applications"* (Nedelec *et al.*, 2021)..	Acknowledged. These papers have been considered in the production of this Chapter (see **Section 8.7.3**) and **Volume 3, Appendix 8.1**.

8.4 Scope of the assessment

8.4.1 Overview

8.4.1.1 This Section sets out the scope of the underwater noise modelling undertaken to support the EIA. This scope has been developed as the Project's design has evolved and responds to stakeholder feedback received to-date, as set out in **Section 8.3**. It includes a summary of the results considered by other receptors' specific assessments (see **paragraph 8.1.1.3**).

8.4.2 Spatial and temporal scope and study area

8.4.2.1 The spatial extent of the underwater noise modelling results has been used to inform the assessments presented in the chapters identified in **paragraph 8.1.1.3**. The results have been used to define the ZOIs for receptors with identified underwater noise impact pathways. The respective study areas of underwater noise receptors scoped in for assessment are, therefore, described in those chapters (see **paragraph 8.1.1.3**).

8.4.2.2 The temporal scope of the underwater noise modelling covers the full lifecycle of the Project, including construction, operation and maintenance (O&M) and decommissioning stages. It is anticipated that the construction of the Project will commence in 2030, with the first phase becoming fully operational by 2037. It is anticipated that the second phase of the Project would become fully operational by 2040 and the third phase by 2043. The operational lifetime of the Project for each phase is expected to be 35 years.

8.4.3 Identified receptors and potential effects

8.4.3.1 Receptors identified as sensitive to underwater noise are detailed in the relevant chapters that assess potential impacts, as referenced in **paragraph 8.1.1.3**.

8.4.3.2 Potential effects of underwater noise on sensitive receptors are not assessed in this Chapter but are summarised in the relevant receptor chapters (see **paragraph 8.1.1.3**), which draw upon the modelling results presented in **Section 8.8**.

8.4.4 Effects scoped out of assessment

8.4.4.1 In line with recommendations from NatureScot and MD-LOT in the Scoping Opinion, transboundary effects of underwater noise have been scoped out of the EIA. Details of scoped-out effects for specific receptors are provided in their respective chapters (see **paragraph 8.1.1.3**).

8.5 Baseline conditions

8.5.1 Current baseline

8.5.1.1 Underwater background or 'ambient' sound is generated by a range of natural and anthropogenic sources. Natural contributors include non-biological sounds (e.g. wind, waves, rain, lightning, tectonic activity) and biological sounds from marine fauna. Anthropogenic sources include engineering and exploratory activities (e.g. pile driving, dredging, seismic surveys, explosions) and vessel traffic.

8.5.1.2 The North Sea is one of the busiest maritime areas in the world. In 2008, the European Union (EU) MSFD identified eleven descriptors determining the environmental status of

European seas. Underwater noise was one of these. In 2018, an EU project, the Joint Monitoring Programme for Ambient Noise in the North Sea (JOMOPANS), was commissioned to develop a framework for evaluating the status of the North Sea (Basan *et al.*, 2024). A series of noise maps were produced, using data from 15 monitoring stations, for the years 2019 and 2020 (de Jong *et al.*, 2022).

8.5.1.3 The JOMOPANS study found the highest sound levels across all stations were recorded in the low-to-mid frequency range, between 100 hertz (Hz) and 500Hz, which is typical of shipping noise and operational wind farm noise (Basan *et al.*, 2024). Low-frequency shipping noise was shown to dominate over wind noise over most of the North Sea during 50 percent of the time. The station closest to the Project had a relatively low volume of shipping, when compared with the southern North Sea, and this was predominantly made up of cargo vessels, followed by fishing and tanker vessels.

8.5.1.4 Wind noise was present across all stations at frequencies above 500Hz, with the station closest to the Project having an above-average wind speed (8.1 metres per second (m/s) at 10m above sea level) (Basan *et al.*, 2024). Annual median wind noise between 10Hz and 20 kilohertz (kHz), in 2019 and 2020, had a sound pressure level (SPL) ranging between 95 decibels (dB) and 105dB re 1 micro pascal (μPa) in the vicinity of the Project, with higher levels in the colder half of the year.

8.5.1.5 The station closest to the Project had lower sound levels when compared to stations with shallower water, in the southern North Sea, but high levels in the high and mid frequencies, with an unknown cause. Spectral probability densities gave median root-mean-square SPLs of 104dB between 25Hz and 160dB between 200Hz and 1.6kHz, and 95dB between 2 kilohertz (kHz) and 10kHz, showing a low level of variation.

8.5.2 Future baseline

8.5.2.1 In the absence of the Project, ambient noise levels in this part of the North Sea are expected to be influenced by temporary construction activities from other offshore developments. However, long-term trends are likely to be shaped more significantly by changes in shipping activity and climate-driven increases in wind speeds. The future baseline is therefore anticipated to follow current trajectories of rising ambient sound levels.

8.6 Basis for the EIA Report

8.6.1 Maximum design scenario

8.6.1.1 The process of assessing using a parameter-based design envelope approach means that the assessment considers a maximum design scenario whilst allowing the flexibility to make improvements in the future in ways that cannot be predicted at the time of submission of the planning application, marine licences applications and section 36 (s.36) consent.

8.6.1.2 The modelling presented in this Chapter is based on the maximum adverse scenario for underwater noise. This ensures that the outputs used to inform receptor-specific assessments represent the worst-case conditions, and that no greater adverse effects would arise should a different scenario (as described in **Chapter 4: Project Description**), be taken forward in the final Project design.

8.6.1.3 The maximum design scenario parameters that have been used for the underwater noise modelling are defined in **Volume 3, Appendix 8.1**. This included for six representative locations covering the OAA and cable route, giving a spread of water depths, distances to shore and bathymetry. Four offshore substation locations were modelled, plus two RCP locations along the export cable corridor. Two impact piling scenarios were considered:

driven piles for foundations and driven pile anchors. Both scenarios involve 3m diameter piles installed with a maximum blow energy of 3,500kJ. The offshore substation and RCP driven piles measure 95m in length and the driven pile anchors measure 30m in length. In a 24-hour period a maximum of two piles can be installed sequentially.

8.6.2 Embedded environmental measures

8.6.2.1 As part of the Project design process, a number of embedded environmental measures have been adopted to reduce the potential for adverse impacts on underwater noise. These embedded environmental measures have evolved over the development process as the EIA has progressed and in response to consultation.

8.6.2.2 These measures also include those that have been identified as good or standard practice and include actions that would be undertaken to meet existing legislation requirements. As there is a commitment to implementing these embedded environmental measures, and also to various standard sectoral practices and procedures, they are considered inherently part of the design of the Project and are set out in the EIA Report.

8.6.2.3 **Table 8.2** sets out the relevant embedded environmental measures within the design and how these affect the underwater noise assessment.

8.6.2.4 Further detail on the embedded environmental measures in **Table 8.2** is provided in the **Volume 3, Appendix 5.2: Commitments Register**, which sets out how and where particular embedded environmental measures will be implemented and secured. Further consideration is also given in the relevant technical aspect chapters referenced in **paragraph 8.1.1.3**.

Table 8.2 Relevant underwater noise embedded environmental measures

ID	Environmental measure proposed	Project stage measure introduced	How the environmental measures will be secured	Relevance to underwater noise assessment
M-032	An **Outline Marine Mammal Mitigation Protocol** (MMMP) has been submitted with this Application (**Volume 4**). The Final MMMP will be completed prior to construction and submitted to MD-LOT for approval. The MMMP will be adhered to and subsequently mitigate potential impacts from underwater noise on marine mammals and fish through good or best practice actions in order to meet legislative requirements.	Scoping Amended at EIA Report.	s.36 conditions and marine licences conditions	Will set out the best practice measures to be undertaken to mitigate the effects of underwater noise on marine mammals.
M-114	The Project will use ‘low order’ techniques such as deflagration for UXO disposal, where possible and required.	Scoping	Required under the Habitats Regulations and marine licence consent conditions.	Seeks to reduce underwater noise emission from UXO detonation.
M-120	An **Outline Construction Method Statement** (CMS) has been submitted with this Application (**Volume 4**). The Final CMS will be completed prior to construction commencing and submitted to MD-LOT for approval. The Final CMS will include: a) details of the commence dates, duration and phasing of key elements of construction, working areas, the construction procedures and good working practices; b) details of the roles and responsibilities; and c) details of how the construction related mitigation step proposed are to be delivered.	EIA Report	s.36 conditions and marine licences conditions	Will set out a logical sequence of actions to be taken to mitigate risks relating to adverse noise effects and maintain a best-practice approach.

8.7 Methodology for underwater noise modelling

8.7.1 Introduction

8.7.1.1 The project-wide approach to assessment is set out in **Chapter 5: Approach to EIA.** The underwater noise modelling presented in this Chapter informs the assessments presented in the chapters outlined in **paragraph 8.1.1.3**, rather than assessing impacts to ecological receptors directly. This is because the underwater noise impact pathways, impact magnitudes, and receptor sensitivities to underwater noise vary between receptor groups. This receptor-specific information is described in the chapters outlined in **paragraph 8.1.1.3**, alongside the baseline for those relevant receptors. The findings of this chapter and the underwater modelling output described in **Volume 3, Appendix 8.1** are subsequently interpreted (as relevant to those receptors), and the impacts from underwater noise are assessed (as relevant to those receptors) within the receptor-group specific chapters specified in **paragraph 8.1.1.3**.

8.7.1.2 This Section, therefore, sets out the approach to underwater noise modelling, rather than the approach to an impact assessment and summarises the information provided in **Volume 3, Appendix 8.1**.

8.7.1.3 Offshore construction activity, particularly piling activities from the installation of driven piles or driven pile anchors on the sea floor, as well as noise associated with the operational functionality of offshore wind turbines including ‘snapping’ noise from the mooring lines, will generate noise and vibration that may be relevant to sensitive receptors. Underwater noise is therefore modelled to inform receptor-specific assessments.

8.7.1.4 Noise can be broadly categorised as either impulsive or non-impulsive / continuous. The characteristics of a sound influence the type and magnitude of the effect on receptors. Impulsive sounds are typified by being of short duration (less than one second), across a broad frequency range (broadband) and with a rapid rise time and decay time.

8.7.1.5 Non-impulsive / continuous sounds can be broadband, narrowband or tonal. They can be of short or long duration but typically do not have such a high peak sound pressure or the rapid rise or decay time of impulsive sounds. It is the generally higher sound levels and rapid rise and decay times that make impulsive sounds more injurious than continuous sounds.

8.7.1.6 While bodily and auditory injuries are of the greatest concern nearest to the noise source, where sound levels are highest, with increasing distance, behavioural effects might still be experienced by receptors. These include disturbance, displacement to another area and difficulties in interpreting the natural sounds of an environment due to masking by noise. These behavioural effects are not assessed in this Chapter but are considered in the relevant receptor chapters using the modelling outputs presented here.

8.7.2 Modelling methodology

8.7.2.1 Predictive modelling was undertaken to estimate the likely underwater noise levels produced during the construction, O&M and decommissioning stages of the Project. The Impulsive Noise Sound Propagation and Impact Range Estimator (INSPIRE) underwater noise model (version 5.3), which has been adopted for this assessment, has been used on a large number of wind farm assessments in UK waters and combines numerical modelling with measured data. It is designed for use in shallow, mixed waters, typical of the conditions found in the North Sea.

8.7.2.2 The source with the greatest potential for injury to ecological receptors and the largest geographical extent of behavioural effects is impact pile driving. Impact piling of driven piles will be used for the offshore substations and reactive compensation platforms (RCPs) foundations. Driven pile anchors could be used for wind turbine generator (WTG) floating unit mooring systems.

8.7.2.3 INSPIRE considers a range of parameters, including bathymetry, source frequency and Project-specific inputs, such as:

- piling hammer blow energies;
- soft-start, ramp-up and strike rate;
- total piling duration; and
- receptor swim speeds.

8.7.2.4 The model then provides estimates of unweighted peak SPLs ($L_{p,pk}$), single-strike sound exposure levels (SEL) ($L_{E,p,ss}$) and cumulative SELs, calculated over a specified time period ($L_{E,p,t}$), as well as other metrics frequency-weighted for particular hearing groups. These can be used to assess the effects of noise on marine mammals and fishes.

8.7.2.5 Impact pile driving was modelled at six representative locations covering the Option Agreement Area (OAA) and offshore export cable route, under a range of scenarios:

- a single pile at a single location;
- two sequential piles at a single location; and
- two simultaneous piles at two locations ('concurrent piling').

8.7.2.6 A simplified modelling approach, based on empirical measurement data and scaled to project-specific parameters, was used to estimate noise levels from other sources, including construction activities (for example cable laying, dredging and drilling), operational WTGs and UXO clearance. This approach did not incorporate bathymetric or environmental data and instead applied standard transmission loss calculations to predict sound propagation across the Red Line Boundary. Given the lower impact of these activities when compared with impact piling, a less detailed modelling approach is considered to be appropriate. Results are therefore not location-specific but applicable to the whole site.

8.7.2.7 Further information on the parameters used and the confidence in the models can be found in **Volume 3, Appendix 8.1**.

8.7.3 Noise exposure criteria

8.7.3.1 To determine whether adverse effects on ecological receptors are likely, it is important to understand the magnitude of the sound, the nature of the sound (e.g. source type and characteristics: impulsive; non-impulsive; continuous), the hearing sensitivity of the receptor at different sound frequencies, and at what level a sound causes a response (e.g. tissue damage, auditory injury, temporary hearing damage, behavioural response).

8.7.3.2 Noise exposure criteria are used in the modelling to predict impact ranges or impact areas of the underwater noise generated by the modelled activity. The results are then interpreted for their ecological significance in receptor-specific chapters. The three main ecological groups for consideration in the EIA are discussed in terms of accepted noise exposure criteria, below.

Marine mammals

8.7.3.3 The Southall *et al*. (2019) paper is currently the most used and recognised reference for marine mammal hearing thresholds for noise exposure. The paper places all marine mammal species, according to their hearing sensitivities (or likely hearing sensitivities), into one of six groups, with two of these – the seals and other carnivores – having thresholds for both in-air and in-water hearing. In-air criteria are not relevant here.

8.7.3.4 The four groups applicable to species living in UK waters are:

- low-frequency cetaceans;
- high-frequency cetaceans;
- very-high-frequency cetaceans; and
- phocid carnivores in water.

8.7.3.5 Criteria have been produced for impulsive sounds and non-impulsive / continuous sounds. For each group, frequency-weighted threshold levels define the onset of permanent threshold shift (PTS) and temporary threshold shift (TTS).

8.7.3.6 Modelling takes into account the peak SPL criterion and the weighted cumulative sound exposure criterion for assessment of auditory injury or PTS. Single-strike SELs can be used to calculate disturbance of marine mammals. It is assumed that marine mammals will move away from the source when exposed to a loud sound. Therefore, a 'fleeing animal' model is used for marine mammals to simulate this movement.

8.7.3.7 It should be noted that an updated set of thresholds was published by the United States of America National Marine and Fisheries Service (NMFS) in 2024. However, these have as yet not been accepted for use in Scottish waters by NatureScot.

Fishes

8.7.3.8 The Popper *et al*. (2014) guidelines are recognised as a suitable reference for underwater noise impacts on fishes, covering a number of noise types, including pile driving, explosions, and shipping and continuous noise. The paper groups fishes based on physiology and hearing capabilities, where data exist. The four categories are:

- fish: no swim bladder (particle motion detection);
- fish: swim bladder is not involved in hearing (particle motion detection);
- fish: swim bladder involved in hearing (primarily pressure detection); and
- eggs and larvae.

8.7.3.9 The three categories of adult fishes identify differences in how fishes hear sound. The first category comprises fishes lacking an internal air cavity and thus unable to detect sound as pressure waves, the way that mammals do. Instead, they sense the back-and-forth movements of the water particles surrounding them as 'particle motion', with ears that function like accelerometers to detect the motion.

8.7.3.10 The middle category fishes have an air cavity but no such adaptation for hearing exists. These fishes also detect sound as particle motion, rather than pressure waves.

8.7.3.11 The third 'pressure detection' group fishes have an internal air cavity, which has adapted to allow them to detect sound as pressure waves and this is their primary facility for sound detection. This adaptation makes these fishes more sensitive to high SPLs in the water.

8.7.3.12 For each group, a threshold level (or a qualitative descriptor in terms of risk, where no quantitative data are available) defines the onset of the following effects, with decreasing levels of severity:

- mortal and potential mortal injury;
- recoverable injury;
- TTS;
- masking; and
- behaviour.

8.7.3.13 No criteria for particle motion detection are currently in existence and, although the relationship between sound pressure and the particle motion of sound is not straightforward in shallow waters, sound pressure criteria are still the accepted criteria for use in the assessment of all fish species (Nedelec *et al*., 2016; 2021).

8.7.3.14 Fishes have been modelled both as fleeing receptors and stationary receptors. The modelling results for fishes are presented in this Chapter and interpreted in **Chapter 13: Fish Ecology** and **Chapter 14: Commercial Fisheries**.

Marine invertebrates

8.7.3.15 It has been shown that many species of marine invertebrate are sensitive to sound in terms of particle motion (see Sole *et al*., 2023 for a review). As stated above for fishes, there exists no established approach for modelling the effects of noise in terms of particle motion, due to a lack of supporting data. The knowledge gaps on the subject mean that the subject is not yet developed enough to produce noise exposure thresholds for marine invertebrates.

8.7.3.16 This Chapter, therefore, does not present quantitative modelling for marine invertebrates, but the qualitative assessment in **Chapter 10: Benthic, Epibenthic and Intertidal Ecology** draws upon the general understanding of sound sensitivity.

8.8 Results of underwater noise modelling

8.8.1 Pile driving

8.8.1.1 Modelled impact ranges from the installation of jacket foundations (offshore substations and RCPs) secured by driven piles and turbine moorings are presented in **Volume 3, Appendix 8.1** and summarised below. These results apply to the offshore substation and RCP foundations, as well as the driven pile anchors. Results are presented in terms of impact ranges and / or areas, according to the Southall *et al*., 2019 and Popper *et al*., 2014 criteria for marine mammals and fishes, respectively. As outlined in **Section 8.7.3**, only a fleeing animal model is used for marine mammals, whereas both a stationary and a fleeing model are used for fishes.

8.8.1.2 The largest modelled ranges are predicted for the installation of driven piles at the offshore substation north corner, due to deep water. Other modelled values are marginally lower, reflecting similar environmental conditions across the site.

Single location modelling

8.8.1.3 The largest impact range for marine mammals is for the low-frequency cetacean group using the weighted 24-hour cumulative sound exposure criterion. For sequentially installed piles, maximum PTS ranges were 25 kilometres (km) with an area of 1,600km^2.

8.8.1.4 For fishes in the two swim bladder groups, the largest recoverable injury ranges, using the unweighted 24-hour cumulative sound exposure criterion, are predicted out to 4.9km (an area of 75km^2) for a stationary receptor, reducing to less than 100 metres (m) (an area of <0.1km^2) for a fleeing (1.5m/s) receptor model.

8.8.1.5 The difference between single piling and sequential piling at the same location is minor for fleeing receptors. This can be explained by the distance that receptors have reached by the time the second piling operation begins. Further from the pile, the sound level is lower and noise exposure is also, therefore, reduced.

Multiple location modelling

8.8.1.6 To investigate the impacts of multiple piling vessels operating at the same time, two scenarios were considered, with sequentially installed piles:

- the Project concurrent piling – offshore substation driven piles at the south-west corner and driven pile anchors at the north corner; and
- the Project and Buchan Offshore Wind Farm concurrent piling – offshore substation driven piles at the west corner and a location at the southern corner of nearby Buchan Offshore Wind Farm (parameters assumed to be the same as for the Project).

8.8.1.7 Buchan Offshore Wind Farm has been included due to its proximity to the MarramWind Offshore Wind Farm OAA, with the array areas of the two projects located approximately 24km apart at their nearest points. The Buchan Offshore Wind Farm is anticipated to undergo construction offshore, commencing around 2028 and taking up to three years to complete (Buchan Offshore Wind Limited, (2025). Given that the construction of MarramWind Offshore Wind Farm is anticipated to commence in 2030 and to have an overall duration of up to 12 years, there is the potential for piling activities for the two projects to occur concurrently. This concurrent scenario is unlikely to occur because the Buchan Offshore Wind Farm piling would be likely complete by the time MarramWind Offshore Wind commenced piling (see **Chapter 4: Project Description** for detail), but this is included as a worst case scenario for the purposes of this EIA Report.

8.8.1.8 Receptors have a greater cumulative exposure to noise under the multiple-location scenario, as fleeing receptors can be closer to a source for a higher number of pile strikes. Piling from multiple sources can therefore increase impact ranges significantly.

8.8.1.9 The modelled scenario provides the greatest geographical spread of noise sources, presenting a worst-case scenario. Results are presented as areas only, as there are multiple starting points for receptors, due to the multiple noise sources.

The Project concurrent piling

8.8.1.10 For the within-Project concurrent piling scenario, the impact ranges for marine mammals are largest for low-frequency cetaceans using the weighted 24-hour cumulative sound exposure criterion. The maximum PTS areas were 1,400km^2 at the south-west corner and 1,300km^2 at the north corner, with an in-combination area of 4,100km^2.

8.8.1.11 For stationary fishes, the largest recoverable injury ranges, using the unweighted 24-hour cumulative sound exposure criterion, are predicted for an area of 74km^2 for the south-west corner and 58 km^2 for the north corner, with an in-combination effect of 140km^2. For fleeing fishes (1.5m/s), the largest recoverable injury ranges are predicted for an area of <0.1km^2 for each individual location, with no in-combination effect.

The Project and Buchan Offshore Wind Farm concurrent piling

8.8.1.12 For the Project and Buchan Offshore Wind Farm concurrent piling scenario, results for marine mammals are largest for low-frequency cetaceans using the weighted 24-hour cumulative sound exposure criterion. For this, maximum PTS areas were 1,400km^2 at the west corner and 1,300km^2 at Buchan south, with an in-combination area of 3,400km^2.

8.8.1.13 For stationary fishes, the largest recoverable injury ranges, using the unweighted 24-hour cumulative sound exposure criterion, are predicted for an area of 74km^2 for the west corner and 71km^2 for Buchan south, with an in-combination effect of 170km^2. For fleeing fishes (1.5m/s), the largest recoverable injury ranges are predicted for an area of <0.1km^2 for each individual location, with no in-combination effect.

8.8.2 Other noise sources

8.8.2.1 While impact pile driving tends to produce the highest noise levels in the lifetime of an offshore wind farm, other noise sources may be present. These include:

- cable laying;
- drag embedment anchors;
- dredging;
- drilling;
- rock placement;
- suction caisson installation;
- trenching;
- vessel noise;
- operational WTGs; and
- UXO clearance.

Noise associated with construction, O&M and decommissioning stages

8.8.2.2 Results in this Section are impact ranges for all of the above-listed sources, except for operational WTGs, mooring cables and UXO clearance, which have their own sections.

8.8.2.3 The results show that all fleeing marine mammals would have to be closer than 100m from the noise source at the start of the activity for PTS to be experienced. For stationary marine mammal receptors, suction caisson installation, rock placement and suction dredging would give impact ranges of 1.1km, 900m and 570m, respectively, for very-high-frequency cetaceans and 130m for suction caisson installation for low-frequency cetaceans. Ranges for stationary marine mammals are expected to be overly conservative, as animals would need to remain at the same distance from the noise source for a 24-hour period to gain such an exposure.

8.8.2.4 Assuming a stationary model for fishes with a swim bladder involved in hearing, all sources are expected to have a range of <50m for recoverable injury over a period of 48 hours exposure.

Operational wind turbine generators

8.8.2.5 For most operational WTGs, noise from the machinery radiates into the water column through the foundation in the water. In a fixed-bottom monopile foundation, the radiating area is the surface area of the cylindrical pile. For floating turbines, this is the weighted, buoyant section, which is a much smaller radiating area. While predicting noise levels from floating turbines is more complex (Tougaard *et al*., 2020), it is expected to be lower than for fixed-bottom foundations (Risch *et al*., 2023).

8.8.2.6 Using the Tougaard *et al*. (2020) calculator for fixed foundations, levels of between 131dB and 134dB re 1µPa (L_p) would be expected at 150m from the floating turbines at the Project.

8.8.2.7 When considering this in terms of sound exposure, for marine mammals spending an hour at a range of 100m, an unweighted level of 174dB ($L_{E,p,1h}$) would be received, which, when weighting is considered, is well below the thresholds for onset of either auditory injury (PTS) or TTS, according to the Southall *et al*. (2019) criteria. This also assumes that a marine mammal remains within that distance for a whole hour, which is unlikely. Therefore, the TTS risk is low.

8.8.2.8 Using the continuous noise criteria for fishes (Popper *et al*., 2014), the levels are far below recoverable injury thresholds and onset of TTS at 158dB (L_p) would require that the individual spend 12 hours within 20m of the source. Given the water depths of around 110m, there is a very low risk of TTS onset.

Mooring cables

8.8.2.9 Measurements at the Statoil Hywind Demonstrator in Norway and a study at Hywind Scotland captured ‘snapping’ and other sounds from the mooring system, caused by strain and friction (Jasco, 2011; Burns *et al*., 2022). Sound levels increased with increasing wave height. This is likely caused by the fact that that cables were designed to be permanently in tension to reduce the potential for entanglement issues for marine mammals (Statoil, 2015).

8.8.2.10 Given that the sounds were found to be variable in their characteristics and a snapping sound was not always present, this may not be an issue for the Project. Even with a set of worst-case assumptions, the predicted SEL for the mooring systems of ten WTGs, based on the Xodus (2015) study for Hywind Scotland Pilot Park, would be approximately 160dB re 1 micropascal squared seconds (μPa^2s). This is below injury criteria for both marine mammals and fishes and, as rare, transient sounds of less than one per hour on average, disturbance is unlikely.

UXO clearance

8.8.2.11 UXO devices of a range of charge weights may be encountered on site and these would need to be cleared prior to construction of the Project. Charge weight indicates the quantity of contained explosive. However, the sound levels produced by two UXOs of the same charge weight may differ, depending upon degradation or positioning on the seabed.

8.8.2.12 A worst-case scenario of maximum explosive charge is considered for each device, detonating either with a high-order method or using the deflagration (low-order) approach, the latter of which produces far lower noise levels. It is expected that a high-order clearance method would only be used in exceptional circumstances, after the use of the quieter low-order technique.

8.8.2.13 The worst-case scenario for use of the high-order technique assumes a blast wave equivalent of full detonation of the device, but does not account for attenuation and is therefore likely to overestimate noise levels.

8.8.2.14 The modelled source levels (at 1m) for UXO clearance range from 269.8dB re 1µPa for a low-order 0.25 kilograms (kg) detonation to 296.6 dB re 1µPa for a high-order 907kg plus donor charge (0.25kg), for peak SPLs. For single-pulse SELs, the results range from 215.2 dB re $1µPa^2s$ for a low-order 0.25kg detonation to 237.9 dB re $1µPa^2s$ for a high-order 907kg plus donor charge (0.25kg).

8.8.2.15 For marine mammals, peak SPL impact ranges are highest for very-high-frequency cetaceans, ranging from 990m for a low-order 0.25kg detonation to 15km for a high-order 907kg plus donor charge (0.25kg). For single-pulse SELs, impact level ranges are highest for low-frequency cetaceans, from 230m for a low-order 0.25kg detonation to 12km for a high-order 907kg plus donor charge (0.25kg). Given the large range of the impact and that sound becomes less impulsive with increased distance (see e.g. Martin *et al*., 2020; Matei *et al*., 2024), non-impulsive criteria have also been modelled. These show a range of <50m for all groups using low-order clearance and a 750m range for low-frequency cetaceans, using high-order clearance. The true effect would be likely to fall between these two modelled ranges.

8.8.2.16 Impact ranges for fishes have been modelled using the explosions noise criteria from Popper et al. (2014). Mortality and potential mortal injury peak SPLs are given as 229dB to 234dB re 1µPa for all categories of adult fish. Impact ranges for a low-order 0.25kg detonation range between <50m to 60m, while impacts of a high-order 907kg plus donor charge (0.25kg) detonation are between 580m and 970m.

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8.10 Glossary and abbreviations

8.10.1 Abbreviations

Acronym	Definition
COLREGS	International Regulations for the Prevention of Collisions at Sea
DEFRA	Department for Environment Food and Rural Affairs
DESNZ	Department for Energy Security and Net Zero
EIA Report	Environmental Impact Assessment Report
EU	European Union
INSPIRE	Impulsive Noise Sound Propagation and Impact Range Estimator
ISO	International Organisation for Standardisation
IMO	International Maritime Organisation
JNCC	Joint Nature Conservation Committee
JOMOPANS	Joint Monitoring Programme for Ambient Noise in the North Sea
MD-LOT	Marine Directorate – Licensing Operations Team
MD-SEDD	Marine Directorate – Science Evidence Data and Digital
MMMP	Marine Mammal Mitigation Protocol
MSFD	Marine Strategy Framework Directive
NMFS	National Marine Fisheries Service
NPF4	National Planning Framework 4
OAA	Option Agreement Area
O&M	Operation and maintenance
PTS	Permanent threshold shift
RCP	Reactive compensation platform
s.36	Section 36
SAC	Special Area of Conservation
SEL	Sound exposure level
SPL	Sound pressure level
TTS	Temporary threshold shift

Acronym	Definition
UXO	Unexploded ordnance
WTG	Wind turbine generator
ZOI	Zone of influence

8.10.2 Glossary of terms

Term	Definition
Decibel	A customary scale commonly used (in various ways) for reporting levels of sound. The dB represents a ratio/comparison of a sound measurement (e.g., sound pressure) over a fixed reference level. The dB symbol is followed by a reference value (e.g., re 1 μPa).
Permanent Threshold Shift	Noise threshold that represents the onset level of a permanent impairment in hearing caused by acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the ear, and thus a permanent reduction of hearing acuity.
Root Mean Square	The square root of the arithmetic average of a set of squared instantaneous values. Used for presentation of an average sound pressure level.
Sound Exposure Level	The constant sound level acting for one second, which has the same amount of acoustic energy, as indicated by the square of the sound pressure, as the original sound. It is the time-integrated, sound-pressure-squared level. Sound exposure level is typically used to compare transient sound events having different time durations, pressure levels, and temporal characteristics.
Sound Exposure Level, cumulative	Single value for the collected, combined total of sound exposure over a specified time or multiple instances of a noise source.
Sound Exposure Level, single strike	Calculation of the sound exposure level representative of a single noise impulse, typically a pile strike.
Sound Pressure Level	The sound pressure level is an expression of sound pressure using the decibel (dB) scale; the standard frequency pressures of which are 1 μPa for water and 20 μPa for air.
Sound Pressure Level Peak	The highest (zero-peak) positive or negative sound pressure, in decibels.
Temporary Threshold Shift	Onset threshold level for a temporary reduction of hearing acuity caused by exposure to sound over time.
Unweighted sound level	Sound levels which are “raw” or have not been adjusted in any way, for example to account for the hearing ability of a species.

Term	Definition
Weighted sound level	A sound level which has been adjusted with respect to a "auditory weighting function" or "weighting envelope" in the frequency domain, typically to make an unweighted level relevant to a particular species.

8.10.3 Units

Unit	Definition
dB	decibel
Hz	hertz
kg	kilogram
kHz	kilohertz
km	Kilometre
m	metre
m/s	metres per second
μPa	micropascal
μPas	micropascal squared seconds

MarramWind