CALEDONIA
Offshore Wind Farm

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Volume 2 Proposed Development (Offshore)

Chapter 5 Fish and Shellfish Ecology

Caledonia Offshore Wind Farm Ltd

5th Floor Atria One, 144 Morrison Street, Edinburgh, EH3 8EX

OCEAN WINDS

Volume 2 Chapter 5 Fish and Shellfish Ecology

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Acronyms and Abbreviations

AET	Apparent Effects Threshold
CAL	Cefas Action Levels
CaP	Cable and Pipeline plan
CBRA	Cable Burial Risk Assessment
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CIEEM	Chartered Institute of Ecology and Environmental Management
CPS	Cable Protection System
CSIP	Cable Specification and Installation Plan
CTV	Crew Transfer Vessel
DAS	Digital Aerial Survey
DE	Design Envelope
DECC	Department of Energy and Climate Change
DESNZ	Department for Energy Security and Net Zero
EEZ	Exclusive Economic Zones
EIA	Environmental Impact Assessment
EIAR	Environmental Impact Assessment Report
EMF	Electromagnetic Fields
ERM	Effects Range Low
EU	European Union
DP	Decommissioning Programme
FAD	Fish Aggregation Devices
FOWF	Floating Offshore Wind Farms

FWPM	Fresh Water Pearl Mussels
FWTG	Floating Wind Turbine Generator
GES	Good Environmental Status
GMF	Geomagnetic Field
HDD	Horizontal Directional Drilling
HRA	Habitats Regulations Assessment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Directional Current
ICES	International Council for the Exploration of the Sea
ICUN	International Union of Conservation of Nature
iE	induced Electrical field
IEF	Important Ecological Features
IER	Individual Ecosystem Role
INNS	Invasive Non-Native Species
JNCC	Joint Nature Conservation Committee
LAT	Lowest Astronomical Tide
LoD	Limit of Detection
MCZ	Marine Conservation Zone
MFS	Mass Flow Excavator
MHWS	Mean High Water Springs
MoU	Memoranda of Understanding
MPCP	Marine Pollution Contingency Plan
MPS	Marine Policy Statement
MSFD	Marine Strategy Framework Directive

MD-LOT	Marine Directorate - Licensing Operations Team
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Mammal Observer
mT	Millitesla
MU	Management Unit
NCMPA	Nature Conservation Marine Protected Area
NGO	Non-governmental Organisation
NMP	Scottish National Marine Plan
NPF4	National Planning Framework 4
O&M	Operation and Maintenance
OCP	Organochlorine Pesticide
OECC	Offshore Export Cable Corridor
OfTI	Offshore Transmission Infrastructure
OSP	Offshore Substation Platform
OSPAR	The Convention for the Protection of the Marine Environment of the North East Atlantic
OWF	Offshore Wind Farm
PAH	Polycyclic Aromatic Hydrocarbon
PBDE	Polybrominated Diphenyl Ether
PCB	Polychlorinated Biphenyl
PEMP	Project Environmental Monitoring Programme
PMF	Priority Marine Features
PS	Piling Strategy
PSA	Particle Size Analysis
PTS	Permanent Threshold Shift

RCP	Representative Concentration Pathway
RIAA	Report to Inform Appropriate Assessment
RMS	Root Mean Square
SAC	Special Area of Conservation
SD	Standard Deviation
SEL_{cum}	cumulative Sound Exposure Levels
SPA	Special Protection Area
SPL	Sound Pressure Level
SPL_{peak}	peak Sound Pressure Levels
SSC	Suspended Sediment Concentration
SSSI	Sites of Special Scientific Interest
TCA	Trade and Cooperation Agreement
THC	Total Hydrocarbon Content
TTS	Temporary Threshold Shift
UK	United Kingdom
UKBAP	United Kingdom Biodiversity Action Plan
UWN	Underwater Noise
UXO	Unexploded Ordinance
VMP	Vessel Management Plan
WCS	Worst-Case Scenario
WTG	Wind Turbine Generator
ZoI	Zone of Influence

Executive Summary

This Fish and Shellfish Ecology Chapter of the Caledonia Offshore Wind Farm (OWF) Environmental Impact Assessment Report presents an overview of the existing fish and shellfish ecology characteristics and identifies the potential effects on these receptors associated with the construction, operation and maintenance and decommissioning phases of the Proposed Development (Offshore) seaward of Mean High Water Springs.

Within the Environmental Impact Assessment (EIA) Scoping stage of assessment, basking sharks and sea turtles were assessed under the category of 'Other Megafauna' alongside Marine Mammals; however, only basking sharks have been brought forward to this stage of the assessment. Therefore, the 'Other Megafauna' category has been removed and basking sharks have been assessed in this Fish and Shellfish Ecology Chapter.

The Fish and Shellfish Ecology study area has been determined based upon the Proposed Development (Offshore) location and proposed infrastructure, alongside spring tidal excursion data and underwater noise modelling. While for basking sharks, a site-specific study area encompassing the Caledonia OWF (Array Area), Caledonia Offshore Export Cable Corridor and 4km buffer, and a broader Regional study area covering the OSPAR Region II: Greater North Sea has been defined.

Site-specific surveys were undertaken to provide an up-to-date characterisation of the benthic habitats and species occurring within the area of the Proposed Development (Offshore), with sampling conducted in April 2023. A site-specific digital aerial survey campaign was conducted from May 2021 to April 2023 within the Caledonia site plus a 4-km buffer, by APEM to characterise basking shark baseline.

Consideration of the Design Envelope has been undertaken to identify worst-case scenario with respect to Fish and Shellfish Ecology. Adopting a source-pathway-receptor approach, the potential impacts associated with the Proposed Development (Offshore) have been assessed, in accordance with the Scoping Opinion and subsequent stakeholder engagement, using a suite of methodologies which include numerical modelling, the evidence-base and expert judgement. Receptors identified include both designated sites with qualifying Fish and Shellfish Ecology features and non-designated sites.

The results of this impact assessment demonstrate that the Proposed Development (Offshore) is likely to have impacts of Negligible to Minor significance, which is considered Not Significant in EIA terms.

5 Fish and Shellfish Ecology

5.1 Introduction

5.1.1.1 This chapter of the Environmental Impact Assessment Report (EIAR) identifies the potential effects on fish and shellfish ecology associated with the construction, operation and decommissioning of the Proposed Development (Offshore). This includes the Caledonia Offshore Wind Farm (OWF) (Array Area) and the Caledonia Offshore Export Cable Corridor (OECC) seaward of Mean High-Water Springs (MHWS).

5.1.1.2 For the purposes of this EIAR chapter, the Proposed Development (Offshore) includes all the offshore components, including Wind Turbine Generators (WTGs), inter-array cables, interconnector cables and offshore substation platforms (OSPs) located within the Caledonia OWF, and offshore export cables located within the Caledonia OECC.

5.1.1.3 The Proposed Development (Offshore) is proposed to include up to 140 Wind Turbine Generators (WTGs) and up to four Offshore Substation Platforms (OSPs), with bottom-fixed foundations only or a combination of bottom-fixed and floating foundation included within the Design Envelope (DE). The Caledonia OWF has an approximate footprint of 423km². The Caledonia OECC covers the area within which up to four offshore export cables are to be installed, extending southward from the Caledonia OWF to the Landfall Site at Stake Ness, with a total footprint of approximately 221.3km².

5.1.1.4 This chapter covers the technical topics of fish and shellfish ecology, in addition to other megafauna. The megafauna considered for this EIAR are the large migratory species that may spatially overlap with the Proposed Development (Offshore). In the context of UK waters, regularly occurring megafauna include basking sharks (*Cetorhinus maximus*) and leatherback turtles (*Dermochelys coriacea*) which have both been recorded in Scottish waters. However, the Offshore Scoping Report (Volume 7, Appendix 2) assessed that leatherback turtles could be excluded from further assessment based on low numbers.

5.1.1.5 As traits of megafauna such as basking shark are notably different from other fish and shellfish species, the Environmental Impact Assessment (EIA) methodology associated with them varies in certain aspects and so certain sections of this chapter have been split into "Fish and Shellfish Ecology" and "Basking Sharks". However, in general, reference to fish and shellfish ecology is considered to incorporate basking sharks unless stated otherwise.

5.1.1.6 This Chapter is supported by, and should be read in conjunction with, the following technical appendices:

- Volume 7B, Appendix 2-1: Marine and Coastal Processes Baseline Technical Report;

- Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report;
- Volume 7B, Appendix 5-1: Fish and Shellfish Ecology Technical Baseline Report;
- Volume 7, Appendix 6: Underwater Noise Assessment; and
- Volume 7, Appendix 19: Caledonia OWF Digital Aerial Surveys.

5.1.1.7 The following supporting EIAR chapters relate to and should be read in conjunction with this chapter:

- Volume 1, Chapter 3: Proposed Development Description (Offshore);
- Volume 2, Chapter 2: Marine and Coastal Process;
- Volume 2, Chapter 3: Marine Water and Sediment Quality;
- Volume 2, Chapter 4: Benthic Subtidal and Intertidal Ecology;
- Volume 2, Chapter 6: Offshore Ornithology;
- Volume 2, Chapter 7: Marine Mammals;
- Volume 2, Chapter 8: Commercial Fisheries; and
- Volume 2, Chapter 9: Shipping and Navigation.

5.2 Legislation, Policy and Guidance

5.2.1.1 This section highlights legislation as well as national and local policy relevant to fish and shellfish ecology, and provides information regarding the legislative context surrounding the assessment of potential effects in relation to fish and shellfish ecology. Full details of all policy and legislation relevant to the Proposed Development (Offshore) are provided within Volume 1, Chapter 2: Legislation and Policy. Caledonia Offshore Wind Farm Limited (hereafter referred to as 'the Applicant') has ensured that the assessment adheres to the relevant legislation.

5.2.1.2 Legislation, policy and guidance that relate to the fish and shellfish ecology assessment are identified and described in Table 5-1. In addition to being broken down into legislation, policy and guidance, the table has separated the items by relevance to both fish and shellfish ecology, and/or basking sharks, where they are only relevant to one topic.

Table 5-1: Legislation, policy and guidance.

Relevant Legislation, Policy and Guidance	Description
Legislation	
The Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention) (The Council of Europe, 1979[1])	The Bern Convention (1979) focuses on safeguarding fish and shellfish ecology by creating Marine Protected Areas (MPAs) and Marine Conservation Zones (MCZs) to preserve marine biodiversity, habitats, and geological features within European wildlife areas. Specifically, the Convention underscores the importance of conserving marine biodiversity by establishing protected zones to sustainably manage fish and shellfish populations and their habitats, as outlined in Article 4, which mandates Contracting Parties to enact legislative measures for habitat conservation of specified flora and fauna species. The basking shark and leatherback turtle are listed under Annex II.
The Convention for the Protection of the Marine Environment of the North East Atlantic (OSPAR Convention) 1992 (OSPAR Convention, 1992[2])	The Oslo and Paris (OSPAR) Convention's Annex III is specifically focused on safeguarding the marine environment from the adverse effects of offshore activities. This annex plays a crucial role in regulating the offshore industry to preserve the delicate ecology of fish and shellfish species in the North-East Atlantic maritime area. By regulating offshore activities and preventing pollution, the OSPAR Convention's Annex III plays a crucial role in conserving the marine ecosystems that are home to a variety of protected fish and shellfish species. This helps to maintain the delicate balance of these fragile environments and ensure the long-term sustainability of these important marine resources. Other megafauna species listed on the OSPAR Convention include basking shark and leatherback turtle.
Convention on Biological Diversity (1992[3])	The Convention on Biological Diversity emphasizes appropriate access to genetic resources, transfer of relevant technologies, and funding mechanisms to support these goals. Furthermore, Article 4 addresses the jurisdictional scope, stating that the provisions apply to areas within national jurisdiction concerning biological diversity components and processes regardless of where their effects occur. Article 5 emphasizes cooperation among Contracting Parties to address matters beyond national jurisdiction related to biodiversity conservation.

Relevant Legislation, Policy and Guidance	Description
The Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention) 1979 (United Nations, 1979[4])	The Bonn Convention establishes specific agreements known as Memoranda of Understanding (MoUs) that focus on the conservation of particular migratory species or groups of species. These MoUs provide a framework for collaborative conservation efforts among countries to protect migratory animals effectively. There are five marine turtle species and 17 shark species listed under Appendix I of the Bonn Convention, including basking shark and leatherback turtle sighted off east Scotland.
Marine Strategy Framework Directive 2008 (UK Parliament, 2008[5])	The Marine Strategy Framework Directive (MSFD) 2008/56/EC establishes a legislative framework for an ecosystem-based approach to the management of human activities that supports the sustainable use of marine goods and services. Following withdrawal from the EU, the MSFD was transposed into Scottish Law, by the Marine Strategy Regulations 2010 and the Marine (Scotland) Act 2010. The overarching goal of the Directive is to achieve 'Good Environmental Status' (GES) by 2020 across Europe's marine environment. To this end, the MSFD requires EU Member States to develop marine strategies that include a detailed assessment of the state of the marine environment, a definition of GES based on 11 descriptors, and the establishment of clear environmental targets and monitoring programmes. Member States must also draw up and implement programmes of measures to achieve GES and cooperate with neighbouring countries within the same marine region or subregion. The MSFD complements the Water Framework Directive by extending environmental protection into EU marine waters beyond the coastal waters. The European Commission is required to review the MSFD by 2023, following an evaluation and impact assessment, which may lead to an updated version of the directive. However, the review process is still ongoing as of 2024.
Wildlife and Countryside Act 1981 (as amended) (UK Parliament, 1981[6])	While the Wildlife and Countryside Act 1981 primarily addresses land-based conservation, its provisions can extend to offshore areas, particularly where activities such as offshore wind energy development may impact protected species, habitats, or designated sites. Developers must ensure compliance with the Act and associated regulations to minimise environmental harm and adhere to conservation objectives. It prohibits the release of any animal species that are "not ordinarily resident in and is not a regular visitor to Great Britain in a wild state". It prohibits the establishment of non-

Relevant Legislation, Policy and Guidance	Description
	native plant species. The act also gives protection to native species, controls the release of non-native species, enhances the protection of SSSIs. The law on non-native species is covered by the Wildlife and Countryside Act 1981.
The Conservation of Offshore Marine Habitats and Species Regulations 2017 (UK Parliament, 2017[7])	The Conservation of Offshore Marine Habitats and Species Regulations 2017 provide legal protection for certain marine species (including leatherback turtle) and habitats located more than 12 nautical miles from the UK coast. The Regulations implement the species protection requirements of the EU Habitats Directive and Birds Directive in the UK's offshore marine area. They establish a system of protection for European protected species, making it an offence to deliberately capture, kill, disturb or damage the breeding sites and resting places of these species. The Regulations also prohibit the use of certain indiscriminate methods of killing or capturing protected species. The Schedules to the Regulations categorize the level of protection afforded to different species, with Schedules 1-3 listing the protected species and methods of capture/killing.
Legislation - Fish and Shellfish Ecology only	
Marine (Scotland) Act 2010 (Scottish Parliament[8])	The Marine (Scotland) Act 2010 establishes a marine spatial planning system, setting the stage for future marine developments and facilitating the establishment of protected marine sites/MPAs within the 12 nautical mile (nm) limit (Scottish territorial seas). These initiatives align with Scotland's and the United Kingdom's commitments to habitat and species protection. The Scottish Ministers, and public authorities must act in the way best calculated to further the achievement of sustainable development, including the protection and, where appropriate, enhancement of the health of that area.
Marine and Coastal Access Act 2009 (UK Parliament, 2009[9])	The Marine and Coastal Access Act 2009 provides devolved authority to Scottish Ministers for marine planning and conservation powers in the Scottish Offshore Region (from 12 to 200nm). Under section 66 of the Marine and Coastal Access Act 2009 (in the context of the Scottish Offshore Region), the Proposed Development (Offshore) requires a Marine Licence for the marine licensable activities beyond 12 nm. MPAs existing beyond the 12nm limit in Scottish Waters are designated under the Marine and Coastal Access Act 2009. These sites (MPAs) are designated areas aimed at conserving marine flora and fauna,

Relevant Legislation, Policy and Guidance	Description
	marine habitats, or features of geological or geomorphological interest.
Nature Conservation (Scotland) Act 2004 (Scottish Parliament, 2004[10])	The Nature Conservation (Scotland) Act 2004 establishes a statutory duty for all public bodies in Scotland to further the conservation of biodiversity when carrying out their responsibilities. This includes requirements for public bodies to report on compliance with the biodiversity duty every three years. The Act also provides for the designation and protection of Sites of Special Scientific Interest (SSSIs), which can include important habitats and species for fish and shellfish. Additionally, the Act empowers Scottish Natural Heritage (NatureScot)[i] to issue land management orders to ensure the appropriate management of SSSIs, which could be relevant for the protection of sensitive fish and shellfish habitats. The Act also requires NatureScot to produce a Scottish Marine Wildlife Watching Code and a Scottish Fossil Code, which could be relevant for managing human interactions with marine species and habitats.
European Union (EU) Habitats Directive (Directive 92/43/EEC) and associate habitats regulation[ii] (The Council of the European Committees, 1992[11]) 1) Conservation (Natural Habitats) (Scotland) Regulations (Scottish Parliament, 1994[12]) 2) The Conservation of Offshore Marine Habitats and Species Regulations (2017[13])	In relation to designated sites, prior to making any decisions to proceed with, or grant approval, consent, or authorisation for, a proposal or undertaking that is expected to have a substantial impact on a UK offshore marine site or a UK site (either independently or in conjunction with other proposals or undertakings), and is not directly linked to or essential for the site's management, a competent authority is required to conduct a suitable assessment of the implications for the site considering its conservation objectives. In addition to the overarching EU habitats directive, the Conservation Regulations and The Conservation of Offshore Marine Habitats and Species Regulations are required for designated sites out to 12nm in Scottish waters.

[i] In 2020, Scottish Natural Heritage was re-branded as NatureScot; however, its legal persona and statutory functions has remained unchanged.

[ii] The Habitats Directive (Council Directive 92/43/EEC) and certain elements of the Wild Birds Directive (Directive 2009/147/EC) (known as the Nature Directives) were transposed into domestic law by the 2017 Regulations. Following the UK's exit from the EU the Regulations were updated by the Conservation of Habitats and Species (Amendment) (EU Exit) Regulations 2019 to reflect that the UK was no longer part of the EU. Any references to Natura 2000 in the 2017 Regulations and in guidance now refers to the new national site network.

Relevant Legislation, Policy and Guidance	Description
1) The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations (2017[14]) 2) The Marine Works (Environmental Impact Assessment) (Scotland) Regulations (2017[15]) 3) Marine Works (Environmental Impact Assessment) Regulations (2007[16])	The Electricity Works Regulations are required for all Section 36 consents out to 12nm off the Scottish coast. For Marine Licence applications out to 12nm, the Marine Works Regulations (2017) must be adhered to, and for any offshore works beyond 12nm, the Marine Works Regulations (2007) are required.
Salmon and Freshwater Fisheries (Consolidation) (Scotland) Act 2003 (Scottish Parliament, 2003[17])	The Salmon and Freshwater Fisheries (Consolidation) (Scotland) Act 2003 is the primary legislation governing the management and conservation of salmon and freshwater fisheries in Scotland. The Act provides the Scottish Government with powers to regulate salmon fishing and protect vulnerable salmon stocks, requiring annual assessments and mandatory catch-and-release or retention bans where necessary. It also empowers the establishment of local District Salmon Fishery Boards to manage fisheries and introduces measures like a ban on the sale of rod-caught salmon to aid conservation efforts.
The Sandeel (Prohibition of Fishing) (Scotland) Order 2024 (Scottish Parliament, 2024[18])	The Sandeel (Prohibition of Fishing) (Scotland) Order 2024 makes provision to prohibit all fishing for sandeel in Scottish waters, using powers provided in section 5 (Powers to restrict fishing for sea fish including for marine environmental purposes) of the Sea Fish (Conservation) Act 1967.
National and Local Policy	
UK Marine Policy Statement (HM Government, 2011[19])	General policy: Ensure a sustainable marine environment which promotes healthy, functioning marine ecosystems and protects marine habitats, species, and our heritage assets. General policy: The marine environment plays an important role in mitigating climate change. General policy: Biodiversity is protected, conserved, and where appropriate recovered, with the cessation of loss. Offshore Wind and Marine Renewable Energy Policy: Marine businesses are acting in a way which respects environmental limits and is socially responsible.

Relevant Legislation, Policy and Guidance	Description
National and Local Policy - Fish and Shellfish Ecology only	
Sectoral Marine Plan for Offshore Wind Energy (Scottish Government, 2020a[20])	Sets out policies and objectives requiring marine planners and decision-makers to consider the potential impacts of development on fish and shellfish ecology and is useful to identify some of the key concerns and issues that should be addressed in any impact assessment. Policies under General Polices GEN 9 and GEN 10 are considered relevant to fish and shellfish ecology. This plan covers the management of both Scottish inshore waters (out to 12nm) and offshore waters (12 to 200nm).
UK Marine Policy Statement (HM Government, 2011[19])	The UK Marine Policy Statement provides the framework for preparing Marine Plans and taking decisions affecting the marine environment across the UK. It aims to ensure consistency in marine planning by setting out the approach and principles and consolidating existing policies relevant to marine management.
Scotland's National Marine Plan (Marine Scotland, 2015[21])	The Scottish National Marine Plan sets out an integrated planning policy framework to guide sustainable development and management of Scotland's marine resources, covering both inshore and offshore waters. It aims to balance the competing demands on the marine environment while protecting the ecosystem. Maintain healthy salmon and diadromous fish stocks (and improve stocks where possible) in support of sustainable fisheries through sound science-based management. Whilst there is uncertainty around the likelihood and severity, potential impacts include disturbance during construction, noise associated with infrastructure such as turbine bases, electro-magnetic fields of infrastructure such as sub-sea grid and cabling and mortality through strike by tidal turbines. Delayed migration or displacement of migratory routes may have effects on salmon and other diadromous species and continued efforts to better understand potential impacts should be encouraged.
National Planning Framework 4 (NPF4) 2023 (Scottish Government, 2023[22])	NPF4 serves as Scotland's overarching spatial strategy, outlining our spatial principles, regional priorities, national developments, and planning policies. It should be comprehensively reviewed and replaces both NPF3 and Scottish Planning Policy.

Relevant Legislation, Policy and Guidance	Description
Scottish Priority Marine Features (NatureScot, 2020a[23])	Scottish Natural Heritage and the Joint Nature Conservation Committee (JNCC) collaborated with Marine Scotland to establish a Priority Marine Features (PMFs) list, which identifies crucial marine habitats and species in Scotland's seas. This list is in line with Marine Scotland's vision for marine nature conservation as articulated in the Marine Nature Conservation Strategy. It functions as a focused roadmap for future conservation endeavours in Scotland. In 2013, Marine Scotland conducted a consultation on the proposed PMFs list. Within this compilation, the subsequent benthic and intertidal species and habitats have either been previously documented in the surrounding area or have the potential to exist in the vicinity of the Proposed Development (Offshore).
UK Post-2010 Biodiversity Framework (UK Government, 2016[24])	The United Kingdom Biodiversity Action Plan (UK BAP) is a comprehensive strategy aimed at conserving and enhancing biodiversity across the UK. It is a collaborative effort involving governments, non-governmental organizations, businesses, and the public to address the decline of biodiversity and promote sustainable practices. As a result of devolution, and new country-level and international drivers and requirements, much of the work previously carried out by the UK BAP is now focussed at a country-level rather than a UK-level, and the UK BAP was succeeded by the 'UK Post-2010 Biodiversity Framework' in July 2012.
Eel Management plans for the United Kingdom: Scotland River Basin District (Defra, 2010[25])	Established in 2010 in response to the Eel Recovery Plan (formed under European Commission Council Regulation No 1100/2007) with the aim of improving the European eel (*Anguilla anguilla*) stocks.
Scottish Wild Salmon Strategy (Scottish Government, 2022b[26])	Published in January 2022, the Scottish Wild Salmon Strategy outlines the objectives, actions to improve the conditions of Scotland's rivers and better manage salmon stocks.
National and Local Policy - Basking sharks only	
Aberdeenshire Council Natural Heritage Strategy[27]	The strategy provides a structured approach to service delivery from 2019-2022 which covers natural heritage work, which can be applied to the marine environment. Relevant objectives include: ▪ Objective 3.2 – Promote, protect and enhance natural heritage through cross-organisation partnership working; and

Relevant Legislation, Policy and Guidance	Description
	▪ Objective 3.4 – Promote prevention and management of invasive non-native species spread in Aberdeenshire.
Guidance - Basking Sharks only	
The protection of Marine European Protected Species from injury and disturbance: Guidance for Inshore Waters (Marine Scotland, 2020[28])	This advice and guidance relate to regulations prohibiting the deliberate and reckless capture, injury, killing, and disturbance of marine European Protected Species (EPS). Although basking sharks are not EPS, the mitigation measures outlined can also be applied to reduce the risk of impacts to this marine wildlife.
Scottish Marine Wildlife Watching Code (NatureScot, 2017[29])	These guidelines provide advice for leisure and commercial activities associated with wildlife watching. They include information detailing activities likely to disturb wildlife, how to safely approach them and how to view with minimum disturbance. This code provides guidance for marine users to reduce the disturbance on marine life, including basking sharks.
The Basking Shark Code of Conduct (The Shark Trust, 2024a[30])	These guidelines developed by the Shark Trust provide advice on how water-users including swimmers, divers, surfers, boat users and people with kayaks or stand-up paddle boards should behave when encountering basking sharks to minimise disturbance to wildlife.
Energy Conversion Factors in Underwater Radiated Sound from Marine Piling – Review of the Method and Recommendations (Wood *et al.*, 2023[31])	This report aims to improve understanding of the Energy Conversion Factor method and provides updates to recommendations for impact piling modelling within EIA within Scottish waters.
Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI (Popper *et al.*, 2014[32])	This book chapter presents thresholds and likelihood of effect at which underwater noise (UWN) generated during offshore activities can cause mortality, recoverable injury, temporary threshold shift (TTS), masking (reduction in the detectability of a given sound (signal) as a result of the simultaneous occurrence of another sound) and behavioural changes in sea turtles and fish, including basking sharks. These values are typically used in conjunction with UWN modelling to assess the effect on species at the individual and population level.

Relevant Legislation, Policy and Guidance	Description
JNCC guidelines for minimising the risk of injury to marine mammals from piling noise (JNCC, 2010a[33])	This set of mitigation measures offers guidance on reducing risk of injury to marine mammals during pile driving. If followed, risk of injury is likely to be greatly reduced. The guidelines are split by survey planning, mitigation, and reporting, to increase ease of use. These guidelines are also applicable to basking sharks and marine turtles.
JNCC guidelines for minimising the risk of injury to marine mammals from using explosives (JNCC, 2010b[34])	This is a set of mitigation measures to reduce risk of injury to marine mammals during detonation of unexploded ordnance (UXO) and the use of other explosives. If followed, risk of injury is likely to be negligible. The guidelines are split by survey planning, mitigation, and reporting, to increase ease of use. These guidelines are also applicable to basking sharks and marine turtles.
Draft guidelines for minimising the risk of injury to marine mammals from unexploded ordnance clearance in the marine environment (JNCC, 2023[35])	This draft guidance document updates the JNCC (2010) guidelines of mitigation measures to reduce the risk of injury to marine mammals during UXO clearance. If followed, risk of injury is likely to be greatly reduced. The guidelines are split by emerging technologies, mitigation, and reporting. The mitigation protocols recommended for marine mammals are also likely to be appropriate for basking sharks and sea turtles.
Marine environment: unexploded ordnance clearance joint interim position statement (Defra *et al.*, 2021[36])	A joint interim position paper regarding the clearance of UXO in the marine environment.
Scottish Natural Heritage Commissioned Report No. 791: Understanding the potential for megafauna entanglement risk from marine renewable energy developments (Benjamins *et al.*, 2014[37])	This report reviews existing information on entanglement risks of moorings on basking sharks and marine turtles, and has developed a qualitative risk assessment approach assessing relative entanglement risks based on the biological and physical risk parameters of other megafauna groups.
Scottish Natural Heritage Research Report No. 1070: A review of noise abatement systems for OWF construction noise, and the potential for their application in Scottish waters (Verfuss *et al.*, 2019[38])	This study undertakes a review of available UWN abatement systems with consideration of their applicability for pile-driving operations for OWF construction in Scottish waters.
JNCC Report 768: Cumulative effects assessments to support marine plan development (Willsteed *et al.*, 2024[39])	This report presents an assessment of cumulative effects assessment methodologies and approaches as a means of supporting marine planning in the UK.

5.3 Stakeholder Engagement

5.3.1 Overview

5.3.1.1 The Offshore Scoping Report (Volume 7, Appendix 2) was submitted to Marine Directorate - Licensing Operations Team (MD-LOT)[iii] in September 2022, who then circulated the report to relevant consultees. A Scoping Opinion (Volume 7, Appendix 3) was received from MD-LOT on 13 January 2023. Relevant comments from the Scoping Opinion specific to fish and shellfish ecology and basking sharks are provided in Table 5-2 and Table 5-3, respectively.

[iii] In 2023, Marine Scotland was renamed Marine Directorate, and thus the marine licensing and consents team is now referred to as Marine Directorate - Licensing Operations Team (MD-LOT).

Table 5-2: Scoping Opinion response (fish and shellfish ecology).

Consultee	Comments	Response
Spey District Salmon Fishery Board	Species know to be accruing within the Moray Firth are White Skate and Sea Lamprey (*Petromyzon marinus*) and within the River Spey, Special Area of Conservation (SAC).	Spey District Salmon Fishery Board confirmed that this an important habitat for Atlantic salmon and sea trout (*Salmo trutta trutta*). The Applicant and Spey District Salmon Fishery Board agreed that it is of greater importance for sea trout as they have a more local migration habit and are likely to remain in the Moray Firth for longer than Salmon. Spey District Salmon Fishery Board confirmed that the Kelp Forest is also a popular spot for recreational diving, with several dive clubs using the area. An assessment of the impacts from the Proposed Development (Offshore) on migratory species present in the Moray Firth has been carried out in Section 5.7.
Spey District Salmon Fishery Board	The Wind Farm location is within probable migration routes for Atlantic Salmon smolts and return of spawning adults. The tracking studies to date show the smolts remaining coastal along the Moray and Aberdeenshire Coast. Even less in known about the path of returning adults, however it would be logical to conclude that they use the same trigger, and therefore route, to return.	The Applicant confirmed that Moray East OWF contributed to 'the missing salmon project' (Atlantic Salmon Trust, 2019[40]) which offered very useful outputs on the movement of smolts from rivers south of the Moray Firth. The Applicant confirmed that SSE Renewables on Beatrice OWF have also had a smolt tracking study in the Cromarty Firth (BOWL, 2016[41]). Spey District Salmon Fishery Board confirmed that the missing salmon project is the best available data on the migration of salmon and shows smolts remain coastal before heading north (Atlantic Salmon Trust, 2019[40]). An assessment of the impacts from the Proposed Development (Offshore) associated with migratory Atlantic salmon in the Moray Firth has been carried out in Section 5.7.
Spey District Salmon Fishery Board	Scoping states that low frequency noise will be created and may effect migration.	The Applicant confirmed that the Offshore Scoping Report suggested that the impact of low frequency UWN would be scoped out the assessment. The Applicant noted that the

Consultee	Comments	Response
		Spey Board would like this impact assessed, and noted the NatureScot response also asked for this to be scoped in. The Applicant confirmed that this will be scoped into the assessment. The Applicant sought to further clarify the specific noise concerns that the Spey Board have during operation. Spey District Salmon Fishery Board asked how these foundations will be installed. The Applicant confirmed that a range of options remain on the table, but it is likely piling with use of a large piling hammer would be used. Spey District Salmon Fishery Board confirmed that this is one of the key concerns. The Applicant confirmed that UWN modelling will be undertaken to assess the worst-case impact from piling on mammals and fish. Spey District Salmon Fishery Board was satisfied that this would be assessed. A full UWN assessment for the Proposed Development (Offshore) has been carried out in Section 5.7 (see Impact 1). Additionally, operational UWN has been assessed (see Impact 11).
Spey District Salmon Fishery Board	Cable to go through an area of rapidly declining kelp forest that may be an important over-wintering habitat for sea trout, and also provides predation refuge for other migratory species.	The Applicant asked Spey District Salmon Fishery Board to confirm the location of the kelp forest on a map. Spey District Salmon Fishery Board confirmed that it appears to be out with the refined cable corridor as it is just off the coast from MacDuff Harbour. Spey District Salmon Fishery Board confirmed that this an important habitat for salmon and sea trout. Impacts such as habitat loss (kelp forests) from the Proposed Development (Offshore) have been assessed in Volume 2, Chapter 4: Benthic Subtidal and Intertidal Ecology.

Consultee	Comments	Response
MD-LOT	The Scottish Ministers are broadly content with the proposed baseline data sources but advise that the additional data sets identified by NatureScot must be used in the assessment in the EIAR and the NatureScot representation must be implemented in full in the EIAR. With regards to the study area, the Scottish Ministers are broadly content but advise that the NatureScot and Spey District Salmon Fishery Board representations regarding noise modelling for sandeel, herring and Atlantic salmon are implemented in full in the EIAR.	A full UWN assessment for the Proposed Development (Offshore) has been carried out and includes noise modelling for sandeel, herring and Atlantic salmon in Section 5.7 (see Impact 1).
MD-LOT	The Scottish Ministers advise that underwater noise should be scoped into the EIAR for the operation and maintenance phases of the Proposed Development (Offshore) in line with the NatureScot representation, for both fixed and floating foundations. In addition, UXO clearance and depending on the foundation type, disturbance caused by underwater noise during the construction phase, should be scoped into the EIAR.	A full UWN assessment for the Proposed Development (Offshore) has been carried out and includes noise modelling for both bottom-fixed and floating foundations, UXO clearance and depending on the foundation type, disturbance caused by UWN during the construction phase in Section 5.7 (see Impact 1).
MD-LOT	The Scottish Ministers disagree with the Applicant's proposal to scope out ("EMF") effects which is a view supported by NatureScot and the Highland Council. Impacts from EMF from subsea electromagnetic cabling should be scoped into the EIAR for the operational phase of the Proposed Development (Offshore) and should be considered for all relevant fish and shellfish species, including elasmobranch species, Nephrops, diadromous fish, including migratory fish.	The impacts associated with electromagnetic fields (EMF) from subsea export cables have been assessed in Section 5.7 (see Impact 10).
MD-LOT	The Scottish Ministers also disagree with the Applicant's proposal to scope out increased risk of introduction and/or spread of Invasive Non-Native Species ("INNS"). In line with the NatureScot and the Highland Council representations	The Applicant notes colonisation of hard structures should be scoped into the EIAR for the operation and maintenance phase of the Proposed Development (Offshore). This is assessed in Section 5.7; see Impact 5, Impact 8 and Impact

Consultee	Comments	Response
	this must be scoped into the EIAR for all phases of the Proposed Development (Offshore) due to an increase in vessel traffic and opportunities for hard structures on which to colonise. The Scottish Ministers agree with the NatureScot representation and advise that that due to the novel nature of floating offshore wind foundations and the FRP fixed foundations, colonisation of hard structures should be scoped into the EIAR for the operation and maintenance phase of the Proposed Development (Offshore).	9 where the potential for impacts on fish and shellfish ecology have been assessed.
MD-LOT	Scottish Ministers advise that more consideration of changes in prey species and their habitats is required in the EIAR. This view is in line with the NatureScot representation, which must be fully addressed in this regard.	Impacts associated with the Proposed Development (Offshore) on prey species (sandeel) and their habitat have been scoped in and are assessed in Section 5.7 (see Impact 8).
MD-LOT	The Scottish Ministers highlight the Spey District Salmon Fishery Board representation which identifies that the proposed cable route runs through an area of kelp forest that may be an important overwintering habitat to sea trout. In addition, the Spey District Salmon Fishery Board suggests that WTGs may have potential to create additional hunting grounds for piscivorous birds, seals and large predatory fish may impose additional pressure on migrating salmonids in the Moray Firth. It also highlights that the construction of the Proposed Development (Offshore) will encompass the probable migration route of Atlantic salmon smolts towards their summer feeding grounds as well as the return path of spawning adults. The Applicant should show consideration of these potential impacts to sea trout and migrating salmonids in the EIAR.	Impacts such as habitat loss (kelp forests) from the Proposed Development (Offshore) have been assessed in Volume 2, Chapter 4: Benthic Subtidal and Intertidal Ecology. Impact to the migratory routes of Atlantic salmon smolts towards their summer feeding grounds as well as the return path of spawning adults have been assessed in Section 5.7 (see Impact 8).

Consultee	Comments	Response
MD-LOT	With regards to the cumulative impacts, the Scottish Ministers advise in line with the NatureScot representation that the Applicant should consider the cumulative effects of key impacts such as habitat loss or change, especially in relation to diadromous fish as well as key fish and shellfish species that contribute to ecological importance as a prey resource.	A cumulative assessment of the impacts associated with the Proposed Development (Offshore) on fish and shellfish receptors has been undertaken in Section 5.8.
MD-LOT	Scottish Ministers advise that all SACs designated for Atlantic salmon in Scotland are screened in at this stage for further assessment, in line with the NatureScot representation. The Scottish Ministers also agree with the NatureScot representation that all SACs with Fresh Water Pearl Mussels ("FWPM") as a qualifying feature should also be screened in for further assessment as Atlantic salmon are a host species for FWPM during a critical parasitic phase of the FWPM life cycle and therefore indirect impacts require consideration to ensure populations are not adversely affected. The Applicant should discuss with NatureScot how this will be assessed in the next stage of the Habitats and Regulation Assessment (HRA) process.	Impacts on designated sites such as SACs within the study area and their designated features, such as Atlantic salmon, arising from the Proposed Development (Offshore) have been scoped into the assessment and are detailed in Section 5.7.
MD-LOT	The Applicant should also note that further consideration is required for in-combination impacts in relation to the HRA Screening given the 100km approach is not appropriate for migratory fish. The Applicant must fully address the NatureScot representation with regards to HRA.	This is considered and assessed within the Report to Inform Appropriate Assessment (Application Documents 13 and 14).
MD-LOT	The Scottish Ministers agree with the Applicant to screen in the River Spey SAC for sea and river lamprey (*Lampetra fluviatilis*) as it is possible migration routes may overlap the Proposed Development (Offshore) which is in line with the NatureScot representation.	This is noted by the Applicant and an assessment of the impacts of the Proposed Development (Offshore) on migratory species has been addressed in Section 5.7.

Table 5-3: Scoping Opinion response (basking sharks).

Consultee	Comment	Response
MD-LOT	Potential impacts from electromagnetic fields (EMF) on cetaceans and basking sharks, and operational noise must be scoped in and the NatureScot representation in this regard addressed in full in the EIAR.	This is noted by the Applicant. EMF impacts considering both bottom-fixed and floating WTG foundations during O&M phase on basking sharks has been scoped in and assessed in Section 5.7.5.
MD-LOT	Indirect entanglement must be considered for the fully restrained platform foundation design.	This is noted by the Applicant. Potential impacts as a result of primary, secondary and tertiary entanglement considering the fully restrained platform (FRP) foundation design has also been scoped in and assessed in Section 5.7.5.
MD-LOT	Increased vessel disturbance in coastal areas should also be assessed in the EIA Report, in line with the University of Aberdeen Lighthouse Field Station representation.	Vessel disturbance impact basking sharks near the Caledonia OECC during construction, O&M and decommissioning phases has been considered and assessed in Sections 5.7.4, 5.7.5 and 5.7.7.
MD-LOT	Where impact pathways have been identified, a full range of mitigation techniques and published guidance should be considered in the EIA Report. The Developer must also develop and adhere to a Marine Mammal Mitigation Protocol as part of the EIA Report.	Noted, published guidance has been detailed in Table 5-1, and relevant embedded mitigation measures have been listed in Table 5-19, including the development of and adherence to Marine Mammal Mitigation Protocol (MMMP; refer to Volume 7, Appendix 13 and Appendix 14 for further details).
NatureScot	The EIAR should consider the impact of all phases of the proposed development on the receiving environment, including effects from pre-construction activities as well as the construction, operation and maintenance and decommissioning phases. Increasingly, there is a need to understand potential impacts holistically at a wider ecosystem scale in addition to the standard set of discrete individual receptor assessments. This assessment should focus on potential impacts across key trophic levels particularly in relation to the availability of prey species.	Separate basking shark licence applications will be prepared for assessing impacts of pre-construction activities. Indirect impact on prey due to changes in prey availability and distribution during construction, operation and maintenance, and decommissioning phases on basking sharks has been scoped in and assessed in Sections 5.7.4, 5.7.5 and 5.7.7. Indirect impact on prey due to changes in prey availability and distribution during construction, operation and maintenance, and decommissioning phases for ornithology (Volume 2, Chapter 6) and marine mammals (Volume 2, Chapter 7).

Consultee	Comment	Response
NatureScot	Potential impacts from EMF should be scoped in, at this stage, for both cetaceans and basking sharks, particularly for floating turbines with dynamic cables.	This is noted by the Applicant. EMF impacts considering both bottom-fixed and floating WTG foundations during O&M phase on basking sharks has been scoped in and assessed in Section 5.7.5.
NatureScot	As the proposal is for a mix of fixed and floating turbines, we advise that operational noise for both types should be scoped in.	This is noted by the Applicant. The impact of operational noise from both bottom-fixed and floating WTG foundations on basking sharks has been scoped in and assessed in Section 5.7.5.
NatureScot	Indirect entanglement is being scoped in for floating turbines only. We consider that this could also be an issue for the Fully Restrained Platform design which uses mooring chain or rope.	This is noted by the Applicant. Potential impacts as a result of primary, secondary and tertiary entanglement considering the fully restrained platform (FRP) foundation design has also been scoped in and assessed in Section 5.7.5.
NatureScot	Note that in section 11.3.2.25, the report states that basking sharks are EPS. This is incorrect. They may be assessed in a similar way to cetaceans (EPS), but they are not EPS themselves. Basking sharks are protected under Schedule 5 of the Wildlife & Countryside Act 1981 (as amended).	This is noted by the Applicant. The legal protection status of basking sharks under Schedule 5 of the Wildlife and Countryside Act 1981 (as amended) (UK Parliament, 1981[6]) has been highlighted in Table 5-1.
University of Aberdeen Lighthouse Field Station	Increased vessel disturbance associated with the windfarm development (for example due to transport of equipment, materials, and personnel from sites on land to the development site during construction) should also be considered in coastal areas (other than the one highlighted in Table 11.3) – particularly where it occurs within the Moray Firth SAC (designated for bottlenose dolphin).	The potential for vessel disturbance impacts on basking sharks in coastal areas during construction, O&M and decommissioning phases has been considered and assessed in Sections 5.7.4, 5.7.5 and 5.7.7. Further assessment on the potential impacts on bottlenose dolphin as a qualifying feature of the Moray Firth SAC has been carried out in Volume 2, Chapter 7: Marine Mammals.

5.3.1.2 Further consultation relevant to basking sharks has been undertaken throughout the pre-application stage. Table 5-4 summarises the consultation activities carried out relevant to basking sharks.

Table 5-4: Basking shark stakeholder engagement activities.

Date	Consultee and Type of Consultation	Summary
06 February 2024	NatureScot; email	NatureScot confirmed that with regards to the mitigation, only instantaneous Permanent Threshold Shift (PTS) metric requires to be mitigated (Sound Pressure Level Peak (SPL_{peak})). This decision was justified by considering the fact that injury ranges based on cumulative Sound Exposure Level (SEL_{cum}) metric are over-precautionary due to considerable conservatism in assessments. This could lead to over-estimation of impact zones, and therefore it would be disproportionate to expect these to be fully mitigated.
21 June 2024	NatureScot; email	Consultation sought with NatureScot regarding structure of the Underwater Noise Modelling Report (Volume 7, Appendix 6) and presentation of results which link through to this chapter.

5.4 Baseline Characterisation

5.4.1 Fish and Shellfish Ecology Study Area

5.4.1.1 The Proposed Development (Offshore) is located in the Moray Firth in the North Sea. The northern limit of the Caledonia OWF is approximately 22km off the coast of Wick, Highlands and the southern limit of the site is approximately 38km off the coast of Banff, Aberdeenshire. The depth range of the Caledonia OWF is approximately 40-88m relative to Lowest Astronomical Tide (LAT).

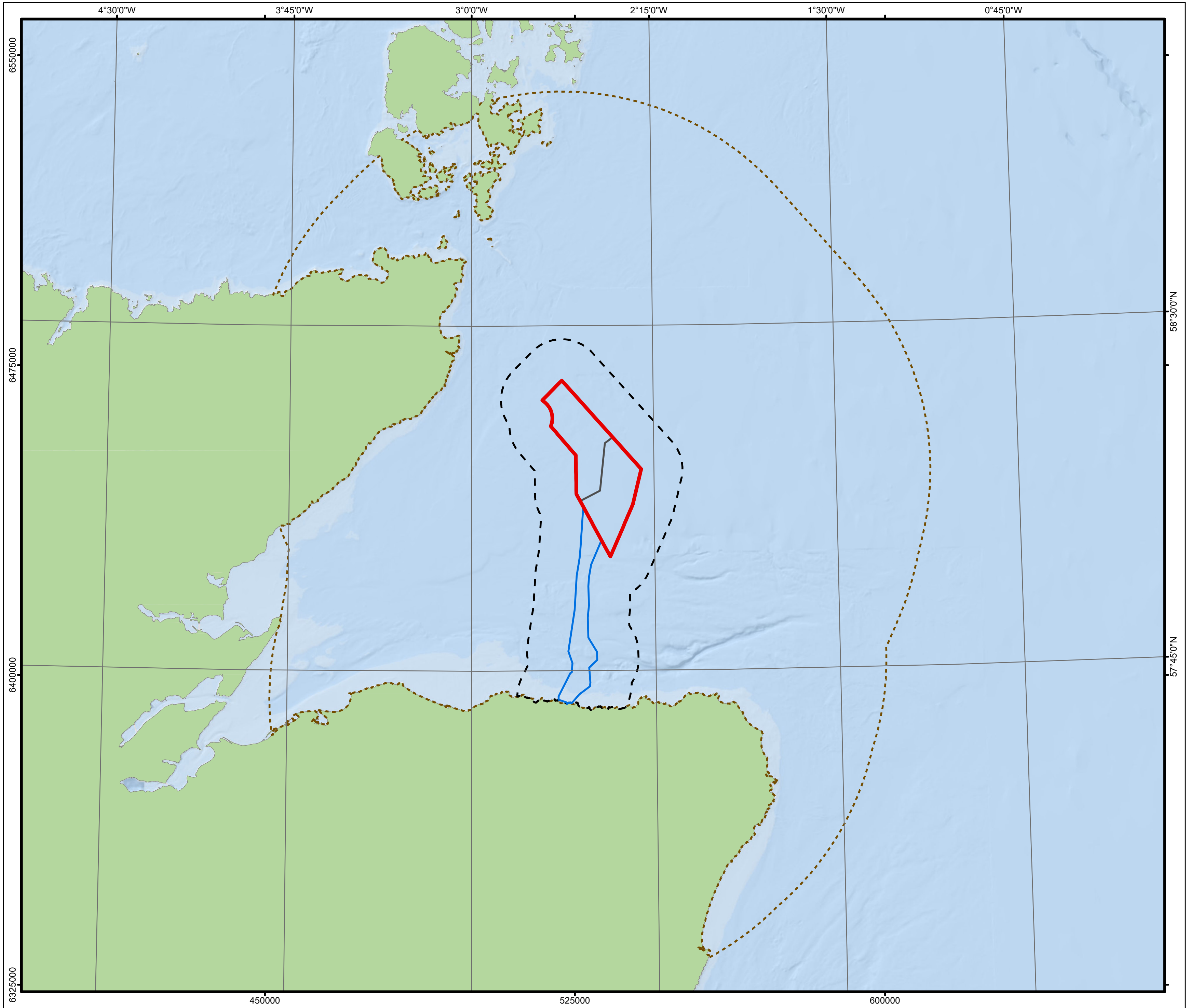
5.4.1.2 The total footprint for the Proposed Development (Offshore) is 644.3km^2. This includes the Caledonia OWF which is approximately 423km^2 and the Caledonia OECC which covers a total footprint of approximately 221.3km^2.

5.4.1.3 The fish and shellfish ecology study area (hereafter referred to as the study area) is defined by the Proposed Development (Offshore) footprint, including the Caledonia OWF and the Caledonia OECC, the primary UWN Zone of Influence (ZoI) and a secondary ZoI as presented in Figure 5-1. This area allows for the robust characterisation of fish and shellfish communities likely to be present within the 70km UWN ZoI.

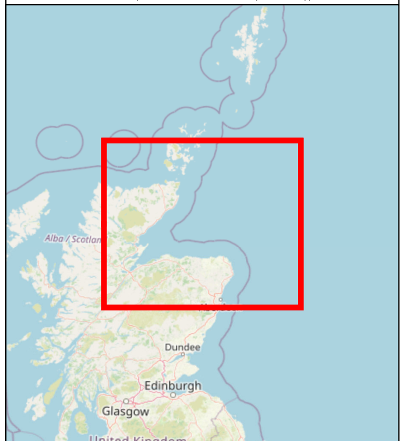
5.4.1.4 Impacts from UWN from piling activities in the Caledonia OWF represent the primary and largest ZoI for the Proposed Development (Offshore) alone assessments. It should be noted that for cumulative impacts a precautionary ZoI of 100km has also been applied, to encapsulate potential cumulative impacts from UWN impacts.

5.4.1.5 Fish responses to UWN stimuli can vary significantly between species, with some species exhibiting fleeing behaviour while others may remain relatively stationary depending on noise thresholds (Popper and Hastings, 2009[42]; Hawkins *et al.,* 2015[43]). To account for this variation, the assessment has considered both fleeing and stationary receptor modelling approaches thus ensuring a comprehensive evaluation of the potential impacts of UWN on different fish species and life stages within the ZoI for the Proposed Development (Offshore). The maximum impact ranges for both stationary (e.g., spawning Atlantic herring (*Clupea harengus*) or spawning sandeels (*Ammodytes* spp.)) and fleeing receptors (e.g., Atlantic salmon), as informed by UWN modelling for recent OWF projects have been utilised to inform the 70km ZoI for UWN impacts, which is considered suitably precautionary for the Proposed Development (Offshore). The extents over which noise effects thresholds will be reached have been determined though detailed UWN modelling (Volume 7, Appendix 6: Underwater Noise Assessment).

5.4.1.6 The 10km secondary ZoI for the assessment of fish and shellfish ecology is based on the maximum distance suspended sediments will travel in one tidal excursion on a mean spring tide, and therefore represents the maximum distance over which indirect impacts on fish and shellfish ecology arising from the Proposed Development (Offshore).



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence



0 10 20 30 40 50 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm
GoBe APEM Group

CONTRACTOR DRAWING NO UKCAL1_GO_WNF_FAS_MAP_00152	CONTRACTOR REV 01

GEODETIC PARAMETERS
WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE
Figure 5-1: Fish and Shellfish Ecology Study Area

STATUS Approved	SCALE 1:1,250,000	
DRAWING NUMBER N/A	SHEET NO 01 of 01	REV N/A

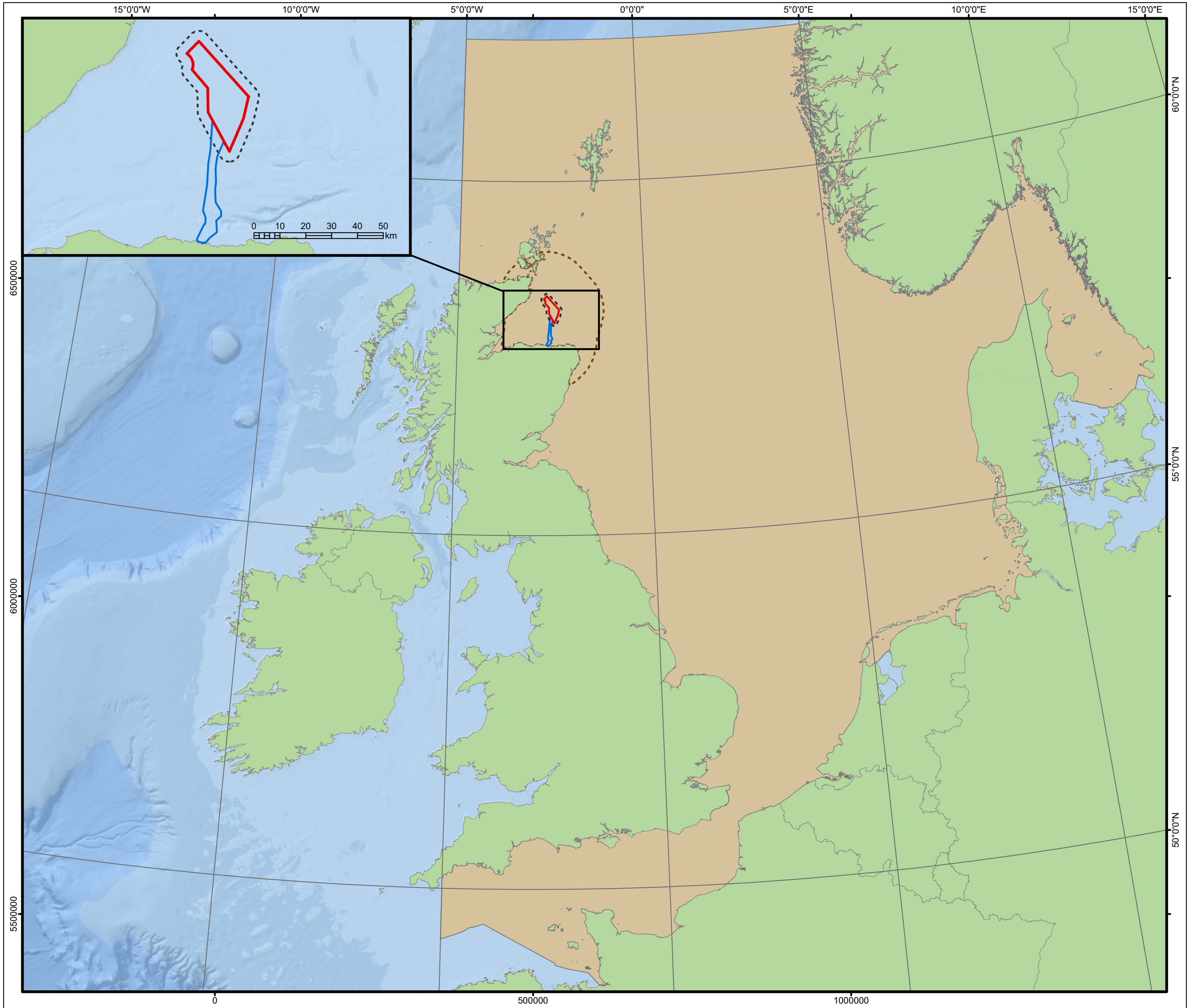
5.4.2 Basking Shark Study Area

5.4.2.1 In view of the high level of mobility and wide distribution range of basking sharks, the basking shark study area is defined by the Proposed Development (Offshore) footprint (including the Caledonia OWF and the Caledonia OECC) within the OSPAR Region II: Greater North Sea (OSPAR, 2024[44]; Figure 5-2) for the purpose of this assessment. Unlike marine mammals, basking sharks do not currently have distinct Management Units (MU) established for monitoring and management of populations in the seas surrounding the UK. Consequently, basking shark relative density and abundance are not reported here, or used in the impact assessment, due to low sample sizes (numbers of sightings) which mean that population estimates are not reliable; therefore, a qualitative assessment has been used.

5.4.2.2 The auditory apparatus of sharks comprises the paired inner ears that, as in all fishes, detect the particle motion component of a sound. Unlike most bony fishes, however, cartilaginous fishes such as basking sharks do not possess a swim bladder, which responds to the pressure component of a sound, and therefore are thought to only be sensitive to particle motion (Chapuis *et al.,* 2019[45]). They may only detect particle motion (Popper *et al.,* 2014[3232]) and are therefore considered less sensitive to UWN compared to other fish hearing groups with gas-filled organs, and teleost with otoliths. The hearing physiology and auditory capabilities of basking sharks are usually inferred from knowledge on other shark species due to the limited relevant knowledge available (Casper and Mann, 2010[46]; Popper *et al.,* 2014[32]). Studies on lemon shark (*Negaprion brevirostris*), scalloped hammerhead (*Sphyrna lewini*) and sharpnosed shark (*Rhisoprionodon terranovae*) reveal that elasmobranch species in general have higher sensitivity to low frequency sound (Casper and Mann, 2010[46], and therefore low frequency noise may be detectable by basking sharks. According to playback studies conducted by the US Navy, other coastal and oceanic shark species were found to avoid sudden onset of loud noise of low frequencies, but became habituated after a few trials (Myrberg, 2001[47]).

5.4.2.3 To account for this variation in behaviour to sound, the assessment has considered both fleeing and stationary receptor modelling approaches thus ensuring a comprehensive evaluation of the potential impacts of UWN on basking sharks within the region (Volume 7, Appendix 6: Underwater Noise Assessment). However, stationary receptor modelling is deemed highly precautionary considering basking sharks are obligate ram ventilators, meaning they require the continual forward motion of water passing the gills to get oxygen into the body (Dolce and Wilga, 2013[305]).

5.4.2.5 Impacts from UWN during piling activities represent the primary and largest ZoI for the alone assessments; however, it should be noted that for cumulative impacts a 100km ZoI has been used as a precautionary assessment area. A secondary ZoI of 10km has been used for remaining impacts. This range is based on the maximum distance suspended sediments will travel in one tidal excursion on a mean spring tide. All remaining impacts have a smaller impact range and is therefore a precautionary secondary ZoI resulting from the Proposed Development (Offshore). Basking shark sensitivity to all impacts are included in the relevant assessment sections.



Regional Study Area (OSPAR Region II Greater North Sea)

Site-specific Study Area

Caledonia OWF

Caledonia OWF 4km Buffer

Offshore Export Cable Corridor

70km Primary Underwater Noise Zone of Influence

0 50 100 150 200 250 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	29/10/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm

GoBe APEM Group

CONTRACTOR DRAWING NO UKCAL1_GO_WNF_FAS_MAP_00217_	CONTRACTOR REV 01
GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 5-2: Basking Shark Study Area	
STATUS Approved	SCALE 1:8,125,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 / REV N/A

5.4.3 Data Sources

Desk Study

Fish and Shellfish Ecology

5.4.3.1 A detailed desktop review was carried out to establish the baseline of information available on fish and shellfish populations in the study area for the Proposed Development (Offshore). Information was sought to ascertain the likely fish and shellfish assemblages present, area usage (i.e., spawning and nursery grounds) and importance of the receptors. The key data sources that have been used to inform the fish and shellfish ecology baseline characterisation are presented within Table 5-5.

Table 5-5: Summary of key publicly available datasets for fish and shellfish ecology.

Title	Author	Data Year(s)
Existing OWF Data		
Beatrice OWF Farm Post-construction Sandeel Survey –Technical Report	BOWL[48]	2021
Beatrice OWF – Post-construction Cod Spawning Survey Technical Report	BOWL[49]	2021
Beatrice O&G Field Decommissioning EIA	Repsol Sinopec Resources UK Limited[50]	2018
Moray East OWF Herring Larval Annual Review – January 2018	Moray Offshore Renewables Limited[51]	2018
Moray Firth Tracking Project Internal Report & Proposal For Trustees October 2018	Atlantic Salmon Trust (AST)[52]	2018
Moray West OWF EMP	Moray Offshore Windfarm (West) Limited[53]	2018
Moray West OWF EIAR - Chapter 8: Fish and Shellfish Ecology	Moray Offshore Windfarm (West) Limited[54]	2018
Beatrice OWF Farm - Diadromous Fish Monitoring	BOWL[55]	2017
Beatrice OWF Herring Larval Survey Results – Technical Reports	BOWL[56]	2015
Beatrice OWF – Pre-construction Cod Spawning Survey – Technical Report	BOWL[57]	2015

Title	Author	Data Year(s)
Beatrice OWF Pre-Construction Baseline Herring Larval Surveys Summary Technical Report	BOWL[58]	2015
Beatrice OWF Farm Pre-Construction Baseline Sandeel Survey –Technical Report	BOWL[59]	2014
Beatrice OWF Environmental Statement – Chapter 11: Fish and Shellfish Ecology	BOWL[60]	2012
Moray East OWF Environmental Statement Technical Appendices – Sandeel Survey Report	Moray Offshore Renewables Limited[61]	2012
Moray East OWF Environmental Statement – Volume 2, Chapter 4: Biological Environment (Section 4.3: Fish and Shellfish Ecology)	Moray Offshore Wind Farm[61]	2012
Beatrice OWF Environmental Statement: Fish and Shellfish Ecology Technical Report	BOWL[62]	2011
Moray East OWF Environmental Statement – Environmental Baseline	Moray Offshore Renewables Limited[63]	2011
Moray East OWF Environmental Statement Impact Assessment	Moray Offshore Renewables Limited[64]	2011
Moray East OWF Environmental Statement Impact Assessment	Moray Offshore Renewables Limited[65]	2011
Publicly Available Datasets		
Basking shark incidental sightings and distribution in Scotland's seas	NatureScot[66]	1980 to 2013
Basking Shark Sightings Report	Shark Trust[67]	2024
UK sea fisheries annual statistics report	MMO[68]	2022
Offshore Energy Strategic Environmental Assessment (OESEA) 4: Environmental Baseline: Appendix 1a.4: Fish and Shellfish	Department for Business, Energy and Industrial Strategy (BEIS)[69]	2022
Scottish Sea Fisheries Statistics, Data from 2016-2020	Scottish Government[70]	2020
Cornwall Wildlife Trust Seaquest Southwest Project	Cornwall Wildlife Trust[71]	2020
MPA network (SPAs, SSSIs, NCMPAs, SACs)	Scottish Government[72]	2018
Information on species of conservation interest	JNCC[73]	2007
ICES Scottish Rockall Survey	ICES[74]	2011-2012

Title	Author	Data Year(s)
ICES North Sea International Bottom Trawl Survey	ICES[75]	2012-2022
ICES Beam Trawl Surveys	ICES[76]	2012-2022
National Biodiversity Network (NBN) atlas Species Search	NBN Trust[77]	1990-2023
Fisheries datasets available from the Marine Scotland MAPS National Marine Plan Interactive (NMPi), including ScotMap data	Marine Scotland[78]	Various
Literature		
Impacts from Piling on Fish at Offshore Wind Sites: Collating Population Information, Gap Analysis and Appraisal of Mitigation Options	Boyle and New, ORJIP[79]	2018
Basking shark satellite tagging project: insights into basking shark (*Cetorhinus maximus*) movement, distribution and behaviour using satellite telemetry	Witt *et al.*[85]	2012-2014
Spawning and Nursery Grounds of Selected Fish Species in UK	Ellis *et al.*[102]	2012
Predicting habitat suitability for basking sharks (*Cetorhinus maximus*) in UK waters using ensemble ecological niche modelling	Austin *et al.*[87]	2002 to 2006, 2011 to 2014
Statistical approaches to aid the identification of Marine Protected Areas for minke whale, Risso's dolphin, white-beaked dolphin and basking shark	Paxton *et al.*[80]	2000-2012
Basking sharks in the northeast Atlantic: spatio-temporal trends from sightings in UK waters	Witt *et al.*[81]	1998-2008
Fisheries Sensitivity Maps in British Waters	Coull *et al*.[94]	1998

Basking Sharks

5.4.3.2 The data sources that have been used to inform the basking shark aspects of this chapter of the EIAR are presented in Table 5-6.

Table 5-6: Summary of key publicly available datasets for baseline characterisation for basking sharks.

Title	Author	Data Year(s)
Existing OWF Data		
Moray West OWF Environmental Statement – Chapter 8: Fish and Shellfish Ecology	Moray Offshore Windfarm (West) Limited[82]	2018
Beatrice OWF Environmental Statement – Chapter 11: Fish and Shellfish Ecology	BOWL[60]	2012
Moray East OWF Environmental Statement – Volume 2, Chapter 4: Biological Environment (Section 4.3: Fish and Shellfish Ecology)	Moray Offshore Renewables Limited[97]	2012
Publicly Available Datasets		
Basking Shark Sightings Report	Shark Trust[83]	2023
Offshore Energy Strategic Environmental Assessment (OESEA) 4: Environmental Baseline: Appendix 1a.4: Fish and Shellfish	Department for Business, Energy and Industrial Strategy (BEIS)[84]	2022
Beatrice O&G Field Decommissioning Environmental Impact Assessment	Repsol Sinopec Resources UK Limited[50]	2018
Basking shark satellite tagging project: insights into basking shark (*Cetorhinus maximus*) movement, distribution and behaviour using satellite telemetry	Witt *et al.*[85]	2012 to 2014
Cornwall Wildlife Trust Seaquest Southwest Project	Cornwall Wildlife Trust[86]	2010 to 2020
Predicting habitat suitability for basking sharks (*Cetorhinus maximus*) in UK waters using ensemble ecological niche modelling	Austin *et al.*[87]	2002 to 2006, 2011 to 2014
Statistical approaches to aid the identification of Marine Protected Areas for minke whale, Risso's dolphin, white-beaked dolphin and basking shark	Paxton *et al.*[88]	2000 to 2012
Basking sharks in the northeast Atlantic: spatio-temporal trends from sightings in UK waters	Witt *et al.*[89]	1998 to 2008
National Biodiversity Network (NBN) atlas Species Search	NBN Trust[90]	1990 to 2023
Basking shark incidental sightings and distribution in Scotland's seas	NatureScot[66]	1980 to 2013

Site-specific Surveys

Fish and Shellfish Ecology

5.4.3.3 Integrated survey work within the Caledonia OWF and Caledonia OECC was conducted by Gardline Limited on behalf of the Applicant between March and June 2023. Environmental operations were undertaken between 14 April 2023 and 22 April 2023. These assessments are presented in Volume 7B, Appendix 4-1: Environmental Baseline Survey Report (Array Area) and Volume 7B, Appendix 4-2: Environmental Baseline Survey Report (Offshore Export Cable Corridor).

Grab Sampling and Camera Transects

5.4.3.4 Sediment composition across the Caledonia OWF and Caledonia OECC was determined with reference to images collected from seven camera stations and observations of 35 grab samples taken across the survey area. This was supported by data from Particle Size Analysis (PSA) undertaken on sediments collected from sites across Caledonia OWF and the OECC. Sediments were classified as muddy sand to sandy gravel according to the modified Folk (1954[91]).

5.4.3.5 Site-specific PSA data have been classified in accordance with the Latto *et al.* (2013[92]) and Reach *et al.* (2013[93]) classifications to identify areas of preferred spawning habitat for sandeel and herring respectively. The site-specific PSA data has been utilised to supplement and ground truth the broadscale data from Coull *et al.* (1988[94]), Ellis *et al.* (2010[102]) and EMODnet (2023[95]) regarding habitat suitability for spawning and nursery grounds to produce habitat maps to show the extent of potential sandeel and herring spawning habitat within the Caledonia OWF and Caledonia OECC (based on suitability of habitats; i.e., the potential for spawning rather than actual contemporary spawning activity).

5.4.3.6 Seabed imagery and observations from grab samples identified that the sediment composition primarily consisted of sand, with occasional gravel and shell fragment components. Observed epifauna was generally sparse, with no visible fauna evident in 34% of images analysed (Volume 7B, Appendix 4-2).

5.4.3.7 PSA data supported the results of the seabed imagery analysis and grab sample observations, with sediment types across the Caledonia OWF being classified as muddy sand to sandy gravel under modified Folk (1954[91]). Generally, across the Caledonia OWF, sand was the dominant fraction accounting for between 49.0% and 97.1% of the sediment composition, with the exception of Station ENV13 in the northeast of the Caledonia OWF where gravel accounted for 50.2% of the sediment (Volume 7B, Appendix 4-1).

Environmental DNA

5.4.3.8 Environmental DNA (eDNA) data has been collected in the Caledonia OWF and Caledonia OECC to provide a supplementary snapshot of fish and shellfish species presence (from approximately the preceding 24-hours) at each sample location (Volume 7B, Appendix 4-1 and Volume 7B, Appendix 4-2). An eDNA survey is a non-intrusive sampling technique utilised to detect species presence by analysing the DNA present in water samples. This method entails collecting environmental DNA (e.g., from excretions or secretions) rather than directly sampling the organism itself.

5.4.3.9 The fish eDNA data set within the Caledonia OWF recorded Atlantic cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), Norway pout (*Trisopterus esmarkii*) right eye flounder (Pleuronectidae) and Atlantic mackerel (*Scomber scombrus*). Additionally, the invasive species pink salmon (*Oncorhynchus gorbuscha*) was also recorded.

5.4.3.10 Additionally, eDNA surveys carried out in the OECC recorded, Atlantic cod, herring, whiting (*Merlangius merlangus*), Norway pout and mackerel.

Basking Sharks

5.4.3.11 The site-specific baseline characterisation of the basking shark study area for the Caledonia OWF consisted of 24 monthly digital aerial surveys (DAS), conducted by APEM Ltd from May 2021 to April 2023 (survey methodology detailed in Volume 7, Appendix 19).

5.4.3.12 Analysis of DAS data collected throughout the 2021-2023 survey period identified one basking shark which was within the southern section of the Caledonia OWF in November 2022. A single 'unidentified' shark species was also recorded within the 4km buffer of the Caledonia OWF in January 2022. Relative density and abundance estimates of basking sharks were calculated for the survey area, but are not reported here or used in the impact assessment due to low sample sizes (numbers of sightings) meaning the estimates are not reliable.

5.4.4 Baseline Characterisation

Fish and Shellfish

5.4.4.1 The following section describes the fish and shellfish communities present within the study area (Figure 5-1). The baseline description of the study area draws on site-specific data collected within the Caledonia OWF and Caledonia OECC, regional datasets and industry specific accounts and monitoring studies undertaken for a number of the existing or proposed OWFs in the northern North Sea region. The baseline description is structured as follows:

- Fish and shellfish assemblage;
- Spawning and nursery grounds;
- Species of commercial importance;
- Species of conservation importance; and
- Designated sites.

5.4.4.2 The datasets include both a snapshot of the current species composition across the northern North Sea and within the study area, alongside long-term time series data (e.g., bottom trawl surveys), which show the species composition to have remained consistent, subject to natural variation overtime. Therefore, the data presented are considered both spatially, and temporally appropriate for the purposes of undertaking an EIA.

Fish and Shellfish Assemblage

5.4.4.3 The spatial distribution of fish in the Moray Firth region is seasonal, with many species using the Moray Firth for overwintering, feeding, breeding, and nursery purposes.

5.4.4.4 Epibenthic beam trawl surveys conducted in the neighbouring (west) Moray West OWF site between May and June 2017 (Moray Offshore Windfarm (West) Limited, 2018[96]) revealed a species assemblage typical of this area of the North Sea. The fish community was largely characterised by demersal species recorded in abundance during surveys, including dragonet (*Callionymus lyra*), dab (*Limanda limanda*) and plaice (*Pleuronectes platessa*). Less abundant species included lemon sole (*Microstomus kitt*), pogge (*Agonus cataphractus*) and grey gurnard (*Eutrigla gurnardus*). Typically, areas with higher diversity tended to be recorded in more heterogenous seabed habitats often present in these areas which included patches of coarser mixed sediment, gravels and stones/cobble and a similar trend was evident at both the Moray East and Beatrice OWF surveys (Moray Offshore Renewables Limited, 2011[97]; BOWL, 2011[98]). Other fish species recorded included monkfish (*Lophius* spp.), Norwegian topknot (*Phrynorhombus norvegicus*), sandeel (Ammodytidae, *Ammodytes* spp.) and elasmobranchs such as the cuckoo ray (*Leucoraja naevus*) and lesser spotted dogfish (*Scyliorhinus canicular*), but generally at low abundances (Moray Offshore Windfarm (West) Limited, 2018[96]).

5.4.4.5 Otter trawl surveys conducted in March 2021 to identify cod distributions across the Beatrice OWF site revealed haddock was the most abundant species accounting for the majority of the total by-catch, followed by whiting and squid (*Loligo forbesi*), whilst cod abundance was relatively low (BOWL, 2021[48]).

5.4.4.6 Between January and March 2012, dredge tow surveys were conducted across the Moray East OWF and Western Moray Firth area to identify sandeel distributions (Moray Offshore Renewables Limited, 2012[61]). Raitt's sandeel (*Ammodytes marinus*), smooth sandeel (*Gymnammodytes semisquamatus*) and greater sandeel (*Hyperoplus lanceolatus*) were identified with Raitt's sandeel being the most abundant within the survey data. Overall, the distribution of sandeel was patchy and abundance was low, with the majority captured in areas characterised with sandy substrate (sand, sandy gravel, gravelly sand, sandy gravel), which is consistent with their preferred habitat type.

5.4.4.7 Similarly, results from sandeel surveys across the Beatrice OWF site in December 2020, indicated patchy distribution with low abundance, with Raitt's sandeel being the most prevalent (BOWL, 2021[48]). The Beatrice OWF post-construction survey findings indicate an increase over the pre-construction survey, and there is no indication that the construction of the Beatrice OWF resulted in negative impacts on the local sandeel population (BOWL, 2014[59]; 2021[48]).

5.4.4.8 Several shellfish species are known to be abundant within the study area, including Nephrops (*Nephrops norvegicus*) (particularly significant for commercial fisheries within the study area) squid *Loligo* spp., and king scallop (*Pecten maximus*) (ICES, 2022[99]). Moray West OWF site epibenthic trawls recorded hermit crabs (*Pagurus prideaux* and *Pagurus bernhardus*), toad crab (*Hyas coarctatus*), long legged crab (*Macropodia rostrata*), squat lobster (*Galathea intermedia*) and saddle oyster (*Anomia ephippium*). Additionally, prawn (*Pandalina brevirostris*) and pink shrimp (*Pandalus montagui*) were present but generally at low abundances (Moray Offshore Windfarm (West) Limited, 2018[96]).

5.4.4.9 Elasmobranch species are also known to be present in the Moray Firth area although with low percentage of total landings in the study area. Elasmobranch species identified include spurdog (*Squalus acanthias*), lesser spotted dogfish, starry ray (*Amblyraja radiata*), cuckoo ray, thornback ray (*Raja clavata*) and spotted ray (*Raja montagui*) (Ellis *et al.,* 2005[100]; ICES, 2022[99]).

Spawning and Nursery grounds

5.4.4.10 As detailed in Volume 7B, Appendix 5-1: Fish and Shellfish Ecology Technical Baseline Report, there are spawning and nursery grounds of several fish species known to be located within or in close proximity to the study area based on available information on spawning and nursery areas for fish species (Coull *et al.,* 1998[94]; supported by data sources from Ellis *et al.,* 2010[101]; 2012[102]).

5.4.4.11 Further information is provided in Aires *et al.* (2014[103]). The study assessed evidence of aggregations of '0 group fish' (fish in the first year of their lives) around the UK coastline. These data were ascertained from species distribution modelling combining observations of species occurrence or abundance with environmental data (Aires *et al.,* 2014[103]). The outputs of this process have been used as a guide for the most likely locations of aggregations of 0 group fish. It should be acknowledged that these data do not represent nursery areas as described in Coull *et al.* (1998[94]), but they can provide an indication of important areas for fish population. Nursery areas can comprise a larger spread of ages and sizes (Aires *et al.,* 2014[103]).

5.4.4.12 In addition, information has been sourced by Gonzalez-Irusta and Wright (2016[104]; 2017[105]), which defines areas of likely spawning activity for key commercial species in the North Sea. These data have been used in this report to supplement the findings of Coull *et al.* (1998[94]) and Ellis *et al.* (2012[102]).

5.4.4.13 Spawning grounds for cod, herring, plaice, sprat (*Sprattus sprattus*), whiting, sandeel and Nephrops overlap with the study area as well as extending over much of the Moray Firth and northern North Sea (Figure 5-3 and Figure 5-4) (Coull *et al.,* 1998[94]; Ellis *et al.,* 2010[101]; 2012[102]).

5.4.4.14 The study area also coincides with high intensity herring, cod and anglerfish (*Lophius piscatorius*) nursery grounds, and many low intensity nursery grounds including lemon sole, haddock, sprat, blue whiting, Nephrops, European hake (*Merluccius merluccius*), ling (*Molva molva*), Atlantic mackerel (*Scomber scombrus*), plaice, sandeel, spotted ray, spurdog and thornback ray (Figure 5-5 to Figure 5-8).

5.4.4.15 Spawning grounds for Nephrops and king scallops are also present within the Moray Firth. The distribution of Nephrops is largely dependent on the presence of seabed habitats comprising muddy substrates. Scallop spawning grounds have been identified in the northern area of the Moray Firth and prefer fine or sandy gravel substrates (Keltz and Bailey, 2010[106]).

5.4.4.16 It should be noted that in a broader context, the study area has a spatially limited interaction with a small portion of the overall spawning sites and nursery grounds for these species. The spawning and nursery grounds of these species in the study area form part of a far greater spawning and nursery grounds within the North Sea system.

Herring Spawning Grounds

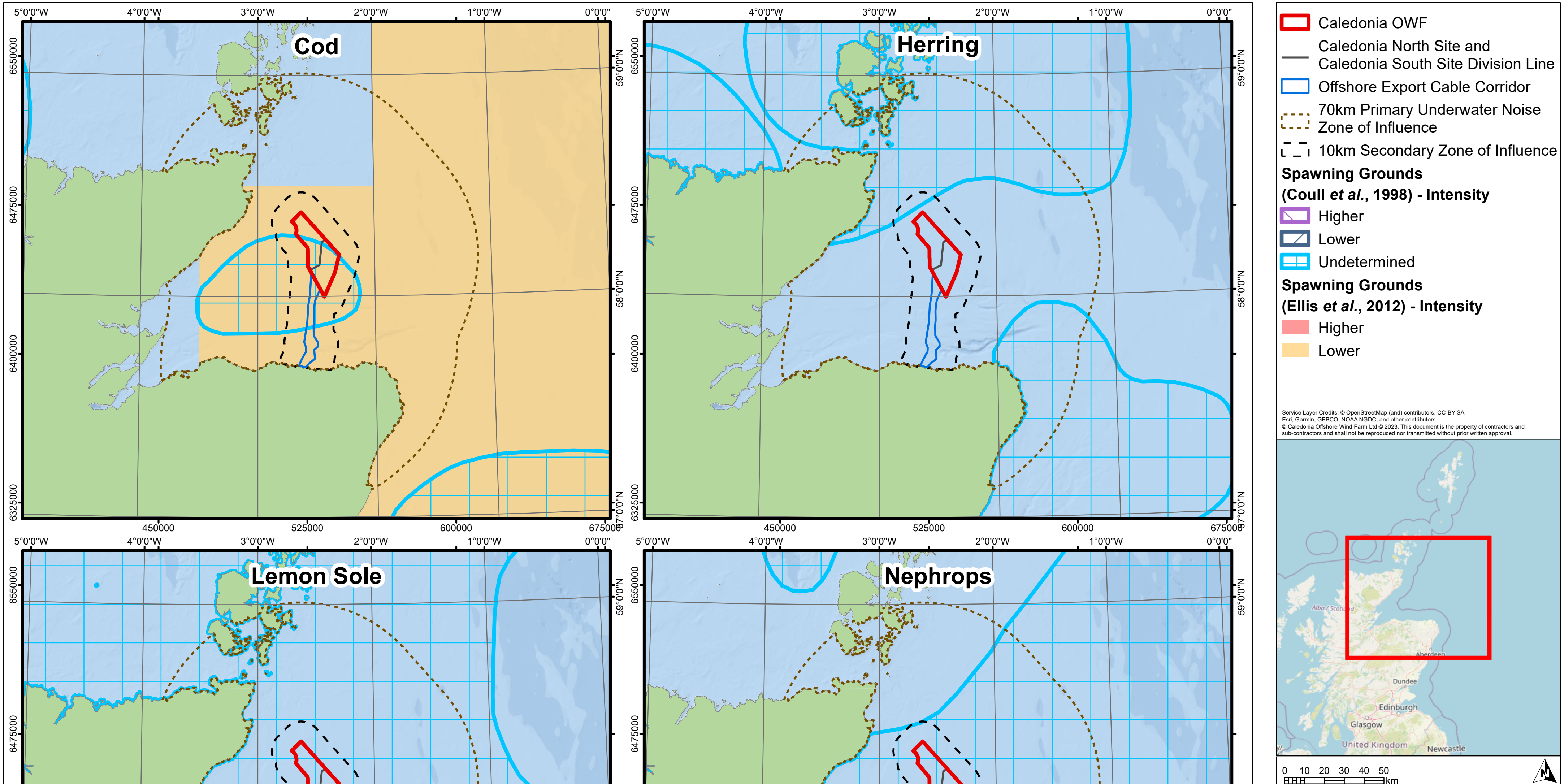
5.4.4.17 There are two large herring stock spawning ground that runs along much of the east coast of Scotland and extends offshore. The Buchan stock overlaps with the south of the study area and the Orkney/Shetland herring spawning grounds overlap with the north of the study area as indicated by Coull *et al.* (1998[94]) (Figure 5-10). Within the study area there is a patchy distribution of "marginal" and "preferred" sediment for herring spawning and the most predominate larval abundance across the study area is from 0.1 to 1,500 per m^2 based of International Herring Larval Survey (IHLS) (2011/2012 – 2023/2024[107]). The study area does include areas of higher larval abundances, up to 14,500 – 20,000 per m^2 at its northern limit with the Shetland stock and at the southern limit with the Buchan stock. However, it should be noted that the study area does not overlap areas of "peak spawning" where larval abundances are between 45,000 to 59,000 per m^2 (Figure 5-10).

5.4.4.18 Additional analysis of particle size distribution at stations within the Caledonia OWF classified the majority of the area to be 'Unsuitable' for spawning, suggesting a very low likelihood of herring spawning (Figure 5-9). This is attributed to the presence of >5% mud or <10% gravel at these grab sampling stations. Discrete areas to the East and West of the Caledonia OWF (within the secondary ZoI) have been classified as ''Marginal' or 'Preferred', corresponding with habitats categorised as 'Coarse Substrates' (EMODnet, 2023[95]). Areas of 'Marginal' and 'Preferred' sediment are also located to the north of the Caledonia OWF (within the study area) between Duncansby Head and the Orkney Islands, corresponding to areas of 'Coarse Substrates' (EMODnet, 2023[95]).

Sandeel Spawning Grounds

5.4.4.19 The sandeel population of the Moray Firth is part of the Central Western North Sea sandeel stock (ICES, 2009[108]; ICES 2022b[109]). The north of the Caledonia OWF overlaps with areas classed as having "High" potential for sandeel spawning to occur, with the rest of the Caledonia OWF and Caledonia OECC being classified as either "medium" or "low". Throughout the study area there is high variability and patchy distribution in areas of "Low", "Medium" and "High" potential for sandeel spawning (Figure 5-11).

5.4.4.20 There is a patchy distribution of suitable sandeel habitat across the Study area, with a large proportion of "preferred" sediment across the Caledonia OWF and Caledonia OECC (Figure 5-12). This is supported with sandeel habitat confidence analysis, whereby this can be presumed with medium confidence across the study area, with some areas of low confidence (Figure 5-13).



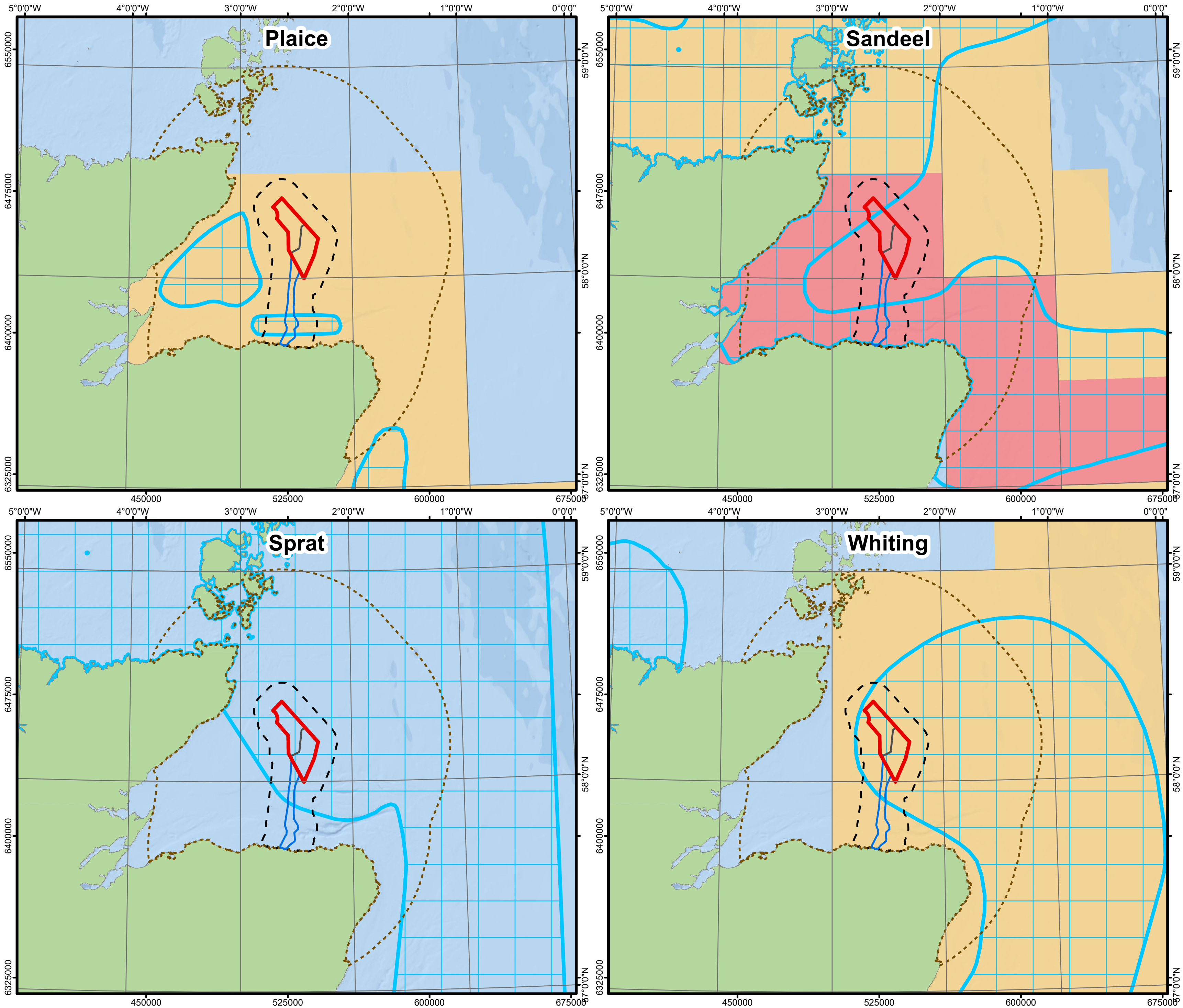
REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm
GoBe APEM Group

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00153
CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)
DRAWING TITLE:

Figure 5-3: Spawning Grounds Within the Study Area (Coull et al., 1998; Ellis et al., 2012)

STATUS: Approved
SCALE: 1:2,750,000
DRAWING NUMBER: N/A
SHEET NO: 01 of 01
REV: N/A



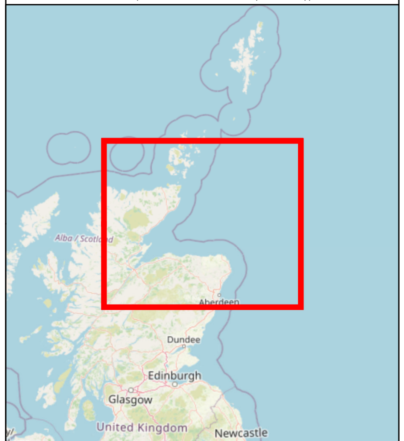
Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence

Spawning Grounds (Coull *et al.*, 1998) - Intensity

Higher
Lower
Undetermined

Spawning Grounds (Ellis *et al.*, 2012) - Intensity

Higher
Lower



0 10 20 30 40 50 km

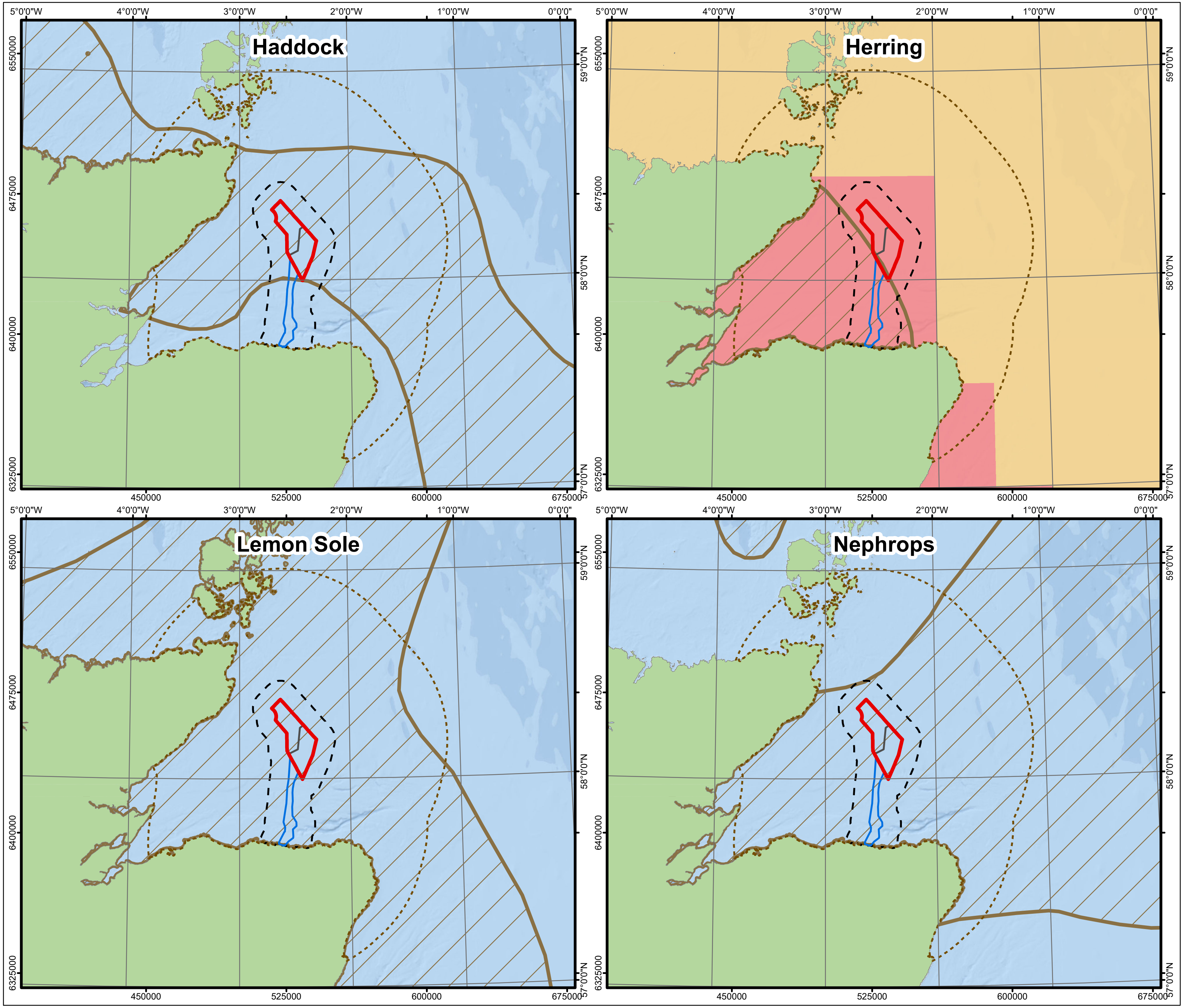
REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

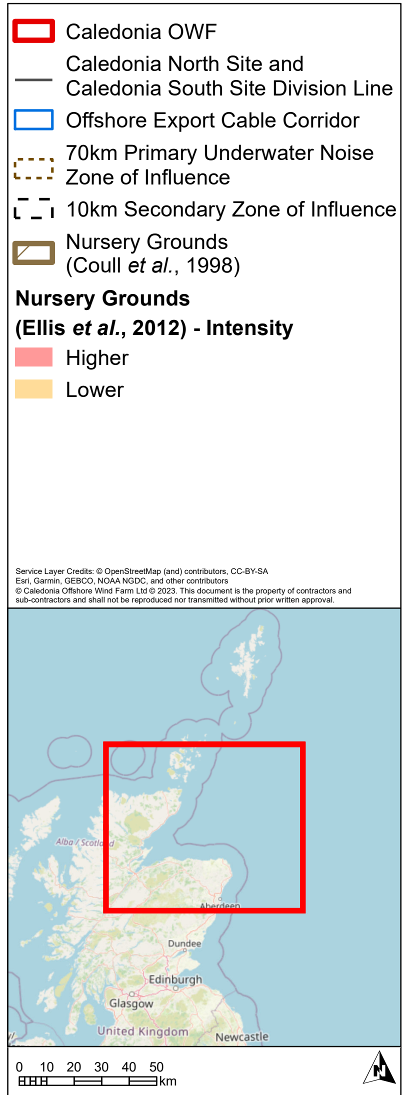
CALEDONIA Offshore Wind Farm
GoBe APEM Group

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00154
CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)
DRAWING TITLE:

Figure 5-4: Spawning Grounds Within the Study Area (Coull et al., 1998; Ellis et al., 2012)

STATUS: Approved
SCALE: 1:2,750,000
DRAWING NUMBER: N/A
SHEET NO: 01 of 01
REV: N/A





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CALEDONIA Offshore Wind Farm

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CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00155

CONTRACTOR REV: 01

GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE:

Figure 5-5: Nursery Grounds Within the Study Area (Coull et al., 1998; Ellis et al., 2012)

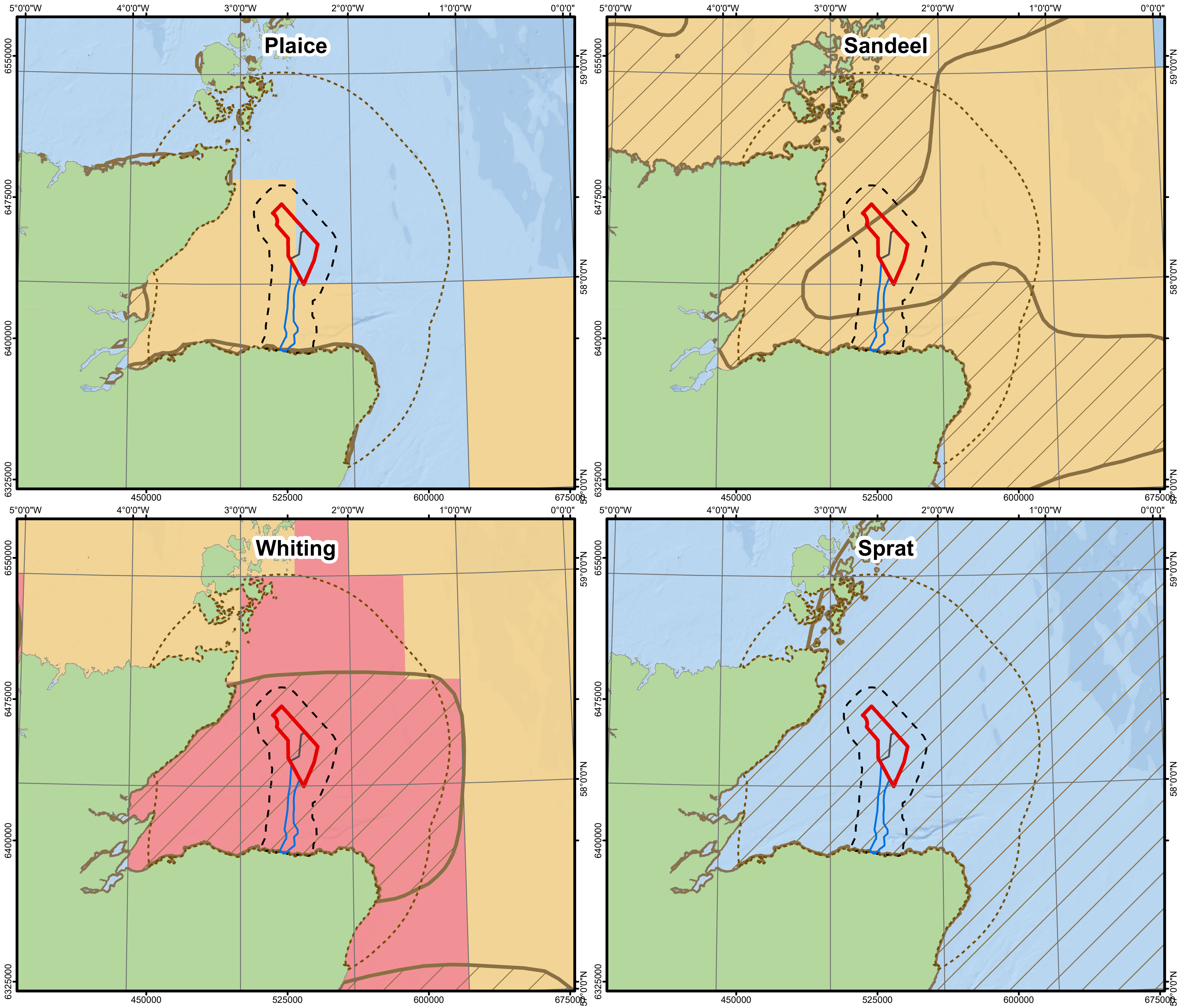
STATUS: Approved

SCALE: 1:2,750,000

DRAWING NUMBER: N/A

SHEET NO: 01 of 01

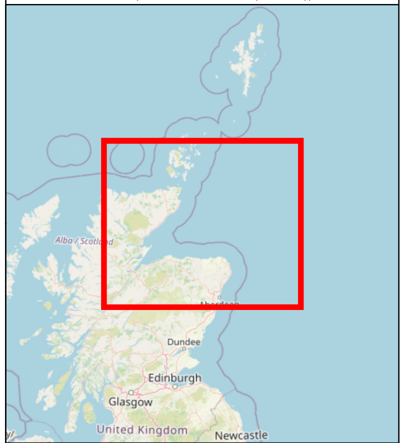
REV: N/A



- Caledonia OWF
- Caledonia North Site and Caledonia South Site Division Line
- Offshore Export Cable Corridor
- 70km Primary Underwater Noise Zone of Influence
- 10km Secondary Zone of Influence
- Nursery Grounds (Coull *et al.*, 1998)

Nursery Grounds (Ellis *et al.*, 2012) - Intensity

- Higher
- Lower



0 10 20 30 40 50 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm
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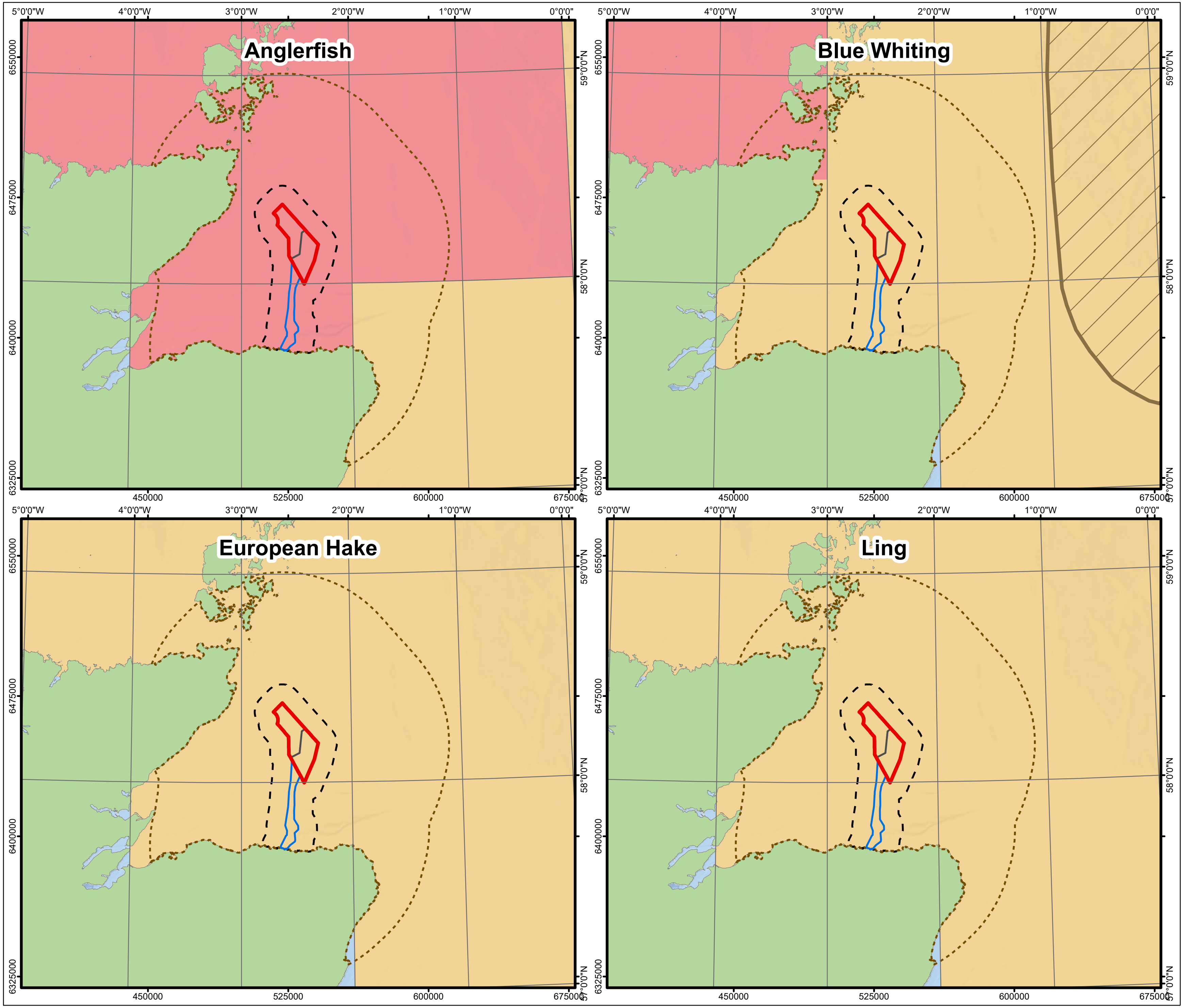
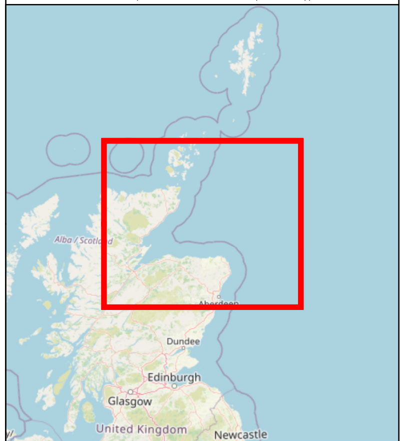
CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00156	CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE: Figure 5-6: Nursery Grounds Within the Study Area (Coull et al., 1998; Ellis et al., 2012)	
STATUS: Approved	SCALE: 1:2,750,000
DRAWING NUMBER: N/A	SHEET NO: 01 of 01 / REV: N/A



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence
Nursery Grounds (Coull *et al.*, 1998)

Nursery Grounds (Ellis *et al.*, 2012) - Intensity
Higher
Lower



0 10 20 30 40 50 km

01	24/09/2024	Approved	EV	BB	DH
REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP

CALEDONIA Offshore Wind Farm
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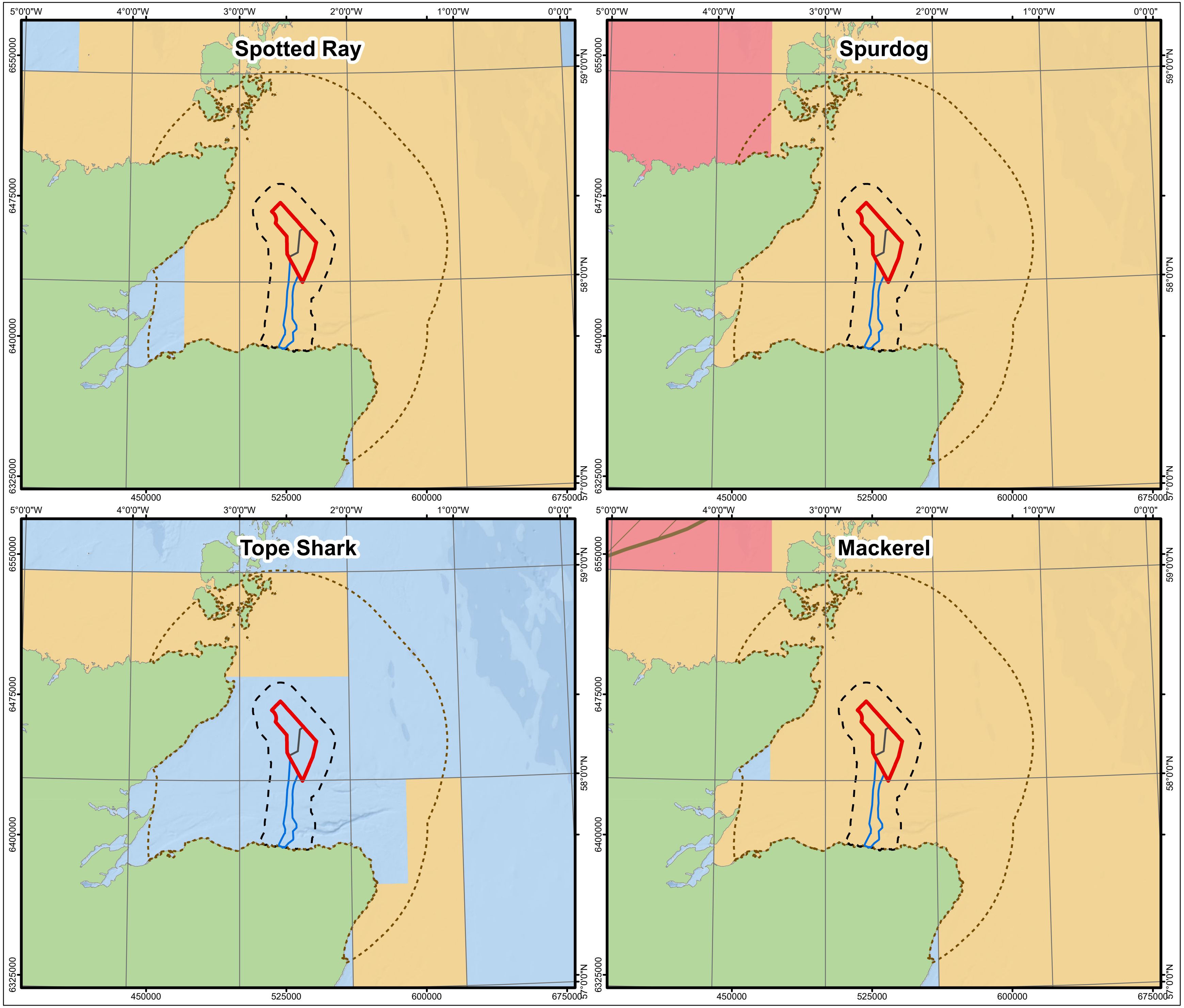
CONTRACTOR DRAWING NO UKCAL1_GO_WNF_FAS_MAP_00157	CONTRACTOR REV 01
GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 5-7: Nursery Grounds Within the Study Area (Ellis et al., 2012)	
STATUS Approved	SCALE 1:2,750,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 / REV N/A



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence
Nursery Grounds (Coull *et al.*, 1998)

Nursery Grounds (Ellis *et al.*, 2012) - Intensity

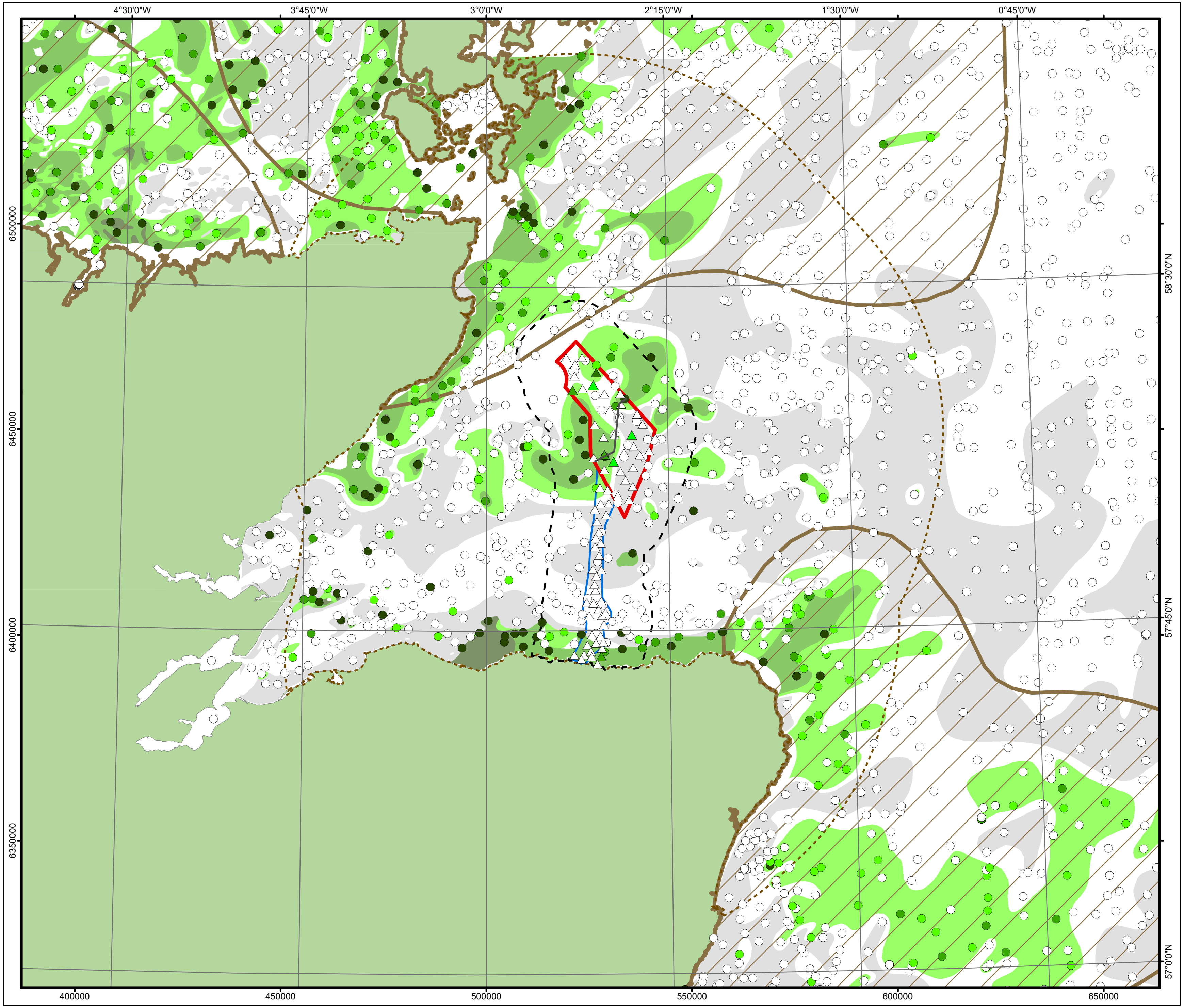
Higher
Lower

0 10 20 30 40 50 km

01	24/09/2024	Approved	EV	BB	DH
REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP

CALEDONIA Offshore Wind Farm
GoBe APEM Group

CONTRACTOR DRAWING NO UKCAL1_GO_WNF_FAS_MAP_00158	CONTRACTOR REV 01
GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 5-8: Nursery Grounds Within the Study Area (Ellis et al., 2012)	
STATUS Approved	SCALE 1:2,750,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 / REV N/A



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence
Herring Spawning Grounds (Coull et al., 1998)

Herring Habitat Suitability (Reach *et al.*, 2013) (Gardline Limited and Titan Environmental Surveys, 2023)

- Prime, Preferred
- Sub-Prime, Preferred
- Suitable, Marginal
- Unsuitable

Herring Habitat Suitability (Reach *et al.*, 2013) (BGS, 2015)

- Prime, Preferred
- Sub-Prime, Preferred
- Suitable, Marginal
- Unsuitable

Seabed Substrate (EMODnet) Herring Habitat Suitability (Reach *et al.*, 2013)

- Preferred
- Sub-Prime, Preferred
- Marginal
- Unsuitable

0 10 20 30 40 50 km

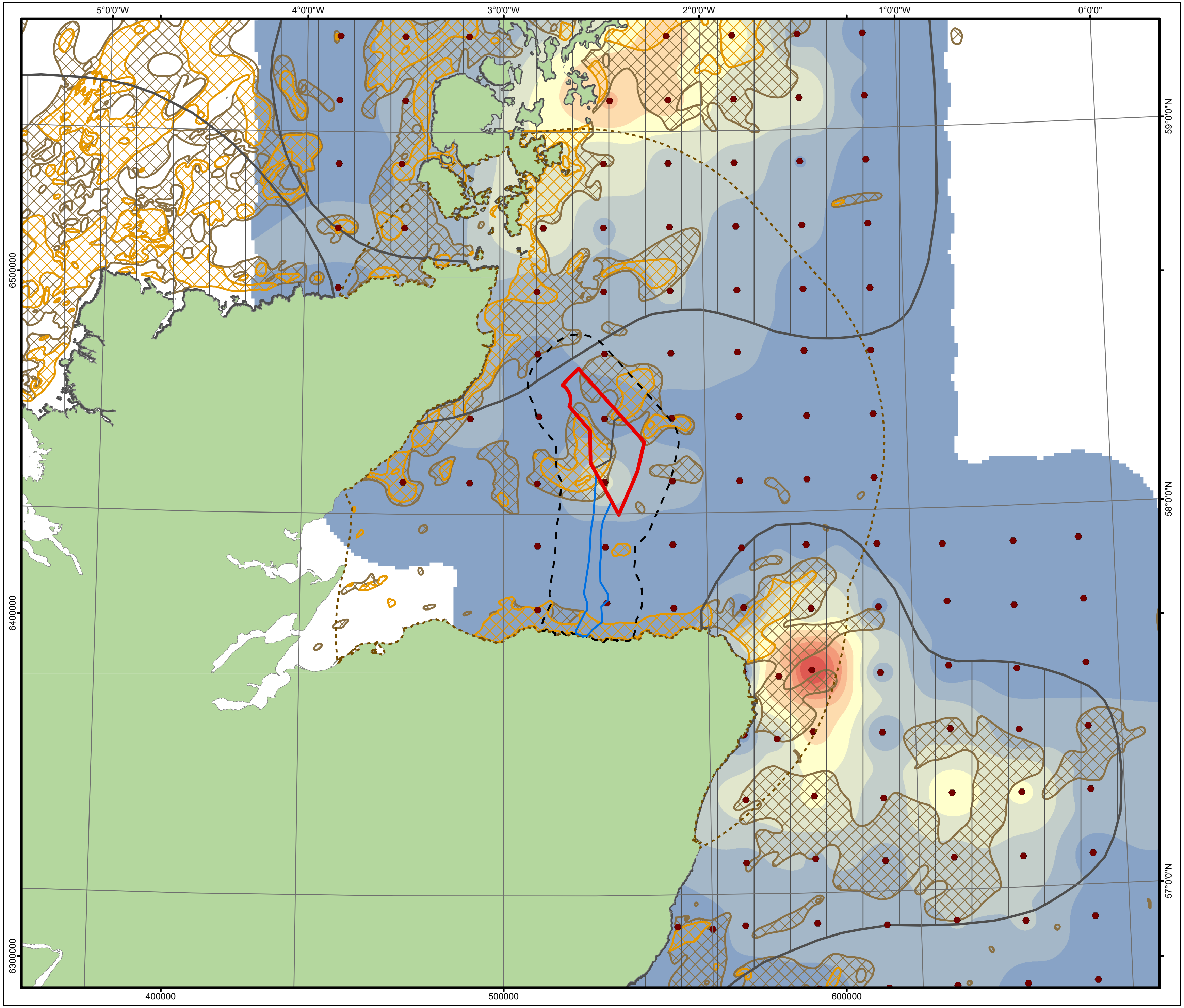
REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm
GoBe APEM Group

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00063
CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)
DRAWING TITLE:

Figure 5-9: Herring Spawning Substrates Relative to the Study Area

STATUS: Approved
SCALE: 1:1,250,000
DRAWING NUMBER: N/A
SHEET NO: 01 of 01
REV: N/A



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence
Herring Spawning Grounds (Coull et al., 1998)

EMODnet Sediment Class Herring Habitat Suitability

Marginal Sediment
Preferred Sediment

International Herring Larvae Survey

Sample Location (2011 - 2024)

IHLS Season 2011-12 to Season 2023-24 - Larval abundance per m^2

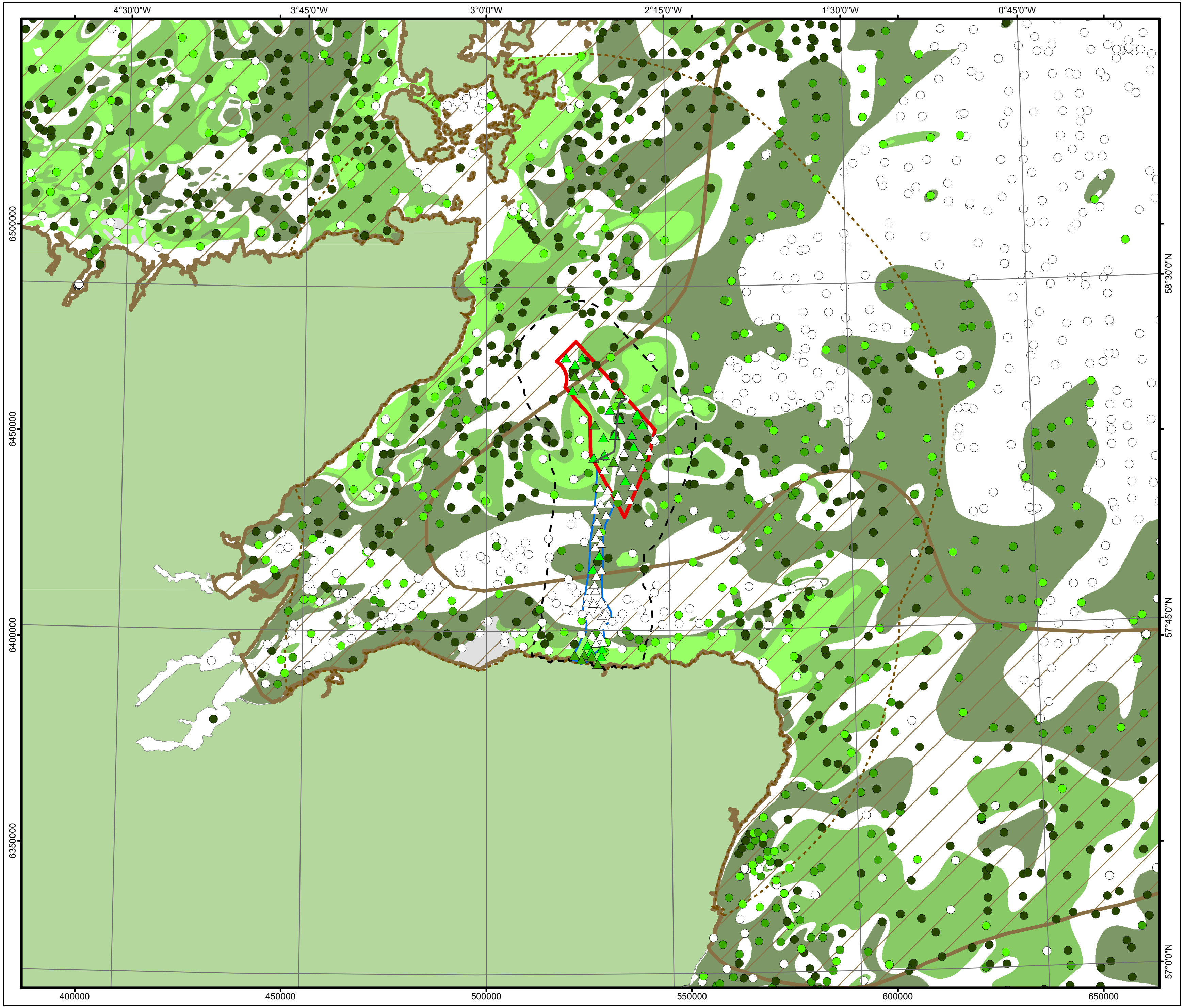
0.1 - 1,500
1,500.1 - 3,500
3,500.1 - 5,500
5,500.1 - 9,500
9,500.1 - 14,500
14,500.1 - 20,000
20,000.1 - 26,000
26,000.1 - 35,000
35,000.1 - 45,000
45,000.1 - 59,000

0 10 20 30 40 50 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm
GoBe APEM Group

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00312
CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)
DRAWING TITLE: Figure 5-10: Indicative Herring Spawning Data Relative to the Study Area (IHLS, 2011-2024)
STATUS: Approved
SCALE: 1:1,500,000
DRAWING NUMBER: N/A
SHEET NO: 01 of 01
REV: N/A



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence
Sandeel Spawning Grounds (Coull et al., 1998)

Sandeel Habitat Suitability (Latto et al., 2013) (Gardline Limited and Titan Environmental Surveys, 2023)

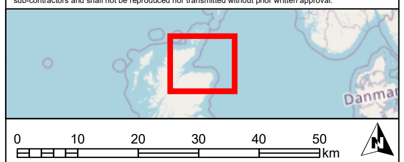
- Sub-Prime, Preferred
- Suitable, Marginal
- Unsuitable

Sandeel Habitat Suitability (Latto et al., 2013) (BGS, 2015)

- Prime, Preferred
- Sub-Prime, Preferred
- Suitable, Marginal
- Unsuitable

Seabed Substrate (EMODnet) Sandeel Habitat Suitability (Latto *et al.*, 2013)

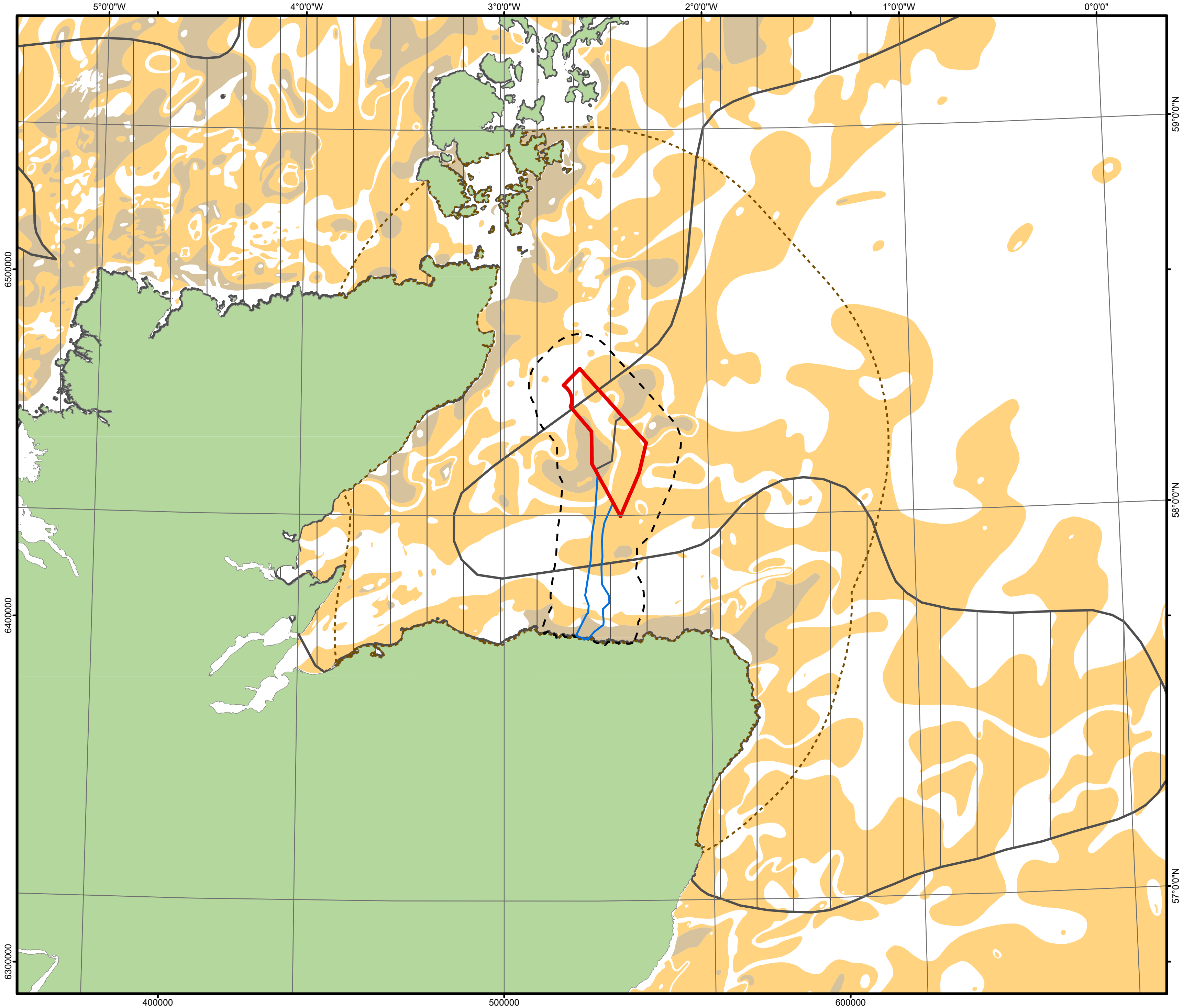
- Preferred
- Sub-Prime, Preferred
- Marginal
- Unsuitable



REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm
GoBe APEM Group

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00064	CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE: Figure 5-11: Sandeel Spawning Substrates Relative to the Study Area	
STATUS: Approved	SCALE: 1:1,250,000
DRAWING NUMBER: N/A	SHEET NO: 01 of 01 / REV: N/A



Caledonia OWF

Caledonia North Site and Caledonia South Site Division Line

Offshore Export Cable Corridor

70km Primary Underwater Noise Zone of Influence

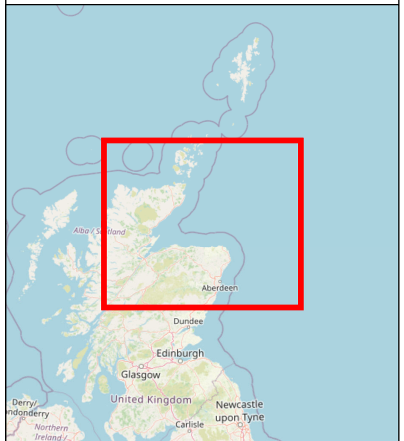
10km Secondary Zone of Influence

Sandeel Spawning Grounds (Coull et al., 1998)

Sandeel Habitat Suitability

Marginal Sediment

Preferred Sediment



0 10 20 30 40 50 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm

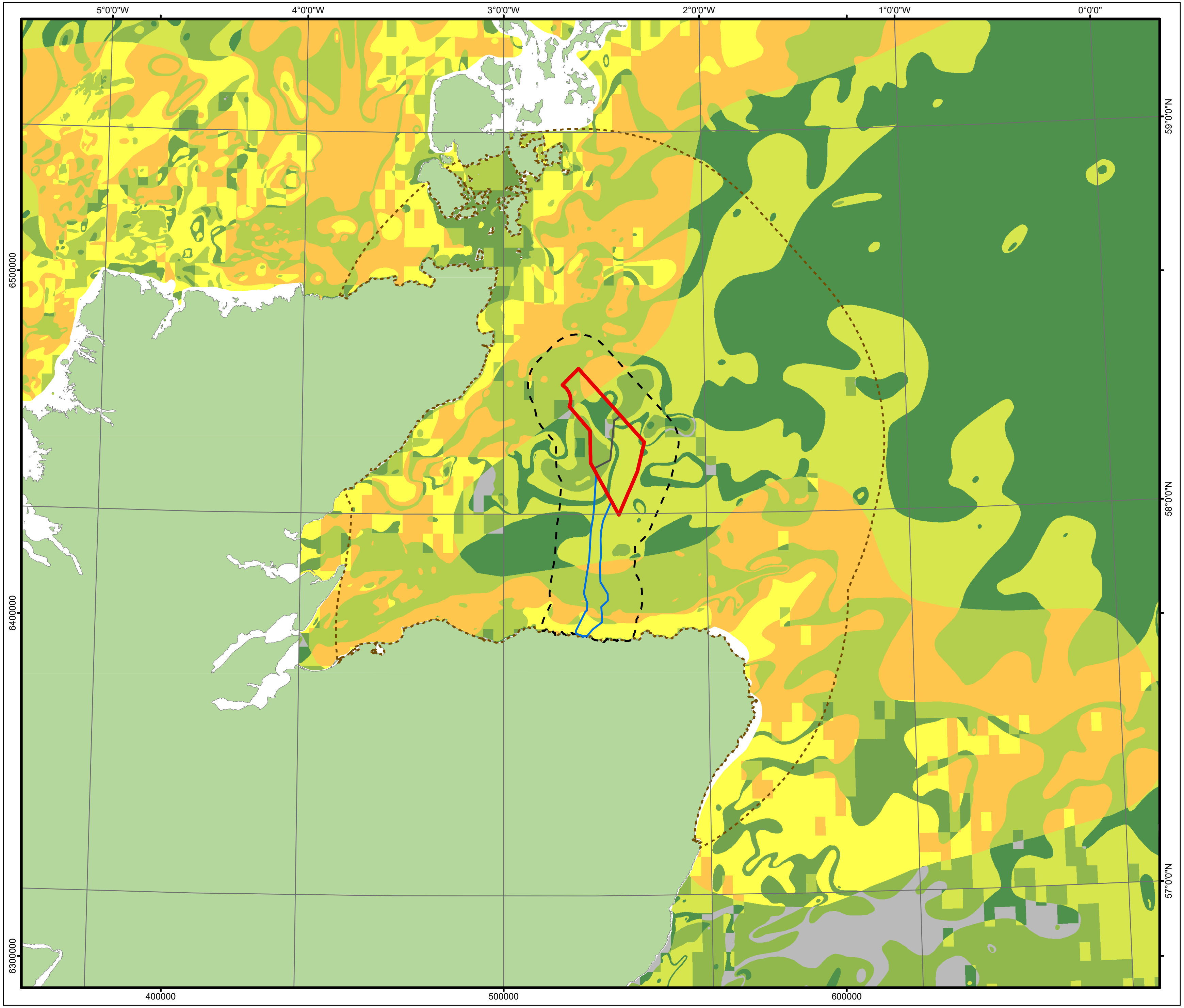
GoBe APEM Group

CONTRACTOR DRAWING NO	CONTRACTOR REV
UKCAL1_GO_WNF_FAS_MAP_00313	01

GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE: Figure 5-12: Indicative Sandeel Spawning Data Relative to the Study Area (Coull *et al.*, 1998)

STATUS	SCALE	
Approved	1:1,500,000	
DRAWING NUMBER	SHEET NO	REV
N/A	01 of 01	N/A



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence

Sandeel Habitat Confidence

- 0
- 2 (Low)
- 3 (Low)
- 4 (Low)
- 5 (Medium)
- 6 (Medium)
- 7 (Medium)
- 8 (Medium)
- 9 (High)
- 10 (High)
- 11 (High)
- 12 (High)

0 10 20 30 40 50 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CONTRACTOR DRAWING NO
UKCAL1_GO_WNF_FAS_MAP_00314

CONTRACTOR REV
01

GEODETIC PARAMETERS
WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE

Figure 5-13: Sandeel Spawning Potential Heat Map Relative to the Study Area

STATUS
Approved

SCALE
1:1,500,000

DRAWING NUMBER
N/A

SHEET NO
01 of 01

REV
N/A

Species of Commercial Importance

5.4.4.21 The Moray Firth supports several commercial fisheries. The study area and surroundings are dominated by landings of long-finned squid (*Loligo forbesii*), Nephrops, haddock, king scallop, European lobster and brown crab (*Cancer pagurus*). Peaks in landings of mackerel were observed in 2019; such patterns in landings by ICES rectangles are typical for pelagic species that swim in fast moving shoals and may not be specifically linked to areas or habitats when caught in the water column (MMO, 2022[110]). ICES rectangles 44E7 and 45E7 support local fishing fleets, targeting brown crab.

5.4.4.22 Shellfish including Nephrops, scallop, European lobster, brown crab and the Scottish squid (*Loligo vulgaris*) are potentially sensitive to the Proposed Development (Offshore), based on their limited mobility and therefore are considered less able to avoid potential disturbances compared to more mobile species. Nephrops are the most valuable shellfish fishery in the Scottish North Sea. A substantial proportion of Scottish squid landings come from the Moray Firth (Young *et al.,* 2006[111]; Beatrice OWF, 2011[62]). The main Scottish fishery for squid occurs in coastal waters and usually exhibits a marked seasonal peak around October and November, corresponding to the occurrence of pre-breeding squid. In the Moray Firth, a directed fishery for squid has developed in late summer and autumn in coastal waters between Troup Head and Spey Bay in the south of the Moray Firth, with additional activity recorded on parts of the Smith Bank and along the north coast (Young *et al.,* 2006[111]; Campbell and McLay, 2007[112]).

5.4.4.23 In regard to fish, herring are one of the most economically important pelagic fisheries in the North Sea although mackerel fishery is the most valuable pelagic fishery in the North Sea. Additionally, the Moray firth supports other fisheries including cod, haddock, mackerel and whiting.

5.4.4.24 Commercial fishing in UK waters, (including Scottish waters), of sandeel is now banned under the Sandeel (Prohibition of Fishing) (Scotland) Order 2024 (Scottish Parliament, 2024[18]) as a strategy to support the wider marine ecosystem and provide greater resilience to vulnerable species. By contrast, commercial fishing of haddock, cod and whiting occurs in the area.

Species of Conservation Importance

5.4.4.25 Within the northern North Sea region, there are records of several marine and estuarine species protected under national and international legislation. These are discussed in full in Volume 7B, Appendix 5-1: Fish and Shellfish Ecology Technical Baseline Report. Among these species, six are listed as Annex II under the EU Habitats Directive (92/43/ECC) (The Council of the European Committees, 1992[11]): river lamprey (*Lampetra fluviatilis*), sea lamprey (*Petromyzon marinus*), twaite shad (*Alosa fallax*), European eel, Atlantic salmon and Allis shad (*Alosa alosa*). All these species except for sea and river lamprey and Atlantic salmon are also listed in the Nature Conservation (Scotland) Act 2004 (Scottish Parliament, 2004[10]).

5.4.4.26 European eel is listed as critically endangered on the International Union for Conservation of Nature (IUCN) red list (IUCN, 2024[113]) and the rest of species are listed as vulnerable, near threatened or no concern.

5.4.4.27 The freshwater pearl mussel (*Margaritifera margaritifera*) is listed as vulnerable, and it listed as an Annex II species for SAC designation (The Council of the European Committees, 1992[11]). This is due to their complex life history involving Atlantic salmon and sea trout (*Salmo trutta trutta*) and prevalence near the study area, in the River Spey and River Devron.

5.4.4.28 Atlantic salmon and sea trout are important hosts species for freshwater pearl mussels, which can have direct effects on physiological stress, reduced swimming performance, and increased mortality at high rates of infestation all support a parasitic character of the mussel during its host dependent phase (Taeubert and Geist, 2017[114]).

5.4.4.29 A detailed list of species defined as Important Ecological Features (IEF) can be found in Volume 7B, Appendix 5-1: Fish and Shellfish Ecology Technical Baseline Report.

Designated Sites

5.4.4.30 The Proposed Development (Offshore) is located in the vicinity of several sites designated for nature conservation. Sites that have qualifying features related to fish and shellfish ecology, or a qualifying feature that is dependent on fish and shellfish populations (e.g., as prey species), have been listed within Table 5-7. It should be noted that while the River Oykel SAC and the River Evelix SAC lie outside the study area, they have been included as a precautionary measure, due to the transient nature of migratory Atlantic Salmon, which are qualifying features for these sites. These sites include:

- Moray Firth SAC;
- River Spey SAC;
- River Oykel SAC;
- River Evelix SAC;
- Berriedale and Langwell Waters SAC;
- Southern Trench Nature Conservation Marine Protected Areas (NCMPA); and
- Noss Head NCMPA.

Table 5-7: Sites designated for nature conservation in the vicinity of the study area.

Site	Approximate distance from the Proposed Development (Offshore)	Qualifying Features
Southern Trench NCMPA	▪ 13km from Caledonia OWF; and ▪ 0km from Caledonia OECC o Intersects with the entire inshore region of the Caledonia OECC (107.6km^2 (4.48%) of the Southern Trench MPA)	Designated for minke whales (*Balaenoptera acutorostrata*), included due to presence of presence of herring, mackerel, and cod (although these species are not designated)
Noss Head NCMPA	▪ 20km from Caledonia OWF; and ▪ 46km from the Caledonia OECC	Horse mussel beds (Annex I habitat, OSPAR threatened and/or declining habitat and a BAP priority habitat)
Moray Firth SAC	▪ 30km from Caledonia OWF; and ▪ 40km from Caledonia OECC	Designated for bottlenose dolphins (Annex II species), included for presence of herring and mackerel as prey species (although these species are not designated).
River Spey SAC	▪ 55km from Caledonia OWF; and ▪ 30km from Caledonia OECC	Freshwater pearl mussel (Annex II species), sea lamprey and Atlantic salmon
River Oykel SAC	▪ 90km from Caledonia OWF; and ▪ 80km from Caledonia OECC	Freshwater pearl mussel and Atlantic salmon (Annex II species)
River Evelix SAC	▪ 75km from Caledonia OWF; and ▪ 80km from Caledonia OECC	Freshwater pearl mussel and Atlantic salmon (Annex II species)
Berriedale and Langwell Waters SAC	▪ 50km from Caledonia OWF; and ▪ 60km from Caledonia OECC	Freshwater pearl mussel and Atlantic salmon (Annex II species)

Basking Sharks

5.4.4.31 Basking sharks visit Scottish waters largely from spring to autumn to feed and breed (Fugro, 2021[115]). The shark species migrates from the western English Channel in spring to seas off the west of Scotland, where they spend the summer and early autumn before moving offshore between November and March (Sims *et al.,* 2003[116]; Solandt and Chassin, 2013[117]). They are seasonal visitors to Scottish seas and are recorded in higher numbers around the western isles of Scotland (Witt *et al.,* 2016[89]; 2019[118]). Sightings have also been recorded in the Moray Firth (Witt *et al.,* 2012[89]; NatureScot, 2020[66]); however, to a much lesser extent compared to the west coast (Paxton *et al.,* 2014[88]; Witt *et al.,* 2016[89]) and around the west English Channel (Cornwall Wildlife Trust, 2020[86]). Increases in sea water temperatures are thought to be related to sightings being observed further north than in previous decades, with occasional records now around Shetland and Orkney north to the

Norwegian coast and in the northern North Sea (Bloomfield and Solandt, 2008[119]; Solandt and Ricks, 2009[120]).

5.4.4.32 According to the NBN Atlas (2024[77]), the closest confirmed sightings of basking sharks to the Proposed Development (Offshore) were off the coast of Spey Bay and Latheronwheel in 2022, Kington in 2015 and Fraserburgh in 2018, with all sightings over 20km away from the Caledonia OWF and Caledonia OECC. There have also been a few incidental sightings of basking sharks made between Burghead and Findhorn, approximately 50 to 70km from the Caledonia OWF and Caledonia OECC, in August 2018 which are not recorded in the NBN Atlas (The Press and Journal, 2018[121]). The Shark Trust (2024b[83]) catalogued a total of 108 basking shark sightings reported around the UK between 2020 and 2023, none of which were recorded within the Moray Firth.

5.4.4.33 Despite the sparse records of basking sharks in the Moray Firth, habitat modelling suggests that areas of the northern North Sea, particularly around the Landfall Site of the Proposed Development (Offshore), are suitable habitat for basking sharks and could be important for the recovery of historically depleted populations (Austin *et al.,* 2019[87]). Modelled density estimates of basking sharks around the east coast of Scotland are higher off Fraserburgh, Cullen Bay and Wick, based on data collected in summer between 2001 and 2012 (Paxton *et al.,* 2014[88]). Nonetheless, the density estimates on the east coast, in general, are much lower compared to those of western Scotland (Paxton *et al.,* 2014[88]; Witt *et al.,* 2016[89]; 2019[85]).

5.4.4.34 There is little information on the population trend and assessment of basking sharks in Scotland and the broader UK (NatureScot, 2020b[66]). Basking sharks are currently listed as a priority marine feature in Scotland and are currently considered as an endangered species by the IUCN Red List (Sims *et al.,* 2015[122]).

5.4.4.35 Analysis of aerial survey data collected throughout the 2021-2023 survey period identified one basking shark which was within the southern section of the Caledonia OWF in November 2022 (see Volume 7, Appendix 19). A single 'unidentified' shark species was also recorded within the 4km buffer of the Caledonia OWF in January 2022. Relative density and abundance estimates of basking sharks were calculated for the DAS area, but are not reported here or used in the impact assessment due to low sample sizes (numbers of sightings) meaning the estimates are not reliable.

5.4.4.36 Based on the information on distribution, abundance, density and modelled habitat suitability presented above, basking sharks were scoped into this EIAR.

5.4.5 Do Nothing Baseline

Fish and Shellfish Ecology

5.4.5.1 The Marine Works (Environmental Impact Assessment) Regulations (2007[16]; 2017[15]) and Electricity Works (Environmental Impact Assessment) Regulations (2017[14]) require that "an outline of the likely evolution thereof without implementation of the 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. From the point of assessment, over the course of the construction and operational lifetime of the Proposed Development (Offshore) (operational lifetime is anticipated to be 35 years), long-term trends mean that the condition of the baseline environment is expected to evolve. This section provides a qualitative description of the evolution of the baseline environment, on the assumption that the Proposed Development (Offshore) is not constructed, using available information and scientific knowledge of fish and shellfish ecology.

5.4.5.2 Recent research has suggested that there have been substantial changes in the fish communities in the northeast Atlantic, specifically the North Sea, over several decades as a result of a number of factors including climate change and fishing activities (Department of Energy and Climate Change (DECC), 2016[123]). These communities consist of species that have complex interactions with one another and the natural environment. Fish and shellfish populations are subject to natural variations in population size and distributions, largely as a result of year-to-year variation in recruitment success and these population trends will be influenced by broad-scale climatic and hydrological variations, as well as anthropogenic effects such as climate change and overfishing.

5.4.5.3 Fish and shellfish play a pivotal role in the transfer of energy from some of the lowest to the highest trophic levels within the ecosystem and serve to recycle nutrients from higher levels through the consumption of detritus. Consequently, their populations will be determined by both top-down factors such as predation, and bottom-up factors such as ocean climate and plankton abundance. Fish and shellfish are important prey items for top marine predators including elasmobranchs, seabirds and cetaceans, and small planktivorous species such as sandeel and herring act as important links between zooplankton and top predators (Frederiksen *et al.,* 2006[124]).

5.4.5.4 Climate change influences fish distribution and abundance, affecting growth rates, recruitment, behaviour, survival and response to changes of other trophic levels (Prakash and Srivastava, 2019[125]). Climate change is contributing to the declining levels of primary production in the North Sea which in turn effects the dynamics of higher trophic levels and fish recruitment (Capuzzo *et al.,* 2018[126]). Projected warming scenarios indicated regime shifts between sandeel and their copepod prey, resulting in sandeel recruitment declines (Regnier *et al.,* 2019[127]). Increased sea surface temperatures in the North Sea may lead to an increase in the relative abundance of species associated with more southerly areas. For example, data that was collected as part of the IHLS indicate a trend for increased herring spawning with colder winters, while warm winters were associated with large catches of sardine (Alheit and Hagen, 1997[128]).

5.4.5.5 One potential effect of increased sea surface temperatures is that some fish species will extend their distribution into deeper, colder waters (Poloczanska *et al.,* 2016[129]). In these cases, however, habitat requirements are likely to become important, with some shallow water species having specific habitat requirements which are not available in these deeper areas. For example, sandeel is less likely to be able to adapt to increasing temperatures as a result of its specific habitat requirements for coarse sandy sediment and declining recruitment in sandeel in parts of the UK has been correlated with increasing temperature (Heath *et al.,* 2012[130]). Climate change may also affect key life history stages of fish and shellfish species, including the timing of spawning migrations (Department for Energy Security and Net Zero (DESNZ), 2016[131]). However, climate change effects on marine fish populations are difficult to predict and the evidence is not easy to interpret and therefore it is difficult to make accurate estimations of the do nothing baseline scenario for the entire lifetime of the Proposed Development (Offshore) (35 years).

5.4.5.6 In addition to climate change, overfishing subjects the populations of many fish species to considerable pressure, reducing the biomass of commercially valuable species, and non-target species. Overfishing can reduce the resilience of fish and shellfish populations to other pressures, including climate change and other anthropogenic impacts. For example, a study on cod in an area where trawl fishing has been banned since 1932 indicated that the population was significantly more resilient to environmental change (including climate change) than populations in neighbouring fished areas (Lindegren *et al.,* 2010[132]). Modelling by Beggs *et al.* (2014[133]) indicated that cod may be more sensitive to climate variability during periods of low spawning stock biomass.

5.4.5.7 The variations and trends in commercial fisheries activity are an important aspect of the do nothing baseline scenario, specifically as existing baseline data do not capture any potential changes in commercial fisheries activity resulting from the withdrawal of the UK from the European Union (EU).

5.4.5.8 Following the UK's withdrawal from the EU, the UK and the EU have agreed to a Trade and Cooperation Agreement (TCA), applicable on a provisional basis from 1st May 2021 (UK Parliament, 2021[134]). The TCA sets out fisheries rights and confirms that from 1st May 2021 and during a transition period until 30 June 2026, UK and EU vessels will continue to access respective Exclusive Economic Zones (EEZs, 12nm to 200nm) to fish. In this period, EU vessels will also be able to fish in specified parts of UK waters between 6nm to 12nm. It is not currently clear whether any changes in fishing pressure will occur following the end of the transition period for fishing post-EU exit; however, it is likely that general trends of fishing pressure will continue in response to existing demand, although as stocks move north as would the corresponding fishing pressure. Whilst warming waters would allow new species to colonise new areas, specific fisheries quotas would have to be developed to allow the fishing of these stocks. As such, it not possible to predict the potential consequences.

5.4.5.9 In conclusion, it is considered that current trends with regard to the northward shift of specific species (e.g., sandeel) and an increase in the abundance of typically warmer water species (e.g., sardines) will continue in a warming climate, which may result in alterations to the existing baseline. However, considering the timescales of warming oceans and changes in distribution of species, it is likely that in the near to medium term, there will be changes in the relative abundances of species rather than wholescale changes in the community structure.

5.4.5.10 The fish and shellfish baseline characterisation described in the preceding sections (and presented in detail in Volume 7B, Appendix 5-1: Fish and Shellfish Ecology Technical Baseline Report) represents a 'snapshot' of the fish and shellfish assemblages of the study area, within a gradual and continuously changing environment. Any changes that may occur during the lifetime of the Proposed Development (Offshore) (i.e., construction, operation and decommissioning) should be considered in the context of the natural variability and other existing anthropogenic effects, including climate change and overfishing.

Basking Sharks

5.4.5.11 If the Proposed Development (Offshore) does not go forward, an assessment of the future baseline conditions has also been carried out and is described within this section. It should be noted that the baseline environment is not static and will exhibit some degree of change over time even without the Proposed Development (Offshore) in place. Therefore, when undertaking impact assessments, it is necessary to place any potential impacts in the context of the envelope of change that might occur naturally in the absence of the Proposed Development (Offshore).

5.4.5.12 From the point of assessment, over the course of the development and operational lifetime of the Proposed Development (Offshore), long-term trends mean that the condition of the baseline environment is expected to evolve. This section provides a qualitative description of the evolution of the baseline environment, on the assumption that the Proposed Development (Offshore) is not constructed, using available information and scientific knowledge of the ecology of basking sharks.

5.4.5.13 The most recent status assessment of basking sharks for the OSPAR Region II: Greater North Sea is summarised in Table 5-8 below (OSPAR, 2021[135]).

Table 5-8: Summary of the OSPAR assessment of basking sharks (OSPAR, 2021[135]).

Species	Distribution	Population Size	Demographics (e.g., productivity)	Status Assessment
Basking sharks	No change observed	Unknown	Unknown	Poor

5.4.5.14 The major threat to basking sharks has been identified as accidental bycatch in fishing nets and entanglement in pot lines (OSPAR, 2021[135]). Surface feeding and vertical movement behaviour means sharks are more susceptible to impacts from vessel traffic, wildlife tourism and fishing activities (International Council for the Exploration of the Sea (ICES), 2019[136]). In addition, coastal development, water pollution and bottom fishing have been identified to impact this filter-feeding species (Beaugard *et al.,* 2002[137]; Doherty *et al.,* 2017[138]).

5.4.5.15 Changes in species population and distribution are also likely to occur due to climate change, as thermoregulation has been proposed as one of the reasons for observed seasonal migration of basking sharks (Skomal *et al.,* 2009[336]). Previous studies (Sims *et al.,* 1997[139]; Beaugrand *et al.,* 2002[137]) also suggest that climate change could alter the distribution of basking shark's preferred prey group, potentially reducing suitable foraging habitat for this species. This could be one of the possible explanations for observed declines in basking shark sightings within some areas of its historical range (Sims and Reid, 2002[140]).

5.4.5.16 Townhill *et al.* (2024[141]) established habitat suitability climate models with input of environmental parameters (near-seabed and sea surface temperatures, salinity, sea surface chlorophyll concentrations, bathymetry and substrate properties) to predict potential changes of suitable habitats for basking sharks between 2005 and 2100. The models considered two climate change scenarios (Representative Concentration Pathway, RCP 4.5 with medium emissions and high mitigation, and RCP 8.4 with high emissions and low mitigation), and spatially covered most of the UK Exclusive Economic Zone except for some deeper areas of northwest Scotland and southwest England due to no environmental data being available to inform the model. Modelled results predict a general increase of 15 to 30% in habitat suitability throughout the study area for basking sharks under both climate change scenarios, except for the very southern region of North Sea. It should however be noted that a spatial food-web model was not conducted for basking sharks and therefore predator-prey interactions, along with species dispersal abilities and food availability (Jennings and Brander, 2010[142]; Robinson *et al.,* 2011[143]; Evans *et al.,* 2015[144]) are not considered in those species distribution models.

5.4.6 Data Gaps and Limitations

Fish and Shellfish Ecology

5.4.6.1 Mobile species, such as fish, exhibit varying spatial and temporal patterns. Surveys across the study area were conducted to provide a semi-seasonal description of the fish and shellfish assemblages. The data collected during these surveys represent snapshots of the fish and shellfish assemblage at the time of sampling, which may vary considerably, both seasonally and annually. Even if species are absent from regional surveys, they should still be included in the baseline characterisation, which draws upon wider scientific literature and available information to ensure a more comprehensive and precautionary baseline, identifying all likely present species within the study area.

5.4.6.2 The efficiency of the surveys varies depending on the nature of the survey methods used and the species recorded. For example, an otter trawl would not characterise pelagic species (e.g., herring and sprat) as efficiently as a pelagic trawl, and a 2-metre scientific beam trawl would not be as efficient at collecting sandeel and some species of shellfish as other methods used commercially in the study area (e.g., sandeel or shrimp trawls and shellfish potting). This limits the data utility in capturing relative abundances of species within the area. To minimise this limitation caused by survey methodology, sensitive receptors have been chosen based on their presence or absence within the study area, rather than whether that species contributes more significantly to the fish assemblage within the survey data.

5.4.6.3 Coull *et al.* (1998[94]), Ellis *et al.* (2012[102]) and Aires *et al.* (2014[103]) are key references for providing broadscale overviews of the potential spatial extent of spawning grounds and the relative intensity and duration of spawning, both based on a collection of various data sources. Many of the conclusions drawn by Coull *et al.* (1998[94]) are based on historic research and data do not necessarily account for more recent changes in fish distributions and spawning behaviour. Ellis *et al.* (2012[102]) is also limited by the wide scale distribution of sampling sites used for the annual international larval survey data used, consequently resulting in broadscale grids of spawning and nursery grounds. The spatial extent of the spawning grounds and the duration of spawning periods indicated in these studies are therefore considered likely to represent the maximum theoretical extent of the areas and periods within which spawning may occur. Spawning grounds may therefore be smaller in extent and display shorter spawning periods and, in some cases, spawning grounds indicated by these sources may no longer be active. Where available, additional research publications and data have been reviewed to provide the best, most contemporary and site-specific information. When considering demersal spawners which display substrate dependency (e.g., herring and sandeel), site-specific PSA and geophysical data have been used to ground truth the Coull *et al.* (1998[94]) and Ellis *et al.* (2012[102]) datasets.

5.4.6.4 The broadscale marine habitat data (EMODnet, 2023[95]) have also been used to identify and predict preferred sandeel and herring spawning habitats. It should be acknowledged, that this dataset is somewhat limited by the broadscale nature of the data, as it does not account for small-scale, localised differences in seabed sediments, unlike the data obtained from site-specific grab sampling. In this case it is important to review all the datasets presented to develop a clear overview of preferred sandeel and herring habitat.

5.4.6.5 The site-specific PSA data have been used to ground truth the broadscale data from Coull *et al.* (1998[94]), Ellis *et al.* (2012[102]) and EMODnet, (2023[95]). This data have been classified in accordance with the Latto *et al.* (2013[92]) and Reach *et al.* (2013[93]) classifications to identify areas of preferred spawning habitat for sandeel and herring, respectively. The use of PSA data and broadscale habitat mapping is intended to provide a proxy for the presence of sandeel and herring spawning habitat in these locations (based on suitability of habitats; i.e., the potential for spawning rather than actual contemporary spawning activity).

5.4.6.6 Whilst grab samples provide detailed information on the sediment types, they cannot cover wide swaths of the seabed and consequently only represent point samples. The PSA data are therefore interpreted in combination with additional PSA data across the site, sourced from the BGS (BGS, 2024[145]), to provide the most comprehensive cover of the study area. It is important to note, that although the data used in the characterisation of the fish and shellfish baseline conditions span a long time period, with some sources published over a decade ago, the information presented represents a long-term dataset. This allows for a detailed overview of the characteristic fish and shellfish species in the study area.

5.4.6.7 It is important to note, that the data used in the characterisation of the fish and shellfish baseline conditions span a long time period, with some sources published over a decade ago, the information therefore used represents a long-term dataset. This allows for a detailed overview of the characteristic fish and shellfish species in the study area. The diversity and abundance of many species, particularly demersal fish species, is linked to habitat types, which have remained relatively constant in the study area which would indicate consistency in location of demersal communities over the time period of the data used in this report.

5.4.6.8 eDNA data have also been collected alongside the geophysical surveys to provide a snapshot of fish and shellfish species presence (from approximately the preceding 24-hours) at each sample location. As eDNA is a relatively new way of supplementing baseline characterisation in offshore wind projects, there is not a wealth of literature or protocols available to understand the implications of these data. Although eDNA shows great promise in identifying receptors and aiding EIA monitoring, there are potentially some challenges when applying such data within the context of a more generic EIA framework within marine environments. As a result of these challenges, the use of eDNA is recommended as a proxy for the presence of a receptor and not a direct measure of presence (Hinz *et al.,* 2022[146]). For example, one of the challenges is defining a sampling unit and sampling strategy with respect to the survey area which can create further challenges in drawing comparisons between different areas, across spatial and temporal scales (Hinz *et al.,* 2022[146]). In addition, statistical modelling presents itself as a challenge when using eDNA in marine EIA assessments due to the possibility of collecting both false positives and negatives in samples. As such, it is considered vital that the uncertainty in presence/absence estimates is provided during data processing (Hinz *et al.,* 2022[146]). The transport of eDNA fragments in marine environments is also generally unknown and influencing factors such as shedding dynamics, biogeochemical and physical processes need to be well understood in order to link a fragment of eDNA with a potential receptor's presence (Hinz *et al.,* 2022[146]).

5.4.6.9 Recent studies suggest that eDNA has limitations in detecting elasmobranch and similar species that usually occupy the upper-level trophic position, as naturally their density is reduced compared to species occupying lower trophic levels (Merten Cruz *et al.,* 2023[147]). Therefore, eDNA methods may not fully capture the diversity of elasmobranch species, leading to the underestimation of their presence (Ip *et al.,* 2021[148]; Merten Cruz *et al.,* 2023[147]). This is due to factors such as the lack of universal primers for comprehensive detection, and the need for multiple markers to minimise bias in eDNA results. Additionally, the use of eDNA metabarcoding is still subject to inherent biases and limitations, such as a lack of information on the spatial origin of eDNA and the size, age, or sex of the detected species. While eDNA is a powerful tool for understanding and characterising the elasmobranch populations in the study area, its limitations in detecting species with minimal presence in the water are considered and supplemented with information from previous OWF surveys in the vicinity along with an extensive literature review.

5.4.6.10 Despite the data limitations detailed within this section of the report, the data as included in Table 5-5 is considered a robust and sufficient evidence base to inform the fish and shellfish baseline characterisation and underpin the assessment process, as confirmed by the stakeholder response to the scoping phase. Suggested incorporated data sources from the Scoping Opinion (Volume 7, Appendix 3) have been integrated into this chapter.

Basking Sharks

5.4.6.11 Regarding site-specific surveys, as with all species of interest, basking sharks were only available for detection on DAS (see Volume 7, Appendix 19) when they were at or just below the surface, resulting in availability bias (where an animal is underwater and therefore not available for detection).

5.4.6.12 The DAS data represent a snapshot over a short time period each month, during daylight hours and in fair weather. Therefore, it was not possible to explore if changes in sighting rates were influenced by environmental conditions. Differences in sighting rates between months may be due to seasonal changes, but environmental conditions also have the potential to influence how and when animals used the area.

5.4.6.13 There is also a lack of fine-scale distribution, density and abundance data of basking sharks around the Caledonia OECC available, as DAS only covered the Caledonia OWF and 4km buffer.

5.4.6.14 In view of the uncertainty and limitation of survey and desk-based information identified, the impact assessment for the Proposed Development (Offshore) has adopted the worst-case scenario to cope with data uncertainty and limitations to reduce the risk of further design modifications falling outside of the assessment envelope. Regarding the desk study, there are limited data collected systematically to inform broad-scale distribution of basking sharks off eastern Scotland and the broader North Sea. Broad-scale occurrence and distribution of basking sharks largely rely on opportunistic sighting data collated by NatureScot and JNCC, and from NGOs such as Shark Trust. The effort of citizen-science surveys could be biased towards suitable vantage points along the coast. More recent data of broad-scale basking shark density and abundance are also lacking, possibly due to few sightings off east coast of Scotland and the broader North Sea.

5.5 EIA Approach and Methodology

5.5.1 Assessment Methodology

5.5.1.1 The project-wide generic approach to assessment is set out in Volume 1, Chapter 7: EIA Methodology. The assessment methodology for fish and shellfish ecology for the EIAR is consistent with that provided in the Offshore Scoping Report (Volume 7, Appendix 2).

5.5.1.2 The methodology for the assessment of fish and shellfish ecology is set out in full in Volume 1, Chapter 7: EIA Methodology and has been used in the production of the EIAR to identify and evaluate the likely significant environmental effects on fish and shellfish ecology from the construction, operation and decommissioning of the Proposed Development (Offshore).

5.5.1.3 The criteria for determining the significance of effects is a three-stage process that involves defining the magnitude of the impacts, the sensitivity of the receptors and the overall significance of effects. This section describes the criteria applied in this chapter to assign values to the sensitivity of receptors and the magnitude of potential impacts.

5.5.1.4 Information about the Proposed Development (Offshore) throughout its life cycle (construction, operation and decommissioning) has been combined with information about the environmental baseline to identify the potential interactions between the Proposed Development (Offshore) and the environment. These potential interactions are known as potential impacts, the potential impacts are then assessed to give a level of significance of effect upon the receiving environment/receptors. The outcome of the assessment is to determine the significance of these effects against predetermined criteria.

Fish and Shellfish Ecology

Magnitude of Impact

5.5.1.5 The magnitude of potential impacts is defined by a number of factors, including the spatial extent of any interaction, the likelihood, duration, frequency and reversibility of a potential impact. The magnitude of impacts for fish and shellfish is the same as provided within the methodology Chapter for this EIAR (Volume 1, Chapter 7, EIA Methodology) and has been reproduced for convenience in Table 5-9.

Table 5-9: Fish and shellfish ecology impact magnitude definitions.

Magnitude	Description/Reason
High	Complete loss and/or alteration to qualifying/key elements and features of the receptor or receiving environment.
Medium	Partial loss and/or alteration to qualifying/key elements and features of the receptor or receiving environment.
Low	Minor loss/divergence from baseline conditions.
Negligible	Very slight/no change to baseline conditions.

Sensitivity of Receptor

5.5.1.6 The sensitivities of fish and shellfish receptors are defined by both their potential vulnerability to an impact from the development, their recoverability, and the value or importance of the receptor. The following parameters are also taken into account:

- Timing of the impact: whether impacts overlap with critical life stages or seasons (i.e., spawning and migration); and
- Probability of the receptor-impact interaction occurring.

5.5.1.7 The determination of a receptor's vulnerability to an impact is based on the ability of a receptor to accommodate a temporary or permanent change. The assessment of the receptor's vulnerability also considers the mobility of the receptor. Receptors that can flee from an impact are considered less sensitive than those that are stationary and unable to flee. When applying this consideration to a fish and shellfish assessment, static receptors typically include shellfish of limited mobility, fish that will potentially be engaging in spawning behaviours, substrate dependant receptors, and eggs and larvae. On this basis, 'static' receptors are considered to be of increased vulnerability to an impact. In determining the overall sensitivity of a receptor to an impact, the vulnerability of a receptor to the impact is typically given the greatest weighting.

5.5.1.8 The recoverability of the receptor is defined as the extent to which a receptor will recover following an impact. The rate of recovery is also taken into consideration in this criterion. Regarding fish and shellfish receptors, the recoverability of a receptor typically relates to the ability of a receptor to return/recolonise an area after an impact, or for normal behaviours to resume.

5.5.1.9 The value and importance of a receptor is a measure of the importance of a receptor in terms of its relative ecological, social or economic value or status. Regarding fish and shellfish receptors, the value and importance of the receptors is primarily informed by the conservation status of the receptor, the receptor's role in the ecosystem, and the receptor's geographic frame of reference. Note that for stocks of species which support significant fisheries, commercial value is also taken into consideration.

5.5.1.10 Regarding the weighting of the sensitivity criteria (vulnerability, recoverability and value and importance), greater weighting is typically assigned to the vulnerability of a receptor. Expert judgement is used as appropriate, in line with the CIEEM (2018[149]), when applying the sensitivity criteria to the sensitivity assessment of receptors. For example, if receptors are considered of high value/importance, or have rapid recovery rates, these criteria may be given greater weighting in the assessment.

5.5.1.11 The sensitivity/importance of the receptor is defined in Table 5-10.

Table 5-10: Fish and shellfish ecology sensitivity of receptor.

Receptor Sensitivity/ Importance	Description/Reason
High	Internationally or nationally important receptors (i.e., Annex II species listed as features of SACs, or species listed on the OSPAR Threatened or Declining Species List) with high vulnerability and no ability for recovery.
Medium	Regionally important receptors (i.e., MCZ/recommended MCZ (rMCZ) features, PMF (species classified as features of conservation importance), or species that are of commercial value to the fisheries which operate within the North Sea) with high vulnerability and no ability for recovery. Internationally or nationally important receptors with medium to high vulnerability and low to medium recoverability.
Low	Locally important receptors (i.e., species of commercial importance but do not form a key component of the fish assemblages within the fish and shellfish study area) with medium to high vulnerability and low recoverability. Regionally important receptors (i.e., MCZ/recommended MCZ (rMCZ) features, PMF (species classified as features of conservation importance), or species that are of commercial value to the fisheries

Receptor Sensitivity/ Importance	Description/Reason
	which operate within the North Sea) with low vulnerability and medium recoverability. Nationally important receptors (i.e., Annex II species listed as features of SACs, or species listed on the OSPAR Threatened or Declining Species List) with low vulnerability and medium to high recoverability. Internationally important receptors (i.e., Annex II species listed as features of SACs, or species listed on the OSPAR Threatened or Declining Species List) with low vulnerability and high recoverability.
Negligible	Receptor is not vulnerable to impacts regardless of value/importance. Locally important receptors with low vulnerability and medium to high recoverability.

Significance of Effect

5.5.1.12 Assessment of the significance of potential effects is described in Table 5-11. The combination of the magnitude of the impact with the sensitivity of the receptor determines the assessment of significance of effect.

5.5.1.13 For the purposes of this assessment, any effect that is of major or moderate significance is considered to be significant in EIA terms, whether this be adverse or beneficial. Any effect that has a significance of minor or negligible is not significant.

Table 5-11: Matrix to determine effect significance.

Significance of Effect		Sensitivity of Receptor			
		Negligible	Low	Medium	High
Impact Magnitude	Negligible	Negligible	Negligible	Negligible	Negligible
	Low	Negligible	Negligible	Minor	Minor
	Medium	Negligible	Minor	Moderate	Moderate
	High	Negligible	Minor	Moderate	Major

Basking Sharks

Magnitude of Impact

5.5.1.14 The magnitude of an impact is the consideration of the spatial extent, duration, frequency and consequence of an impact from the construction, operation and decommissioning phases of the Proposed Development (Offshore). For the purposes of this EIAR chapter, to ensure a robust assessment of environmental impacts, a worst-case scenario was identified and assessed. Where it was not necessarily clear which scenario would represent the worst-case, all relevant scenarios have been considered and reported within the impact assessment of this EIAR chapter. Table 5-12 provides a description for each term of magnitude of impact.

Table 5-12: Basking shark impact magnitude definitions.

Magnitude	Description
High	Extent/Duration: The impact occurs over a large spatial extent and over long-term duration, with the potential to affect a large proportion of a receptor population. Probability/frequency: The effect is very likely to occur and/or will occur at a high frequency. Consequence: The effect could affect a large enough proportion of the population to alter the favourable conservation status and/or the long-term trajectory of the population in the long term.
Medium	Extent/Duration: The impact occurs over a medium spatial extent and over medium-term duration, with potential affect a moderate proportion of a receptor population. Probability/frequency: The effect is likely to occur and/or will occur at a moderate frequency. Consequence: The effect could affect a moderate proportion of the population although not large enough to alter the population trajectory in the long term.
Low	Extent/Duration: The impact is localised and temporary or short-term, with potential to result in a noticeable effect on a small proportion of a receptor population. Probability/frequency: The effect may occur but at low frequency. Consequence: The effect could affect a small proportion of the population and the population trajectory would not be altered.
Negligible	Extent/Duration: The impact is highly localised and short-term, with potential to result in very slight or imperceptible changes to a receptor population. Probability/frequency: The effect is very unlikely to occur; if it does, it will occur at a very low frequency. Consequence: The effect will not alter the population trajectory.

Sensitivity of Receptor

5.5.1.15 The sensitivity of basking shark receptors is determined by their adaptability to an impact from the Proposed Development (Offshore), their vulnerability and recoverability of the receptors. The criteria for defining sensitivity in this chapter are outline in Table 5-13.

5.5.1.16 Basking shark is the only other megafauna receptor considered in this EIAR chapter, and this species is afforded a high degree of legislative protection and is currently listed as a priority marine feature in Scotland and as endangered conservation status on the IUCN Red List (Rigby *et al.,* 2021[150]). Consequently, the basking shark is considered to be of very high value and therefore the concept of value is not considered within the definition of sensitivity. Rather, value is considered further in terms of suitable mitigation, if required.

Table 5-13: Basking shark sensitivity of receptor.

Sensitivity	Description
High	Adaptability: No ability to avoid or adapt to an impact so that individual survival and reproduction rates are affected. Vulnerability: No tolerance – Effect will cause a change in both individual reproduction and survival rates. Recoverability: No ability for the animal to recover from any impact on vital rates (reproduction and survival rates).
Medium	Adaptability: Limited ability to avoid or adapt to an impact so that individual survival and reproduction rates may be affected. Vulnerability: Limited tolerance – Effect may cause a change in both individual reproduction and survival of individuals. Recoverability: Limited ability for the animal to recover from any impact on vital rates (reproduction and survival rates).
Low	Adaptability: Reasonable ability to avoid or adapt to an impact so that individual reproduction rates may be affected but survival rates not likely to be affected. Vulnerability: Some tolerance – Effect unlikely to cause a change in both individual reproduction and survival rates. Recoverability: Ability for the animal to recover from any impact on vital rates (reproduction and survival rates).
Negligible	Adaptability: Receptor is able to avoid or adapt to an impact so that individual survival and reproduction rates are not affected. Vulnerability: Receptor is able to tolerate the effect without any impact on individual reproduction and survival rates. Recoverability: Receptor is able to return to previous behavioural states/activities once the impact has ceased.

Significance of Effect

5.5.1.17 As outlined in Volume 1, Chapter 7: EIA Methodology, the significance of a potential impact is a function of its magnitude and the sensitivity of the receptor. The particular method employed for this assessment is presented in Table 5-14. Negligible or Minor impacts are categorised as ‘not significant’ in EIA terms. Major or moderate effects are categorised as ‘significant’ in EIA terms, as highlighted in grey.

5.5.1.18 In all cases, the evaluation of receptor sensitivity, impact magnitude and significance of effect has been informed by professional judgement and is underpinned by narrative to explain the conclusions reached.

Table 5-14: Assessment matrix for basking shark receptors.

Significance of Effect		Sensitivity of Receptor			
		Negligible	Low	Medium	High
Impact Magnitude	Negligible	Negligible	Negligible	Negligible	Negligible
	Low	Negligible	Negligible	Minor	Minor
	Medium	Negligible	Minor	Moderate	Moderate
	High	Negligible	Minor	Moderate	Major

5.5.2 Impacts Scoped into the Assessment

5.5.2.1 The Offshore Scoping Report (Volume 7, Appendix 2) was submitted to MD-LOT in September 2022. The Offshore Scoping Report set out the overall approach to assessment and allowed for the refinement of the Proposed Development (Offshore) over the course of the assessment.

5.5.2.2 The proposed scope of the assessment for fish and shellfish ecology is set out in Table 5-15. The proposed scope of the assessment for basking shark is set out in Table 5-16.

Table 5-15: Fish and shellfish ecology scope of assessment.

Potential Impact	Phase	Nature of Impact
Mortality, injury, behavioural impacts and auditory masking arising from noise and vibration	Construction	Direct
Temporary increases in suspended sediment concentrations (SSCs)	Construction	Direct
Temporary habitat loss and disturbance	Construction	Direct
Direct and indirect seabed disturbance leading to release of sediment contaminants	Construction	Direct and Indirect
Increased risk of introduction and/or spread of Invasive Non-Native Species (INNS) from vessel traffic	Construction	Indirect
Temporary habitat loss and disturbance	Operation and Maintenance	Direct
Long-term loss of habitat due to the presence of turbine foundations, scour protection and cable protection	Operation and Maintenance	Direct
Colonisation of hard substrate	Operation and Maintenance	Indirect

Potential Impact	Phase	Nature of Impact
Increased risk of introduction and/or spread of INNS due to vessel traffic	Operation and Maintenance	Indirect
Electromagnetic fields (EMF) effects arising from cables during operational phase	Operation and Maintenance	Indirect
Impacts arising from operational UWN	Operation and Maintenance	Indirect
Mortality, injury, behavioural impacts and auditory masking arising from noise and vibration	Decommissioning	Direct
Temporary increases in SSC and sediment deposition	Decommissioning	Direct
Temporary habitat disturbance	Decommissioning	Direct
Direct and indirect seabed disturbance leading to release of sediment contaminants	Decommissioning	Direct and indirect

Table 5-16: Basking Shark Scope of Assessment

Potential Impact	Phase	Nature of Impact
UWN from pile-driving	Construction	Direct
UWN from unexploded ordnance (UXO) clearance	Construction	Direct
UWN from other construction activities	Construction	Direct
Vessel collisions	Construction	Direct
Vessel disturbance	Construction	Direct
Indirect impacts on prey	Construction	Indirect
Water quality changes	Construction	Direct
Vessel collisions	Operation and Maintenance	Direct
Vessel disturbance	Operation and Maintenance	Direct
Indirect impacts on prey	Operation and Maintenance	Indirect
Electromagnetic fields (EMF) effects arising from cables during operational phase	Operation and Maintenance	Direct

Potential Impact	Phase	Nature of Impact
Operational noise	Operation and Maintenance	Direct
Entanglement	Operation and Maintenance	Direct
Long term displacement/habitat loss/barrier effects	Operation and Maintenance	Direct
UWN from other decommissioning activities	Decommissioning	Direct
Vessel collisions	Decommissioning	Direct
Vessel disturbance	Decommissioning	Direct
Indirect impacts on prey	Decommissioning	Indirect
Water quality changes	Decommissioning	Direct

5.5.3 Impacts Scoped out of the Assessment

5.5.3.1 The impacts scoped out of the assessment during EIA scoping for fish and shellfish ecology, and the justification for this, are provided in Table 5-17. The impacts scoped out of the assessment during EIA scoping for basking shark, and the justification for this, are provided in Table 5-18.

Table 5-17: Impacts scoped out for fish and shellfish ecology.

Potential Impact	Justification
Direct damage (e.g., crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from construction activities (Construction)	Affected species are likely to be mobile and can move away from disturbance. The habitats that will be disturbed represent a very small area of the study area.
Accidental pollution events resulting in potential effects on fish and shellfish receptors (Construction)	The magnitude of an accidental spill will be limited by the size of chemical or oil inventory on construction vessels. In addition, released hydrocarbons would be subject to rapid dilution, weathering and dispersion and would be unlikely to persist in the marine environment. The likelihood of an incident will be reduced by implementation of an Environmental Management Plan (EMP) and Marine Pollution Contingency Plan (MPCP). See embedded mitigation in Section 5.5.4.

Potential Impact	Justification
Accidental pollution events resulting in potential effects on fish and shellfish receptors (Operation and Maintenance)	The magnitude of an accidental spill will be limited by the size of chemical or oil inventory on O&M vessels. In addition, released hydrocarbons would be subject to rapid dilution, weathering and dispersion and would be unlikely to persist in the marine environment. The likelihood of an incident will be reduced by implementation of an EMP and MPCP. See embedded mitigation in Section 5.5.4.

Table 5-18: Impacts scoped out for basking shark.

Potential Impact	Justification
Accidental pollution (Construction, Operation and Maintenance, Decommissioning)	Accidental releases of pollutants may arise as a result of accidental spills from vessels or other equipment. Any release is likely to facilitate high dispersal and there will be limited interaction with basking sharks. With the implementation of an EMP and MPCP, accidental spillages from machinery (which may have potential to cause mortality among basking sharks) are unlikely to occur. Any impact is predicted to be of local spatial extent, short-term duration, intermittent frequency and reversible, within the context of regional basking shark populations. See embedded mitigation in Section 5.5.4.

5.5.4 Embedded Mitigation

5.5.4.1 Where possible, mitigation measures have been embedded into the design of the Proposed Development (Offshore) applications, specifically Caledonia North and Caledonia South. Where embedded mitigation measures have been developed into the design with specific regard to fish and shellfish ecology (and basking shark), these are described in Table 5-19. The impact assessment presented in Sections 5.7 to 5.10 take into account this embedded mitigation.

Table 5-19: Embedded mitigation.

Code	Mitigation Measure	Securing Mechanism
M-1	Development of and adherence to a Cable Plan (CaP). The CaP will confirm planned cable routing, burial and any additional protection and will set out methods for post-installation cable monitoring.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South.
M-3	Development of and adherence to a Construction Method Statement (CMS). The CMS will confirm construction methods and the roles and responsibilities of parties engaged in construction. It will detail any construction-related mitigation measures.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South.
M-5	Where practicable, cable burial will be the preferred means of cable protection. Cable burial will be informed by the cable burial risk assessment and detailed within the CaP.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South
M-7	Suitable implementation and monitoring of cable protection (via burial, or external protection where adequate burial depth as identified via risk assessment is not feasible), as detailed within the CaP.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South
M-8	Development of and adherence to an Offshore Environmental Management Plan (EMP). The EMP will set out mitigation measures and procedures relevant to environmental management, including but not limited to the following topics: entanglement, chemical usage, invasive non-native marine species, dropped objects, pollution prevention and contingency planning, and waste management.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South.
M-9	Development of and adherence to a Marine Pollution Contingency Plan (MPCP). The MPCP will identify potential sources of pollution and associated spill response and reporting procedures.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South.

Code	Mitigation Measure	Securing Mechanism
M-10	Development of and adherence to a Decommissioning Programme (DP). The DP will outline measures for the decommissioning of the Proposed Development (Offshore).	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South.
M-11	Development of and adherence to a Piling Strategy (PS) (applicable where piling is undertaken). The PS will detail the method of pile installation and associated noise levels. It will describe any mitigation measures to be put in place (e.g., soft starts and ramp ups, use of Acoustic Deterrent Devices) during piling to manage the effects of underwater noise on sensitive receptors.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South.
M-12	Development of and adherence to a Project Environmental Monitoring Programme (PEMP). The PEMP will set out commitments to environmental monitoring in pre-, during and post-construction phases of the Proposed Development (Offshore).	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South.
M-13	Development of and adherence to a Vessel Management Plan (VMP). The VMP will confirm the types and numbers of vessels that will be engaged on the Proposed Development (Offshore), and consider vessel coordination including indicative transit route planning.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South.
M-14	Development of and adherence to a Lighting and Marking Plan (LMP). The LMP will confirm compliance with legal requirements with regards to shipping, navigation and aviation marking and lighting.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South.
M-16	Development of and adherence to Marine Mammal Mitigation Plan (MMMP). This will identify appropriate mitigation measures during offshore activities that are likely to produce underwater noise and vibration levels capable of potentially causing injury or disturbance to marine mammals. This will be developed alongside the PS and referred to in European Protected Species (EPS) licence applications.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South.

Code	Mitigation Measure	Securing Mechanism
M-74	Pre-construction surveys will identify potential UXO hazards within the boundaries of the Proposed Development (Offshore), with UXO removal/clearance activities, and/or construction micro-siting and cable re-routing, undertaken as required.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South.
M-106	Landfall installation methodology (Horizontal Directional Drilling) will avoid direct impacts to the intertidal area.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South
M-107	Unexploded ordnance (UXO) hazards will be avoided where practicable and appropriate. If avoidance is not possible, decision making will relate to removal, with disposal *in-situ* considered if avoidance or removal is not possible. If disposal is required, and where practicable and appropriate, low-order deflagration will be the preferred method.	To be secured as a condition of the Generation Asset and Transmission Asset Marine Licences for both Caledonia North and Caledonia South

5.6 Key Parameters for Assessment

5.6.1.1 Volume 1, Chapter 3: Proposed Development Description (Offshore) details the parameters of the Proposed Development (Offshore) using the Rochdale Envelope approach. This section identifies those parameters during construction, operation and decommissioning relevant to potential impacts on fish and shellfish ecology and basking sharks.

5.6.1.2 The worst-case scenario assumptions regarding fish and shellfish ecology are summarised in Table 5-20. The worst-case scenario assumptions regarding basking sharks are summarised in Table 5-21.

Table 5-20: Fish and shellfish ecology worst-case scenario considered for each impact as part of the assessment of likely significant effects.

Potential Impact	Assessment Parameter	Explanation
Construction		
Impact 1: Mortality, injury and behavioural changes resulting from UWN	**Spatial worst-case scenario:** *Cumulative Sound Exposure Level* Concurrent piling of eight pin pile foundations at two locations in a 24-hour period represents the worst-case scenario for the cumulative sound exposure level (SEL_{cum}) for the remaining SEL_{cum} thresholds (mortality and potential mortal injury, recoverable injury and Temporary Threshold Shift (TTS) for each receptor group) (both stationary and fleeing). This is comprised of: - 140 WTGs on pin pile foundations (4m diameter pin piles per jacket) = 560 pin piles; - Four OSPs on pin pile foundations (4m diameter pin piles) = 16 pin piles; and - Maximum hammer energy 4,400 kJ (186 dB SEL_{cum} produces a maximum impact range of 14,000km^2). *Peak Sound Pressure Level* Additionally, the concurrent piling of two monopile foundations at two locations within a 24-hour period at multiple locations represent the greatest spatial impact range for fish and shellfish for peak sound pressure levels (SPL_{peak}) for mortality injury ranges (213 dB SPL_{peak} and 213 dB SPL_{peak}) as well as the cumulative sound exposure level (SEL_{cum}) for recoverable injury for fleeing receptors (203 dB SEL_{cum}). This is comprised of:	In a 24-hour period, it is expected that two anchor pile foundations, two monopiles or four multi-leg pile foundations can be installed sequentially from the same piling vessel, which has been taken into consideration for the modelling. There is also the possibility that two piling vessels could be operational and piling concurrently across the Caledonia OWF. It should be noted that both SEL_{cum} and SPL_{peak} can be used to assess the risk of potential lethal and sub-lethal effects, as both metrics describe different characteristics of sound waves. The standard approach is to use SEL_{cum} values to account for the duration of piling and any associated effects on TTS and TTS-induced changes in fitness. The spatial worst-case scenario is represented by the sequential piling of four pin piles in a 24-hour period. This was provided by the model results of sequential piling of four pin piles at UWN modelling location CAL01 concurrently with four pin piles at UWN modelling location CAL08. Full details are presented in Volume 7, Appendix 6. The temporal worst-case scenario represents the longest duration of effects from subsea noise and is from the piling of a up to four pin piles or two anchor piles in a 24-hour period.

<table>
<tr><th>Potential Impact</th><th>Assessment Parameter</th><th>Explanation</th></tr>
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140 WTGs on monopile foundations (5m diameter monopile) = 140 monopiles.
Four OSPs on monopile foundations (5m diameter monopiles) = 4 monopiles.
Maximum hammer energy 6,600 kJ (186 dB SEL_{cum} produces a maximum impact range of 11,000km^2).

Temporal worst-case scenario:
Sequential Piling of pin piles for bottom-fixed foundations (jackets) and anchor pin piles for floating foundations (tension leg platforms). This is comprised of:

101 WTGs and 4 OSPs on jacket with pin pile foundations (4m diameter pin piles per jacket) = 420 pin piles (four pin piles per jacket);

Maximum hammer energy 4,400 kJ (186 dB SEL_{cum} (St) 14,000km^2);
Four pin piles per day;
105 piling days;

39 WTGs on floating foundations (tension leg platform) with pin piles for anchors (4.8m diameter of anchor) = 702 anchors (18 anchors per WTG);

Maximum hammer energy 2,000 kJ;
Max two pin piles per day;
410 piling days (assumes average of 1.71 anchor/day)

515 piling days (over an approximate 18 month piling period); and
Cumulative sound exposure level (SEL_{cum}) for the remaining SEL_{cum} thresholds; mortality and potential mortal injury, and recoverable injury and TTS for each receptor group.

</td><td>
The worst-case scenario for UXO is based on the Applicant's experience from Moray East and Moray West OWFs. A detailed UXO survey will be completed prior to construction. The type, size and number of possible low order clearances (deflagration) and duration of UXO clearance operations is therefore not known at this stage.

Other seabed clearance and installation activities such as cable laying, dredging and vessel movements may introduce an effect receptor pathway for UWN, however these activities are established as producing low levels of noise, in the case of vessel movement no greater than the existing baseline of regional vessel noise, affecting a relatively small area in the immediate vicinity of activities. These general activities are therefore considered to fall within the worst-case scenario associated with piling and as such are not considered separately.
</td></tr>
</table>

Potential Impact	Assessment Parameter	Explanation
	UXO clearance: ▪ Two clearance events within 24 hours; and ▪ Undertaken over a 12-month period.	
Impact 2: Temporary Increases in suspended sediment concentrations (SSCs)	**Construction/installation:** ▪ Dredging of WTG and OSP foundations: o 140 jacket with suction caissons WTG foundations; o The volume of sediment disturbed per WTG is estimated at 90,750m^3, which corresponds to a total of 12,705,000m^3; o Four OSPs with suction caissons foundations; o The volume of sediment disturbed per OSP is anticipated to be 90,750m^3, which corresponds to a total of 363,000m^3; o Overall total sediment disturbed by dredging = **13,068,000m^3** (WTG and OSP foundations). ▪ 140 inter-array cables with a total length of 655km; o Affected seabed width of 15m; o Burial depth of 3m; o Jet trencher installation method; and o Assumed installation rate of 700m/hr. o Total volume of disturbance = **29,475,000m^3**. ▪ Two interconnector cables with a total length of 60km; o Affected seabed width of 15m; o Burial depth of 3m; o Jet trencher installation method; and o Assumed installation rate of 700m/hr; o Total volume of disturbance = **2,700,000m^3**. ▪ Four offshore export cables with a total length of 330km; o Affected seabed width of 15m;	The worse-case-scenario for sediment disturbance activities will be temporally and spatially variable (depending upon the metocean conditions at the time). For sediment plumes, the worse-case-scenario is intended to be representative in terms of peak concentration, plume extent and plume duration but will not correspond to a single sediment disturbance activity (see details in Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report). The same applies for sediment deposition at the bed, where the worse-case scenario is a representation of maximum deposit thickness, maximum footprint extent or likely duration. The creation of biogenic reef is not expected to result in any increases in SSC. Seabed preparation works would be required prior to installation. The use of a Trailer Suction Hopper Dredger (TSHD) is considered to be the realistic worst-case scenario option. Sediment volumes disturbed through seabed levelling are greatest for WTGs and OSPs with suction caisson foundations. It is noted that the drilling of monopile WTG and OSP foundations could give rise to increased SSCs, however the worst-case scenario in terms of maximum temporary disturbance has been

Potential Impact	Assessment Parameter	Explanation
	o Burial depth of 3m; o Assumed installation rate of up to 700m/hr; o Sandwave clearance via dredging within the Caledonia OWF; o Total volume of disturbance = **14,850,000m³**. ▪ HDD drilling fluid release: o Volume and mass of drilling fluid released per HDD conduit: 450m³; o Number of HDD conduits: 4; and o Total volume and mass of drilling fluid released = **1,800m³**.	assumed to be dredging associated with the installation of jacket with suction caisson foundations. The greatest volume of drill arisings from a single foundation location is associated with monopiles for the OSPs. The greatest volume of drill arisings for the entire Caledonia OWF (i.e., Array Area) is associated with a layout comprising of 140 monopiles. Although, the volumes of material released via drilling is less than for seabed preparation via dredging, drilling has the potential to release larger volumes of relatively finer sediment. Cable installation may require some combination of jetting, ploughing, trenching and/or cutting type installation techniques. The realistic worst-case scenario option is the use of jet trenching methods, which develops the largest trench cross-section with the greatest potential to displace fine sediments into the water column to the same height as the depth of the trench. The fastest trenching rate of 700m/hr represents the highest release rate of sediments operating in locations with the largest contribution of fine sediments. HDD operations are expected to have localised and short-term effects on SSC concentrations due to the potential release of bentonite during punch-out in the nearshore exit pit. The period of release for bentonite is estimated to be 12 hours to accommodate both initial punch-out and the subsequent reaming processes.

Potential Impact	Assessment Parameter	Explanation
		Accordingly, the release rate has been estimated at 3,195g/s over this period. The assessment of sandwave clearance requirements for the Caledonia OWF and Caledonia OECC have been considered separately in Volume 2, Chapter 2: Marine and Coastal Processes.
Impact 3: Temporary habitat loss and disturbance	Maximum temporary habitat disturbance within the Proposed Development (Offshore) = **17,603,592m²**. **Caledonia OWF:** ▪ Foundation seabed drilling = 1,656,000m² o 140 WTGs (jacket foundations with suction caissons (including scour protection)) = 1,610,000m² o Four OSPs (jacket foundations with suction caissions (including scour protection)) = 46,000m² ▪ Jack-up Vessels (JUVs) and anchoring operations= 272,160m² o Maximum seabed footprint for JUVs (264,600m² (140 WTGs) and 7,560m² (four OSPs)) = 272,160m² ▪ Cable seabed preparation and installation in the Array Area = 10,725,000m² o Maximum total area of seabed disturbed by installation of 140 inter-array cables (total length = 655km) = 9,825,000m² o Maximum total area of seabed disturbed by installation of two interconnector cables (total length = 60km) = 900,000m² **Caledonia OECC:**	The temporary disturbance relates to seabed preparation for foundations and cables, jack up and anchoring operations, and cable installation. It should be noted that where boulder clearance overlaps with sandwave clearance, the boulder clearance footprint will be within the sandwave clearance footprint and therefore not counted twice. For foundations (WTGs and OSPs), jacket foundations with suction caissons have been selected and assessed as the worst-case scenario due to having the largest footprint of all the foundation types. The worst-case design scenario presents a precautionary approach to temporary habitat disturbance because it counts both the total footprint of seabed clearance as well as cable burial across both the Caledonia OWF and Caledonia OECC. This approach effectively counts the footprint of seabed habitat to be impacted by construction in the same area twice. However, this precautionary approach has been taken because there is some potential for recovery of habitats between the activities due to timescales for the construction.

Potential Impact	Assessment Parameter	Explanation
	▪ Cable seabed preparation and installation in the OECC = 4,950,432m^2 o Maximum total area of seabed disturbed by installation of offshore export cables (total length = 330km) = 4,950,000m^2 o HDD installation will require four HDD pits (15m x 6m x 1.2m), the maximum area of four HDD pits = 432m^2.	Given the extensive rocky habitat and exposed bedrock features at Stake Ness Landfall Site (see Volume 7B, Appendix 4-5: Intertidal Survey Report), it is anticipated that the HDD punch-out location will be situated within the shallow subtidal (likely between 10m and 40m water depths). It is not envisaged that cofferdams will be required at the HDD punch-out locations, and it is considered unlikely that access to the foreshore at Stake Ness Landfall Site will be required.
Impact 4: Direct and indirect seabed disturbance leading to release of sediment contaminants	Refer to Impact 2.	The worst-case scenario represents the maximum total seabed disturbance and therefore the maximum amount of contaminated sediment that may be released into the water column during construction activities.
Impact 5: Increased risk of introduction and/or spread of INNS	▪ Increased risk of introduction or spread of INNS by construction vessel movements: o 3,992 vessel movements during the construction period.	Maximum number of vessel movements during the contractional phase. It should be noted that not all vessel movements will have equal potential for the increased risk of introduction and/or spread of INNS. For example, JUVs traveling from other regions pose more of a risk than crew transfer vessels (CTVs) going to and from local ports.
Operation and Maintenance		
Impact 6: Temporary habitat loss and disturbance	Total direct disturbance to seabed from maintenance activities = **815,800m^2**. **Caledonia OWF:**	The worst-case scenario is defined by the maximum area of habitat disturbance arising from maintenance activities during the 35-year operational phase. The worst-case scenario is defined by the maximum number of jack-up and

Potential Impact	Assessment Parameter	Explanation
	▪ WTG repairs = **113,400m²**: o Total seabed disturbance by JUV events for WTG maintenance (1,890m2 disturbance per JUV event x 60 JUV events) = 113,400m2. ▪ Inter-array cable repair and replacement activities = **389,000m²**: o Seabed disturbance per major fault for inter-array cable maintenance (1,890m2 footprint per JUV x 10 JUV events) = 18,900m2 of disturbance per major fault; o 1km of cable replacement per major fault = 20,000m2; o Estimated number of major faults: 10. **Caledonia OECC:** ▪ Offshore export cable repair and replacement activities = **313,400m²**: o Seabed disturbance per major fault for offshore export cable maintenance (1,890m² disturbance per JUV x 6 JUV events) = 11,340m² per major fault. o 1km of offshore export cable replacement per major fault = 20,000m²; o Estimated number of major faults: 10.	anchoring operations and the total cable replacement and repairs through maintenance activities that could have an interaction with the seabed during operation. The operation and maintenance strategy is not yet defined, so the values given are predicted from previous experience. A precautionary estimate assumes: ▪ 60 WTG maintenance events; ▪ 10 major events for inter-array cables; ▪ 10 JUV events to repair one major inter-array cable fault (the length of repair will be 1km of cable replaced); ▪ 10 major events for offshore export cables; and ▪ 6 JUV events to repair one major offshore export cable fault (the length of repair will be 1km of cable replaced).
Impact 7: Long-term loss of habitat due to the presence of turbine foundations, scour protection and cable protection	Maximum long-term habitat loss/alteration = **9,366,000m²**. ▪ Maximum WTG footprints and scour protection = **1,656,000m²**: o Turbine total structure footprint including scour protection, based on 140 jacket foundations with suction caissons = 1,610,000m²; o Structure footprint of four OSPs (jacket foundations) = 46,000m².	The worst-case design scenario is defined by the maximum area of seabed lost by the footprint of anchors on the seabed, OSP foundations, scour and cable protection, and cable crossings. Habitat loss from drilling and drill arisings is of a smaller magnitude than presence of infrastructure. There is the potential for the introduction of localised seabed abrasion associated with OWF infrastructure that moves, for example anchor or

Potential Impact	Assessment Parameter	Explanation
	▪ Maximum cable protection footprint in the Caledonia OWF = **4,362,000m²**: o Maximum total area of seabed covered by cable protection for inter-array cables (based on cable protection being required for 196.5km of the inter-array cables) = 3,930,000m²; o Maximum total area of seabed covered by cable protection for interconnector cables (based on cable protection being required for 18km of the interconnector cables) = 360,000m²; o Total area of seabed covered by cable protection for inter-array cable crossings (based on 20 (150m x 20m) cable crossings) = 60,000m²; o Total area of seabed covered by cable protection for interconnector cable crossings (based on four (150m x 20m) cable crossings) = 12,000m². ▪ Maximum cable protection footprint in the Caledonia OECC = **3,348,000m²**: o Maximum total area of seabed covered by cable protection for offshore export cables (based on cable protection being required for 165km of the offshore export cables) = 3,300,000m²; and o Total area of seabed covered by cable protection for offshore export cable crossings (based on 16 (150m x 20m) cable crossings) = 48,000m².	mooring chains and dynamic inter-array cables, under the influence of waves, currents, and movement of the turbines ('strimmer effects'). However, the worst-case scenario in terms of habitat loss/alteration has been assumed to be associated with the installation of jacket with suction caisson foundations. Worst-case scenario footprints for cable protection have been determined based on: ▪ Up to 30% of cable protection being required for the inter-array cables; ▪ Up to 30% of cable protection being required for the interconnector cables; and ▪ Up to 50% of cable protection being required for the offshore export cables.
Impact 8: Introduction/ colonisation of hard substrate	Total surface area of introduced hard substrates = **10,162,205m²**. ▪ Hard substrates in the water column = **796,205m²**: o 140 WTGs and four OSPs, jackets with suction caissons (144 towers total), each with a radius of 2.5m, within a	The worst-case design scenario is defined by the maximum area of structure, introduced into the water column, including mooring lines, floating platforms, and dynamic cables. Man-made substructures such as WTG and OSP foundations and any associated scour/cable protection on the seabed are expected to be colonised by marine

Potential Impact	Assessment Parameter	Explanation
	maximum water depth of 88m, giving a per tower surface area of 5,529.20m², with a total area of 796,205m². ▪ Hard substrates on the seabed = **9,366,000m²**: o Total surface area of scour protection for 140 WTGs and four OSPs (144 total jacket foundations with suction caissons) = 1,656,000m²; o Total surface area of cable protection in the Caledonia OECC = 3,348,000m²; and o Total surface area of cable protection in the Caledonia OWF = 4,362,000m².	organisms. This colonisation is expected to result in an increase in local biodiversity and alterations to the near field benthic ecology of the area.
Impact 9: Increased risk of introduction and/or spread of INNS	Total surface area of introduced hard substrates = **10,162,205m²** (refer to Impact 8). Increased risk of introduction or spread of INNS by operational vessel movements: ▪ Daily crew transfer vessel (CTV) trips, with two CTVs, plus weekly service operation vessel movements; ▪ 938 vessel movement annually; and up to ▪ 25 vessels on-site simultaneously (in the case of major maintenance).	Maximum surface area created by offshore infrastructure in the water column and maximum number of vessel movements during the operational phase.
Impact 10: Electromagnetic fields (EMF) effects arising from cables	▪ 140 inter-array cables: o 655km combined length, operating at up to 132kV; o Minimum cable burial depth: 1m; ▪ Two interconnector cables: o 60km combined length, operating at up to 275kV; o Minimum cable burial depth: 1m; ▪ Four offshore export cables: o 330km combined length, operating at up to 275kV;	The maximum length and operating current of inter-array (including dynamic), interconnector and offshore export cables will result in the greatest potential for EMF effects. The minimum target cable burial depth represents the worst-case scenario as EMF exposure will be reduced with greater burial depth. Dynamic inter-array cables represent the worst-case scenario for EMF due to being suspended in

Potential Impact	Assessment Parameter	Explanation
	o Minimum cable burial depth: 1m; and ▪ Operational lifetime of the Proposed Development (Offshore): 35 years.	the water column and having a greater attenuation of EMF compared to buried cables.
Impact 11: Effects arising from UWN	**Operation of (noise from):** ▪ 140 WTGs: o 234 mooring lines (39 WTGs with semi-submersible platform foundations, each with 6 mooring lines); and ▪ Four OSPs.	There are no reliable noise thresholds that would be recommended to identify disturbance for rare/intermittent impulses of this type. Mooring lines associated with floating WTGs have been described as producing a "snapping" noise related to tension release. As any snapping occurs at an average rate of less than one snap per hour, disturbance leading to avoidance behaviour is considered unlikely. The semi-submersible foundation specifications per WTG provided are the worst-case scenario in this instance, as it is not a taut system.
Decommissioning		
Impact 12: Mortality, injury and behavioural changes resulting from UWN	The worst-case design scenario will be equal to (or less than) that of the construction phase. Refer to Impact 1.	The worst-case design scenario assumes complete removal of all infrastructure, including cables and cable protection where it is possible and appropriate to do so. If any infrastructure is left *in situ*, this will result in reduced disturbance during decommissioning. It should be noted that there will be no piledriving activities (which represent the worst-case scenario for UWN) during decommissioning and, therefore, effects from UWN will be significantly lower compared to the construction phase.

Potential Impact	Assessment Parameter	Explanation
Impact 13: Temporary Increases in suspended sediment concentrations (SSCs) and changes to seabed levels	The worst-case design scenario will be equal to (or less than) that of the construction phase. Refer to Impact 2.	The worst-case design scenario assumes complete removal of all infrastructure, including cables and cable protection, where it is possible and appropriate to do so. If any infrastructure is left *in situ*, this will result in reduced levels of suspended sediment and associated deposition during decommissioning.
Impact 14: Temporary habitat disturbance	The worst-case design scenario will be equal to (or less than) that of the construction phase. Refer to Impact 3.	The worst-case design scenario assumes complete removal of all infrastructure, including cables and cable protection where it is possible and appropriate to do so. If any infrastructure is left *in situ*, this will result in reduced areas of temporary habitat disturbance during decommissioning.
Impact 15: Direct and indirect seabed disturbance leading to release of sediment contaminants	The worst-case design scenario will be equal to (or less than) that of the construction phase. Refer to Impact 4.	The worst-case design scenario assumes complete removal of all infrastructure, including cables and cable protection, where it is possible and appropriate to do so. If any infrastructure is left *in situ*, this will result in reduced levels of sediment disturbance during decommissioning.

Table 5-21: Basking shark worst-case scenario considered for each impact as part of the assessment of likely significant effects.

Potential Impact	Assessment Parameter	Explanation
Construction		
Impact 1: UWN from pile-driving	**Spatial worst-case scenario:** Concurrent piling of eight pin pile foundations at two locations at two locations in a 24-hour period represents the worst-case scenario. This is comprised of: - 140 WTGs on pin pile foundations (4m diameter pin piles per jacket) = 560 pin piles; - Four OSPs on pin pile foundations (4m diameter pin piles) = 16 pin piles; and - Maximum hammer energy 4,400 kJ. **Temporal worst-case scenario:** Sequential piling of pin piles for bottom-fixed foundations (jackets) and anchor pin piles for floating foundations (tension leg platforms). This is comprised of: - 101 WTGs and 4 OSPs on jacket with pin pile foundations (4m diameter pin piles per jacket) = 420 pin piles (four pin piles per jacket); o Maximum hammer energy 4,400 kJ (186 dB SEL_{cum} (St) 14,000km^2); o Four pin piles per day; o 105 piling days; - 39 WTGs on floating foundations (tension leg platform) with pin piles for anchors (4.8m diameter of anchor) = 702 anchors (18 anchors per WTG); o Maximum hammer energy 2,000 kJ; o Max two pin piles per day; o 410 piling days (assumes average of 1.71 anchor/day)	In a 24-hour period, it is expected that two anchor pile foundations, or four multi-leg pile foundations can be installed sequentially from the same piling vessel, which has been taken into consideration for the modelling. There is also the possibility that two piling vessels could be operational simultaneously across the Caledonia OWF. The spatial worst-case scenario is represented by concurrent piling. This was provided by the model results of sequential piling of four pin piles at UWN modelling location CAL01 concurrently with four pin piles at UWN modelling location CAL08. Full details are presented in Volume 7, Appendix 6. The temporal worst-case scenario represents the longest duration of effects from subsea noise and is from the sequential piling of a up to four pin piles or two anchor piles in a 24-hour period (no concurrent piling). It should however be noted that assessment of a stationary receptor is highly precautionary; therefore, the results of the fleeing receptor model will be presented for comparison.

Potential Impact	Assessment Parameter	Explanation
	▪ 515 piling days (approximately 18 months piling period)	
Impact 2: UWN from unexploded ordnance (UXO) clearance	**UXO clearance:** ▪ Two clearance events within 24 hours; and ▪ Undertaken over a 12-month period.	The worst-case scenario for UXO is based on the Applicant's experience from Moray East and Moray West OWFs. A detailed UXO survey will be completed prior to construction. The type, size and number of possible clearances and duration of UXO clearance operations is therefore not known at this stage.
Impact 3: UWN from other construction activities	▪ Sequential construction of application areas (i.e., Caledonia North and Caledonia South): ▪ Installation of cables by jet trenching, mechanic trenching and/or cable ploughing, along with dredging, drilling, and rock placement activities undertaken on a 24-hour/7-day basis; and ▪ Works duration of 30 months.	The longest duration of other construction activities was considered as the worst-case scenario with greatest UWN impact.
Impact 4: Vessel collisions	**Vessel movements:** ▪ Total of 3,992 vessel movements: o 280 return trips for WTG foundation piling; o 397 return trips for WTG installation; o 793 return trips for WTG commissioning; o 560 return trips for construction of substructures; o 1,450 return trips for installation and hook-up of cables; o 396 return trips for OSP installation (foundation, substructure and topside); and o 116 return trips for installation of offshore export cables. ▪ Maximum number of vessels on site at once: 25.	The maximum number of vessels and associated vessel operations represents the maximum risk of vessel collisions.

Potential Impact	Assessment Parameter	Explanation
Impact 5: Vessel disturbance	Refer to Impact 4.	The maximum number of vessels and associated vessel operations represents the maximum potential for UWN disturbance from vessels.
Impact 6: Indirect impacts on prey	Refer to Impacts 1 to 5 in Table 5-20.	The worst-case scenario presented for fish and shellfish ecology represents the maximum potential for indirect impact on prey.
Impact 7: Water quality changes	Refer to Impact 1 in Volume 2, Chapter 2: Marine and Coastal Processes.	The worst-case scenario considering the maximum number of cables, burial depth, volume of sandwave clearance and installation is assumed to result in the highest concentration of suspended solids and, therefore, present the worst-case scenario for the proposed construction activities in the Caledonia OWF and Caledonia OECC.
Operation and Maintenance		
Impact 8: Vessel collisions	▪ Maximum number of vessels on site at one time during the operation phase: One Service Operation Vessel (SOV) and two Crew Transfer Vessels (CTVs), with up to five vessels where maintenance is unplanned; and ▪ Indicative vessel movements during the operation phase: 104 SOV movements per year and 365 CTV movements per year per CTV. ▪ 938 vessel movements annually throughout the 35-year operational lifespan of the Proposed Development (Offshore).	The maximum number of vessels and associated vessel operations represents the maximum risk of vessel collisions.
Impact 9: Vessel disturbance	Refer to Impact 8.	Refer to Impact 8.

Potential Impact	Assessment Parameter	Explanation
Impact 10: Indirect impacts on prey	Refer to Impacts 6 to 11 in Table 5-20.	The worst-case scenario presented for fish and shellfish ecology represents the maximum potential for indirect impact on prey.
Impact 11: Electromagnetic fields (EMF)	▪ 140 inter-array cables: o 655km combined length, operating at up to 132kV; o Minimum cable burial depth: 1m; ▪ Two interconnector cables: o 60km combined length, operating at up to 275kV; o Minimum cable burial depth: 1m; ▪ Four offshore export cables: o 330km combined length, operating at up to 275kV; o Minimum cable burial depth: 1m; and ▪ Operational lifetime of the Proposed Development (Offshore): 35 years.	The maximum length and operating current of inter-array (including dynamic), interconnector and offshore export cables will result in the greatest potential for EMF effects. The minimum target cable burial depth represents the worst-case scenario as EMF exposure will be reduced with greater burial depth. Dynamic inter-array cables represent the worst-case scenario for EMF due to being suspended in the water column and having a greater attenuation of EMF compared to buried cables.
Impact 12: Operational noise	**Operation of (noise from):** ▪ 140 WTGs: o 234 mooring lines (39 WTGs with semi-submersible platform foundations, each with 6 mooring lines); ▪ Four OSPs; and ▪ Operational lifespan of 35 years.	There are no reliable noise thresholds that would be recommended to identify disturbance for rare/intermittent impulses of this type. The scenario with maximum number of wind turbines and largest rotor diameter represents the worst-case scenario of operational WTG noise. Mooring lines associated with floating WTGs have been described as producing a "snapping" noise related to tension release. As any snapping occurs at an average rate of less than one snap per hour, disturbance leading to avoidance behaviour is considered unlikely. The semi-submersible foundation specifications per WTG provided are the

Potential Impact	Assessment Parameter	Explanation
		worst-case scenario in this instance, as it is not a taut system.
Impact 13: Entanglement	▪ Total cross section of mooring lines in water column = **45,000m²** for semi-submersible foundation. **Mooring parameters:** ▪ 234 mooring lines (six mooring lines per WTG); ▪ Total length of moorings 234km for catenary; ▪ Top section is chain, mid-section is fibre rope, bottom section is chain; ▪ The presence of the mooring lines and dynamic cables will be restricted to the Caledonia OWF only; and ▪ Operational lifetime of 35 years.	The scenario with maximum number and cross-section of mooring lines and inter-array cables represents the worst-case scenario of entanglement impact.
Impact 14: Long term displacement/habitat loss/barrier effects	Maximum long-term habitat loss/alteration = **9,366,000m²**. ▪ Maximum WTG footprints and scour protection = **1,656,000m²**: o Turbine total structure footprint including scour protection, based on 140 jacket foundations with suction caissons = 1,610,000m²; o Structure footprint of four OSPs (jacket foundations) = 46,000m². ▪ Maximum cable protection footprint in the Caledonia OWF = **4,362,000m²**: o Maximum total area of seabed covered by cable protection for inter-array cables (based on cable protection being required for 196.5km of the inter-array cables) = 3,930,000m²;	The worst-case design scenario is defined by the maximum area of seabed lost by the footprint of anchors on the seabed, OSP foundations, scour and cable protection, and cable crossings. Habitat loss from drilling and drill arisings is of a smaller magnitude than presence of infrastructure. There is the potential for the introduction of localised seabed abrasion associated with OWF infrastructure that moves, for example anchor or mooring chains and dynamic inter-array cables, under the influence of waves, currents, and movement of the turbines ('strimmer effects'). However, the worst-case scenario in terms of habitat loss/alteration has been assumed to be associated with the

Potential Impact	Assessment Parameter	Explanation
	o Maximum total area of seabed covered by cable protection for interconnector cables (based on cable protection being required for 18km of the interconnector cables) = 360,000m^2; o Total area of seabed covered by cable protection for inter-array cable crossings (based on 20 (150m x 20m) cable crossings) = 60,000m^2; o Total area of seabed covered by cable protection for interconnector cable crossings (based on four (150m x 20m) cable crossings) = 12,000m^2. ▪ Maximum cable protection footprint in the Caledonia OECC = **3,348,000m^2**: o Maximum total area of seabed covered by cable protection for offshore export cables (based on cable protection being required for 165km of the offshore export cables) = 3,300,000m^2; and o Total area of seabed covered by cable protection for offshore export cable crossings (based on 16 (150m x 20m) cable crossings) = 48,000m^2.	installation of jacket with suction caisson foundations. Worst-case scenario footprints for cable protection have been determined based on: ▪ Up to 30% of cable protection being required for the inter-array cables; ▪ Up to 30% of cable protection being required for the interconnector cables; and ▪ Up to 50% of cable protection being required for the offshore export cables.
Decommissioning		
Impact 15: Underwater noise	The worst-case scenario will be equal to (or less than) that of the construction phase. Refer to Impact 1, 2 and 3.	The worst-case design scenario assumes complete removal of all infrastructure, including cables and cable protection where it is possible and appropriate to do so. If any infrastructure is left *in situ*, this will result in reduced disturbance during decommissioning. It should be noted that there will be no piledriving activities (which represent the worst-case scenario for UWN) during decommissioning and, therefore, effects from

Potential Impact	Assessment Parameter	Explanation
		UWN will be significantly lower compared to the construction phase.
Impact 16: Vessel collisions	The worst-case scenario will be equal to (or less than) that of the construction phase. Refer to Impact 4.	The maximum number of vessels and associated vessel operations represents the maximum potential for UWN disturbance from vessels.
Impact 17: Vessel disturbance	The worst-case scenario will be equal to (or less than) that of the construction phase. Refer to Impact 5.	The maximum number of vessels and associated vessel operations represents the maximum potential for UWN disturbance from vessels.
Impact 18: Indirect impacts on prey	The worst-case scenario will be equal to (or less than) that of the construction phase. Refer to Impact 6.	The worst-case scenario presented for fish and shellfish ecology represents the maximum potential for indirect impact on prey.
Impact 19: Water quality changes	The worst-case scenario will be equal to (or less than) that of the construction phase. Refer to Impact 7.	The worst-case scenario considering the maximum number of cables, burial depth, volume of sandwave clearance and installation is assumed to result in the highest concentration of suspended solids and, therefore, present the worst-case scenario for the proposed construction activities in the Caledonia OWF and Caledonia OECC.

5.7 Potential Effects

Fish and Shellfish Ecology

5.7.1 Construction

5.7.1.1 This section presents the assessment of impacts arising from the construction phase of the Proposed Development (Offshore).

Impact 1: Mortality, Injury, Behavioural Impacts and Auditory Masking Arising from Noise and Vibration

5.7.1.2 The assessment below focuses on the potential impacts of UWN and its effects on fish and shellfish during construction of the Caledonia OWF. These include, impacts of UWN from pile-driving for the installation of foundations for offshore structures within the Caledonia OWF (i.e., WTGs, OSPs), and UXO clearance.

5.7.1.3 Impact piling modelling for various foundation types has been undertaken at four representative locations, with the loudest levels of noise and the greatest impact ranges predicted for the multi-leg jacket foundation scenario at the easternmost corner of the site, due to the deep water at, and surrounding, this location.

5.7.1.4 To inform the assessment of potential impacts associated with UWN from installation of foundations, predictive UWN modelling has been undertaken for the relevant piling WCS, full details of which are presented in Volume 7, Appendix 6: Underwater Noise Assessment.

5.7.1.5 The spatial and temporal WCS for UWN impacts from foundation installation (pilling of bottom-fixed pin piles and monopiles and floating semi-submersible foundations and tension leg platform foundations), are defined according to a maximum scenario (i.e., the maximum design parameters that may be utilised during the construction of the Proposed Development (Offshore)). In this context it is important to note that the maximum hammer energies assumed in the WCS are likely to be precautionary and that in fact for many piling events, a lesser hammer energy will be required to complete the pile installation (they represent the upper limit of the equipment, rather than the likely energy that will be required to install any given foundation).

5.7.1.6 The spatial WCS equates to the greatest area of effect from subsea noise during piling. The following scenario represents the spatial WCS:

- In combination effects as a result of the simultaneous sequential[iv] piling of eight pin piles in a 24-hour period, comprising the sequential piling of four pin piles at the northwest of the Caledonia OWF (UWN Modelling location CAL01) occurring simultaneously with the sequential piling of four pin piles at the southeast of the Caledonia OWF (UWN modelling location CAL08).

5.7.1.7 The temporal WCS represents the longest duration of effects from subsea noise. The following scenarios represent the temporal WCS:

- The installation of four pin piles for bottom-fixed foundations (jackets) in a 24 hour period or the instillation of two anchor pin piles for floating foundations (tension leg platforms) in a 24 hour period which equates to an approximate 18-month piling period (515 days of pilling).

5.7.1.8 For the purposes of the assessment, Volume 7, Appendix 6: Underwater Noise Assessment presents the impact ranges for fish and shellfish mortality and potential mortal injury, recoverable injury and for temporary auditory injury (i.e., TTS), which are shown for both the sequential and sequential simultaneous installation of monopiles and pin-piles against their respective maximum hammer energy (6,600kJ and 4,400kJ).

5.7.1.9 The sequential piling of 140 WTGs and four OSPs on monopile foundations, represent the greatest spatial impact range for fish and shellfish for peak sound pressure levels (SPL_{peak}) for mortality injury ranges (213 dB SPL_{peak} and 213 dB SPL_{peak}) as well as the cumulative sound exposure level (SEL_{cum}) for recoverable injury for fleeing receptors (203 dB SEL_{cum}). See Table 5-24 for further detail.

5.7.1.10 The sequential piling of 140 WTGs and four OSPs on pin pile foundations represents the WCS for the cumulative sound exposure level (SEL_{cum}) for the remaining SEL_{cum} thresholds (mortality and potential mortal injury, recoverable injury and TTS for each receptor group) add detail and receptor responses (both stationary and fleeing). See Table 5-24 for further detail.

5.7.1.11 The UWN impact assessment has been broken down into each injury criteria for fish and shellfish and by each receptor group. The greatest impact ranges for each threshold criteria are therefore taken forward as the WCS for the assessment (see Table 5-24).

5.7.1.12 The modelling results for SEL_{cum} provide outputs for both fleeing receptors (with the receptors fleeing from the source at a consistent rate of $1.5ms^{-1}$), and stationary receptors to account for static demersal spawners such as sandeel and herring, and for non-mobile receptors such as eggs and larvae or slow-moving shellfish species (scallop).

[iv] The simultaneous sequential piling of up to eight pin piles in a 24-hour period, comprising the sequential piling of four pin piles at the northwest of Caledonia OWF (UWN Modelling location CAL 01) occurring simultaneously with the sequential piling of four pin piles at the southeast of Caledonia OWF (UWN modelling location CAL 08).

Injury Criteria

5.7.1.13 UWN can potentially have a negative impact on fish and shellfish species ranging from behavioural effects to physical injury/mortality. In general, biological damage as a result of sound energy is either related to a large pressure change (barotrauma) or to the total quantity of sound energy received by a receptor. Barotrauma injury can result from exposure to a high intensity sound even if the sound is of short duration (i.e., UXO clearance or a single strike of a piling hammer). However, when considering injury due to the energy of an exposure, the time of the exposure becomes important. Fish and shellfish are also considered to be sensitive to the particle motion element of UWN; an impact considered more important than sound pressure for many species, particularly invertebrates. However, research into this impact on fish populations is scarce, representing a source of uncertainty in the assessment process. Despite the lack of thresholds for particle motion, the criteria detailed within Popper *et al.* (2014[32]) remain the best available evidence to inform the assessment of underwater noise impacts to fish and shellfish (Popper and Hawkins, 2021[151]).

5.7.1.14 The fish IEFs within the study area have been grouped into the Popper *et al.* (2014[32]) categories based on their hearing system, as outlined in Table 5-22 below. It is important to note that there are differences in impact thresholds for the different hearing groups (Table 5-22). The Popper *et al.* (2014[32]) guidelines are recognised as a suitable reference for underwater noise impacts on marine fauna in UK waters. For each sound source, the marine fauna is categorised into groups of fish, sea turtles, and eggs and larvae. Due to their diversity and quantity, fish are categorised further into four groups depending on their hearing capabilities, which can be indicated by whether they possess a swim bladder or not, and whether the swim bladder is involved in hearing. Despite defining four groups, there are only three groupings for thresholds, due to "group 3" and "group 4" having the same thresholds.

Table 5-22: Hearing categories of fish receptors (Popper *et al.,* 2014[32]).

Category	IEFs relevant to the Proposed Development (Offshore)
Group 1 (least sensitive)	Lemon sole, plaice, sandeel, anglerfish, mackerel, thornback ray, spotted ray, blonde ray, common skate, spurdog, tope shark (*Galeorhinus galeus*), basking shark, river lamprey and sea lamprey.
Group 2	Atlantic salmon and sea trout.
Group 3 (most sensitive)	Herring, Cod, Sprat, Whiting, blue whiting, ling, Norway pouting, European eel, twaite shad, allis shad, haddock and European hake.
Eggs and larvae	Species with spawning grounds within the study area (cod, herring, plaice, sprat, whiting, sandeel and Nephrops).

5.7.1.15 UWN can result in a range of effects on fish and shellfish receptors (Popper *et al.* 2014[32]) as summarised in the following sections.

Mortality and Potential Mortal Injury

5.7.1.16 Instantaneous or delayed mortality. The potential for mortality or mortal injury is likely to only occur in extreme proximity to intense sounds and the risk of mortality or mortal injury occurring during piling will be reduced by use of soft start techniques, meaning mobile fish will move outside of the impact range before noise levels reach a level likely to cause irreversible injury.

Recoverable Injury

5.7.1.17 Recoverable injury is a survivable injury with full recovery occurring after exposure, although decreased fitness during the recovery period may result in increased susceptibility to predation or disease (Popper *et al.,* 2014[32]). The risk of this occurring will be reduced by use of soft start techniques at the start of the piling sequence, allowing mobile fish to move outside of the impact range.

Temporary Threshold Shift (TTS)

5.7.1.18 TTS is a temporary reduction in hearing sensitivity caused by exposure to intense sound or sounds of long duration (e.g., tens of minutes to hours). TTS has been demonstrated in some fishes, resulting from the loss or damage of sensory hair cells of the inner ear and/or damage to auditory nerves. However, sensory hair cells are constantly added to fishes and are replaced when damaged, and therefore the extent of TTS is of variable duration and magnitude. Normal hearing ability returns following cessation of the noise causing TTS, though this period is variable between species, lasting between a few hours to several days.

Behavioural Effects

5.7.1.19 Behavioural effects as a result of construction related underwater noise include a wide variety of responses including startle responses (C-turn), strong avoidance behaviour, changes in swimming or schooling behaviour, or changes of position in the water column (e.g., Hawkins *et al.,* 2014[152]). Depending on the intensity, timing and duration of exposure there is the potential for some of these responses to lead to significant effects at an individual level (e.g., reduced fitness, increased susceptibility to predation) or at a population level (e.g., interference with foraging, avoidance or delayed migration to key spawning grounds) (e.g., Popper and Hawkins, 2019[304]).

5.7.1.20 Popper *et al.* (2014[32]) provides separate criteria, depending on the species and the noise source, for the various impacts associated with noise exposure given above. Impact thresholds for pile driving are presented as both single strike, unweighted peak Sound Pressure Levels (SPLpeak) and cumulative unweighted Sound Exposure Levels (SELcum) (Table 5-23). SPLpeak represents the maximum sound energy level of individual impulse sounds measured as differential pressure from positive to zero. By contrast, SELcum is a measure of the accumulated sound energy an animal is exposed to over an exposure period. It takes account of repeated impulse sounds such as those emitted during pile driving (Popper *et al.,* 2014[32]). These dual criteria (SPLpeak and SELcum) have been referred to throughout to assess the risk of mortality or injury on marine receptors to multiple impulsive sounds.

5.7.1.21 Where insufficient data is available to define impact thresholds, Popper *et al.* (2014[32]) instead gives a qualitative description. This summarises the effect of the noise as having either a high, moderate or low relative risk of an effect on an individual in either near (tens of meters), intermediate (hundreds of meters) or far (thousands of meters) distances from the source. Most species described by Popper *et al.* (2014[32]) are likely to move away from a sound that is loud enough to cause harm (Popper *et al.,* 2014[32]). For those species that flee, a speed of 1.5m/s is considered a conservative speed at which to base a fleeing animal model. However, considering the diversity of species described by Popper *et al.* (2014[32]), whether an animal flees or remains stationary in response to a loud noise will differ between species.

5.7.1.22 In the case of shellfish, there are no specific impact criteria; therefore, an assessment has been based on a review of peer-reviewed literature on the current understanding of the potential effects of underwater noise on shellfish species, with a focus on the potential implications of particle motion associated with UWN.

Table 5-23: Criteria for pile driving (Popper *et al.,* 2014[32]).

Receptor	Mortality and Potential Mortal Injury	Impairment			Behaviour
		Recoverable Injury	TTS	Masking	
Group 1 Fish: no swim bladder	> 219 dB SEL_{cum} > 213 dB SPL_{peak}	> 216 dB SEL_{cum} > 213 dB SPL_{peak}	> 186 dB SEL_{cum}	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Group 2 Fish: swim bladder not involved in hearing	210 dB SEL_{cum} > 207 dB SPL_{peak}	203 dB SEL_{cum} > 207 dB SPL_{peak}	> 186 dB SEL_{cum}	(N) Moderate (I) Low (F) Low	(N) High (I) Moderate (F) Low
Group 3 Fish: swim bladder involved in hearing	207 dB SEL_{cum} > 207 dB SPL_{peak}	203 dB SEL_{cum} > 207 dB SPL_{peak}	186 dB SEL_{cum}	(N) High (I) High (F) Moderate	(N) High (I) High (F) Moderate
Eggs and larvae	> 210 dB SEL_{cum} > 207 dB SPL_{peak}	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low

WSC Impact Ranges

5.7.1.23 The noise modelling for injury ranges for fleeing and stationary fish is presented in the Underwater Noise Assessment (Volume 7, Appendix 6), and referred to as appropriate in the following assessments.

5.7.1.24 Table 5-24 summarises the WCS results for sequential piling and Table 5-25 summarises the WCS for simultaneous piling. The letters in parenthesis in Table 5-24 indicate which type of installation was responsible for the WCS. Generally, sequential piled monopile foundations (MP) resulted in the largest SEL_{peak} impact ranges, whilst sequential piling of pin-pile foundations (PP) resulted in the largest SEL_{cum} impact ranges. The exception was the recoverable injury SEL_{cum} (fleeing) which resulted from MP, as opposed to PP installation, although the ranges were of a similar scale.

Table 5-24: Underwater noise modelling results for injury ranges for fleeing and stationary receptors from the sequential piling of foundations scenarios within the Caledonia OWF.

Criteria	Noise Level (dB re 1µPa Sound Exposure Level (SEL)/dB re 1µPa2 Sound Exposure Level (SEL))	WCS Injury Ranges from Sequential Pilling of Monopile Foundations (MP) and Pin-Pile Foundations (PP)
Mortality and Potential Mortal Injury and Potentially Mortal Injury		
SPL_{peak}	213	140m (MP)
SPL_{peak}	207	380m (MP)
SEL_{cum} (static)	219	950m (PP)
SEL_{cum} (fleeing)	219	<100m (PP)
SEL_{cum} (static)	210	3800m (PP)
SEL_{cum} (fleeing)	210	<100m (PP)
SEL_{cum} (static)	207	5900m (PP)
SEL_{cum} (fleeing)	207	<100m (PP)
Recoverable Injury		
SPL_{peak}	213	130m (PP)
SPL_{peak}	207	340m (PP)
SEL_{cum} (static)	216	1500m (PP)
SEL_{cum} (fleeing)	216	<100m (PP)
SEL_{cum} (static)	203	10,000m (PP)

Criteria	Noise Level (dB re 1μPa Sound Exposure Level (SEL)/dB re 1μPa2 Sound Exposure Level (SEL))	WCS Injury Ranges from Sequential Pilling of Monopile Foundations (MP) and Pin-Pile Foundations (PP)
SEL_{cum} (fleeing)	203	950m (MP)
TTS		
SEL_{cum} (static)	186	64,000m (PP)
SEL_{cum} (fleeing)	186	45,000m (PP)

Table 5-25: Underwater noise modelling results for in-combination impact areas for fleeing and stationary receptors from the simultaneous piling of foundations within the Caledonia OWF.

Criteria	Noise Level (dB re 1µPa Sound Exposure Level (SEL)/dB re 1µPa2 Sound Exposure Level (SEL))	Multi-leg Piles Impact In-combination Area (Simultaneous Sequential Piling of up to Four Pin Piles at CAL01 and CAL08)
Mortality and Potentially Mortal Injury		
SEL_{cum} (static)	219 (Group 1)	6.3km^2
SEL_{cum} (fleeing)	219 (Group 1)	No in-combination effect
SEL_{cum} (static)	210 (Group 2)	89km^2
SEL_{cum} (fleeing)	210 (Group 2)	No in-combination effect
SEL_{cum} (static)	207 (Group 3)	210km^2
SEL_{cum} (fleeing)	207 (Group 3)	No in-combination effect
Recoverable Injury		
SEL_{cum} (static)	216 (Group 1)	15km^2
SEL_{cum} (fleeing)	216 (Group 1)	No in-combination effect
SEL_{cum} (static)	203 (Group 2 & 3)	650km^2
SEL_{cum} (fleeing)	203 (Group 2 & 3)	300km^2
TTS		
SEL_{cum} (static)	186 (Group 1, 2 & 3)	14,000km^2
SEL_{cum} (fleeing)	186 (Group 1, 2 & 3)	8,100km^2

Mortality and Potential Mortal Injury

5.7.1.25 The following section provides the assessment of potential impacts on each IEF within their associated hearing group for the spatial WCS and temporal WCS for underwater noise associated with foundation installation. Initial consideration is given to the sensitivity of each IEF within the hearing group to underwater noise, before characterising the scale and magnitude of effect before providing the overall conclusion.

Group 1 IEFs

Magnitude of Impact

5.7.1.26 When considering the potential for mortality and potential mortal injury on stationary Group 1 receptors (e.g., sandeel) from piling in the Caledonia OWF

(>219dB SEL_{cum}), the greatest magnitude ranges result from the in-combination simultaneous sequential piling of up to four pin piles in a 24-hour period (hammer energy 4,400kJ, 4m pin pile diameter) at both the NW (CAL01) and SE (CAL08) of the Caledonia OWF. An in-combination impact range for mortality and potential mortal injury of up to 6.3km^2 is predicted from this piling within the Caledonia OWF (Figure 5-14).

5.7.1.27 When considering the spatial WCS of mortality and potential mortal injury of fleeing Group 1 receptors from sequential piling within Caledonia OWF, the maximum predicted range of impact for mortality and potential mortal injury of fleeing Group 1 receptors occurs within the immediate vicinity of the works is less than 100m (>219dB SEL_{cum}) from the sequential piling pin-pile foundations and 140m (>213dB SPL_{peak}) from the sequential piling of monopiles. There is no in-combination effect from the simultaneous piling of monopiles, jacket foundations or anchor piles in the Caledonia OWF on fleeing Group 1 receptors.

5.7.1.28 Consequently, the magnitude of the impact is predicated to be of small spatial extent compared to existing spawning and nursery grounds, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

5.7.1.29 All other Group 1 fleeing receptors and their respective spawning and nursery grounds are widely distributed. Moreover, all group 1 fleeing receptors are considered able to move outside of the impact range during soft-start procedures before sound levels reach a level likely to cause mortality. Based on this and considering the small area potentially affected, any effects upon Group 1 receptors are assessed to be barely discernible from baseline conditions.

5.7.1.30 Consequently, the magnitude of the impact for all other Group 1 fleeing receptors is predicated to be of small spatial extent compared to existing spawning and nursery grounds, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptor

5.7.1.31 Group 1 IEFs (mortality onset at >213 dB SPL_{peak} or >219 dB SEL_{cum}) lack a swim bladder and are therefore considered less sensitive to underwater noise (than other species). As discussed previously sandeel are considered as stationary receptors. Sandeel spawning grounds overlap with the Caledonia OWF and PSA data indicates the presence of prime, sub-prime and suitable sandeel habitat throughout the Caledonia OWF, based on categories from Latto *et al.* (2013[92]). Additionally, site-specific eDNA surveys within Caledonia OWF indicated the presence of sandeel (Volume 7B, Appendix 4-1 and Volume 7B, Appendix 4-2). However, sandeel spawning grounds are widely distributed across the region and given the low spatial extent (5.6km^2) for mortality and potential mortal injury on stationary Group 1 receptors from piling in the Caledonia OWF Site (>219 dB SEL_{cum}) are likely to only effect a small number of individuals. Due to the potential for an annual pilling schedule which encapsulates the spawning period for the sandeel spawning, they have the potential to be disturbed throughout the entirety of the spawning period. Despite being more sensitive in winter months, sandeel have a high fecundity, quick maturation and short-term egg hatching rate and therefore, recovery from any reduced recruitment to the population is assessed to occur within the short-term (high recoverability).

5.7.1.32 Sandeel spawning grounds are located within the Caledonia OWF and suitable spawning habitats are widely distributed across the North Sea (Figure 5-11, Figure 5-12 and Figure 5-13). Sandeel are considered stationary receptors, due to their burrowing nature, substrate dependency, and demersal spawning behaviours, and therefore may have limited capacity to flee the area compared to other Group 1 receptors. Sandeel are thought to be affected by vibration through the seabed, so are more vulnerable to recoverable injury and mortality thresholds from UWN when buried in the seabed during winter months when in hibernation.

5.7.1.33 Taking this into account, sandeel are deemed to be of low vulnerability, high recoverability and are of national importance and therefore considered to have **Medium** sensitivity to mortality and potential mortal injury.

5.7.1.34 Lemon sole and plaice all have spawning grounds within the study area and across the North Sea (Coull *et al.,* 1998[94]; Figure 5-3 and Figure 5-4). Lemon sole, plaice, anglerfish, mackerel, ling, thornback ray, spotted ray, blonde ray, spurdog and tope all have nursery grounds across the study area. Additionally, sea and river lamprey may migrate past the Proposed Development (Offshore). These Group 1 IEFs are of mobile nature and unconstrained (not limited to specific sedimentary areas for spawning within the study area) and are therefore able to flee from noise disturbance before the onset of mortality and potential mortal injuries. Based on their low vulnerability to noise impacts, and their mobile nature, these receptors are expected to recover quickly, returning to normal behaviours and recolonising areas shortly after disturbance.

5.7.1.35 Taking this into account, the receptors are deemed to be of low vulnerability, high recoverability and are of regional to international importance and therefore considered to have **Low** sensitivity to mortality and potential mortal injury.

Significance of Effects

5.7.1.36 The impact of mortality and potential mortal injury on sandeel is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.37 The impact of mortality and potential mortal injury on fleeing Group 1 IEFs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Group 2 IEFs

Magnitude of Impact

5.7.1.38 When considering the spatial WCS of mortality and potential mortal injury of fleeing Group 2 receptors from piling within the Caledonia OWF, the maximum predicted range of impact for mortality and potential mortal injury of fleeing Group 2 receptors occurs within the immediate vicinity of the works are <100m (210dB SEL_{cum}) for the sequential piling of pin-pile foundations and 380m (>207dB SPL_{peak}) from the sequential piling of monopiles. There is no in-combination effect from the simultaneous sequential piling of monopiles, jacket foundations or anchor piles in the Caledonia OWF on fleeing Group 2 receptors (Figure 5-16, Figure 5-20 and Figure 5-24).

5.7.1.39 Like Group 1 fleeing receptors, Group 2 fleeing receptors (Atlantic salmon and sea trout) might experience mortality or potential mortal injury during impact piling close to the sound source. Atlantic salmon and sea trout have the potential to be within range of injurious effects from piling noise, however these IEFs are anticipated to be transient across the site, and therefore any temporal impacts on these receptors are anticipated to be minimal. Additionally, they are able to move outside of the impact range during soft-start procedures before sound levels reach a level likely to cause mortality.

5.7.1.40 Consequently, the magnitude of the impact is predicated to be of small spatial extent (not overlapping with migratory rivers), short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.41 Group 2 receptors (mortality onset at >207dB SPLpeak or 210dB SELcum) have a swim bladder and are therefore considered more sensitive to underwater noise than Group 1 species, however, the swim bladder is not involved in hearing (e.g., not linked to the inner ear) and as such they are less sensitive than Group 3 receptors. As Group 2 receptors, they are considered to be primarily sensitive to particle motion and so are likely to mainly sense underwater noise through movement of the water particles.

5.7.1.42 Atlantic salmon and sea trout occur throughout several of the rivers which flow into the Moray Firth (i.e., River Spey and River Deveron) and are likely to migrate past the Proposed Development (Offshore) during their migration to and from rivers. In late spring to early summer, adult Atlantic salmon return to rivers to spawn, whilst juvenile salmon migrate out to sea in spring, typically during April and May to feed. Sea trout are known to inhabit coastal waters for the majority of their marine life history stage before migrating into rivers in June and then migrate back out to sea in October (Malcolm *et al.,* 2010[153]). Given the mobile and transient nature of the receptors and the small area potentially affected, any potential effects on Group 2 fleeing receptors are anticipated to be discernible from baseline conditions. While these species are expected to be able to avoid noise sources before potential mortal injuries could occur, this may impede upon or delay their migration.

5.7.1.43 They have been deemed to be of medium vulnerability and recoverability and are of regional (sea trout) to international (Atlantic salmon are afforded protection under the OSPAR threatened or declining species list) importance, therefore their overall sensitivity is considered to **Medium**.

Significance of Effects

5.7.1.44 The impact of mortality and potential mortal injury on Group 2 fleeing receptors (Atlantic salmon and sea trout) is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor Adverse and Not Significant in EIA terms**.

Group 3 IEFs

Magnitude of Impact

5.7.1.45 When considering the potential for mortality and potential mortal injury of group 3 receptors (207dB SEL_{cum}), the greatest spatial WCS arise from the concurrent pilling of 4 pin piles at two locations in a 24-hour period (hammer energy 4,400kJ, 4m pin pile diameter). Piling at both the northwest (CAL01) and southeast (CAL08) of the Caledonia OWF results in an in-combination effect of 210km^2 for stationary receptors (Figure 5-15).

5.7.1.46 When considering the spatial WCS of mortality and potential mortal injury of fleeing Group 3 receptors from piling within the Caledonia OWF, the maximum predicted range of impact for mortality and potential mortal injury of fleeing Group 3 receptors occurs within the immediate vicinity of the works, <100m (207dB SEL_{cum}) for the sequential piling of pin-piles and 380m (>207dB SPL_{peak}) from the sequential piling of monopiles (Figure 5-17 and Figure 5-21). There is no in-combination effect from the simultaneous piling of monopiles, jacket foundations or anchor piles in the Caledonia OWF on fleeing Group 3 receptors.

5.7.1.47 The noise contours for piling within the Caledonia OWF, in relation to the presence of Buchan spawning grounds to the south and Orkney/Shetland herring spawning grounds to the north (Coull *et al.,* 1998[94] and IHLS data 2011/2012 – 2023/2024[107]) indicate the potential for mortality and potential mortal injury on spawning herring. A partial overlap of the mortality and potential mortal injury noise contours with the Buchan and Orkney/Shetland herring spawning grounds (Coull *et al.,* 1998[94]) can be observed although as shown by annual IHLS data (ICES, 2011/2012 – 2023/2024[107]), the main spawning area utilised by the Buchan spawning stock overlaps with the south of the study area and the Orkney/Shetland herring stock overlaps with the north of the study area. The total larval density from the combined 10-year dataset within the study area ranges from 0 to 6,000 herring larvae per m². In comparison, the peak larval density in the main spawning area of the Buchan and Orkney/Shetland herring spawning grounds ranges from 45,000 to 59,000 larvae per m². Therefore, as evidenced by the IHLS data, the larval density and therefore spawning herring stock that would be impacted is minimal when compared to areas of peak herring spawning (<10% of the peak density). In addition, suitable herring spawning substrates are located across the site, and across the wider region. Therefore, UWN from piling within the Caledonia OWF, is unlikely to have a population level effect on the Buchan and Orkney/Shetland herring stock.

5.7.1.48 With regards to the temporal WCS, the maximum duration of piling results from the sequential piling of jacket foundations or anchor pile foundations in the Caledonia OWF, resulting in a total piling duration of up to 18 months . The spawning period for the Buchan and Orkney/Shetland herring spawning stock typically occurs between August and October (Coull *et al.,* 1998[94]). Due to the potential for an annual pilling schedule which encapsulates the spawning period for the Buchan and Orkney/Shetland herring spawning stock, spawning herring have the potential to be disturbed throughout the entirety of the spawning period.

5.7.1.49 Considering the small overlap of the mortality and potential mortal injury noise contours on the herring spawning grounds (210km^2) and the overlap with areas of low-density herring larvae, short-term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

5.7.1.50 Group 3 fleeing receptors likely to be present within the study area include cod, sprat, whiting, haddock, European eel, allis shad, twaite shad and European hake. Most Group 3 fleeing receptors and their respective spawning and nursery grounds are widely distributed throughout the North Sea (with European eel and allis shad spawning in rivers and thus only impacted during migration). Moreover, all receptors are considered able to move outside of the impact range during soft-start procedures before sound levels reach a level likely to cause irreversible injury. Based on this and considering the small area potentially affected, together with the intermittent and temporary nature of the impact, any effects upon Group 3 receptors are assessed to be small from baseline conditions.

5.7.1.51 Consequently, the magnitude of the impact is predicated to be of small spatial extent (relative to their spawning and nursery grounds), short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.52 Group 3 receptors (mortality onset at >207dB SPL_{peak} or >207dB SEL_{cum}) have a swim bladder which is linked to the inner ear and so is directly involved in hearing. These species are the most sensitive to underwater noise, with direct detection of sound pressure, rather than just particle motion.

5.7.1.53 The study area overlaps two herring spawning areas as indicated by Coull *et al.* (1998[94]), the Buchan herring spawning grounds to the south and the Orkney/Shetland herring spawning grounds to the north (August-October). However, as stated in paragraph 38, the Coull *et al.* (1998[94]) data represent historical spawning grounds, which may be recolonised in the future, whereas the IHLS data (ICES, 2011/2012 – 2023/2024[107]) provide an indication of the areas of seabed in active use for spawning. The IHLS data indicates that the main spawning is located to the south of the Caledonia OWF at the Buchan spawning grounds (based on distribution and density of larvae) and then to the north with the Orkney/Shetland herring spawning grounds (Figure 5-9 and Figure 5-10).

5.7.1.54 Herring are demersal spawners and are therefore considered stationary receptors in the assessment during the spawning season, increasing their theoretical exposure to UWN from the construction phase of the development. Taking this into account, herring are considered to be of high vulnerability, with medium recoverability and are of national importance (Section 41 Priority species), therefore the sensitivity of spawning herring to noise impacts is considered to be **Medium**.

Significance of Effects

5.7.1.55 The impact of mortality and potential mortal injury on spawning adult herring is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor Adverse and Not Significant in EIA terms**.

5.7.1.56 The impact of mortality and potential mortal injury on Group 3 fleeing IEFs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Eggs and Larvae

Magnitude of Impact

5.7.1.57 Thresholds of effects for eggs and larvae have been defined separately within the Popper *et al.* (2014[32]) guidance, with damage expected to occur at >210dB SEL_{cum} or >207dB SPL_{peak}. With regards to the potential for the mortality or potential mortal injury of eggs and larvae from piling in the Caledonia OWF the maximum predicted range of impact for mortality and potential mortal injury of eggs and larvae occurs from the concurrent pilling of 4 pin piles in a 24-hour period (hammer energy 4,400kJ, 4m pin pile diameter) at two locations; the northwest (CAL01) and southeast (CAL08) of the Caledonia OWF results in an in-combination effect of 210km^2 for stationary receptors.

5.7.1.58 Considering the small overlap of the mortality and potential mortal injury noise contours of the historic Buchan and Orkney/Shetland herring spawning ground (Coull *et al.,* 1998[94]), short term duration, intermittent but not reversible, therefore the magnitude of the impact is deemed to be **Low**.

5.7.1.59 The piling duration encapsulates the cod spawning period (January to April), the sprat spawning period (May to August) and the whiting spawning period (February to June). However, for all receptors this assumes that all piling will occur within the spawning periods and that the noise contours overlap the entire spawning grounds, and therefore the actual temporal impact on the receptors will be significantly less. Spawning grounds for cod, herring, plaice, sprat, whiting, sandeel and Nephrops are widely distributed across the southern North Sea and therefore in the context of the wider environment, the impacts from underwater noise are considered to be of local scale.

5.7.1.60 Given the broadscale distribution of these spawning grounds, and the intermittent nature of the piling activities, the maximum magnitude of impact from mortality and potential mortal injury on eggs and larvae is expected to be **Low**.

Sensitivity of Receptors

5.7.1.61 Cod, herring, lemon sole, mackerel, plaice, sandeel, sole, sprat and whiting all have spawning grounds within the vicinity of the Caledonia OWF. Eggs and larvae are considered organisms of concern by Popper *et al.* (2014[3232]), due to their vulnerability, reduced mobility and small size.

5.7.1.62 Taking this into consideration and given the broadscale nature of the spawning grounds, the sensitivity of eggs and larvae to mortality and potential mortal injury from underwater noise is considered to be **Medium**.

Significance of Effects

5.7.1.63 The impact of mortality and potential mortal injury on eggs and larvae is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Shellfish

Magnitude of Impact

5.7.1.64 Pile driving is recognised as a source of particle motion, with increased levels of particle motion likely to occur in the near-field (Hazelwood and Macey, 2016[155]). However, evidence suggests that this is unlikely to cause mortality or mortal injury to shellfish species.

5.7.1.65 Considering the broad distribution of these receptors across the study area, the available literature suggesting a low risk of mortality or significant injury, and the relatively short-term nature of the impact, it is considered unlikely that there will be any more than a highly localised effect, with rapid recovery of the remaining stock avoiding a population level effect.

5.7.1.66 Consequently, the magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent but not reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.67 Shellfish do not possess swim bladders or other gas filled organs and are primarily sensitive to particle motion and disturbance from UWN rather than sound pressure (Popper and Hawkins, 2018[154]).

5.7.1.68 Pile driving is recognised as a source of particle motion, generating high levels of particle motion in the nearfield (Hazelwood and Macey, 2016[155]) which could potentially result in injury or mortality to sensitive shellfish receptors. Impacts from particle motion are also likely to occur locally to the source, with studies having demonstrated the rapid attenuation of particle motion with distance (Mueller-Blenkle *et al.,* 2010[156]). Studies on lobsters have shown no mortality effect on the species (>220dB) (Payne *et al.,* 2007[157]). Similarly, studies of molluscs (e.g., blue mussel (*Mytilus edulis*) and periwinkles (*Littorina* spp.)) exposed to a single airgun at a distance of 0.5m have shown no effects after exposure (Moriyasu *et al.,* 2004[158]). Additionally, pile driving is associated with disturbance effects on shellfish, leading to oxidative stress and altered behaviour (Stenton *et al.,* 2022[159]).

5.7.1.69 Taking this into consideration, shellfish IEFs within the study area are deemed to be of local to international importance, medium vulnerability, and high recoverability. The sensitivity of these receptors is therefore considered to be **Low**.

Significance of Effects

5.7.1.70 The impact of mortality and potential mortal injury on shellfish is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Summary of Effects for Mortality and Potential Mortal Injury

5.7.1.71 Taking into account the highest magnitude across all receptors groups as **Low** and highest sensitivity across all receptor groups as **Medium**, the overall significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Recoverable Injury

5.7.1.72 Recoverable injury is a survivable injury with full recovery occurring after exposure, although decreased fitness during this recovery period may result in increased susceptibility to predation or disease (Popper *et al.,* 2014[32]). The impact ranges for recoverable injury and mortality/potential mortal injury are more or less the same due to the thresholds used, the potential for mortality or mortal injury is likely to only occur in extreme proximity to the pile, although the risk of this occurring will be reduced by use of soft start techniques at the start of the piling sequence. This means that fish in close proximity to piling operations will move outside of the impact range, before noise levels reach a level likely to cause irreversible injury.

Group 1 IEFs

Magnitude of Impact

5.7.1.73 Regarding the potential for recoverable injury (>216dB SEL_{cum}) of stationary Group 1 receptors (i.e., sandeel) the WCS is from the simultaneous sequential pilling of four pin piles in a 24-hour period (hammer energy 4,400kJ, 4m pin pile diameter) at both the northwest (CAL01) and southeast (CAL08) of the Caledonia OWF results in an in-combination effect of 15km^2.

5.7.1.74 Regarding the spatial WCS for fleeing Group 1 receptors from piling within the Caledonia OWF, the maximum predicted range of impact for recoverable injury of fleeing Group 1 receptors occurs within the immediate vicinity of the works less than 100m (>216dB SEL_{cum}) for the sequential piling of pin-pile foundations and 140m for (>213dB SPL_{peak}) from the sequential piling of monopiles foundations.

5.7.1.75 As discussed previously, sandeel spawning grounds overlap with the Caledonia OWF and PSA data indicates the presence of prime, sub-prime and suitable sandeel habitat throughout the Caledonia OWF. However, sandeel spawning grounds are widely distributed and therefore any noise impacts are anticipated to be small in the context of the wider environment. Given the intermittent and temporary nature of the impact, the low number of individuals likely to be impacted and the very small proportion of the population this represents, any potential recoverable injury to sandeel during impact piling is considered to be undiscernible from baseline conditions.

5.7.1.76 Consequently, the magnitude of the impact is predicated to be of small spatial extent (relative to their spawning and nursery grounds), short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

5.7.1.77 All Group 1 fleeing receptors and their respective spawning and nursery grounds are widely distributed. Moreover, all receptors are considered able to move outside of the impact range during soft-start procedures before sound levels reach a level likely to cause injury. Based on this and considering the small area potentially affected, any effects upon Group 1 receptors and their spawning and nursery grounds are assessed to be discernible from baseline conditions.

5.7.1.78 Consequently, the magnitude of the impact is predicated to be of small spatial extent (relative to their spawning and nursery grounds), short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.79 Group 1 IEFs (Sandeel) have recoverable injury onset at >216 dB SEL_{cum} and >213 dB SPL_{peak}. As previously stated, they lack a swim bladder and are therefore considered less sensitive to underwater noise (than other species). Sandeel spawning grounds are located within Caledonia OWF and suitable spawning habitats are widely distributed across the North Sea (Figure 5-11, Figure 5-12 and Figure 5-13). Sandeel are considered stationary receptors, due to their burrowing nature, substrate dependency, and demersal spawning behaviours, and therefore may have limited capacity to flee the area compared to other Group 1 receptors. Sandeel are thought to be affected by vibration through the seabed, so are particularly sensitive to recoverable injury and mortality thresholds from UWN when buried in the seabed during winter months when in hibernation.

5.7.1.80 Taking this into account, sandeel are deemed to be of low vulnerability, medium recoverability and are of national importance and therefor considered to have **Medium** sensitivity recoverable injury.

5.7.1.81 Lemon sole and plaice all have spawning grounds within the study area and across the North Sea (Coull *et al.,* 1998[94]; Figure 5-3 and Figure 5-4). Lemon sole, plaice, anglerfish, mackerel, ling, thornback ray, spotted ray, blonde ray, spurdog and tope all have nursery grounds across the study area. Additionally, sea and river lamprey may migrate past the Proposed Development (Offshore). These Group 1 receptors are of mobile nature and unconstrained (not limited to specific sedimentary areas for spawning within the study area) and are therefore able to flee from noise disturbance before the onset of mortality and potential mortal injuries. Based on their low vulnerability to noise impacts, and their mobile nature, these receptors are expected to recover quickly, returning to normal behaviours and recolonising areas shortly after disturbance. Taking this into account, the receptors are deemed to be of low vulnerability, high recoverability and are of regional to international importance.

5.7.1.82 Taking this into account, these receptors are considered to be of low vulnerability, with medium recoverability and of regional importance, therefore their overall sensitivity is considered to be **Low**.

Significance of Effects

5.7.1.83 The impact of recoverable injury on sandeel is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.84 The impact of recoverable injury on fleeing Group 1 IEFs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Group 2 IEFs

Magnitude of Impact

5.7.1.85 Regarding group 2 receptors, recoverable injury threshold (203dB SEL_{cum}) WCS results from the simultaneous sequential pilling of four pin piles in a 24-hour period (hammer energy 4,400kJ, 4m pin pile diameter) at both the northwest (CAL01) and southeast (CAL08) of the Caledonia OWF with in an in-combination effect of 650km^2 for stationary receptors and 300km^2 for fleeing receptors.

5.7.1.86 Atlantic salmon and sea trout have the potential to be within range of injurious effects from piling noise, however these IEFs are anticipated to be transient across the site, and therefore any temporal impacts on these receptors are anticipated to be minimal.

5.7.1.87 Given the mobile and transient nature of the receptors and the small area potentially affected (relative to migratory rivers), any potential effects on Group 2 fleeing receptors, of short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.88 Group 2 receptors have recoverable injury onset at 203dB SEL_{cum} and >207dB SPL_{peak}. As previously stated, they have a swim bladder and are therefore considered more sensitive to underwater noise than Group 1 species, however, the swim bladder is not involved in hearing. Group 2 receptors are considered to be primarily sensitive to particle motion and so are likely to mainly sense underwater noise through movement of the water particles.

5.7.1.89 Atlantic salmon and sea trout occur throughout several of the rivers which flow into the Moray Firth (i.e., River Spey and River Deveron) and are likely to migrate past the Proposed Development (Offshore) during their migration to and from rivers. While these species are expected to be able to avoid noise sources before potential mortal injuries could occur, this may impede upon or delay their migration.

5.7.1.90 They have been deemed to be of medium vulnerability and recoverability and are of regional (sea trout) to international (Atlantic salmon are afforded protection under the OSPAR threatened or declining species list) importance, therefore their overall sensitivity has been assessed as **Medium**.

Significance of Effects

5.7.1.91 The impact of recoverable injury on Group 2 IEFs (Atlantic salmon and sea trout) is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Group 3 IEFs

Magnitude of Impact

5.7.1.92 Regarding the recoverable injury threshold for group 3 receptors (203 SEL_{cum}), the concurrent pilling of four pin piles in a 24-hour period (hammer energy 4,400kJ, 4m pin pile diameter) at two locations; the northwest (CAL01) and southeast (CAL08) of the Caledonia OWF results in the greatest WCS, with an in-combination effect of 650km^2 for stationary receptors and 300km^2 for fleeing receptors.

5.7.1.93 Regarding the spatial WCS for fleeing receptors from piling within the Caledonia OWF, the maximum predicted range of impact for recoverable injury of fleeing Group 3 receptors occurs within the immediate vicinity of the works, less than 100m (203dB SEL_{cum}) from the sequential piling of pin-piles foundations and 380m for (>207dB SPL_{peak}) from the sequential piling of monopiles foundations.

5.7.1.94 The noise contours from piling in the Caledonia OWF shown in relation to historic Buchan and Orkney/Shetland herring spawning grounds, and larvae abundances (Coull *et al.,* 1998[94] and IHLS data, 2011/2012 – 2023/2024[107]) indicate the potential for recoverable injury of spawning herring. A partial overlap of the recoverable injury noise contour with herring spawning ground (Coull *et al.,* 1998[94]) can be observed. The larval density within the study area ranges from 0 to 9,500 herring larvae per m^2. In comparison, the peak larval density in the main spawning area ranges from 45,000 to 59,000 larvae per m^2. Therefore, as evidenced by the IHLS data, the larval density and therefore spawning herring stock that would be impacted is minimal when compared to areas of peak herring spawning. This is further supported by PSA datasets which show the availability of suitable herring spawning substrates across the Proposed Development (Offshore), and the North Sea. Therefore, underwater noise from piling within the Caledonia OWF is unlikely to have a population level effect on the Buchan and Orkney/Shetland herring spawning stock.

5.7.1.95 Considering the overlap of the recoverable injury noise contours with the historic Buchan and Orkney/Shetland herring spawning grounds (Coull *et al.,* 1998[94]) and of areas of low-density herring larvae, and the broadscale distribution of available spawning substrates for herring across the North Sea, underwater noise from piling is not anticipated to cause a population level effect. Consequently, the magnitude of the impact is predicated to be of small spatial extent (relative to their spawning and nursery grounds), short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

5.7.1.96 All Group 3 fleeing receptors and their respective spawning and nursery grounds are widely distributed. Moreover, all receptors are considered able to move outside of the impact range during soft-start procedures before sound levels reach a level likely to cause irreversible injury.

5.7.1.97 Based on this and considering the small area (relative to their spawning and nursery grounds), intermittent and temporary nature of the impact, any effects upon Group 3 receptors and their spawning and nursery grounds are therefore deemed to be of **Low** magnitude.

Sensitivity of Receptors

5.7.1.98 Group 3 receptors have recoverable injury onset at 203dB SEL_{cum} and >207dB SPL_{peak}. They have a swim bladder which is linked to the inner ear and so is directly involved in hearing. These species are considered to be the most sensitive to underwater noise, with direct detection of sound pressure, rather than just particle motion.

5.7.1.99 Herring are demersal spawners and are therefore considered stationary receptors in the assessment during the spawning season, increasing their theoretical exposure to UWN from the construction phase of the development. Taking this into account, herring are considered to be of high vulnerability, with medium recoverability and are of national importance (Section 41 Priority species), therefore the sensitivity of spawning herring to noise impacts is considered to be **Medium**.

5.7.1.100 Cod, sprat and whiting all have spawning grounds within the study area and across the North Sea (Coull *et al.,* 1998[94]). These IEFs are pelagic spawners and are therefore not limited to specific sedimentary areas for spawning, and consequently are considered likely to move away from injurious effects during soft-start procedures. Similarly, other group 3 receptors (blue whiting, ling) are highly mobile and will be able to avoid noise sources before the onset of mortal injuries.

5.7.1.101 Based on their mobile nature, these IEFs are expected to recover quickly, return to normal behaviours and recolonise areas shortly after disturbance, therefore the sensitivity of these IEFs to noise impacts is considered to be **Low**.

5.7.1.102 European eel, twaite shad, and allis shad have been identified within the study area. European eel migration routes within the Moray Firth and wider North Sea are widely understudied (Verhelst *et al.,* 2022[170]). Additionally, migratory routes for twaite shad and allis shad are broadly understudied. These is some evidence from recent research that suggests shad migrate offshore of the northeast of Scotland (Sabatino *et al.,* 2022[171]). Due to their conservation importance, it is assumed that the migratory routes of European eel, twaite shad and allis shad pass the Proposed Development (Offshore) area into the rivers entering the Moray Firth.

5.7.1.103 Considering their sensitivity as Group 3 receptors and their international importance, they have been determined to be of **Medium** sensitivity to the effects from underwater noise during piling.

Significance of Effects

5.7.1.104 The impact of recoverable injury on spawning adult herring is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.105 The impact of recoverable injury on Group 3 fleeing IEFs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Eggs and Larvae

Magnitude of Impact

5.7.1.106 Taking into consideration the Popper *et al.* (2014[32]) criteria, the extent of noise disturbance potentially causing recoverable injury to eggs and larvae would result in a moderate degree of disturbance at a near field distance from the source, and a low degree of disturbance in the near and far field.

5.7.1.107 Considering the small overlap of the mortality and potential mortal injury noise contours of the historic Buchan and Orkney/Shetland herring spawning ground (Coull *et al.,* 1998[94]), the magnitude of impact on herring eggs and larvae from piling activities is considered to be **Low**.

5.7.1.108 Spawning grounds for cod, herring, plaice, sprat, whiting, sandeel and Nephrops are widely distributed across the southern North Sea and therefore in the context of the wider environment, the impacts from underwater noise are considered to be of local scale.

5.7.1.109 Given the broadscale distribution of these spawning grounds, and the intermittent nature of the piling activities, the maximum magnitude of impact is expected to be **Low**.

Sensitivity of Receptors

5.7.1.110 Cod, herring, lemon sole, mackerel, plaice, sandeel, sole, sprat and whiting all have spawning grounds within the vicinity of the Caledonia OWF. Eggs and larvae are considered organisms of concern by Popper *et al.* (2014[32]), due to their vulnerability, reduced mobility and small size.

5.7.1.111 Taking this into consideration and given the broadscale nature of the spawning grounds, the sensitivity of eggs and larvae to recoverable injury from underwater noise is considered to be **Medium**.

Significance of Effects

5.7.1.112 The impact of recoverable injury on eggs and larvae is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Shellfish

Magnitude of Impact

5.7.1.113 Pile driving is recognised as a source of particle motion, with increased levels of particle motion likely to occur in the near-field (Hazelwood and Macey, 2016[155]). However, evidence suggests that this is unlikely to cause injury to shellfish species. Based on this and considering the temporary and intermittent nature of the impact, it is considered unlikely that there will be discernible changes to shellfish population.

5.7.1.114 Consequently, the magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.115 As previously stated, shellfish do not possess swim bladders or other gas filled organs and are primarily sensitive to particle motion and disturbance from UWN rather than sound pressure (Popper and Hawkins, 2018[154]).

5.7.1.116 Taking this into consideration, shellfish IEFs within the study area are deemed to be of local to international importance, medium vulnerability, and high recoverability. The sensitivity of these receptors is therefore considered to be **Low**.

Significance of Effects

5.7.1.117 The impact of recoverable injury on shellfish is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Summary of Effects for Recoverable Injury

5.7.1.118 Taking into account the highest magnitude across all receptors groups as **Low** and highest sensitivity across all receptor groups as **Medium**, the overall significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

TTS

5.7.1.119 TTS is a temporary reduction in hearing sensitivity caused by exposure to intense sound. TTS has been demonstrated in some fishes, resulting from temporary changes in sensory hair cells of the inner ear and/or damage to auditory nerves. However, sensory hair cells are constantly added to fishes and are replaced when damaged and therefore the extent of TTS is of variable duration and magnitude. Normal hearing ability returns following cessation of the noise causing TTS, though this period is variable. When experiencing TTS, fish may have decreased fitness due to a reduced ability to communicate, detect predators or prey, and/or assess their environment.

Group 1 IEFs

Magnitude of Impact

5.7.1.120 The potential for onset of TTS/hearing damage of stationary Group 1 receptors (e.g., sandeel) is >>186 dB from piling within the Caledonia OWF. It is important to note that due to the onset being >>186 dB, the threshold for the onset of TTS is likely to be much higher, (i.e., a much higher sound level is needed to induce TTS). Therefore, the modelled impacts ranges are not actually representative of the risk of TTS onset for these species as the true range will be much less.

5.7.1.121 The maximum predicted range of impact occurs from the simultaneous sequential pilling of four pin piles in a 24-hour period (hammer energy 4,400kJ, 4m pin pile diameter) at both the northwest (CAL01) and southeast (CAL08) of the Caledonia OWF results in an in-combination effect of 14,000km^2 for stationary receptors and 8,100km^2 for fleeing receptors.

5.7.1.122 Regarding the spatial WCS for fleeing receptors from piling within the Caledonia OWF, the maximum predicted range of impact for TTS of fleeing Group 1 receptors occurs over a broader vicinity of the works (45,000m at 186 dB SEL_{cum}) from the sequential piling of pin-piles foundations.

5.7.1.123 As discussed previously, sandeel spawning grounds overlap with the Caledonia OWF and PSA data indicates the presence of prime, sub-prime and suitable sandeel habitat throughout the Caledonia OWF. However, sandeel spawning grounds are widely distributed and therefore any noise impacts are anticipated to be small in the context of the wider environment. Regarding the magnitude of TTS it is crucial to note that TTS by nature is a temporary impact, as the auditory hair cells which are damaged by UWN are able to regenerate (as reviewed in Popper *et al.,* 2014[32]). Further to this, there are multiple conservatisms inbuilt into the underwater noise modelling; specifically, a stationary model is used, which is inherently precautionary, as it assumes receptors to be static for a full 24 hours, which is not realistic. It is on this basis that the impact ranges are more likely to lie somewhere between the fleeing and the stationary impact ranges modelled (which are provided in Table 5-24). Additionally, the TTS impact ranges are modelled on the assumption that impulsive noise reaches this distance, however the main characteristics of impulsive noise are lost over distance. Specifically, a study undertaken by the Offshore Renewables Joint Industry Programme (ORJIP) (2024[160]), observed a decrease in impulsive characteristics as sounds travel further away from the source. Although the report acknowledged that there is still insufficient evidence to establish a range of distances from which these sounds are no longer impulsive, a marked decline in each noise metric was observed within the first five kilometres from the sound source.

5.7.1.124 Therefore, taking the above into consideration, given the temporary nature of TTS, the excessive conservatisms built into the underwater noise model, and the intermittent and temporary nature of the impact, and the recoverability of receptors the magnitude of the impact is deemed to be **Low**.

5.7.1.125 All Group 1 fleeing receptors and their respective spawning and nursery grounds are widely distributed. Despite the spatial extent, given the conservatism built into the modelling and intermittent and temporary nature of the impact and recoverability of receptors the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.126 Group 1 IEFs have TTS at >186dB SEL_{cum}. As previously stated, they lack a swim bladder and are therefore considered less sensitive to underwater noise (than other species).

5.7.1.127 Sandeel spawning grounds are located within Caledonia OWF and suitable spawning habitats are widely distributed across the North Sea (Figure 5-11, Figure 5-12 and Figure 5-13). Sandeel are considered stationary receptors, due to their burrowing nature, substrate dependency, and demersal spawning behaviours, and therefore may have limited capacity to flee the area compared to other Group 1 receptors.

5.7.1.128 Sandeel are less sensitive to TTS and behavioural effects when buried as they will have recovered from TTS before exiting hibernation and won't respond to external stimulus when hibernating (Leonhard *et al.,* 2013[161]). At TTS and behavioural threshold, sandeel are anticipated to recover from noise impacts shortly after noise disturbance, with normal behaviours resuming (Hassel *et al.,* 2004[162]).

5.7.1.129 Taking this into account, sandeel are deemed to be of low vulnerability, medium recoverability and are of national importance (Section 41 priority species). Considering the proximity to sandeel spawning grounds and their substrate dependency, the sensitivity of sandeel to TTS is considered to be **Medium**.

5.7.1.130 Other Group 1 receptors are of mobile nature and unconstrained (not limited to specific sedimentary areas for spawning within the study area) and are therefore able to flee from noise disturbance before the onset of TTS. Based on their low vulnerability to noise impacts, and their mobile nature, these receptors are expected to recover quickly, returning to normal behaviours and recolonising areas shortly after disturbance.

5.7.1.131 Taking this into account, the receptors are deemed to be of low vulnerability, high recoverability and are of regional to international importance, therefore the overall sensitivity of these receptors to TTS impacts is therefore considered to be **Low**.

Significance of Effects

5.7.1.132 The impact of TTS/hearing damage on sandeel is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be

Medium. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.133 The impact of recoverable injury on fleeing Group 1 IEFs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Group 2 IEFs

Magnitude of Impact

5.7.1.134 It should be noted that as with Group 1 receptors, the criteria for impact ranges for onset of TTS in Group 2 receptors at >186dB SEL_{cum} means that true ranges will be smaller than modelled.

5.7.1.135 Regarding the spatial WCS for Group 2 receptors, TTS threshold (> 186 SEL_{cum}), the simultaneous sequential pilling of four pin piles in a 24-hour period (hammer energy 4,400kJ, 4m pin pile diameter) at both the northwest (CAL01) and southeast (CAL08) of the Caledonia OWF results in an in-combination effect of 14,000km^2 for stationary receptors and 8,100km^2 for fleeing receptors.

5.7.1.136 Atlantic salmon and sea trout have the potential to be within range of TTS effects from piling noise, however these IEFs are anticipated to be transient across the site, and therefore any temporal impacts on these receptors are anticipated to be minimal. Regarding the magnitude of TTS, it is crucial to note that TTS by nature is a temporary impact, as the auditory hair cells which are damaged by UWN are able to regenerate (as reviewed in Popper *et al.,* 2014[32]). Further to this, there are multiple conservatisms inbuilt into the underwater noise modelling; specifically a stationary model is used, which is inherently precautionary, as it assumes receptors to be static for a full 24 hours, which is not realistic. It is on this basis that the impact ranges are more likely to lie somewhere between the fleeing and the stationary impact ranges modelled (which are provided in Table 5-24). Additionally, the TTS impact ranges are modelled on the assumption that impulsive noise reaches this distance, however the main characteristics of impulsive noise are lost over distance. Specifically, a study undertaken by the Offshore Renewables Joint Industry Programme (ORJIP) in 2024, observed a decrease in impulsive characteristics as sounds travel further away from the source. Although the report acknowledged that there is still insufficient evidence to establish a range of distances from which these sounds are no longer impulsive, a marked decline in each noise metric was observed within the first five kilometres from the sound source.

5.7.1.137 Therefore, taking the above into consideration, given the temporary nature of TTS, the excessive conservatisms built into the underwater noise model, and the intermittent and temporary nature of the impact, and the recoverability of receptors the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.138 Group 2 receptors have TTS onset at >186dB SEL_{cum}. Atlantic salmon and sea trout occur throughout several of the rivers which flow into the Moray Firth (i.e., River Spey and River Deveron) and are likely to migrate past the Proposed Development (Offshore) during their migration to and from rivers. While these species are expected to be able to avoid noise sources before potential mortal injuries could occur, this may impede upon or delay their migration.

5.7.1.139 There is potential for barrier effects to arise from UNW due to construction of Caledonia OWF. TTS contours (186dB SEL_{cum}) are widespread across most of the Moray Firth and have the potential to disrupt Atlantic Salmon Migration route. One of the most significant concerns regarding UWN is its impact on the migration of Atlantic Salmon (Gill *et al.,* 2012[163]). Successful migration is crucial for the survival and reproduction of this species. Studies have shown that noise can act as a physical and psychological barrier, disrupting migration routes and timing. Such disruption could include a delayed/ increased duration for migration. Noise-induced avoidance could lead to energetic costs and reduced reproductive success (Knudsen *et al.,* 1992[165]; 1994[166]). The extent of this remains uncertain, with some evidence showing that smolt migration was not impacted when exposed to noise levels at 114 dB (Knudsen *et al.,* 1992[165]; 1994[166]). Deleau (2018[164]) observed avoidance behaviour in European Eel and river lamprey in the presence of sound in a controlled environment. However, their results indicate a varied response between individuals.

5.7.1.140 Research has shown that salmon migrating through noisy areas were more likely to become disoriented, delaying their journey to spawning grounds (Knudsen *et al.,* 1992[165]; 1994[166]; Gill and Bartlett, 2011[167]; Bagočius, 2015[168]). Additionally, there is potential for noise barriers to increase the vulnerability of diadromous species to marine predation and other environmental stressors.

5.7.1.141 It should be noted that there is a distinct lack of robust evidence regarding specific migratory routes for diadromous species, especially when considering impacts to these routes associated with OWF developments, making it difficult to determine the effect of UWN (Gill *et al.,* 2012[163]).

5.7.1.142 Subsequently, diadromous species have been deemed to be of medium vulnerability and recoverability and are of regional (sea trout) to international importance (Atlantic salmon are afforded protection under the OSPAR threatened or declining species list) importance, therefore their overall sensitivity is considered to be **Medium**.

Significance of Effects

5.7.1.143 The impact of TTS/hearing damage on Group 2 IEFs (Atlantic salmon and sea trout) is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Group 3 IEFs

Magnitude of Impact

5.7.1.144 Regarding the spatial WCS for Group 3 receptors, TTS threshold (186 SEL_{cum}), the simultaneous sequential pilling of four pin piles in a 24-hour period (hammer energy 4,400kJ, 4m pin pile diameter) at both the northwest (CAL01) and southeast (CAL08) of the Caledonia OWF results in an in-combination effect of 14,000km^2 for stationary receptors and 8,100km^2 for fleeing receptors.

5.7.1.145 Regarding the spatial WCS for fleeing receptors from piling within the Caledonia OWF, the maximum predicted range of impact for TTS of fleeing Group 3 receptors occurs in a broader vicinity of the works (45,000m at 186 dB SEL_{cum}) from the sequential piling of pin-piles foundations. Regarding the magnitude of TTS it is crucial to note that TTS by nature is a temporary impact, as the auditory hair cells which are damaged by UWN are able to regenerate (as reviewed in Popper *et al.,* 2014[32]). Further to this, there are multiple conservatisms inbuilt into the UWN modelling; specifically a stationary model is used, which is inherently precautionary, as it assumes receptors to be static for a full 24 hours, which is not realistic; as reported by (Slotte, 2004[169]), herring spawning events (during which the receptor is assumed to be stationary) only typically last up to two to four days. It is on this basis that the impact ranges are more likely to lie somewhere between the fleeing and the stationary impact ranges modelled (which are provided in Table 5-24). Additionally, the TTS impact ranges are modelled on the assumption that impulsive noise reaches this distance, however the main characteristics of impulsive noise are lost over distance. Specifically, a study undertaken by the Offshore Renewables Joint Industry Programme (ORJIP) in 2024, observed a decrease in impulsive characteristics as sounds travel further away from the source. Although the report acknowledged that there is still insufficient evidence to establish a range of distances from which these sounds are no longer impulsive, a marked decline in each noise metric was observed within the first five kilometres from the sound source.

5.7.1.146 As discussed previously, the IHLS data indicates that impacts upon herring larval densities and therefore spawning herring stock are likely to be minimal when compared to areas of peak Buchan and Orkney/Shetland herring spawning stock. This is further supported by PSA datasets which show the availability of suitable herring spawning substrates across the Proposed Development (Offshore), and the wider North Sea. Considering the overlap of the TTS noise contours with the historic Buchan and Orkney/Shetland herring spawning grounds (Coull *et al.,* 1998[94]) and of areas of low-density herring larvae, and the broadscale distribution of available spawning substrates for herring across the North Sea, underwater noise from piling is not anticipated to cause a population level effect.

5.7.1.147 Therefore, taking the above into consideration, given the temporary nature of TTS, the excessive conservatisms built into the underwater noise model, and the intermittent and temporary nature of the impact, and the recoverability of receptors the magnitude of the impact is deemed to be **Low**.

5.7.1.148 Group 3 fleeing receptors including cod, sprat, whiting, haddock and their respective spawning and nursery grounds are widely distributed across the study area and wider North Sea (excluding European eel, allis shad which just have the potential to migrate through the study area). Based on this and considering the intermittent and temporary nature of the impact, any effects upon Group 3 receptors and their spawning and nursery grounds are assessed to be discernible from baseline conditions. Despite the spatial extent, given the intermittent and temporary nature of the impact and recoverability of receptors the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.149 Group 3 receptors have TTS onset at > 186dB SEL_{cum}. They have a swim bladder which is linked to the inner ear and so is directly involved in hearing. These species are considered to be the most sensitive to underwater noise, with direct detection of sound pressure, rather than just particle motion.

5.7.1.150 Herring are demersal spawners and are therefore considered stationary receptors in the assessment during the spawning season, increasing their theoretical exposure to UWN from the construction phase of the development.

5.7.1.151 Taking this into account, herring are considered to be of high vulnerability, with medium recoverability and are of national importance (Section 41 Priority species), therefore the sensitivity of spawning herring to noise impacts is considered to be **Medium**.

5.7.1.152 Cod, sprat and whiting all have spawning grounds within the study area and across the North Sea (Coull *et al.,* 1998[94]). These IEFs are pelagic spawners and are therefore not limited to specific sedimentary areas for spawning, and consequently are considered likely to move away from injurious effects during soft-start procedures. Similarly, other Group 3 receptors (blue whiting, ling) are highly mobile and will be able to avoid noise sources before the onset of mortal injuries.

5.7.1.153 Based on their mobile nature, these IEFs are expected to recover quickly, return to normal behaviours and recolonise areas shortly after disturbance. Therefore, the sensitivity of these IEFs to noise impacts is considered to be **Low**.

5.7.1.154 European eel, twaite shad, and allis shad have been identified within the study area. European eel migration routes within the Moray Firth and wider North Sea are widely understudied (Verhelst *et al.,* 2022[170]). Additionally, migratory routes for twaite shad and allis shad are broadly understudied. These is some evidence from recent research that suggests shad migrate offshore of the northeast of Scotland (Sabatino *et al.,* 2022[171]). Due to their conservation importance, it is assumed that the migratory routes of European eel, twaite shad and allis shad pass the Proposed Development (Offshore) into the rivers entering the Moray Firth.

5.7.1.155 Considering their sensitivity as Group 3 receptors and their international importance, they have been determined to be of **Medium** sensitivity to the effects from underwater noise during piling.

Significance of Effects

5.7.1.156 The impact of TTS/hearing damage on spawning adult herring is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.157 The impact of TTS/hearing damage on Group 3 fleeing IEFs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Eggs and Larvae

Magnitude of Impact

5.7.1.158 The Popper *et al.* (2014[32]) criteria for TTS are the same as that of risk of recoverable injury and therefore the impact assessment for eggs and larvae replicates that undertaken for recoverable injury.

5.7.1.159 Despite the spatial extent, given the intermittent and temporary nature of the impact and recoverability of receptors the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.160 Cod, herring, lemon sole, mackerel, plaice, sandeel, sole, sprat and whiting all have spawning grounds within the vicinity of the Caledonia OWF. Eggs and larvae are considered organisms of concern by Popper *et al.* (2014[32]), due to their vulnerability, reduced mobility and small size.

5.7.1.161 Taking this into consideration and given the broadscale nature of the spawning grounds, the sensitivity of eggs and larvae to TTS from underwater noise is considered to be **Medium**.

Significance of Effects

5.7.1.162 The impact of TTS/hearing damage on eggs and larvae is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Shellfish

Magnitude of Impact

5.7.1.163 It is understood that particle motion attenuates rapidly, therefore any impacts on shellfish are likely to be localised. Taking this into account, and the broad distribution of these species along the UK coasts, and across the southern North Sea and despite the spatial extent of TTS contours, given the intermittent and temporary nature of the impact and recoverability of receptors the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.164 As previously stated, shellfish do not possess swim bladders or other gas filled organs and are primarily sensitive to particle motion and disturbance from UWN rather than sound pressure (Popper and Hawkins, 2018[154]).

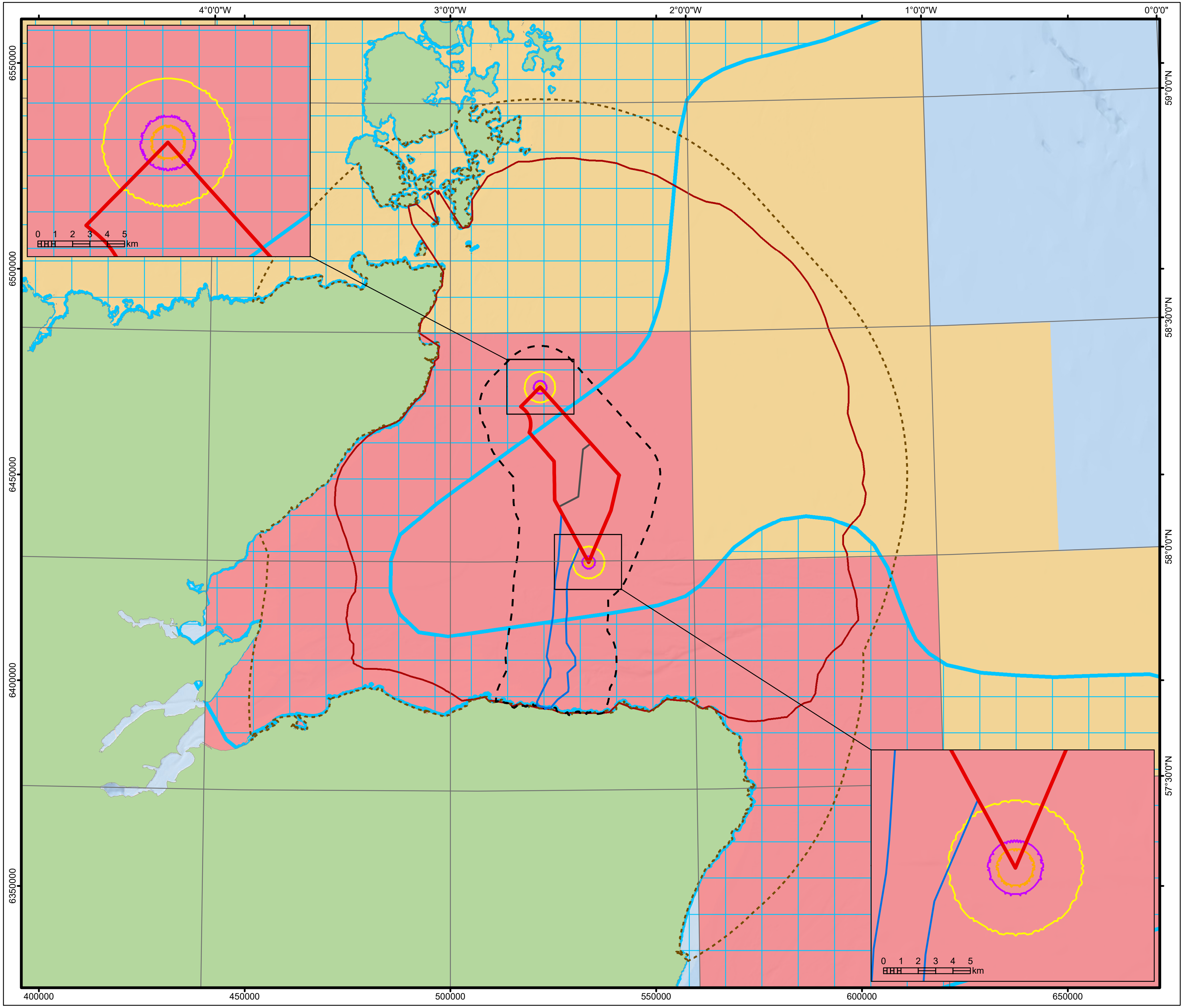
5.7.1.165 Taking this into consideration, shellfish IEFs within the study area are deemed to be of local to international importance, medium vulnerability, and high recoverability. The sensitivity of these receptors is therefore considered to be **Low**.

Significance of Effects

5.7.1.166 The impact of TTS/hearing damage on shellfish is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Summary of Effects for TTS

5.7.1.167 Taking into account the highest magnitude across all receptors groups as **Low** and highest sensitivity across all receptor groups as **Medium**, the overall significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence

Pin Piles x4 Contours (Stationary)

186dB (SELcum)
210dB (SELcum)
216dB (SELcum)
219dB (SELcum)

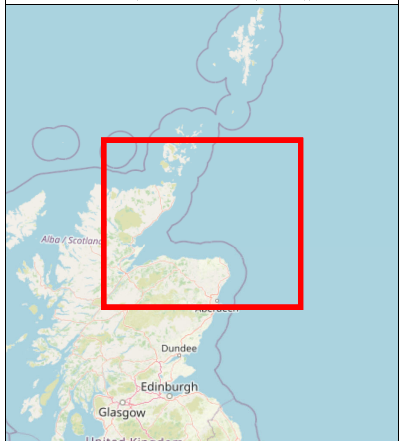
Sandeel Spawning Grounds

(Coull *et al.*, 1998) - Intensity

Undetermined

(Ellis *et al.*, 2012) - Intensity

Higher
Lower

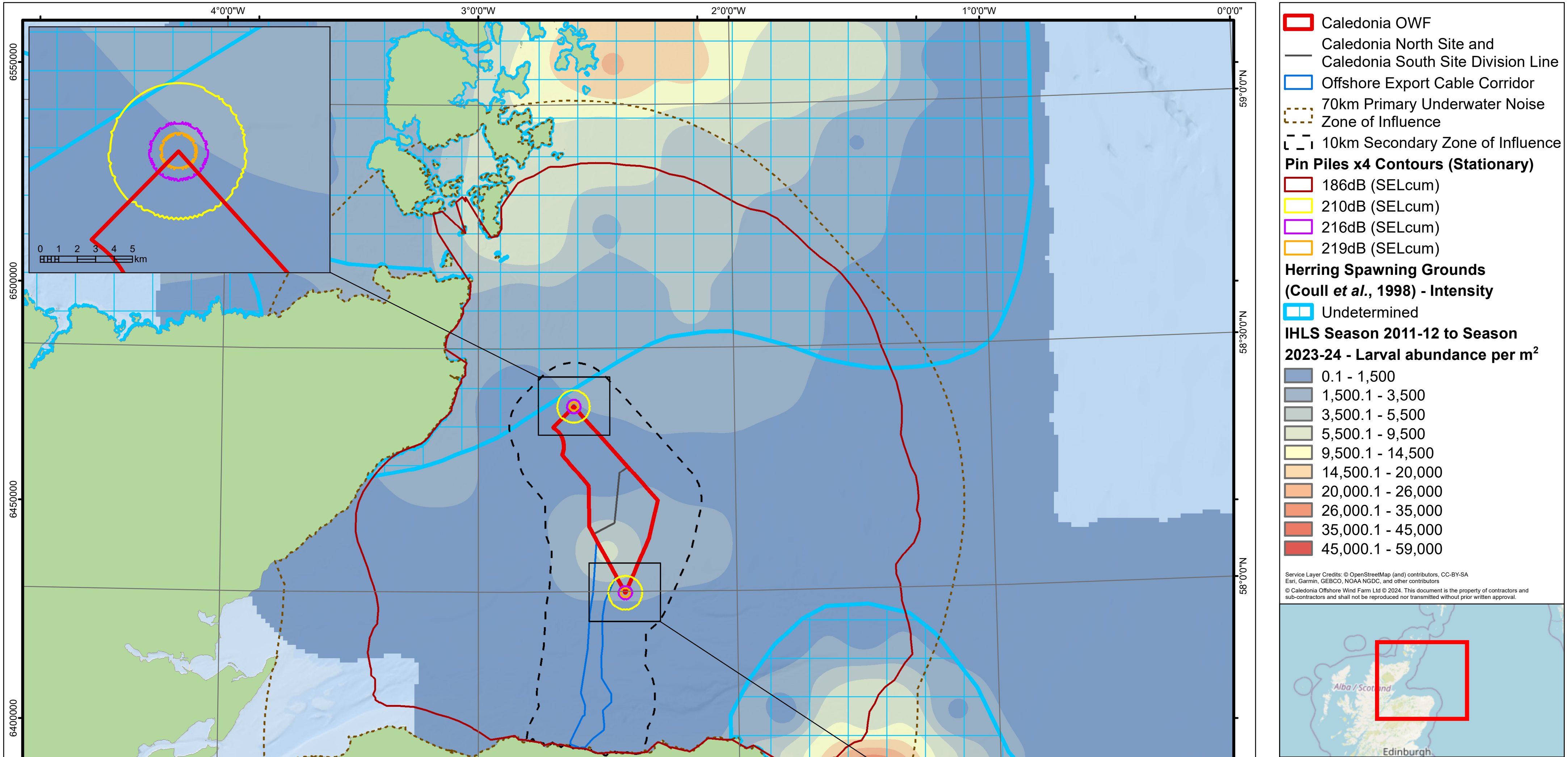


0 5 10 15 20 25 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm
GoBe APEM Group

CONTRACTOR DRAWING NO UKCAL1_GO_WNF_FAS_MAP_00268	CONTRACTOR REV 01
GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 5-14: Predicted Worst Case Impact Ranges for Spawning Sandeel from the Simultaneous Sequential Pilling of 4 Pin Piles at the North and South of Caledonia OWF	
STATUS Approved	SCALE 1:1,250,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 / REV N/A



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REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm
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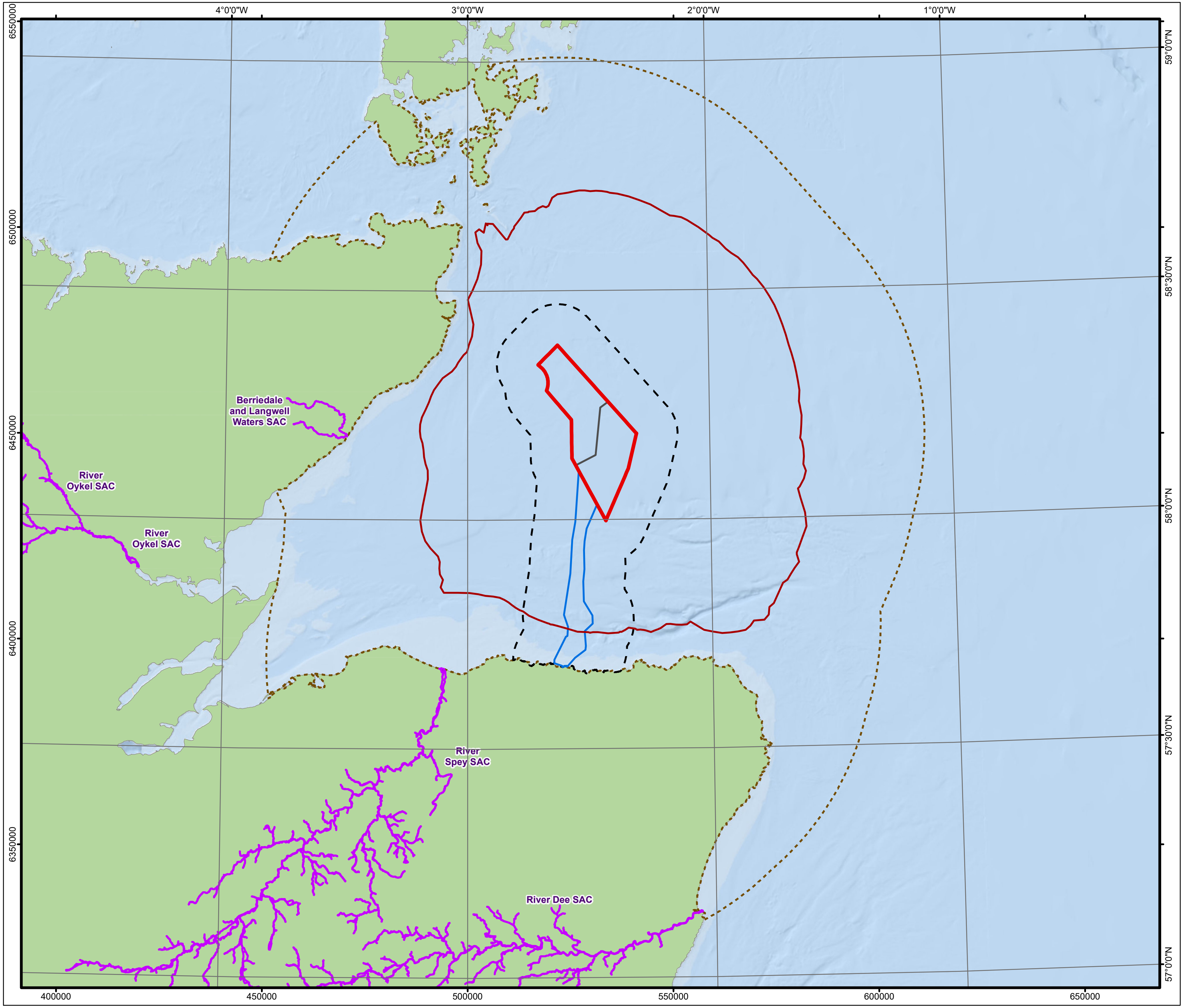
CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00269
CONTRACTOR REV: 01

GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE: Figure 5-15: Predicted Worst Case Impact Ranges for Spawning Herring from the Simultaneous Sequential Pilling of 4 Pin Piles at the North and South of Caledonia OWF

STATUS: Approved
SCALE: 1:1,250,000
DRAWING NUMBER: N/A
SHEET NO: 01 of 01
REV: N/A



- Caledonia OWF
- Caledonia North Site and Caledonia South Site Division Line
- Offshore Export Cable Corridor
- 70km Primary Underwater Noise Zone of Influence
- 10km Secondary Zone of Influence
- Special Area of Conservation (SAC)

Pin Piles x4 Contours (Fleeing)

- 186dB (SELcum)

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0 5 10 15 20 25 km

01	24/09/2024	Approved	EV	BB	DH
REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP

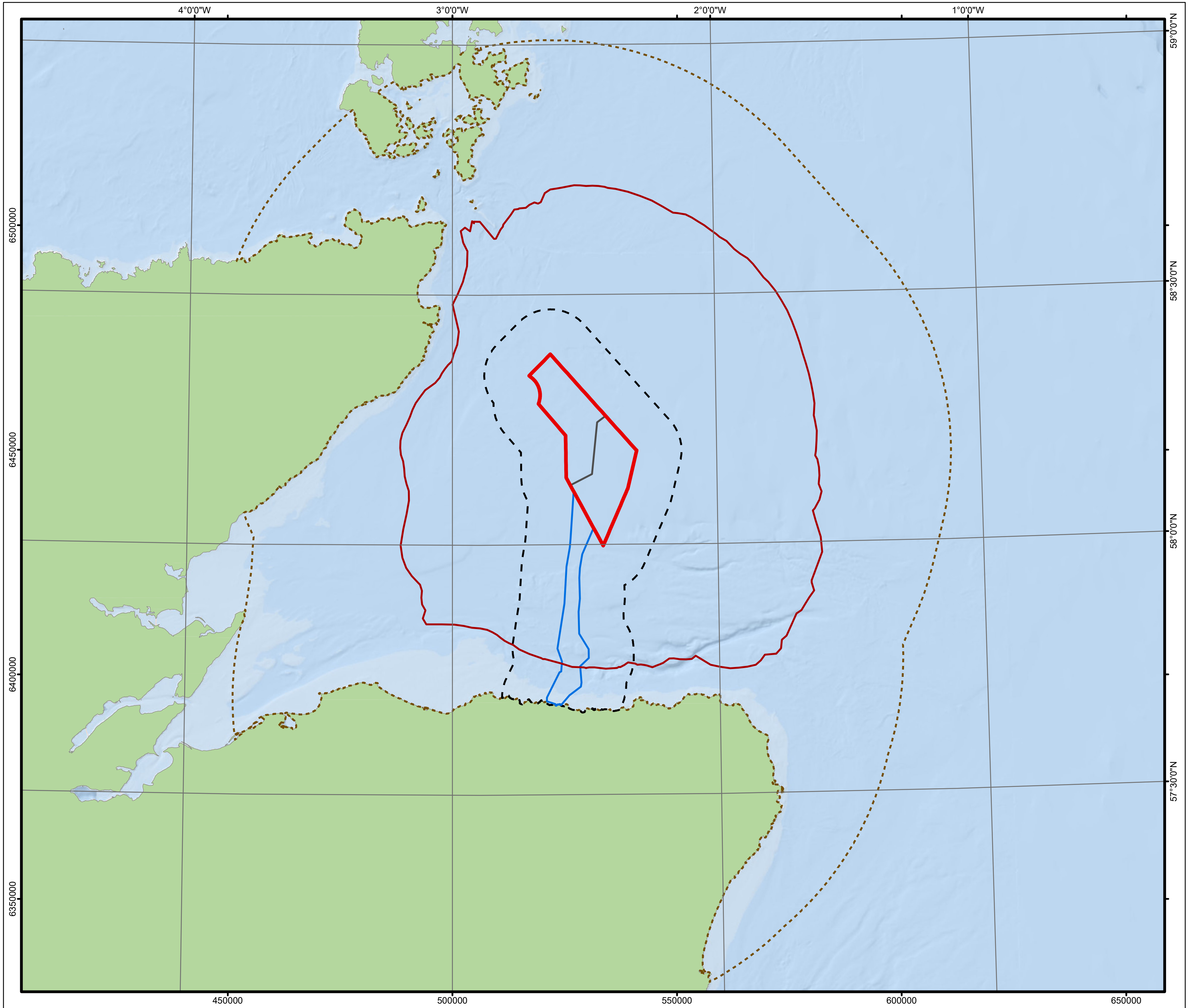
CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00270
CONTRACTOR REV: 01

GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE:
Figure 5-16: Predicted Worst Case Impact Ranges for Salmon from the Simultaneous Sequential Pilling of 4 Pin Piles at the north and south of Caledonia OWF

STATUS: Approved
SCALE: 1:1,250,000

DRAWING NUMBER: N/A
SHEET NO: 01 of 01
REV: N/A



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence

Pin Piles x4 Contours (Fleeing)

186dB (SELcum)

0 5 10 15 20 25 km

01	24/09/2024	Approved	EV	BB	DH
REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00271

CONTRACTOR REV: 01

GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE

Figure 5-17: Predicted Worst Case Impact Ranges for Group 3 Fleeing IEFs from the Simultaneous Sequentia Pilling of 4 Pin Piles at the North and South of Caledonia OWF

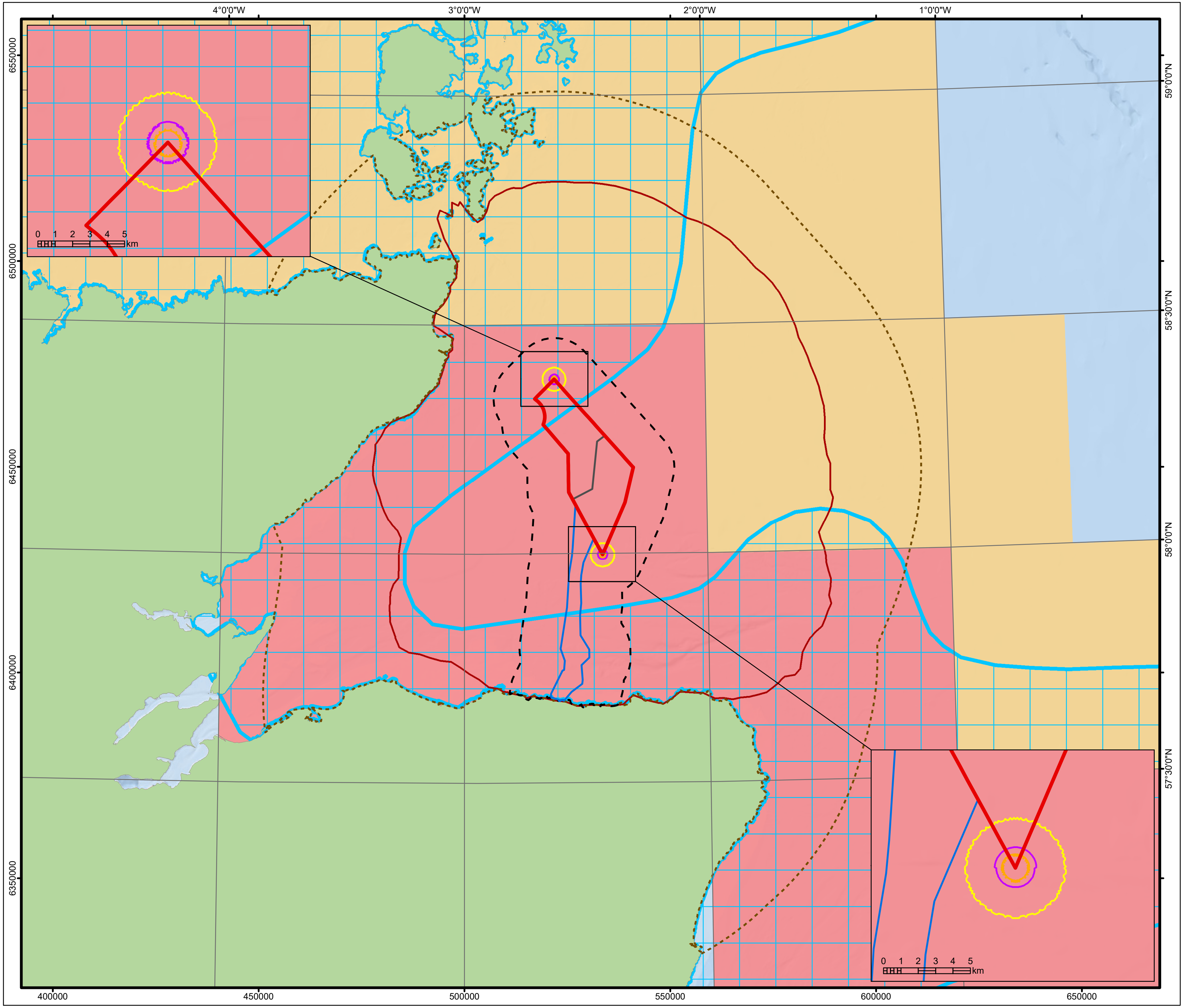
STATUS: Approved

SCALE: 1:1,150,000

DRAWING NUMBER: N/A

SHEET NO: 01 of 01

REV: N/A



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence

Monopile x2 Contours (Stationary)

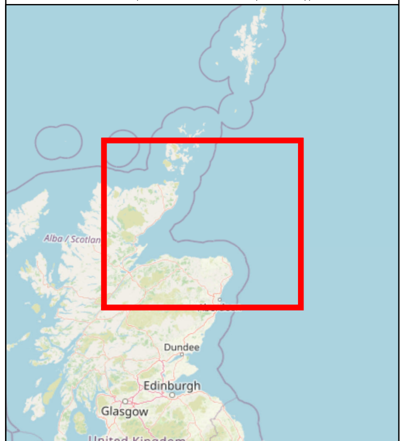
186dB (SELcum)
210dB (SELcum)
216dB (SELcum)
219dB (SELcum)

Sandeel Spawning Grounds (Coull *et al.*, 1998) - Intensity

Undetermined

(Ellis *et al.*, 2012) - Intensity

Higher
Lower

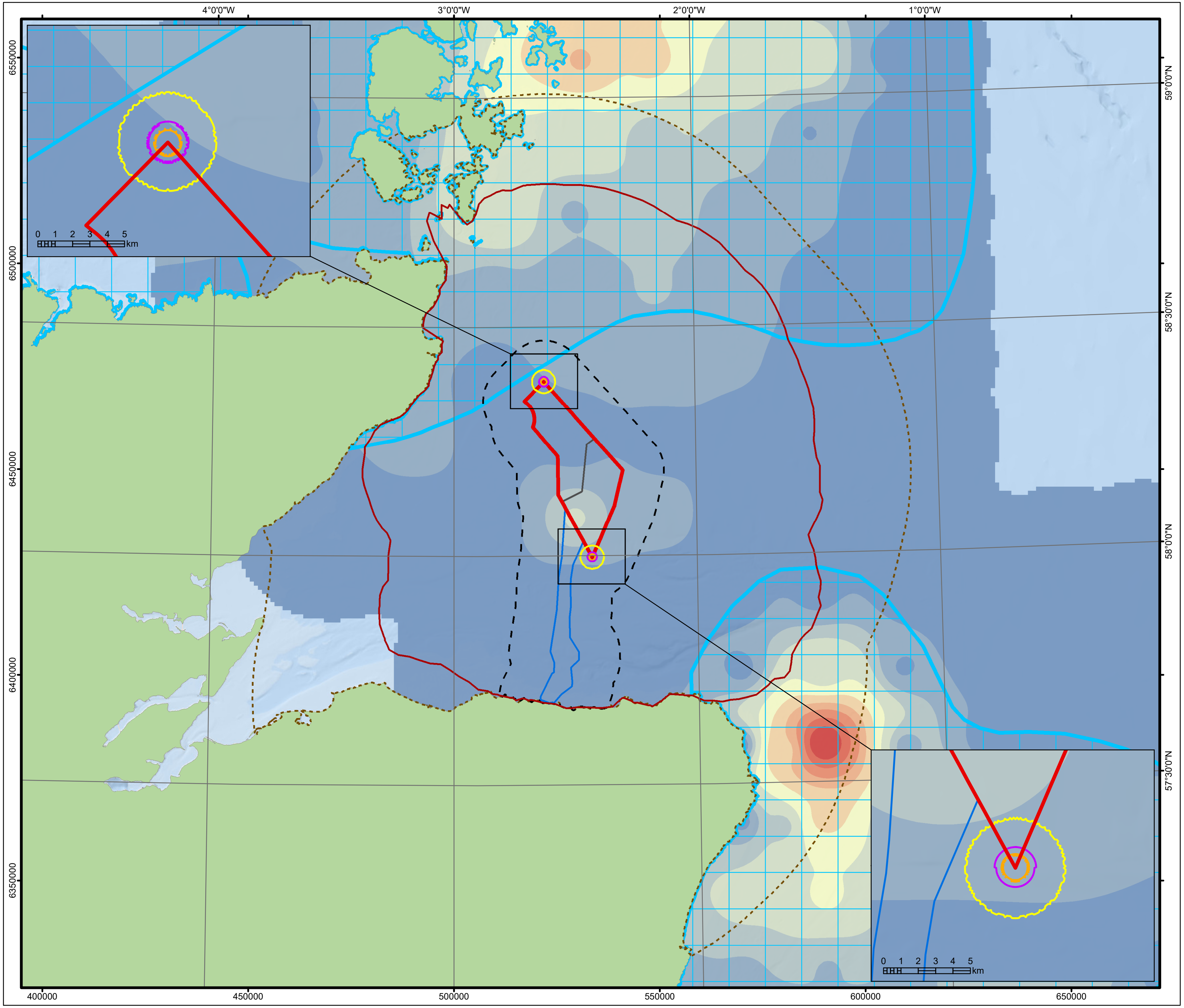


0 5 10 15 20 25 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm
GoBe APEM Group

CONTRACTOR DRAWING NO UKCAL1_GO_WNF_FAS_MAP_00272	CONTRACTOR REV 01
GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 5-18: Predicted Worst Case Impact Ranges for Spawning Sandeel from the Simultaneous Sequential Pilling of 2 Monopiles at the North and South of Caledonia OWF	
STATUS Approved	SCALE 1:1,250,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 / REV N/A



Caledonia OWF

Caledonia North Site and Caledonia South Site Division Line

Offshore Export Cable Corridor

70km Primary Underwater Noise Zone of Influence

10km Secondary Zone of Influence

Monopiles x2 Contours (Stationary)

186dB (SELcum)

210dB (SELcum)

216dB (SELcum)

219dB (SELcum)

Herring Spawning Grounds (Coull *et al.*, 1998) - Intensity

Undetermined

IHLS Season 2011-12 to Season 2023-24 - Larval abundance per m^2

0.1 - 1,500

1,500.1 - 3,500

3,500.1 - 5,500

5,500.1 - 9,500

9,500.1 - 14,500

14,500.1 - 20,000

20,000.1 - 26,000

26,000.1 - 35,000

35,000.1 - 45,000

45,000.1 - 59,000

0 5 10 15 20 25 km

01	24/09/2024	Approved	EV	BB	DH
REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00273

CONTRACTOR REV: 01

GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE

Figure 5-19: Predicted Worst Case Impact Ranges for Spawning Herring from the Simultaneous Sequential Pilling of 2 Monopiles at the North and South of Caledonia OWF

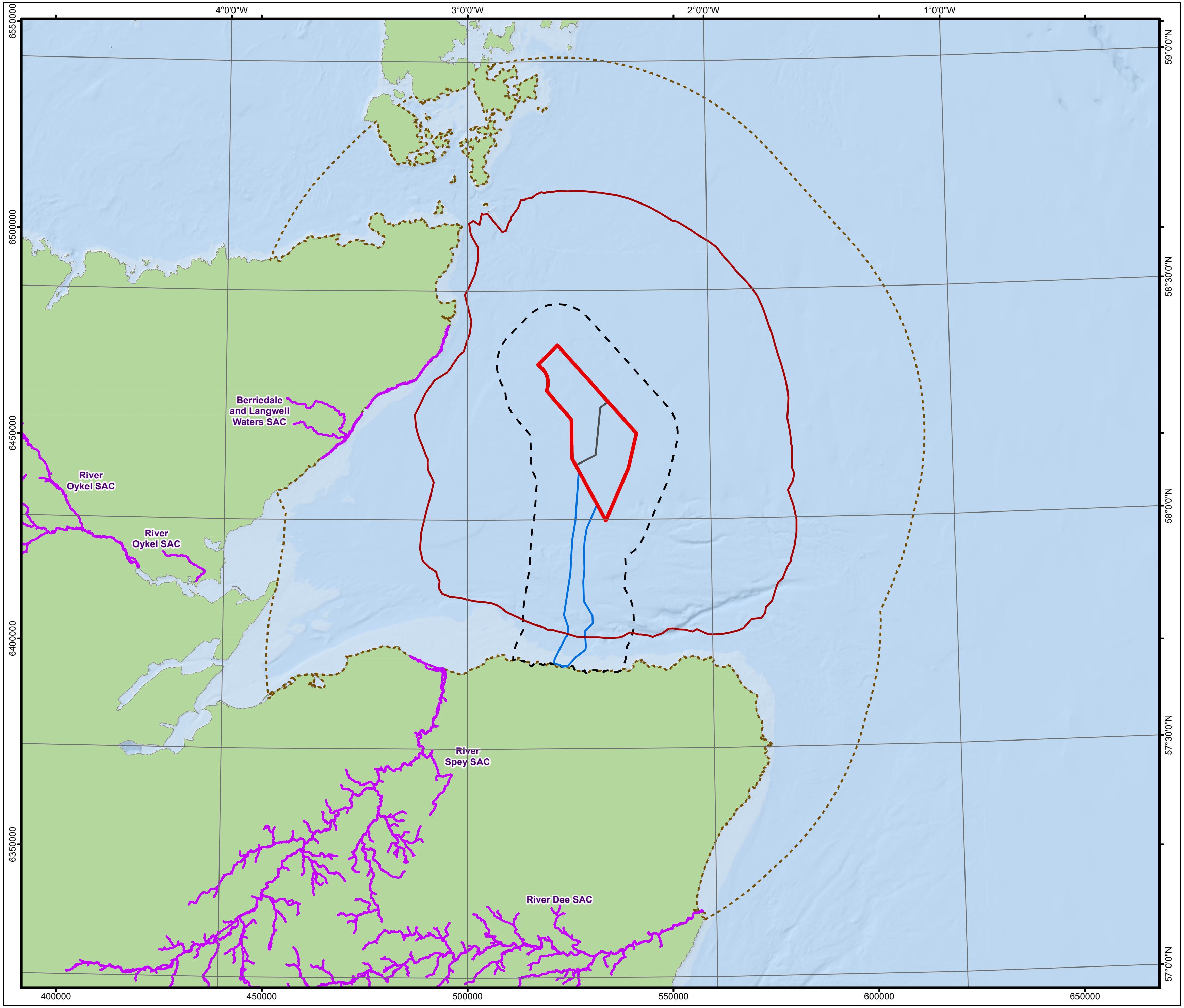
STATUS: Approved

SCALE: 1:1,250,000

DRAWING NUMBER: N/A

SHEET NO: 01 of 01

REV: N/A



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence
Special Area of Conservation (SAC)

Monopiles x2 Contours (Fleeing)

186dB (SELcum)

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0 5 10 15 20 25 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00274

CONTRACTOR REV: 01

GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)

DRAWING TITLE

Figure 5-20: Predicted Worst Case Impact Ranges for Salmon from the Simultaneous Sequential Pilling of 2 Monopiles at the North and South of Caledonia OWF

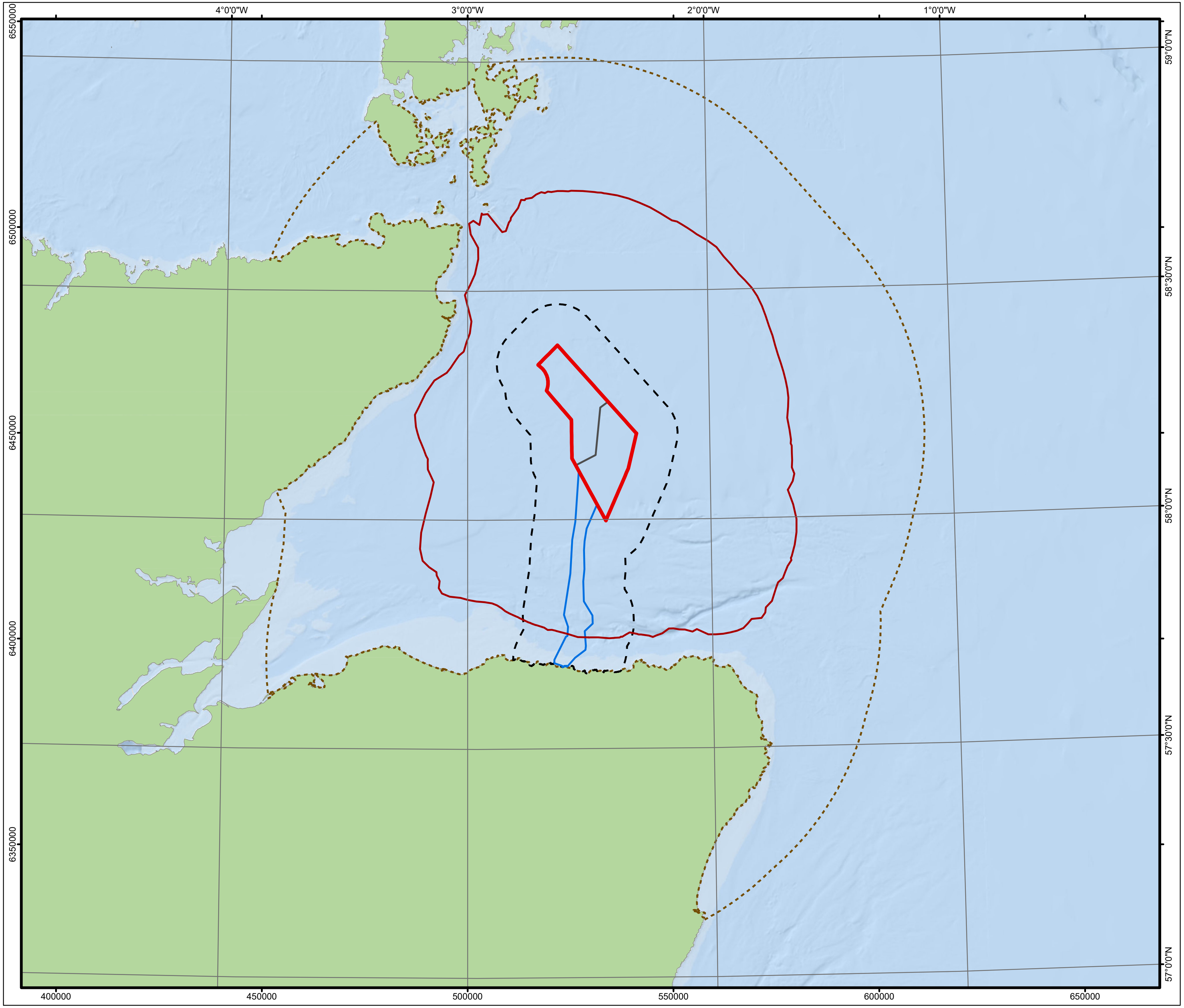
STATUS: Approved

SCALE: 1:1,250,000

DRAWING NUMBER: N/A

SHEET NO: 01 of 01

REV: N/A



Caledonia OWF
Caledonia North Site and Caledonia South Site Division Line
Offshore Export Cable Corridor
70km Primary Underwater Noise Zone of Influence
10km Secondary Zone of Influence

Monopiles x2 Contours (Fleeing)

186dB (SELcum)

Service Layer Credits: © OpenStreetMap (and) contributors, CC-BY-SA
Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

0 5 10 15 20 25 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm

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CONTRACTOR DRAWING NO UKCAL1_GO_WNF_FAS_MAP_00275	CONTRACTOR REV 01
GEODETIC PARAMETERS WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE Figure 5-21: Predicted Worst Case Impact Ranges for Group 3 Fleeing IEFs from the Simultaneous Sequential Pilling of 2 Monopiles at the North and South of Caledonia OWF	
STATUS Approved	SCALE 1:1,250,000
DRAWING NUMBER N/A	SHEET NO 01 of 01 / REV N/A

Behavioural Effects

5.7.1.168 Despite sounds exposure criteria providing a threshold for TTS/hearing damage (Popper *et al.,* 2014[32]) these do not provide a quantitative assessment for behavioural responses. Popper *et al.* (2014[32]) sets out criteria for the qualitative assessment of behavioural effects and disturbance. Behavioural effects from UWN and impulsive sound are particularly difficult to assess since they are highly dependent on species (due to different hearing abilities), context (proximity to source) and how different species respond to stimuli (bury in the substrate, swim away) (Popper *et al.,* 2014[32]). This is further supported and contextualised by Popper and Hawkins (2016[172]; 2019[304]) whereby this guidance is referenced as remaining the most suitable for assessments. Therefore, the Popper *et al.* (2014[32]) guidance has been used to inform the quantitative assessment as presented below.

5.7.1.169 Behavioural effects as a result of construction related underwater noise include a wide variety of responses including startle responses (C-turn), strong avoidance behaviour, changes in swimming or schooling behaviour, or changes of position in the water column (e.g., Hawkins *et al.,* 2014[152]). Depending on the intensity, timing and duration of exposure there is the potential for some of these responses to lead to significant effects at an individual level (e.g., reduced fitness, increased susceptibility to predation) or at a population level (e.g., interference with foraging, avoidance or delayed migration to key spawning grounds) (e.g., Popper and Hawkins, 2019[304]). Some behavioural responses may only be short-term with no wider effects for the individual or population, particularly once acclimatisation to the sound has taken place (Popper and Hawkins, 2019[304])

5.7.1.170 Different fish and shellfish have varying sensitivities to piling noise, depending on how these species perceive sound in the environment. Regarding shellfish and Group 1 fish, these receptors lack a swim bladder, and so are largely considered to be less sensitive to sound pressure, instead detecting sound in the environment through particle motion. The sensitivity of the receptors to acoustic particle velocity component of the sound field has been noted by a number of researchers (Hawkins *et al.,* 2014[152]; Nedwell *et al.,* 2007[173]; Popper and Hastings, 2009) and the potential for piling activity to generate the type of sound fields that may contain substantial acoustic-driven particle velocity components has also been noted in the literature (Hawkins, 2009[174]).

5.7.1.171 The sensitivity to particle motion in the Group 1 fish receptors and shellfish is more likely to be important for behavioural responses rather than sound pressure due to the main cause of injury from sound is barotrauma which primarily affects air filled sacs, with group 1 species therefore being less vulnerable to injury too because of the lack of a swim bladder. Therefore particle motion is equally important for injury and behavioural effects for these species (Hawkins, 2009[174]; Hawkins and Popper*,* 2014[152]; Mueller-Blenkle *et al.,* 2010[156]).

5.7.1.172 It has also been reported that slow, rolling interface waves that move out from a source like a pile driver can produce particle motion amplitudes travelling considerable distances (Popper *et al.,* 2014[32]), with implications for demersal and sediment dwelling fish (such as sandeel) and shellfish in close proximity to piling operations. Specifically, demersal dwelling receptors such as sandeel (Group 1 receptors) may be particularly affected by vibration through the seabed when sandeel are buried in sandy sediments.

5.7.1.173 Particle motion generated from piling is expected to attenuate more rapidly than the acoustic pressure component in the water, with a low risk of behavioural effects in the far-field (i.e., kilometres from the source).

5.7.1.174 Mueller-Blenkle *et al.* (2010[156]) measured behavioural responses of Dover sole to sounds representative of those produced during marine piling, with considerable variation across subjects (i.e., depending on the age, sex, condition etc. of the fish, as well as the possible influence of confinement in cages on the overall stress levels in the fish). This study concluded that it was not possible to find an obvious relationship between the level of exposure and the extent of the behavioural response, although an observable behavioural response was reported at 144 to 156dB re 1 μPa SPLpeak for Dover sole. However, this threshold should not be interpreted as the level at which an avoidance reaction will be elicited, as the study was not able to show this, especially considering the varied responses observed across subjects.

5.7.1.175 Research into the impact of UWN on shellfish receptors is scarce, and no attempt has been made to set exposure criteria (Hawkins *et al.,* 2014[152]). Studies on marine invertebrates have shown sensitivity of shellfish receptors to substrate borne vibration (Roberts *et al.,* 2016[175]). Aquatic decapod crustaceans are equipped with a number of receptor types potentially capable of responding to the particle motion component of underwater noise (e.g., the vibration of the water molecules which results in the pressure wave) and ground-borne vibration. It is generally their hairs that provide the sensitivity, although these animals also have other sensor systems which could be capable of detecting vibration.

5.7.1.176 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 group 2 and group 3 receptors. Mueller-Blenkle *et al.* (2010[176]) measured behavioural responses of cod to sounds representative of those produced during marine piling and observed behavioural responses at 140 to 161dB re 1 μPa SPLpeak for cod. However, variable responses were observed across subjects and consequently this threshold should not be interpreted as the level at which an avoidance reaction will be elicited, as the study was not able to show this. A study by Pearson *et al.* (1992[177]) on the effects of seismic airgun noise on caged rockfish (*Sebastes spp*.) 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. Studies by Curtin University in Australia for the oil and gas industry by McCauley *et al.* (2000[178]) exposed various fish species in large cages, in open water to seismic airgun noise and assessed behaviour, physiological and pathological changes. The study made the following observations:

- A general fish behavioural response to move to the bottom of the cage during periods of high-level exposure (greater than Root Mean Square (RMS) levels of around 156 to 161dB re 1 μPa; approximately equivalent to SPLpeak levels of around 168 to 173dB re 1 μPa);
- A greater startle response by small fish to the above levels;
- A return to normal behavioural patterns some 14 to 30 minutes after airgun operations ceased;
- No significant physiological stress increases attributed to air gun exposure; and
- Some preliminary evidence of damage to the hair cells when exposed to the highest levels, although it was determined that such damage will only likely occur at short range from the source.

5.7.1.177 The authors did, however, note that any potential seismic effects on fish may not necessarily translate to population scale effect or disruption to fisheries and McCauley *et al.* (2000[178]) show that caged fish experiments can lead to variable results. Picciulin *et al.* (2024[179]) undertook a study based on free-living brown meagre (*Sciaena umbra*) fish and observed no influence on breeding site selection of brown meagre fish when exposed to vessel noise. Similar observations were made by Bruintjes *et al.* (2014), who observed no influence on the early-life survival and growth of the cichlid fish (*Neolsmprologus pulcher*) when exposed to moderate noise increases (164dB; frequency range 2–30,000Hz) (motorboat noise). Although it should be noted that this study was conducted on captive fish.

5.7.1.178 Atlantic salmon possess a swim bladder and therefore are sensitive to the sound pressure from underwater noise. 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 Atlantic salmon (Harding *et al.,* 2016[180]; Hawkins and Popper, 2014[152]; Nedwell *et al.,* 2006[181]). Behavioural changes as a result of UWN have been shown in regard to foraging and movement patterns (Harding *et al.,* 2016[180]). UWN associated with pile driving could act as a barrier to migration and impact Atlantic salmon by either delaying or preventing the migration to native rivers and delay spawning (Harding *et al.,* 2016[180]).

5.7.1.179 Hawkins *et al.* (2014[152]) undertook a study on schools of sprat and mackerel, observing behavioural responses to pile driving. A range of responses were observed at sound pressure levels of 163.2 SPL peak-to-peak and estimated single strike SEL of 135dB re 1 μPa2 s for sprat and 163.3dB re 1 μPa peak-to-peak and estimated single strike SEL 142dB re 1 μPa2 s for mackerel. Responses were found to vary (to the same stimulus type and intensity), differing between the two species, depending on whether the fish were schooling or as individuals, during night and day, and, for sprat, dependent on whether mackerel (a predator) were also present. As such, this supports previous studies which have shown how fish behaviour to external stimulus can vary depending on whether fish are already engaged in specific activities, including spawning (Skaret *et al.,* 2005[182]). It should also be noted that this threshold is based on a study undertaken within a quiet loch and it is therefore not considered appropriate to apply the outcomes of this study to a much noisier area such as the North Sea (which is subject to high levels of anthropogenic activity and consequently noise) as the fish within this area will be acclimated to the noise and would be expected to have a correspondingly lower sensitivity to noise levels. The change in reaction to noise in the presence of a predator should also be considered alongside the study by Skaret *et al.* (2005[182]), as this suggests that when fish are involved in life history critical activities (i.e., predator avoidance or spawning), reactions can diverge from expected behaviours, either increasing or decreasing the likelihood of a response.

Group 1 IEFs

Magnitude of Impact

5.7.1.180 Considering the Popper *et al.* (2014[32]) criteria, any risk of behavioural effects or auditory masking in Group 1 species (particularly the less mobile species) from piling are expected to be low in the intermediate field. Near field behavioural impacts are considered likely to be fully contained within TTS/ hearing damage effects and so are not considered further.

5.7.1.181 Consequently, the magnitude of the impact is predicated to be of small spatial extent (relative to spawning and nursery grounds), short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.182 Group 1 receptors are deemed to be of low vulnerability, high recoverability and are of regional to international importance. The sensitivity of these receptors to behavioural impacts from are therefore considered to be **Low**.

Significance of Effects

5.7.1.183 The impact of behavioural effects on sandeel is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.184 The impact of behavioural effects on fleeing Group 1 IEFs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Group 2 IEFs

Magnitude of Impact

5.7.1.185 Considering the Popper *et al.* (2014[32]) criteria, any risk of behavioural effects from pilling is expected to be high in the near field, moderate in the intermediate field and low in the far fields. Auditory masking is expected to be moderate in the near field and low in the intermediate and far fields.

5.7.1.186 As identified in Volume 7B, Appendix 5-1: Fish and Shellfish Ecology Technical Baseline Report, several rivers containing populations of Atlantic salmon and sea trout flow into the Moray Firth. It is believed that Atlantic salmon undertake an Easterly to North Easterly migration route out of the Moray Firth (Newton *et al.,* 2021[183]). Sea trout on the other hand may occupy locally constrained areas or may undertake migrations out of the Moray Firth.

5.7.1.187 Atlantic salmon and sea trout are expected to be able to avoid injurious effects by moving away to avoiding pilling events before the onset of injuries. However, avoidance of pilling events may delay their migration. With regards to the temporal WCS, the maximum duration of piling results from the sequential piling of jacket foundations or anchor pile foundations in the Caledonia OWF, resulting in a total piling duration of up to 18 months . Therefore, pilling may occur during migration periods. Given the low extent of the underwater noise generated, behavioural effects are only expected to affect a small number of individuals passing through or close by to the Caledonia OWF. The Caledonia OWF is not situated directly at the mouth of any of the major salmon spawning rivers (River Oykel, River Spey, River Deveron).

5.7.1.188 Consequently, the magnitude of the impact is predicated to be of small spatial extent (relative to migratory rivers), short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.189 Group 2 receptors are deemed to be of medium vulnerability, high recoverability and are of regional to international importance. The sensitivity of these receptors to behavioural impacts from are therefore considered to be **Medium**.

Significance of Effects

5.7.1.190 The impact of behavioural effects on Group 2 IEFs (Atlantic salmon and sea trout) is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Group 3 IEFs

Magnitude of Impact

5.7.1.191 Considering the Popper *et al.* (2014[32]) criteria, any risk of behavioural and auditory masking effects from pilling is expected to be high in the near and intermediate fields and moderate in the far fields.

5.7.1.192 There is potential for behavioural impacts for spawning herring due to the proximity Buchan and Orkney/Shetland herring spawning stock. However, as discussed previously, the IHLS data indicates that impacts upon herring larval densities and therefore spawning herring stock are likely to be minimal when compared to areas of peak. This is further supported by PSA datasets which show the availability of suitable herring spawning substrates across Caledonia OWF and the wider North Sea. Considering the proximity of Caledonia OWF to the Buchan and Orkney/Shetland herring spawning grounds (Coull *et al.,* 1998[94]) and of areas of low-density herring larvae, and the broadscale distribution of available spawning substrates for herring across the North Sea, UWN from piling is not anticipated to cause a population level behavioural effects.

5.7.1.193 Consequently, the magnitude of the impact is predicated to be of small spatial extent (relative to spawning and nursery grounds), short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

5.7.1.194 Additionally, spawning grounds for a number of Group 3 species overlap with the study area or are within the wider area. Skaret *et al.* (2005[182]) identified that herring (a Group 3 species), had a significantly reduced reaction to external stimulus when involved in spawning activity than when swimming. As such, it is likely that any behavioural impacts to fish would be significantly reduced when they are engaged in spawning events.

5.7.1.195 Consequently, the magnitude of the impact is predicated to be of small spatial extent (relative to spawning and nursery grounds), short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.196 Receptors are deemed to be of low vulnerability, high recoverability and are of regional to international importance. The sensitivity of these receptors to behavioural impacts from are therefore considered to be **Low**.

Significance of Effects

5.7.1.197 The impact of behavioural effects on spawning adult herring is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.198 The impact of behavioural effects on Group 3 fleeing IEFs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Eggs and Larvae

Magnitude of Impact

5.7.1.199 Given the considered stationary nature of eggs and larvae the potential for behavioural impacts is considered limited. As such, it is considered that the assessment of behavioural impacts to eggs and larvae is sufficiently captured within consideration of behavioural effects for this group.

5.7.1.200 Consequently, the magnitude of the impact is predicated to be of small spatial extent (relative to their spawning and nursery grounds), short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.201 Cod, herring, lemon sole, mackerel, plaice, sandeel, sole, sprat and whiting all have spawning grounds within the vicinity of the Caledonia OWF. Eggs and larvae are considered organisms of concern by Popper *et al.* (2014[32]), due to their vulnerability, reduced mobility and small size.

5.7.1.202 Taking this into consideration and given the broadscale nature of the spawning grounds, the sensitivity of eggs and larvae to TTS from underwater noise is considered to be **Medium**.

Significance of Effects

5.7.1.203 The impact of behavioural effects on eggs and larvae is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Shellfish

Magnitude of Impact

5.7.1.204 It is understood that particle motion attenuates rapidly, and therefore impacts on shellfish from particle motion are likely to occur local to the source.

5.7.1.205 Taking this into account, and the broad distribution of these species along the UK coasts, the magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.1.206 receptors are deemed to be of low vulnerability, high recoverability and are of regional to international importance. The sensitivity of these receptors to behavioural impacts from are therefore considered to be **Low**.

Significance of Effects

5.7.1.207 The impact of behavioural effects on shellfish is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Summary of Effects for Behavioural Effects

5.7.1.208 Taking into account the highest magnitude across all receptors groups as **Low** and highest sensitivity across all receptor groups as **Medium**, the overall significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

UXO Clearance

5.7.1.209 Based on experience of other OFW projects in the Moray Firth, UXO clearance is anticipated to be required during seabed preparation prior to construction taking place. UXO clearance will be consented under a separate assessment and Marine Licence application at the time; however, as it is considered a reasonably foreseeable activity, high level consideration has been provided of the potential effects arising from this activity.

5.7.1.210 Prior to detailed surveys being undertaken across the Caledonia OWF and Caledonia OECC, the exact number of potential UXO is unknown.

5.7.1.211 UXO are typically managed through avoidance (through micro siting), repositioning of the UXO (where safe to do so) or by clearance through low order techniques. Evidence from Moray West has demonstrated that the low order deflagration technique has been proven to be successful in reducing UWN impacts typically associated with high order clearance methods (Ocean Winds, 2024[184]). As noted in Table 5-19, low order deflagration will be the preferred method of UXO clearance (Embedded Mitigation M-107).

5.7.1.212 For explosive noise sources such as UXO detonation, quantitative criteria for assessment are only available for mortality and potential mortal injury (Table 5-26). For other potential effects the qualitative approach described for pile driving is applicable.

Table 5-26: Recommended guidelines for explosions according to Popper *et al.* (2014[32]) for species of fish and eggs and larvae.

Receptor	Mortality and Potential Mortal Injury	Impairment			Behaviour
		Recoverable Injury	TTS	Masking	
Group 1 Fish: no swim bladder	229 – 234 dB peak	(N) High (I) Low (F) Low	(N) High (I) Moderate (F) Low	NA	(N) High (I) Moderate (F) Low
Group 2 Fish: swim bladder not involved in hearing	229 – 234 dB peak	(N) High (I) High (F) Low	(N) High (I) Moderate (F) Low	NA	(N) High (I) High (F) Low
Group 3 Fish: swim bladder involved in hearing	229 – 234 dB peak	(N) High (I) High (F) Low	(N) High (I) High (F) Low	NA	(N) High (I) High (F) Low
Eggs and larvae	>13 mm s-1 peak velocity	(N) High (I) Low (F) Low	(N) High (I) Low (F) Low	NA	(N) High (I) Low (F) Low
N = near-field; I = intermediate-field, F = far-field.					

Magnitude of Impact

5.7.1.213 Low order deflagration of UXO would represent a short-term (i.e., seconds) increase in UWN (i.e., SPL and particle motion) and while noise levels will be elevated such that this may result in injury or behavioural effects on fish and shellfish species. It should be noted that the Applicant will be seeking consent for UXO clearance within a separate Marine Licence application post-consent.

5.7.1.214 For explosive noise sources such as UXO detonation, quantitative criteria for assessment are only available for mortality and potential mortal injury (Table 5-26). For other potential effects the qualitative approach described for pile driving is applicable.

5.7.1.215 UXO detonations are considered to have a lower likelihood of triggering a population level effect than that associated from piling operations, due to the significantly reduced temporal footprint that would arise from UXO operations.

5.7.1.216 UXO clearance through low order deflagration has been committed to where practicable and appropriate (Table 5-19; Embedded Mitigation M-107). Deflagration is proposed for destruction of the UXO, intended to result in a ‘low order’ burn of the explosive material in a UXO, which destroys, but does not detonate, the internal explosive.

5.7.1.217 Where the technique proceeds as intended, it is still not without noise impact. The process requires an initial shaped explosive donor charge, typically 250g or less, to breach the casing and ignite the internal high explosive (HE) material without full detonation. The shaped charge and burn will both produce noise, although it will be significantly less than the high order detonation of the much larger UXO. It may not destroy all of the HE, necessitating further deflagration events or collection of the remnants. The deflagration may produce an unintentional high-order event, although this is rare (Ocean Winds, 2024[184]). There is risk of mortality and potential mortal injury of <50m at 234 dB SPL_{pk} rising to 60m at 229 dB SPL_{pk}.

5.7.1.218 Consequently, the magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Significance of Effects

5.7.1.219 The impact on Group 1 Individual Ecosystem Role (IERs) (sandeel), Group 2 IERs (Atlantic salmon, sea trout), Group 3 IERs (herring, European eel, allis shad, twaite shad), eggs and larvae and Shellfish IERs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptors is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.220 The impact on all other IEFs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptors is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Continuous Noise Source

5.7.1.221 Continuous sound sources associated with the construction phase of the Proposed Development (Offshore) include vessel movements, dredging and seabed preparation works. Quantitative criteria for assessment are only available for recoverable injury and TTS for Group 3 fish (Table 5-27). For other potential effects the qualitative approach described for pile driving is applicable.

Table 5-27: Recommended guidelines for continuous noise sources according to Popper *et al.* (2014[32]) for species of fish and eggs and larvae.

Receptor	Mortality and Potential Mortal Injury	Impairment			Behaviour
		Recoverable Injury	TTS	Masking	
Group 1 Fish: no swim bladder	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Group 2 Fish: swim bladder not involved in hearing	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Group 3 Fish: swim bladder involved in hearing	(N) Low (I) Low (F) Low	170 dB rms for 48 hrs	158 dB rms for 12 hours	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Eggs and larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low
N = near-field; I = intermediate-field; F = far-field.					

Magnitude of Impact

5.7.1.222 General construction noise, arising from vessel movements, dredging and seabed preparation works will generate low levels of continuous sounds (i.e., from the vessels themselves and/or the sounds from dredging tools) throughout the construction phase. The study area is subject to relatively high levels of shipping activity currently, and it is expected that the vessel activity would be no greater than the baseline during construction activities (due to construction exclusion zones reducing current shipping activity and the number of construction vessels expected to be much lower than that which currently transit the area). The underwater noise impacts from vessel noise are generally spatially limited to the immediate area around the vessel rather than having impacts over a wide area (e.g., Mitson, 1995[185]).

5.7.1.223 Consequently, the magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Significance of Effects

5.7.1.224 The impact on Group 1 IERs (sandeel), Group 2 IERs (Atlantic salmon, sea trout), Group 3 IERs (herring, European eel, allis shad, twaite shad), eggs and larvae and Shellfish IERs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptors is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.225 The impact on all other IEFs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptors is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Summary of Effects Arising from UWN

5.7.1.226 Taking into account the highest magnitude across all receptors groups as low and highest sensitivity across all receptor groups as medium, the overall significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**. A summary of the potential impacts due to UWN during construction is provided in Table 5-28 for each receptor group/type.

Table 5-28: Summary of assessment for UWN during construction.

Effect	Receptor Group	Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
Mortality and Potential Mortal Injury	Group 1	Low	Medium	Minor Adverse	M-11 (see Table 5-19)	Minor Adverse
	Group 2	Low	Medium	Minor Adverse		Minor Adverse
	Group 3	Low	Medium	Minor Adverse		Minor Adverse
	Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible
Recoverable Injury	Group 1	Low	Medium	Minor Adverse	M-11 (see Table 5-19)	Minor Adverse
	Group 2	Low	Medium	Minor Adverse		Minor Adverse
	Group 3	Low	Medium	Minor Adverse		Minor Adverse
	Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible
TTS	Group 1	Low	Medium	Minor Adverse	M-11 (see Table 5-19)	Minor Adverse
	Group 2	Low	Medium	Minor Adverse		Minor Adverse
	Group 3	Low	Medium	Minor Adverse		Minor Adverse
	Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible

Effect	Receptor Group	Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
Behavioural Effects	Group 1	Low	Low	Negligible	M-11 (see Table 5-19)	Negligible
	Group 2	Low	Medium	Minor Adverse		Minor Adverse
	Group 3	Low	Low	Negligible		Negligible
	Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible
UXO Clearance	Group 1	Low	Low	Negligible	M-74, M-107 (see Table 5-19)	Negligible
	Group 2	Low	Medium	Minor Adverse		Minor Adverse
	Group 3	Low	Low	Negligible		Negligible
	Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible

Impact 2: Temporary Increases in SSCs

5.7.1.227 Temporarily, localised increases in SSC and associated sediment deposition and smothering are expected to occur during foundation and cable installation works (including trenchless technique installation) and seabed preparation works (including sandwave clearance). This assessment should be read in conjunction with Volume 2, Chapter 3: Marine Water and Sediment Quality, which provides the detailed offshore physical environment assessment.

5.7.1.228 During the construction of the Proposed Development (Offshore), sediment will be disturbed and released into the water column. This will give rise to suspended sediment plumes and localised changes in seabed levels as material settles out of suspension. The activities associated with the Proposed Development (Offshore) which will result in the greatest disturbance of seabed sediments are:

- Pre-lay cable trenching using a jet trencher tool at the seabed;
- Seabed preparation (including both seabed levelling for WTG foundations and sandwave clearance) including spoil disposal via a TSHD;
- Foundation installation using drilling techniques; and
- Drilling fluid release during Horizontal Directional Drilling (HDD) operations.

5.7.1.229 A full assessment of the impacts associated with disturbance to sediment (listed above), including the methodological approach used to assess the characteristics of sediment plumes and associated changes in bed level arising from settling of material is set out in Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report. To provide a robust assessment, a range of realistic combinations have been considered, based on conservatively representative location (environmental) and the Proposed Development (Offshore) (Worst-Case Design Scenario) specific information, including a range of water depths, heights of sediment ejection/initial resuspension, and sediment types.

Magnitude of Impact

5.7.1.230 Table 5-20 presents the WCS associated with increases in SSC and deposition across the Caledonia OWF and Caledonia OECC. The maximum subtidal sediment volumes a result of all construction activities across Caledonia OWF and Caledonia OECC is 60,094,800m^3. This has been derived from seabed preparation for foundations, sandwave clearance for cable installation, cable trenching, drilling for foundations and spoil disposal are all predicted to result in sediment plumes and localised increases in SSC. Site-specific modelling of sediment plumes and deposition from seabed preparation and installation activities along the Caledonia OECC, and within the Caledonia OWF has been undertaken to quantify the potential footprint of the plumes, their longevity and the concentration of SSC as well as the subsequent sediment deposition on the seabed.

5.7.1.231 The release events that have been simulated within the numerical model, as described in Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report, have been specifically designed to capture the full range of realistic WCS outcomes as the maximum:

- Sediment plume concentrations;
- Sediment plume extent;
- Vertical deposition depth (bed level change); and
- Horizontal extent of deposition (spatial extent (area) of bed level change).

5.7.1.232 A full assessment of the above, including the methodological approach used to assess the characteristics of sediment plumes and associated changes in bed level arising from settling of material is set out Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report.

5.7.1.233 To provide a robust assessment, a range of realistic combinations have been considered, based on conservatively representative location (environmental) and WCS (Table 5-20).

5.7.1.234 The maximum distance and as such the overall spatial extent that any resultant plume might be reasonably experienced can be estimated as the spring tidal excursion distance. Any location beyond the tidal excursion distance is unlikely to experience any measurable change in SSC from a sediment plume.

5.7.1.235 Given the nature of the sediment disturbance (temporary), any impacts are also anticipated to be short-lived, with any deposited material re-worked. Specifically, the numerical modelling for seabed disturbance resulting from mass flow excavator (MFE), seabed levelling and sandwave clearance indicated that:

- MFE, seabed levelling and sandwave clearance activities may produce sediment plumes with SSC up to thousands of mg/l, however these concentrations will be spatially restricted and short-lived. Elevated SSC may be advected by tidal currents up to 10km away, although these concentrations will be low. In the vast majority of cases, elevated SSC will be indistinguishable from background levels after 20 hours from the start of activities and can therefore be considered temporary and localised;
- Associated deposition from sediment plumes is generally in the order of tens to low hundreds of mm within several hundreds of metres from the point of disturbance. Sediment deposition following MFE activities of up to 50mm is expected in the immediate vicinity of the active disturbance. With thicknesses between 5 and 20mm deposited up to 600m away from the active disturbance area, reducing to low tens of mm

downstream of the disturbance. Sediment deposition is generally not measurable beyond 3km to 5km away from the associated activities and is therefore generally small-scale and restricted to the near field. This deposition is likely to become integrated into the local sediment transport regime and will be redistributed by tidal currents.

5.7.1.236 MFE, seabed levelling and sandwave clearance activities may produce sediment plumes with SSC up to thousands of mg/l, however these concentrations will be spatially restricted and short-lived. Elevated SSC may be advected by tidal currents up to 20km away, although these concentrations will be low. In the majority of cases, elevated SSC will be indistinguishable from background levels after 20 hours from the start of activities. For sandwave clearance activities, elevated SSC may remain past 20 hours from the start of activities, although this is expected to continue to disperse and become indistinguishable from background levels within several tidal cycles and can therefore be considered temporary and localised. Further information on sediment plume distances and modelling are provided in Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report.

5.7.1.237 To note the sediment plume and deposition modelling takes into consideration a single sediment dispersion event, from the deposition of one hopper load of sediment. As informed by the modelling, a single deposition event will result in the rapid dissipation of the sediment plume and localised deposition impacts. However, due consideration should also be given to the volume of sediment dispersion and deposition during the entire construction phase (as detailed in Table 5-20). It is likely that the sediments being dispersed and deposited locally will be combined during dispersion events and therefore increased deposition and SSC are expected compared to the single event modelling, discussed above.

5.7.1.238 The subsea export cable ducts will be installed underneath the beach using trenchless installation techniques, with HDD techniques identified as the WCS (Table 5-20). The drilling activity utilises a viscous drilling fluid which consists of a mixture of water and bentonite, a non-toxic, naturally occurring clay mineral. The release of drilling fluid and drill cuttings from HDD operations will result in a plume of elevated SSC. The drilling fluid has an overall density and viscosity similar to seawater and so is expected to behave in a similar manner.

5.7.1.239 The results of bentonite release modelling demonstrate that:

- The maximum SSC during the 15-day period over which the statistics were calculated indicates a resultant plume up to 6km long (in east to west direction) and 2.5km wide (in north to south direction). The highest SSC (above 50mg/l) is simulated to occur over an area of less than 1km long (in an east to west direction) and 500m wide (in a north to south direction). SSC reduces to 15mg/l within 3km east to west and approximately 700m north to south within 3.6 hours;

- SSC is advected along the coast (following the tidal axis) to distances of up to 8km to the east and 6km to the west, although concentrations at this distance are limited to below 1mg/l. All measurable SSC will have dispersed after 3 days. Considering generally higher background SSC conditions along the coast, these changes are likely to be indiscernible from background conditions; and
- Sediment deposition is predicted to be within several hundreds of meters of the exit pits, reducing rapidly to below 1mm. The maximum extent of deposition is predicted to be approximately 700m from release, with deposition less than 0.1mm identified at these distances. This deposition is small-scale, highly localised and likely to be rapidly redistributed by wave action.

5.7.1.240 Background surface SSCs within the Scottish continental shelf and therefore within the Caledonia OWF are known to vary seasonally, with higher concentrations occurring during winter and spring (0.363 mg/l) and lower concentrations in summer (0.001mg/l) (Cefas, 2016[186]). This is because through winter and spring there are typically more storm conditions and increased river discharge of sediments due to greater levels of precipitation. Within the Caledonia OWF, surface SSCs are generally low, with average annual concentrations of up to 0.012mg/l being recorded between the period 1998 to 2015. Resultantly, SCC from construction would be more likely to cause a measurable effect in summer when background levels are low.

5.7.1.241 Associated deposition from sediment plumes is generally in the order of tens to low hundreds of millimetres within several hundreds of metres from the point of disturbance, reducing to low tens of millimetres beyond this. Sediment deposition is generally not measurable beyond 3km to 5km away from the associated activities and is therefore generally small-scale and restricted to the near-field. This deposition is likely to become integrated into the local sediment transport regime and will be redistributed by tidal currents.

5.7.1.242 Maximum sediment suspension for installation of up to four offshore export cables with a total length of up to 330km are anticipated to result in the suspension of 14,850,000m^3 of sediment. Within the nearshore zone of the Caledonia OECC, SSCs are much higher, being directly under the influence of terrestrial sources such as the River Spey and River Devron which lead directly into the Moray Firth (Cefas, 2016[186]). These concentrations also coincide with the winter months when a greater frequency of storm events and fluvial inputs (including storm runoff) can be expected to occur. Bentonite release during HDD operations within the Caledonia OECC will produce low levels of SSC and is likely to be indiscernible from background conditions. This will correspond to low sediment deposition of tens of mm within several hundred metres of the activity and a maximum deposition extent of 500m. The effect of these activities is therefore considered to be restricted to the near-field, temporary, and indiscernible from background conditions.

5.7.1.243 Taking the above into consideration, increased SSC and smothering from sediment deposition associated with construction activities is noticeable but temporary, with the majority of effects limited to the near field of short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptor

5.7.1.244 The sensitivity rating assigned to each IEF, and associated justification is provided below. The fish and shellfish communities within the Caledonia OWF and Caledonia OECC are typical of the wider North Sea where relatively high levels of SSC occur naturally. Consequently, communities are exposed to and are tolerant of variations in SSC and some degree of sediment deposition.

Pelagic Spawning IEFs

5.7.1.245 Sole, lemon sole, plaice, whiting, sprat and mackerel all have spawning grounds overlapping the Caledonia OWF. These receptors are pelagic spawners and do not exhibit substrate dependency. Therefore, sediment deposition within these spawning grounds will not result in any potential loss of available spawning habitats. These receptors are mobile, widely spread across the southern North Sea, and will experience exposure to naturally high variability to SSC within their natural range. The receptors are therefore considered to be broadly insensitive to sediment deposition.

5.7.1.246 These pelagic IEFSs are deemed to be of low vulnerability, medium recoverability and of regional importance, and therefore the sensitivity of the receptor is **Low**.

Demersal Spawning IEFs

5.7.1.247 Demersal spawning species within the study area include herring and sandeel. Sandeel are highly substrate specific spawners and rarely occur in sediments where the silt content (particle size <0.63μm) is greater than 4%, and they are absent in substrates with a silt content greater than 10% (Holland *et al.,* 2005[187]; Wright *et al.,* 2000[188]). Sandeel eggs are likely tolerant to increases in SSC and smothering from sediment deposition, due to the nature of resuspension and deposition within their natural high energy environment. High intensity sandeel spawning grounds (Ellis *et al.,* 2010[101]) are located within the Caledonia OWF. Furthermore, the secondary effects of increased concentrations of SSC in the water column and smothering (from deposition of particles as a result of comparable activities such as dredging and screening of cargo), have been shown to be inconsequential to sandeel species (MarineSpace Ltd., 2010[189]). Sandeel eggs are also considered tolerant to increases in SSC and smothering from sediment deposition, due to the nature of resuspension and deposition within their natural high energy environment. Sandeel deposit eggs on the seabed in the vicinity of their burrows between December and January. Sandeel are an important prey species for many species of marine fish, sea birds and marine mammals so impacts to sandeel populations can have the potential for wider ecological impacts. However, any impacts on sandeel are expected to be relatively small in the context of the spawning habitat available across the North Sea.

5.7.1.248 Therefore, sandeel are deemed to be of low vulnerability, medium recoverability and are of national importance, and therefore the sensitivity of the receptor is **Low** to increases in SSC and sediment deposition from construction activity of the Proposed Development (Offshore).

5.7.1.249 Adult herring are mobile and as such would be expected to avoid unfavourable areas. However, herring are demersal spawners and impacts from increased SSC and sediment deposition are of greatest concern for herring eggs due to smothering which can disrupt the development of the larvae, through either the sediment grains retarding growth or through the reduction in oxygen availability around the eggs. Herring spawning grounds, while present within the study area, do not overlap the Caledonia OWF. However, PSA data indicates the presence of several areas classified as prime, sub-prime and suitable for herring spawning according to Reach *et al.* (2013[93]).

5.7.1.250 Spawning herring are deemed to be of medium vulnerability, medium recoverability and are of national importance, and therefore the sensitivity of the receptor is **Medium** to increases in SSC and sediment deposition from construction activity of the Proposed Development (Offshore).

Diadromous IEFs

5.7.1.251 Due to the location of the Caledonia OWF in the Moray Firth it is likely that migrant species including Atlantic salmon, sea trout and European eel migrate through or close to the Caledonia OWF on their entry to, or emergence from, rivers such as the Spey and Dee. Increased SSC and sediment plumes have the potential to cause a barrier effect for migratory species such as Atlantic salmon (Silva *et al.,* 2020[190]). However, this is expected to occur over a small spatial extent and short temporal span, and therefore have minimal impact to migratory routes for Atlantic salmon. Additionally, Atlantic salmon can navigate through estuarine waters when entering or emerging from rivers, where turbidity levels may be as high or higher than those expected during construction activities.

5.7.1.252 Other diadromous species such as Sea trout and lamprey species are mobile, and distributed through the Moray Firth and Scottish waters where they will experience exposure to naturally high variability to SSC within their natural range, with no substrate dependence for spawning.

5.7.1.253 Diadromous species within the study area are deemed to be of low vulnerability, high recoverability and of regional to international importance, and therefore the sensitivity of the receptor is **Low** to increases in SSC and sediment deposition from construction activity of the Proposed Development (Offshore).

Elasmobranch IEFs

5.7.1.254 Elasmobranch IEFs (such as tope, common smooth, stary smooth hound throwback ray, blonde ray, spotted ray, spurdog and small-spotted catshark (see Volume 7B, Appendix 5-1: Fish and Shellfish Ecology Technical Baseline Report)) are mobile, and widespread throughout the Moray Firth and North Sea and will experience exposure to naturally high variability to SSC within their natural range. Therefore, elasmobranch species within the study area are deemed to be of low vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **Low** to increases in SSC and sediment deposition from construction activity of the Proposed Development (Offshore).

Shellfish IEFs

5.7.1.255 Brown crab are considered to have a high tolerance to SSC and are reported to be insensitive to short-term increases in turbidity; however, they may avoid areas of increased SSC as they rely on visual acuity during predation (Neal and Wilson, 2008[191]). Berried female brown crab exhibit a largely sedentary lifestyle during the overwintering period whilst brooding eggs. During this time, they are considered a stationary receptor, burying themselves into soft mud and sand, and are therefore unlikely to move away from disturbances. Berried females are considered more vulnerable to smothering from sediment deposition, due to their sedentary nature at this time, and as the eggs carried require regular aeration.

5.7.1.256 Taking this into account, brown crab are considered to be of medium vulnerability during the overwintering period, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **Low**.

5.7.1.257 European lobsters (*Homarus gammarus*) are considered a key species within the area (ecologically and commercially). However, the species are not thought to exhibit a sedentary overwintering habit (as is observed in brown crab), being typically mobile and therefore considered able to move away from sources of disturbance. Berried females are likely to be more vulnerable to increased SSC and smothering impacts as the eggs carried require regular aeration. Lobster are therefore considered to be of medium vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **Low** to increases in SSC and sediment deposition from construction activity of the Proposed Development (Offshore).

5.7.1.258 Nephrops rely on burrowing in soft substrates for shelter and protection. Increased SSC can affect their ability to burrow effectively. Campbell *et al.* (2009[192]) examined the impact of sediment deposition on Nephrops burrowing behaviour. The researchers found that sediment deposition can inhibit burrowing activity and disrupt the structure of burrows, potentially leading to increased vulnerability to predation and reduced reproductive success. Katoh *et al.* (2013[193]) investigated the effects of SSC on the behaviour and physiology of Nephrops and found that exposure to elevated levels of suspended sediment led to changes in the behaviour and physiology of Nephrops, including reduced feeding activity and altered respiratory responses. These changes can negatively impact their overall health and fitness. Suitable habitat for Nephrops within the study area is limited and therefore any impacts are from SSC are expected to be highly localised. Additionally, MarESA assesses Nephrops as having low vulnerability to increases in SSC, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **Medium** to increases in SSC and sediment deposition from construction activity of the Proposed Development (Offshore).

5.7.1.259 SSC have the potential to clog the feeding apparatus of scallops; however, scallops have some capacity to avoid the impact (mobile across short distances) and are widespread across a range of habitat types. The MarESA assessment assess scallops as having a low vulnerability, high recoverability and low sensitivity to smothering and increases in suspended sediments (Marshall and Wilson, 2008[194]). Therefore, the sensitivity of the receptor is **Low** to increases in SSC and sediment deposition from construction activity of the Proposed Development (Offshore).

Significance of Effect

5.7.1.260 The impact of increased SSC and sediment deposition on spawning herring is considered to be of **Low** magnitude, and the sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.261 The impact of increased SSC and sediment deposition on sandeel is considered to be of **Low** magnitude, and the sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

5.7.1.262 The impact of increased SSC and sediment deposition on Nephrops is considered to be of **Low** magnitude, and the sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.263 The impact of increased SSC and sediment deposition on all other fish and shellfish receptors throughout the Caledonia OWF is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

5.7.1.264 The overall WCS impact of increased SSC and sediment deposition on fish and shellfish IEFs is concluded to be **Minor and Not Significant in EIA terms.**

Impact 3: Temporary Habitat Loss and Disturbance

5.7.1.265 Temporary habitat loss and disturbance across the study area will be a likely occurrence from foundation seabed preparation, the use of jack-ups and anchored vessels and cable seabed preparation and installation works. These construction activities have the potential to impact on fish and shellfish ecology via direct loss/disturbance to individuals and the temporary removal of essential habitats for survival (e.g., spawning, nursery and feeding habitats).

Magnitude of Impact

5.7.1.266 The maximum area of temporary habitat loss across the Caledonia OWF and Caledonia OECC due to the presence of foundations, scour protection and seabed preparation works (presented in Table 5-20) is 17.6km^2 which equates to 3.3% of the total seabed areas within the Proposed Development (Offshore). Comparable habitats and fish and shellfish species assemblages are present and widespread within the wider area.

5.7.1.267 Of the total temporary habitat loss across the Proposal Development (Offshore), approximately 12.47km^2 is predicted to be temporarily disturbed within the Caledonia OWF as a result of seabed footprint foundations (1.65km^2), JUV operations and the seabed preparation (0.08km^2), installation and burial of inter-array and interconnect cables (10.75km^2). Of the total area of temporary habitat loss, 4.95km^2 will be temporarily disturbed within the Caledonia OECC. This will be due to sandwave and boulder clearance and instillation of export cables.

5.7.1.268 It should be noted that the WCS presents a precautionary approach to temporary habitat disturbance because it counts both the total footprint of seabed clearance as well as cable burial across both the Caledonia OWF and Caledonia OECC. This approach effectively counts the footprint of the seabed habitat to be impacted by construction in the same area twice. However, this precautionary approach has been taken because there is some potential for recovery of habitats between the activities, dependant on the timing and delivery of the activities.

5.7.1.269 The recovery timeframe for temporary habitat loss associated with construction activities varies depending on the habitat type being impacted (Perkol-Finkel and Airoldi, 2010[195]). For example, some benthic habitat such as soft sediment substrate which are subject to temporary habitat loss from activities such as JUV operations whereas as the same activity would cause long term habitat loss for areas of maerl beds (there are no MPAs within the Moray Firth designated for Maerl beds). The intensity of the disturbance is also a crucial factor in determining the magnitude of the habitat loss. For example, Dernie *et al.* (2003[196]) found communities in soft sediment habitats to recover from lover intensity habitat loss causing activities significantly faster (64 days to recover to baseline) compared to high intensity habitat loss causing activities (208 days to recover to baseline). The study area is comprised of heterogenous soft sediment habitat, primarily sandbanks, gravel, sandy gravel, gravely sand (Folk, 1954[91]) which is known to recover relatively quickly from temporary habitat loss and/or disturbance (Reice *et al.,* 1990[197]; Dernie *et al.,* 2003[196]).

5.7.1.270 The temporary habitat loss during construction activities would therefore impact a very limited footprint, particularly when compared to the overall extent of such habitats. This loss is not expected to undermine regional ecosystem functions or diminish biodiversity. Therefore, the impact of temporary habitat loss associated with construction activities within the study is predicted to be of local spatial extent (i.e., within and in the vicinity of the Caledonia OWF and Caledonia OECC), of short-term duration and reversible. It is predicted that the impact will affect fish and shellfish receptors directly, for example where spawning areas might be disturbed, or indirectly, should prey items that rely on the associated habitats be impacted by disturbance.

5.7.1.271 Consequently, the magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptor

Herring

5.7.1.272 Although pelagic as adults, herring are demersal spawners, with eggs remaining attached to the seabed during their development. Therefore, for the purposes of the assessment herring are considered as stationary receptors with low to no adaptability to the impact. Herring spawning grounds, while present within the study area, do not overlap the Caledonia OWF. PSA data indicates the presence of several areas classified as prime, sub-prime and suitable for herring spawning according to Reach *et al.* (2013[93]). Additional analysis of particle size distribution within the Caledonia OWF classified the majority of the area to be 'Unsuitable' for spawning, suggesting a very low likelihood of herring spawning (Figure 5-9). This is attributed to the presence of >5% mud or <10% gravel at these grab sampling stations. Discrete areas to the east and west of the Caledonia OWF (within the secondary ZoI) have been classified as ''Marginal' or 'Preferred', corresponding with habitats categorised as 'Coarse Substrates' (EMODnet, 2023[95]). Areas of 'Marginal' and 'Preferred' sediment are also located to the North of the Caledonia OWF (within the study area) between Duncansby Head and the Orkney Islands, corresponding to areas of 'Coarse Substrates' (EMODnet, 2023[95]).

5.7.1.273 Temporary habitat loss/disturbance may result in some mortality of individuals, or it may directly damage or dislodge eggs, which may lead to increased egg mortality rates and reduced recruitment success. Herring have a high fecundity (laying 40,000 to 100,000 eggs per annum), a quick maturation (sexually mature at 3 to 4 years old) and a short term egg incubation period of 10 to 15 days (Hare and Richardson, 2014[198]).

5.7.1.274 Therefore, spawning Herring are deemed to be of medium vulnerability, high recoverability and are of national importance, and therefore the sensitivity of the receptor is **Medium** to temporary habitat loss and disturbance from construction activity of the Caledonia OWF.

Sandeel

5.7.1.275 Sandeel exhibit strong site fidelity and spend large amounts of time buried in the sediment. In addition, sandeel are demersal spawners, with eggs remaining attached to the seabed during their development. Therefore, for the purposes of the assessment sandeel are considered as stationary receptors with low to no adaptability to the impact. Sandeel spawning grounds overlap with the Caledonia OWF and PSA data indicates the presence of prime, sub-prime and suitable sandeel habitat throughout the Caledonia OWF, based on categories from Latto *et al.* (2013[92]) (Figure 5-11). The north of the Caledonia OWF overlaps with areas classed as having "High" potential for sandeel spawning to occur, with the rest of the Caledonia OWF and Caledonia OECC being classified as either "medium" or "low". There is a patchy distribution of suitable sandeel habitat across the study area, with a large proportion of "preferred" sediment across the Caledonia OWF and Caledonia OECC (Figure 5–11). This is supported with sandeel habitat confidence analysis, whereby this can be presumed with medium confidence across the study area, with some areas of low confidence to the west of the OECC and east of Caledonia OWF (Figure 5-12). Temporary habitat loss/disturbance may result in some mortality of individuals, or it may directly damage or dislodge eggs, which may lead to increased egg mortality rates and reduced recruitment success. Sandeel have a high fecundity, quick maturation and short-term egg hatching rate (i.e., lesser sandeel lay between 2,700 and 15,00 eggs per annum and reach sexual maturation at approximately 2 to 3 years old (Gauld and Hutcheon, 1990[199]; Bergstad *et al.,* 2001[200])).

5.7.1.276 Therefore, sandeel are deemed to be of medium vulnerability, high recoverability and are of national importance, and therefore the sensitivity of the receptor is **Medium** to temporary habitat loss and disturbance from construction activity of the Proposed Development (Offshore).

Diadromous and Pelagic IEFS

5.7.1.277 Diadromous and pelagic IEFs include Atlantic salmon, basking shark, European eel, sea lamprey, river lamprey, Atlantic mackerel, twaite shad, allis shad and sea trout. Pelagic IEFs do not depend upon benthic habitats for part, or all of their life cycle and diadromous species are unlikely to spend significant amount of time within the study area and are not considered susceptible to temporary habitat loss/disturbance.

5.7.1.278 Therefore, these are deemed to be of low vulnerability, high recoverability and of regional to international importance, and therefore the sensitivity of the receptor is **Low** to temporary habitat loss and disturbance from construction activity of the Proposed Development (Offshore).

Demersal IEFs

5.7.1.279 Cod, whiting, plaice and lemon sole spawning grounds have been identified as overlapping with the Proposed Development (Offshore) and study area. These IEFs are pelagic spawners and do not display substrate dependency and therefore temporary habitat loss/disturbance is unlikely to greatly impact upon recruitment. Other species of demersal fish, with no known spawning grounds or spawning grounds which do not overlap with the study area, include European hake, blue whiting, anglerfish and haddock. As demersal IEFs these species depend upon benthic habitats (i.e., for nursery grounds and/or foraging). Any potential displacement would likely be temporary (high recoverability), and as mobile IEFs, individuals would be able to return to effected areas upon cessation of construction activities.

5.7.1.280 Therefore, demersal IEFs are deemed to be of medium low, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **Low** to temporary habitat loss from construction activity of the Proposed Development (Offshore).

Shellfish IEFs

5.7.1.281 Brown crabs are known to be associated with rocky substrates but also inhabit mixed, coarse, sand, and soft sediments (Hall *et al.,* 1993[201]). Berried female brown crab bury themselves into soft mud and sand, while brooding eggs in the overwintering period. For the purposes of the assessment brown crab are therefore considered a stationary receptor with a limited ability to move away from physical impacts to the seabed. MarESA assesses brown crab as having an intermediate tolerance, moderate recoverability and moderate sensitivity to substratum loss (Neal and Wilson, 2008[191]).

5.7.1.282 Considering their stationary nature and broad habitat preferences, brown crab have been assessed as having low vulnerability, high recoverability and of national importance, and therefore the sensitivity of the receptor is **Low** to temporary habitat loss and disturbance from construction activity of the Proposed Development (Offshore).

5.7.1.283 European lobster are broadly distributed across the southern North Sea and are found across a range of habitats. They are not known to exhibit substrate dependant behaviours and are mobile receptors. Therefore, European Lobster within the study area are deemed to be of low vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **Low** to temporary habitat loss and disturbance.

5.7.1.284 Nephrops typically inhabit soft, muddy substrates and construct burrows in the substrate where they spend much of their time, emerging to forage for food at night. The choice of substrate is crucial for their survival and reproduction, with soft substrates providing them with the ability to burrow easily and create shelter, protection from predators, and suitable conditions for feeding and mating. Therefore, the availability and quality of substrate play a significant role in the distribution and abundance of Nephrops. The Caledonia OWF consists mostly of coarse sediments and sands and therefore is unlikely to contain large abundances of Nephrops. Additionally, the OECC comprises a mixture of substrate types including muddy sand and sandy mud and overlaps with Nephrops spawning grounds. Therefore, the OECC is likely to contain discrete populations of Nephrops. MarESA assesses Nephrops as a high intolerance, moderate recoverability and moderate sensitivity to substratum loss (Hill and Sabatini, 2008[202]).

5.7.1.285 Due to the localised and temporary nature of habitat loss, low vulnerability and high recoverability Nephrops are considered to be of **Low** sensitivity to temporary habitat loss and disturbance from construction activities.

5.7.1.286 MarESA assesses scallops as having a high intolerance, high recoverability and a moderate sensitivity to substratum loss (Marshall and Wilson, 2008[203]). Scallops have some capacity to avoid the impact (mobile across short distances) and are widespread across a range of habitat types.

5.7.1.287 Therefore, scallop within the study area are deemed to be of low vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **Low** to temporary habitat loss and disturbance.

Elasmobranch IEFs

5.7.1.288 Juvenile and adult elasmobranch species are considered to have a high adaptability and tolerance to seabed disturbance events as they are mobile and would therefore be able to relocate to nearby unimpacted areas and recolonise effected areas shortly after cessation of construction activities. Spotted rays, common skate and thornback ray lay demersal eggs, and while spawning grounds for these species are unknown, they are assumed to spawn in suitable areas throughout their distribution. Skate and ray eggs are long lived with many of these species having low fecundity rates. For example, common skates lay approximately 40 eggs per annum with the eggs taking approximately 17 months to hatch (Walker and Hislop, 1998[204]; Benjamins *et al.,* 2021[205]) and thornback rays lay between 48-150 eggs per annum, taking 4-6 months to hatch, with individuals maturing between 5 and 12 years old (Gallagher *et al.,* 2005[206]; Pawson and Ellis, 2005[207];). However, mortality is only expected to affect a small number of eggs given the wider context of suitable spawning areas.

5.7.1.289 Therefore, these receptors are deemed to have some ability to avoid the impact as adults (medium vulnerability), medium recoverability and are of local to international importance and are considered to be of **Medium** sensitivity.

5.7.1.290 Spurdog and tope are considered to have a high adaptability and tolerance to disturbance events given that they are mobile and would therefore be able to move to nearby unimpacted areas and recolonise affected areas upon cessation of construction activities. There receptors bear live young, and therefore physical damage or disturbance of the seabed within the study area would not result in any disturbance or loss of spawning areas. Spur dog and tope do however depend on the benthic environment for foraging. Based on their high adaptability, tolerance and recoverability the sensitivity of the receptors is deemed to be **Low**.

Significance of Effect

5.7.1.291 The impact of temporary habitat loss on sandeel is considered to be of **Low** magnitude, and the sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.292 The impact of temporary habitat loss on spawning herring is considered to be of **Low** magnitude, and the sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.293 The impact of temporary habitat loss of shellfish receptors is considered to be of **Low** magnitude, and the maximum sensitivity of the receptors is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

5.7.1.294 The impact of temporary habitat loss on elasmobranch receptors is considered to be of **Low** magnitude, and the maximum sensitivity of the receptors is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.295 The impact of temporary habitat loss of all other fish and shellfish receptors is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Negligible**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

5.7.1.296 Overall, the temporary habitat loss during the construction phase will represent a short-term and localised effect. The magnitude of the impact was determined to be **Low**. The maximum sensitivity of the receptors was assessed as **Medium**. The significance of the effect is therefore considered to be a maximum of **Minor and Not Significant in EIA terms**.

Impact 4: Direct and Indirect Seabed Disturbance Leading to Release of Sediment Contaminants

5.7.1.297 Construction activities will re-suspend sediments, while in suspension, there is the potential for sediment-bound contaminants, such as metals, hydrocarbons and organic pollutants, to be released into the water column and lead to an effect on fish and shellfish receptors.

5.7.1.298 To provide a robust assessment, a range of realistic combinations have been considered, based on conservatively representative location (environmental) and WCS (Table 5-20).

Magnitude of Impact

5.7.1.299 Full details of sediment quality and contaminant concentrations in sediment samples collected from across the Caledonia OWF and Caledonia OECC are provided in Volume 2, Chapter 3: Marine Water and Sediment Quality. In summary, concentrations of metals, organotins, polycyclic aromatic hydrocarbons (PAHs), total hydrocarbon content (THC), polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs) and organochlorine pesticides (OCPs) in sediments were low, frequently below limits of detection (LOD) and sediment quality assessment thresholds.

5.7.1.300 It has previously been shown that demersal species (including shellfish) suffer adverse effects when THC is in excess of 50µg g^{-1} (Kjeilen-Eilertsen *et al.,* 2004[208]) and as such, this value represents the threshold above which hydrocarbons are expected to have a 'significant environmental impact'. Kingston (1992[209]) also previously reported that benthic fauna (including shellfish) had adverse effects, such as reduced diversity, when THC is more than 50µg g^{-1} to 60µg g^{-1} and that specific sensitive species may be impacted at levels more than 10µg g^{-1}.

5.7.1.301 Total PAH concentrations and those for individual compounds were well below their respective Effect Range Low (ERL) values, indicating that toxic effects to fauna by PAHs are unlikely. The Apparent Effects Threshold (AET) represent the concentrations above which adverse biological impacts would be expected on the biological indicator due to exposure to that contaminant alone. Total and individual PAH concentrations were also well below their respective AETs at all stations, further suggesting that overall adverse biological impacts would be extremely unlikely. Concentrations of metals were positively correlated with the proportion of fines and negatively correlated with sand, indicating that fluctuations in metal concentrations could be influenced by variations in sediment particle size and the resultant adsorption properties.

5.7.1.302 Taking into consideration the level of sediment contaminates across the Caledonia OWF and Caledonia OECC, the maximum magnitude of impact arising from the direct and indirect seabed disturbance leading to release of sediment contaminants associated with construction activities is noticeable but temporary, with the majority of effects limited to the near field and of small spatial extent. Consequently, the magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Negligible.**

Sensitivity of Receptor

5.7.1.303 Construction activities leading to the resuspension of sediments will have varying levels of effect dependent on the species present and pollutants involved. As sediment-bound contaminants would be expected to be dispersed quickly in the subtidal environment, the level of effect is predicted to be small.

Fish and Elasmobranch IEFs

5.7.1.304 Due to their high mobility, adult fish and elasmobranch species are less likely to be affected by marine pollution and are therefore not considered to be vulnerable to the release of sediment bound contaminants (McKinley *et al.,* 2010[210]; Hylland *et al.,* 2017[211]). Adult fish such as herring and sandeel are mobile and as such would be expected to avoid unfavourable areas.

5.7.1.305 Therefore, fish IEFs within the study area are deemed to be of low vulnerability, high recoverability and of regional to national importance, and therefore the sensitivity of the receptor is **Low** to direct and indirect seabed disturbance leading to release of sediment contaminants.

5.7.1.306 Elasmobranch IEFs are mobile, and widespread throughout the wider Moray Firth and North Sea. Due to being mobile they are considered to be able to move away from sources of increased sediment contaminants (Alves *et al.,* 2022[212]; Gelsleichter and Walker, 2010[213]).

5.7.1.307 Therefore, elasmobranch IEFs within the study area are deemed to be of low vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **Low** to Direct and indirect seabed disturbance leading to release of sediment contaminants.

Diadromous IEFs

5.7.1.308 Atlantic salmon and sea trout spawn in rivers so their eggs and larvae will not be impacted by increased sediment contaminants as a result of disturbance. Additionally, these species are mobile and are considered to be able to move away from sources of sediment contaminants (Milligan and Law, 2013[214]).

5.7.1.309 Therefore, diadromous IEFs within the study area are deemed to be of low vulnerability, high recoverability and of regional to international importance, and therefore the sensitivity of the receptor is **Low** to Direct and indirect seabed disturbance leading to release of sediment contaminants.

Eggs and Larvae

5.7.1.310 Fish eggs and larvae are likely to be particularly sensitive, with potentially toxic effects of pollutants on fish eggs and larvae (Westerhagen *et al.,* 1989[215]). Effects of resuspension of sediment-bound contaminants (e.g., heavy metals and hydrocarbon pollution) on fish eggs and larvae are likely to include abnormal development, delayed hatching and reduced hatching success (Bunn *et al.,* 2000[216]). It is on this basis, that eggs and larvae are considered to be of low vulnerability, medium recoverability and of **Medium** sensitivity to the impact.

5.7.1.311 The secondary effects arising from the release of sediment contaminants and increased concentrations in the water column from sediment disturbance have been shown to be inconsequential to sandeel species (MarineSpace Ltd, 2010[189]). Sandeel eggs are also likely tolerant to increases in sediment contaminants and SSC, due to the nature of resuspension and deposition within their natural high energy environment.

5.7.1.312 Sandeel are deemed to be of low vulnerability, medium recoverability and are of national importance, and therefore the sensitivity of the receptor is **Low** to direct and indirect seabed disturbance leading to release of sediment contaminants.

5.7.1.313 Impacts arising from the release of sediment contaminants and increased concentrations in the water column from sediment disturbance are of greatest concern for herring eggs. Herring eggs are considered to be of **Medium** sensitivity to effects arising from the release of sediment contaminants from disturbance during construction activity of the Proposed Development (Offshore).

Shellfish IEFs

5.7.1.314 Filter-feeding shellfish are more sensitive to marine pollution due to the recognised bioaccumulation which occurs within this group. Shellfish also display limited mobility and are therefore not anticipated to flee from the direct and indirect seabed disturbance leading to release of sediment contaminants (McDowell, 2005[217]).

5.7.1.315 European lobsters are considered a key species within the study area (ecologically and commercially). Typically, they are regarded as a mobile species and therefore considered able to move away from sources of increased sediment contaminants as a result of disturbance (Chou *et al.,* 2004[218]). Additionally, research has shown lobsters to accumulate high concentrations of metals from the environment and to synthesize metallothionein's which bind metals in their digestive gland, reducing their sensitivity (Chou *et al.,* 1991[219]; 2004[218]).

5.7.1.316 Lobster are therefore considered to be of medium vulnerability, medium recoverability and of regional importance, and therefore the sensitivity of the receptor is **Medium**.

5.7.1.317 Nephrops which have been exposed to elevated levels of suspended sediment contaminants have been observed to have changes in the behaviour and physiology, including reduced feeding activity and altered respiratory responses (Katoh *et al.,* 2013[193]).

5.7.1.318 These changes can negatively impact their overall health and fitness. Overall, Nephrops are considered to be of medium vulnerability, medium recoverability and of regional importance, and therefore the sensitivity of the receptor is **Medium**.

5.7.1.319 Brown crab are considered to be of medium vulnerability, medium recoverability (Neal and Wilson, 2008[191191]) and of regional importance, and therefore the sensitivity of the receptor is **Medium**.

Significance of Effect

5.7.1.320 The impact of sediment disturbance and the release of contaminates on spawning herring is considered to be of **Negligible** magnitude, and the sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.321 The impact of sediment disturbance and the release of contaminates on sandeel is considered to be of **Low** magnitude, and the sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

5.7.1.322 The impact of sediment disturbance and the release of contaminates on shellfish is considered to be of **Negligible** magnitude, and the sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.1.323 The impact of sediment disturbance and the release of contaminates on all other fish and shellfish receptors through the Caledonia OWF is considered to be of **Negligible** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Impact 5: Increased Risk of Introduction and/or Spread of Invasive Non-Native Species (INNS) from Vessel Traffic

5.7.1.324 Invasive/ non-indigenous species (INNS) are one of the main reasons for biodiversity loss globally (Wood *et al.,* 2024[220]). Kerckhof *et al.* (2016[221]) defined introduced species as "non-indigenous species that are introduced in a certain region (in this case the North Sea) from anthropogenic activities". INNS present a multifaceted threat by disrupting ecosystem services, altering native habitats and predating on native species. The Joint Nature Conservation Committee (JNCC) biodiversity indicators showed an increase in the number of marine INNS established across 10% or more of coastline from 2010 to 2017, compared to 2000 to 2009 (UK Biodiversity Indicators, JNCC, 2023[222]). A UK monitoring and surveillance list for marine INNS has been developed by under the EU Marine Strategy Framework Directive (MSFD) (2022[223]) to streamline efforts on priority species and identify those that could or do have high environmental impact. The majority of these species are sessile benthic invertebrates, and which do not pose as significant an impact on marine fish and shellfish populations within the study area.

5.7.1.325 Marine INNS can have a detrimental effect on fish and shellfish ecology, either by indirectly by outcompeting native species for habitat and food resources or directly though predation (Payne *et al.,* 2016[224]; Tillin *et al.,* 2020[225]). This can result in biodiversity changes in the existing habitats present within the benthic ecology subtidal study area. Introduced marine INNS could potentially lead to the complete loss of certain species and may result in new habitats forming (e.g., introduction of reef-forming species).

5.7.1.326 The main pathway for INNS is from vessel traffic during construction, as the ballast water from ships can carry nonnative marine organisms, although they can be transferred via any construction plant that come into contact with the sea. Most marine INNS in UK waters have been recorded in the English Channel, with many then moving northwards (Minchin *et al.,* 2013[226]). Of these, the majority of INNS in UK water have been identified as originating in the North Pacific (35 species) and North-west Atlantic (22 species). (Minchin *et al.,* 2013[226]; Payne *et al.,* 2015[227]). Another potential pathway for INNS is the towing of infrastructure such as floating WTGs to the Caledonia OWF.

Magnitude of Impact

5.7.1.327 The main factor contributing to the magnitude of the risk of INNS is dependent upon the specific vessels being used for construction activities and where they have come. If the vessels primarily work in the North Sea, then the magnitude for the risk of INNS is significancy lower, compared to vessels which operate globally (Padilla *et al.,* 2011[228]; Cinar *et al.,* 2014[229]; Tan *et al.,* 2023[230]).

5.7.1.328 The number and type of vessels supporting offshore construction will be determined post-consent and will be informed by the final design of the Proposed Development (Offshore), Transport and Installation (T&I) Strategies and the availability of vessels. The typical vessel types required for construction works associated with the installation of foundations, WTGs, OSPs and cables are set out in Volume 1, Chapter 3: Proposed Development Description (Offshore). Out of the 3,992 total vessel movements (the transit to and from the construction port and site (centre)) during construction of the Proposed Development (Offshore), vessels which operate internationally are more likely to contribute to the risk of INNS compared to vessels which just go to and from local ports. There is already a widespread presence of marine INNS across the North Sea, and it is unlikely that the Proposed Development (Offshore) will contribute to this (NatureScot, 2024[231]).

5.7.1.329 Impacts associated with the risk/introduction of INNS from construction vessel traffic is predicted to be of a localised spatial extent, medium term duration and continuous (occurring during the construction of the Proposed

Development (Offshore)), therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptor

Pelagic and Demersal spawning Fish

5.7.1.330 Pelagic and demersal fish species are less susceptible to direct impacts from INNS. The main pathway adult fish can be impacted is through predation from the introduction of a novel predator (Green *et al.,* 2012[232]). INNS can exert predation pressure on the eggs and larvae of pelagic and demersal spawning fish, potentially leading to reduced recruitment and population declines. In the Mediterranean and North Atlantic, the invasive Indo-Pacific lionfish (*Pterois volitans* and *P. miles*) is a demersal predator and known to predate on the eggs and larvae of demersal spawners such as cod and flounder (Green *et al.,* 2012[232]). They could contribute to a decline in the recruitment of native species (van Kessel *et al.,* 2011[233]).

5.7.1.331 Taking this into account, pelagic and demersal spawning fish are considered to be of low vulnerability, with medium recoverability and of regional to national importance, therefore their overall sensitivity is considered to be **Low**.

Shellfish

5.7.1.332 One of the primary impacts of INNS on shellfish is competition for resources such as food and habitat. The pacific oyster (*Crassostrea gigas*) is non-native to the UK and directly compete with native oysters for space and resources, leading to the decline of native oyster populations (Ruesink *et al.,* 2006[234]).

5.7.1.333 Shellfish populations within the study area are anticipated to have a low vulnerability to increased presence of INNS. Shellfish within the study area are of commercial importance at a regional scale and are of a low vulnerability and high recoverability to this impact and have been assessed as having a **Low** sensitivity to the risk of INNS.

Elasmobranchs

5.7.1.334 INNS have the potential alter the habitats that elasmobranchs rely on for feeding, breeding, and nursery areas. As previously mentioned, the invasive carpet sea squirt has found in various UK coastal waters including Scottish waters, is a prime example of a species that can drastically change the structure of benthic environments. These dense mats over the seabed, smothering the natural habitats used by benthic elasmobranchs, such as skates and rays, for feeding and egg-laying (Lengyel *et al.,* 2009[235]). Another example is the invasive red algae (*Gracilaria vermiculophylla*), which has established itself in parts of the UK. This species can dominate shallow coastal areas, displacing native seagrasses and altering the structure of nursery habitats used by species like the thornback ray. The loss of seagrass beds, which provide essential cover and foraging grounds for juvenile rays, can lead to higher predation rates and reduced juvenile survival (Nyberg *et al.,* 2009[236]).

5.7.1.335 Many elasmobranchs are carnivorous and primarily feed on benthic invertebrates and fishes. They could potentially benefit from any increased food availability from new prey species (Methratta and Dardick, 2019[249]).

5.7.1.336 Elasmobranchs are internationally importance and are considered to have a low vulnerability and high recoverability to INNS and are assessed to have a **Low** sensitivity to the risk of INNS.

Diadromous fish

5.7.1.337 Numerous migratory species, such as Atlantic salmon and European eel, migrate through the study area, either in their juvenile stage or as adults. Migratory species could be vulnerable to increased presence of INNS due to vessel traffic.

5.7.1.338 INNS can also serve as vectors for diseases that affect native marine fish. An example is the introduction of the parasitic salmon louse (*Lepeophtheirus salmonis*), through the expansion of aquaculture (Costello, 2006[237]). Sea lice infestations have been shown to negatively impact wild Atlantic salmon populations by increasing mortality rates and reducing reproductive success. The spread of such parasites by vessel traffic can have negative effects on wild diadromous fish populations, particularly in areas where aquaculture operations are prevalent (Vormedal, 2024[238]).

5.7.1.339 Although the significance of Caledonia OWF and Caledonia OECC as a gathering point for Atlantic salmon and sea trout, and thus its potential impact, remains uncertain, current indications suggest that post-smolts from rivers on the East coast of Scotland are inclined to migrate eastward, through the Moray Firth. Moreover, while not definitive, it seems improbable that a considerable portion of post-smolts from other Scottish rivers will traverse the study area, given the broader availability of habitat along Scotland's Moray Firth coast.

5.7.1.340 Diadromous species within the study area are internationally important receptors, they are considered to have a low vulnerability, with medium recoverability and are assessed to be of **Low** sensitivity to the risk of INNS.

Significance of Effect

5.7.1.341 Taking into account the **Low** sensitivity and **Low** magnitude of fish to increased risk of introduction and/or spread of INNS due to construction activities, it is considered to be **Negligible and Not Significant in EIA terms**.

5.7.1.342 Accounting for the **Low** sensitivity of shellfish and the **Low** magnitude of impact, the overall effect of increased risk of introduction and/or spread of INNS is considered to be **Negligible and Not Significant in EIA terms**.

5.7.1.343 Taking the **Low** sensitivity of elasmobranchs and the **Low** magnitude of impact, the overall the impact of increased risk of introduction and/or spread of INNS is considered to be **Negligible and Not Significant in EIA terms**.

5.7.1.344 Considering the **Medium** sensitivity of diadromous fish and the **Low** magnitude of impact, the overall impact of increased risk of introduction and/or spread of INNS is considered to be **Minor and Not Significant in EIA terms**.

5.7.2 Operation and Maintenance

5.7.2.1 This section presents the assessment of impacts arising from the operation and maintenance phase of the Proposed Development (Offshore).

Impact 6: Temporary Habitat Loss and Disturbance

Magnitude of Impact

5.7.2.2 Temporary subtidal habitat loss will arise from the use of JUVs for operational activities as well as from cable maintenance and cable replacement. The total Worst-Case Design Scenario is presented in Table 5-20, which is predicted to occur over the design life of the Proposed Development (Offshore).

5.7.2.3 Cable replacement works will require de-burial and re-burial of cables or cable sections. These activities, along with cable preventative maintenance, will result in increased SSC and an increase in sediment deposition. However, the impacts from these operational works will be spread over the life span of the Proposed Development (Offshore) with only a limited number of activities occurring within any single year.

5.7.2.4 The magnitude of temporary habitat disturbance from JUVs and cable maintenance activities relating to the Proposed Development (Offshore) is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptor

5.7.2.5 Given that the fish and shellfish communities within the study area are common and widespread throughout the Moray Firth (as described in Section 5.4), the temporary habitat loss occurring through operational activities would have an impact on a very limited footprint in relation to their overall extent in Caledonia OWF and OECC. Refer to the species-specific sensitivity assessment for temporary habitat loss detailed under Impact 3 (see paragraphs 5.7.1.272 to 5.7.1.290).

5.7.2.6 Taking this into account, the most sensitive of all receptors are considered to be of medium vulnerability, with medium recoverability and of regional to international importance, therefore their overall sensitivity is considered to be **Medium**.

Significance of Effect

5.7.2.7 Overall, the impact of temporary habitat disturbance is considered to be of **Low** magnitude. The sensitivity of receptors affected by this impact is predicted to be at worst-case **Medium**. Therefore, the significance of the residual effect of temporary habitat disturbance is assessed to be **Minor and Not Significant in EIA terms**.

Impact 7: Long-term Habitat Loss due to the Presence of Foundations, Scour Protection and Cable Protection

5.7.2.8 Long-term habitat loss associated with the presence of bottom-fixed infrastructure such as WTG and OSP foundations, anchors and mooring lines for floating WTG foundations, scour protection, interconnection cables and export cables and cable protection, have the potential to impact on fish and shellfish ecology by the removal and degradation of essential habitats such as spawning, nursery and feeding habitats.

5.7.2.9 During the operation and maintenance phase, there will be instances of temporary habitat loss and seabed disturbance caused by maintenance activities such as the use for jack-up vessels, the WCS from these activities are shown in Table 5-20. This disturbance will occur periodically throughout the 35-year operational life of the Proposed Development (Offshore). However, its spatial impact will be limited to localized areas and is not anticipated to surpass the effects evaluated during the construction phase. Thus, the sensitivity and magnitude assessments for temporary habitat loss and disturbance during construction are deemed relevant for the operation and maintenance phase as well.

Magnitude of Impact

5.7.2.10 The long-term footprint of the Proposed Development (Offshore) is comprised of the presence of bottom-fixed infrastructure such as WTG and OSP foundations, anchors and mooring lines, scour protection, interconnection cables and export cables and all associated cable protection which equates to 9.34km^2. This will be present for the duration of the operational phase (35 years), and accounts for approximately 1.53% of the total site boundary (see Table 5-20). This is derived from the presence of foundations and the associated scour protection (1.65km^2), cable protection measures for interconnector and inter-array cables (3.9km^2) and maximum cable protection footprint in the OECC (3.3km^2) will lead to a change from a sedimentary habitat to one characterised by hard substrate (see specific details in Table 5-20). This will be a permanent habitat loss (for the design life duration of the Proposed Development (Offshore)) and a permanent change of habitat. It should be noted that this habitat loss will initially occur during the construction stage when the infrastructure is installed. However, the effects will continue throughout the duration of the 35-year long operation and maintenance phase.

5.7.2.11 The installation of floating WTG foundation anchors may result in seabed disturbance during construction, potentially altering the habitat for fish species in the area and disrupt the seabed environment, affecting fish habitats and breeding grounds. There is potential for habitat loss area from mooring line sweep/strimming effect (catenary configuration) for semi-submersible WTG foundations. This impact is expected to be limited to demersal communities in the form of continuous long-term abrasion. Floating WTG foundation anchors could potentially obstruct fish migration routes, particularly if they are located in areas known for significant fish migration. Further evidence from Davis *et al.* (2016[239]) notes that any biota that comes into contact with a dragging anchor or a sweeping anchor chain will sustain some sort of damage, whether being swept from the sea floor, or being crushed altogether.

5.7.2.12 The magnitude of impact of long term habitat loss on fish and shellfish ecology IEFs is predicted to be of local spatial extent and of long-term duration, continuous and irreversible (35 years/within the lifetime of the Proposed Development (Offshore)). Consequently, the magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptor

Demersal Spawning IEFs

5.7.2.13 Sandeel are demersal spawners and are reliant upon the presence of suitable substrates for spawning (i.e., sandy sediments). Furthermore, as well as laying demersal eggs, sandeel also have specific habitat requirements throughout their juvenile and adult life history. Potential sandeel spawning grounds (as defined by Coull *et al.,* 1998[94]), and 'Preferred' habitats (as determined by sand content) are located in the northern extent of the Caledonia OWF. A heatmapping exercise (as detailed in Volume 7B, Appendix 5-1: Fish and Shellfish Ecology Technical Baseline Report) identified the Caledonia OWF as having high confidence that the seabed may be suitable for spawning. Additionally, high intensity sandeel spawning grounds defined by Ellis *et al.* (2010[101]) are located across the Caledonia OWF. However, any impacts on this species are expected to be relatively small in the context of the spawning habitat available across the North Sea. Potential sandeel habitats and spawning grounds are located across the North Sea, with low intensity sandeel nursery grounds defined by Ellis *et al.* (2010[101]) located across the Caledonia OWF.

5.7.2.14 Considering the localised nature of the impact, any effects of habitat loss are not likely to have a population level effect on sandeel. Sandeel are consequently deemed to be of medium vulnerability to long-term changes in substrate, with limited ability for recovery, and are of national importance within the southern North Sea, and therefore are considered to be of **Medium** sensitivity.

5.7.2.15 Herring are also demersal spawners, reliant upon the presence of suitable substrates for spawning (i.e., gravelly sediments). The northern extent of the study area overlaps with an area identified for herring spawning grounds (as defined by Coull *et al.,* 1998[94]). Considering the localised nature of the impact, any effects of habitat loss are not likely to have a population level effect on herring.

5.7.2.16 Herring are deemed to be of medium vulnerability to long-term habitat loss, and are of national importance within the North Sea, and therefore are considered to be of **Medium** sensitivity.

Pelagic Spawning IEFs

5.7.2.17 Pelagic spawning IEFs including cod, common sole, lemon sole, plaice, whiting, sprat, mackerel, horse mackerel have spawning and nursery grounds overlapping the Caledonia OWF. However, as these receptors are pelagic spawners and therefore do not display substrate dependency, and therefore are not considered vulnerable to long-term habitat loss, deemed to be of high recoverability and of low vulnerability and as such the sensitivity of these species is considered to be **Negligible**.

Shellfish IEFs

5.7.2.18 Brown crabs are known to be associated with rocky substrates but also inhabit mixed coarse, sand, and soft sediments (Hall *et al.,* 1993[201]). Berried female brown crab bury themselves into soft mud and sand, while brooding eggs in the overwintering period, are not considered vulnerable to long-term habitat loss, deemed to be of high recoverability and of low vulnerability and as such the sensitivity of this species is considered to be **Low**.

5.7.2.19 European lobster are broadly distributed across the southern North Sea and are found across a range of habitats. Lobster are not known to exhibit substrate dependant behaviours but are considered of low vulnerability to long-term habitat loss, deemed to be of high recoverability and of low vulnerability and as such the sensitivity they are considered to be **Low** sensitivity to impacts from long-term habitat loss.

5.7.2.20 Nephrops are vulnerable to potential long term habitat loss associated with the development. Habitat degradation and destruction through due to the presence of infrastructure, can have significant impacts, particularly in areas where Nephrops burrow in soft substrates. The removal of habitat-forming structures like burrows can disrupt Nephrops populations and lead to declines in abundance. Nephrops within the study area are of commercial importance at a regional scale and are deemed to be of high recoverability, of a low vulnerability and have been assessed as having a **Low** sensitivity to long-term habitat loss.

5.7.2.21 All other shellfish IEFs are distributed widely throughout the Southern North Sea and are not of high value to fisheries in the region. As a result of this, all other IEFs are considered to be of high recoverability, low vulnerability and of **Low** sensitivity to impacts from long-term habitat loss.

Diadromous IEFs

5.7.2.22 Diadromous fish, including Atlantic salmon, European eel, allis shad, twaite shad, river and sea lamprey, sea trout do not display substrate dependency in the marine environment, and therefore are not considered vulnerable to long-term habitat loss, of high recoverability and as such the sensitivity of these species is considered to be **Negligible**.

Elasmobranch IEFs

5.7.2.23 Some elasmobranchs such as skates and rays are known to exhibit habitat selection preferences, and many sharks occupy broad range of habitats and therefore are not considered vulnerable to long-term habitat loss, of high recoverability and as such the sensitivity elasmobranchs is considered to be **Low**.

Significance of Effect

5.7.2.24 Long-term or permanent habitat loss will represent a long-term and continuous impact throughout the lifetime of the Proposed Development (Offshore). However, only a relatively small proportion of the fish and shellfish habitats are likely to be affected in the context of wider habitats in the area. Most receptors are predicted to have some tolerance to this impact.

5.7.2.25 The impact of long-term or permanent habitat loss on sandeel is considered to be of **Low** magnitude, and the sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.2.26 The impact of long-term or permanent habitat loss on spawning herring is considered to be of **Low** magnitude, and the sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.2.27 The impact of long-term or permanent habitat loss on shellfish receptors is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

5.7.2.28 The impact of long-term or permanent habitat loss of all other fish and shellfish receptors is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Negligible**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Impact 8: Colonisation of Hard Substrates

5.7.2.29 The introduction of subsea infrastructure from OWFs can provide potential novel hard substrate for colonisation by species within the study area. The introduction of hard infrastructure may alter previously soft sediment habitat areas, attract new species with a preference for hard substrate, and increase the habitat complexity biodiversity of the area. Subtidal infrastructure associated with OWF can serve as novel habitats for various fish and shellfish species, functioning as artificial reefs. The introduction of such hard infrastructure transforms previously soft sediment habitats, attracting new species and enhancing habitat complexity and biodiversity in the area (Degraer *et al.,* 2020[240]).

Magnitude of Impact

5.7.2.30 Up to 10.2km^2 of hard substrate will be installed and present for the duration of the operational phase (35 years), and accounts for approximately 1.5% of the Proposed Development (Offshore). This included the total area of colonisable surface including all foundation area from seabed to sea surface of up to 140 WTG and four OSP foundations and all the cable protection area (Table 5-20).

5.7.2.31 To reduce the extent of the cable protection, offshore export cables will be buried where possible (minimum depth of 1m). In instances where adequate burial cannot be achieved, an alternative form of cable protection will be deployed. The cable protection methods being considered include concrete mattresses, rock placement, grout bags, iron cast and an engineered Cable Protection System (CPS).

5.7.2.32 The introduction of hard substrate is considered unlikely to result in any substantial reef or aggregation effects and the impact of colonisation of hard substrate is predicted to be of local spatial extent, long-term duration, but reversible once the infrastructure is removed. Although it may be that some hard substrate (i.e., cable and/or scour protection) will remain *in situ*.

5.7.2.33 Impacts from the colonisation of hard substrate is predicted to be of a highly localised spatial extent, long term duration and continuous (occurring during the lifetime of the Proposed Development (Offshore)), the magnitude is therefore, considered to be **Low.**

Sensitivity of Receptors

5.7.2.34 Hard substrate habitats are comparatively rare within the study area, which is predominantly dominated by sedimentary habitats. The introduction of hard substrate, and associated increased in biodiversity, could alter the ecological communities that characterise the area. This will be long-term, lasting for the duration of the Proposed Development (Offshore). Any effects on fish and shellfish ecology arising from the introduction of hard substrates will likely be localised to the Caledonia OWF and OECC (where foundations/cable protection are present). Regarding the introduction of new species, infrastructure associated with OWF can have the potential to act as Fish Aggregation Devices (FADs). The introduction of novel structures into the marine environment has been shown have an artificial reefs effect (Inger *et al.,* 2009[241]) providing refuge and niche space boosting the species richness of the area (Langhamer and Wilhelmsson, 2014[242]; Wilhelmsson *et al.,* 2006[243]; Inger *et al.,* 2009[241]) and facilitating spawning activity of certain species such as squid (Hasaruddin *et al.,* 2015[244]). This is the same for, midwater and surface structures, such as mooring lines and floating substructures associated with floating OWFs, may act as fish aggregation devices and substrate colonisation (Farr *et al.,* 2021[245]).

5.7.2.35 The extent of the reef or aggregation effect is anticipated to be most pronounced in areas where WTGs are installed within homogeneous substrate compared to regions with more heterogeneous substrate composition (Bergstöorm *et al.,* 2013[246]; Degraer *et al.,* 2020[240]). It is important to account for the effects of reef formation and FADs associated with Caledonia OWF due to changes to predator and prey abundances, such as increased in piscivorous fish, marine mammals, and seabirds, once OWFs are operational as the introduction of more predators could have adverse implications for diadromous fish migrating through the area (Kerckhof *et al.,* 2016[221]).

5.7.2.36 The introduction of new hard substrate could represent a potential shift in the baseline condition within a small proportion of the Caledonia OWF and Caledonia OECC. Potential beneficial effects that may occur are associated within the likely increase in biodiversity and biomass, which has been observed at the Egmond aan Zee OWF (in the Dutch part of the North Sea, located approximately 10km from the coast near Egmond aan Zee) (Lindeboom *et al.,* 2011[247]). Species with the potential to benefit from the introduction of hard substrate are those which are typical of rocky habitats and intertidal environments.

5.7.2.37 The species that are potentially introduced to the study area may also have indirect, adverse effects on the existing habitats and/or species through increased predation on, or competition with, neighbouring soft sediment species. Such effects are difficult to predict. The increased biodiversity associated with hard structure could provide benefits at higher trophic levels as they provide an additional food source.

5.7.2.38 There is also potential for the introduction of INNS to the area due to the introduction of new hard substrate habitats, however, this is discussed in more detail in the Impact 9 below.

Pelagic and Demersal spawning Fish

5.7.2.39 Pelagic spawners (cod, plaice, whiting, lemon sole, mackerel, sole, sprat) with spawning grounds overlapping the Proposed Development (Offshore) are widespread across the southern North Sea and do no display substrate dependency (unlike herring and sandeel).

5.7.2.40 The introduction of hard substrate can lead to the provision of shelter and increased food availability, particularly benefiting higher trophic level species (Degraer *et al.,* 2020[240]). A study by Reubens *et al.* (2013[248]) observed elevated catches of cod at an operational wind farm site in the Belgian part of the North Sea as cod congregated around WTG foundations and areas with hard substrate. The introduction of hard substrate such as scour or cable protection could lead to the displacement of fish species that prefer sandy substrates, such as sandeel. However, monitoring studies generally indicate that the potential reef and aggregation effects associated with OWFs are unlikely to result in adverse effects for marine finfish species (Methratta and Dardick, 2019[249]).

5.7.2.41 Pelagic and demersal fish are or regional importance, are considered to have a low vulnerability, high recoverability to the impact associated with the colonisation of hard substrate. As a result of this, sandeel are of **Low** sensitivity to this impact.

5.7.2.42 Sandeel preferred habitats and spawning areas are typically dominated by coarse sediments and sandy habitats. The Caledonia OWF and Caledonia OECC are located in preferred sandeel habitat and spawning grounds. Due to specific habitat requirements of sandeel, their broad spatial distributions across the southern North Sea and their ecological value as key prey species, they are considered to be of low vulnerability to the introduction of hard substrate, with high ability for recovery, and are of national importance . As a result of this, sandeel are of **Low** sensitivity to this impact.

5.7.2.43 Herring are also demersal spawners, reliant upon the presence of suitable substrates for spawning (i.e., gravelly sediments). Herring spawning habitats are widely distributed across the North Sea. The overlap of the Proposed Development (Offshore) with historic herring spawning grounds is small compared to the overall extent of the Buchan and Shetland/Orkney herring spawning ground across the North Sea (Coull *et al.,* 1998[94]). It should be noted however, that as stated in paragraph 38, the Coull *et al.* (1998[94]) data represent historical spawning grounds, which may be recolonised in the future, whereas the IHLS data (ICES, 2011/2012 –

2023/2024[107]) provide an indication of the areas of seabed in active use for spawning.

5.7.2.44 Herring is deemed to be of low vulnerability, high recoverability to the colonisation of hard substrate, and are of national importance within the North Sea, and therefore are considered to be of **Low** sensitivity.

Shellfish

5.7.2.45 Shellfish populations within the study area are anticipated to have a low vulnerability to the introduction of novel substrate. Some shellfish species could benefit from an increase in hard substrate due to the provision of refuge areas. For example, Krone *et al.* (2017[250]) showed that monopile foundations with scour protection were associated with approximately 5,000 brown crabs per foundation, which is twice the amount found on foundations without scour protection, in the German Bight, North Sea. Studies at the Horns Rev OWF in Denmark provided evidence that OWF structures are used as successful nursery habitats for the commercial species *Cancer pagurus* (Stenberg *et al.,* 2011[251]). However, any direct benefits are only likely to occur on a very localised basis. Additionally, the wind farm served as a nursery ground for brown crab (Krone *et al.,* 2017[250]). One exception to this trend may be scallops, which are typically found in clean sand, fine, or sandy gravel habitats.

5.7.2.46 Shellfish within the study area are of commercial importance at a regional scale and are of a low vulnerability, high recoverability to this impact and have been assessed as having a **Low** sensitivity to the risk of introduced hard substrate.

Elasmobranch IEFs

5.7.2.47 Elasmobranchs are expected to have a low vulnerability to the introduction of novel substrate. Many elasmobranchs are carnivorous and primarily feed on benthic invertebrates and fishes. They could benefit from the provision of shelter and increased food availability from new prey species associated infrastructure such as WTGs (Methratta and Dardick, 2019[249]).

5.7.2.48 Elasmobranchs are internationally importance and are considered to have a low vulnerability, high recoverability and are assessed to have a **Low** sensitivity.

Diadromous IEFs

5.7.2.49 Numerous migratory species, such as Atlantic salmon and European eel, migrate through the study area, either in their juvenile stage or as adults. Migratory species could be vulnerable to the presence of additional substrate.

5.7.2.50 Migratory species could be vulnerable to increased predation associated with reef/aggregation effects associated with WTGs. A study by Reubens *et al.* (2013[248]) observed elevated catches of cod, (known to prey on Atlantic salmon post-smolts), at an operational wind farm site in the Belgian part of the North Sea. Additional research on seals also suggests that operational wind farms may serve as foraging habitats (Bailey *et al.,* 2014[252]). Consequently, it is conceivable that an increase in piscivorous fish and other predators, such as marine birds, might aggregate at Caledonia OWF, potentially intensifying predation on fish species including Atlantic salmon and sea trout which could migrate through the study area. Marine predation is a significant factor contributing to decreased post-smolt survival rates. Atlantic salmon and sea trout and has been shown to increase in some instances due to reef affects (Friedland *et al.,* 2017[253]). Predation during the post-smolt phase of migration along the coat could reduce the number of adults returning, however it is not expected that the Proposed Development (Offshore) will contribute to this decline (Gillson *et al.,* 2022[254]). Although the significance of the study area as a gathering point for Atlantic salmon and sea trout, and thus its potential impact, remains uncertain, current indications suggest that post-smolts from rivers on the East coast of Scotland are inclined to migrate eastward, through the Moray Firth. Moreover, while not definitive, it seems improbable that a considerable portion of post-smolts from other Scottish rivers will traverse the study area, given the broader availability of habitat along Scotland's Moray Firth coast.

5.7.2.51 Diadromous species with the study area internationally important receptors and are considered to have a medium vulnerability and high recoverability to potential impacts associated from the colonisation of hard substrate and are therefore assessed to be of a **Low** sensitivity.

Significance of Effect

5.7.2.52 The introduction of hard structures such as scour protection can lead to an increase in biomass and biodiversity which may be considered beneficial, but it also represents a change from the baseline environment which may be considered adverse. Any beneficial effects associated with an increase in biodiversity will be highly localised in nature and are not considered to represent mitigation for the loss of sedimentary habitat associated with the installation of these structures.

5.7.2.53 Considering the **Low** sensitivity and **Low** magnitude of pelagic and demersal fish to the colonisation of hard substrate during operation and maintenance is considered to be **Negligible and Not Significant in EIA terms**.

5.7.2.54 Taking the **Low** sensitivity of elasmobranchs and the **Low** magnitude of impact, the overall the effect of the colonisation of hard substrate is considered to be **Negligible and Not Significant in EIA terms**.

5.7.2.55 Taking the **Low** sensitivity of shellfish and the **Low** magnitude of impact, the overall the effect of the colonisation of hard substrate is considered to be **Negligible and Not Significant in EIA terms**.

5.7.2.56 Accounting for the **Low** sensitivity of diadromous fish and the **Low** magnitude of impact, the overall effect of colonisation of hard substrate during operation and maintenance is considered to be **Negligible and Not Significant in EIA terms**.

Impact 9: Increased Risk of Introduction and/or Spread of INNS due to Vessel Traffic

5.7.2.57 As previously assessed under Impact 5, INNS present a multifaceted threat by disrupting ecosystem services, altering native habitats and predating on native species. The Joint Nature Conservation Committee (JNCC) biodiversity indicators showed an increase in the number of marine INNS established across 10% or more of coastline from 2010 to 2017, compared to 2000 to 2009 (UK Biodiversity Indicators, JNCC, 2023[222]).

5.7.2.58 One pathway for INNS is from O&M Vessels servicing the WTGs as the ballast water from ships can carry nonnative marine organisms. The majority of marine INNS in UK waters have been recorded in the English Channel, with many then moving northwards (Minchin *et al.,* 2013[226]).

Magnitude of Impact

5.7.2.59 It should be noted that there is a widespread presence of marine INNS across the North Sea (NatureScot, 2024[231]). Although the final type and quantity of O&M vessels is still to be determined post-consent and will be informed by the final design parameters of the Proposed Development (Offshore) and the availability of vessels the predicted number of vessel trips is expected to be 104 SOV movements per year and 730 CTV Movements per year per CTV.

5.7.2.60 Embedded mitigation measures, including an EMP with a marine biosecurity plan (Table 5-19) will ensure that the risk of potential introduction and spread of marine INNS will be minimised as far as practicable. The impact is predicted to be of long-term permanent duration, continuous and irreversible, though the impact is predicted to affect the receptors indirectly. The Moray Firth is already subject to existing vessel traffic and the Proposed Development (Offshore) is unlikely to cause any serious addition to this baseline. The impact of INNS due to O&M vessel traffic is predicted to be of a localised spatial extent, long term duration and continuous (during the lifetime of the Proposed Development (Offshore)).

5.7.2.61 It is predicted that the impact will affect the fish and shellfish receptors indirectly. Due to the localised spatial extent, the magnitude is therefore, considered to be **Low.**

Sensitivity of Receptor

5.7.2.62 Please refer to the sensitivity assessment of fish and shellfish species within the study area has been carried out under Impact 5.

Significance of Effect

5.7.2.63 Taking into account the **Low** sensitivity and **Low** magnitude of fish to INNS, it is considered to be **Negligible and Not Significant in EIA terms**.

5.7.2.64 Accounting for the **Low** sensitivity of shellfish and the **Low** magnitude of impact, the overall effect of INNS is considered to be **Negligible and Not Significant in EIA terms**.

5.7.2.65 Taking the **Low** sensitivity of elasmobranchs and the **Low** magnitude of impact, the overall the impact of INNS arising from marine infrastructure is considered to be **Negligible and Not Significant in EIA terms**.

5.7.2.66 Considering the **Medium** sensitivity of diadromous fish and the **Low** magnitude of impact, the overall effect of INNS is considered to be **Minor and Not Significant in EIA terms**.

Impact 10: Electromagnetic Fields (EMF) Effects Arising from Cables During Operational Phase

5.7.2.67 The presence of EMF-generating infrastructure such as underwater cables associated with the Proposed Development (Offshore) may lead to displacement for fish and shellfish species. Displacement from habitat areas due to EMF or other factors associated with wind farm construction and operation could potentially impact local populations (Gill and Kimber, 2005[278]). EMF comprises both the electrical (E) fields, measured in volts per metre (V/m), and the magnetic (B) fields, measured in microtesla (μT) or milligauss (mG) (1 μT = 10 mG). Direct E-field are typically blocked using conductive sheathing, meaning that the EMFs that are emitted into the marine environment are the B-field and the resultant induced electrical field (iE). EMFs are generated by the current that passes through an electrical cable. It is known that EMFs can be detected by fish and elasmobranchs, and it is thought that benthic invertebrates can also detect EMFs.

Magnitude of Impact

5.7.2.68 The WCS for EMF associated with the various cable types and their design parameters (see Table 5-29) is represented by the unprotected dynamic cables associated with floating WTGs. Three types of fields are generated by underwater electric cables: electric fields (E-fields), magnetic fields (B-fields) and induced electric fields (iE-fields). Inter-array, interconnector cables and export cables will all be buried of have cable protection to reduce the attenuation of their EMF (see Table 5-29). This is standard industry practice is for the cables used to have sufficient shielding to contain the E-fields generated and the cable system descriptions for the inter-array and offshore export cables for the Proposed Development (Offshore) are compliant with this approach (Volume 1, Chapter 3: Proposed Development Description (Offshore)). Shielding and/or burial does not reduce the B-fields and it is these fields that allow the formation of iE-fields. As such, further reference here to EMFs is limited to B-fields and associated iE-fields.

Table 5-29: Cable design parameters.

Cable Type	Maximum Number of Cables	Maximum Length of Cables	Maximum Length of Cable where Cable Protection may be Required	Maximum Length of Floating Cable per WTG	Maximum Voltage
Inter-array Cables	140	655km	196km	N/A	132kV
Floating WTG Inter-array Cables (note, part of the above total)	39	182.5km	N/A	4km	275 kV
Interconnector Cables	2	60km	18km	N/A	275 kV
Offshore Export Cables	4	330km	165km	N/A	275 kV

5.7.2.69 EMFs are likely to be generated by subsea cables and would be detectable above background levels near the cables. Although burial does not mask EMFs, it increases the distance between species that may be affected by EMFs and the source. As the cable will be buried or protected, any behavioural responses are likely to be mitigated.

5.7.2.70 Tricas (2012[255]) provides a table to show the attenuation of EMF and subsequent decay of field strength from buried power cables (Table 5-30). Magnetic Field Strength decreased from 7.85μT at 0m above a cable to 0.13μT at 10m above the cable.

Table 5-30: AC magnetic fields (μT) reflecting averaged values from 10 AC projects at intervals above and horizontally along the sea bed, assuming 1 meter burial (Tricas, 2012[255]).

Distance Above Seabed (m)	Magnetic Field Strenght (μT) Horizontal Distance from Cable (m)		
	0	4	10
0	7.85	1.47	0.22
5	0.35	0.29	0.14
10	0.13	0.12	0.08

5.7.2.71 Inter-array cables connect WTGs together, as well as branches of WTGs to OSPs. The inter-array cables will be multi-core High Voltage Alternating Current (HVAC) cables, up to 230mm diameter (may vary depending on the voltage or material of the cable itself), with a maximum voltage of 132kV, and a fibre optic system (up to 48 fibres). The total length of inter-array cables will be up to a maximum of 655km for the Proposed Development (Offshore). EMFs monitored around subsea electricity cables have been shown to attenuate exponentially vertically and horizontally away from surface laid cables, with the EMF generated by the cables typically having reached zero within 10m of the surface laid cable (reviewed by Tricas and Gill, 2011[288]; CSA Ocean Sciences Inc. and Exponent, 2019[256]).

5.7.2.72 Burial of the cables and protection with cable protection where shallow buried or surface laid will not reduce the strength of the fields, however, it moves the cables further from the receptors, and as such the receptors will be subject to reduced field strengths. iE fields may cause either attraction or repulsion, with varying strength fields having been demonstrated to cause both reactions (Gill and Taylor 2001[347]; Kimber *et al.,* 2011[257]). The threshold for the change between attraction and avoidance of iE fields in elasmobranchs is considered to be between 400 - 1,000μV/m (reviewed in CMACS, 2003[341]) and these levels would only likely be found at or within 1 - 2m of the seabed for a cable buried at 1m. For deeper burial, the iE field at the seabed would be correspondingly lower.

5.7.2.73 Unlike bottom-fixed WTGs, inter-array cables associated with floating WTGs are dynamic and sections of them are suspended within the water column, instead of being fully buried along the sea floor and therefore have the potential for a larger attenuation and reduced decay of EMF (Farr *et al.,* 2021[245]), as there is nothing to separate/shield the receptors from the source. While field studies have been conducted on the effects of EMF from cables buried in the seabed (Hutchison *et al.,* 2018[258]), there is a limited understanding of the EMF impacts arising from dynamic cables suspended in the water column before they reach the seabed as will be the configuration for FOWF inter-array cables (Gill and Desender, 2020[259]; Hutchison *et al.,* 2020b[260]). More work needs to be done to understand attraction or aversion effects of suspended cables, particularly on pelagic species (Taormina *et al.,* 2018[261]).

5.7.2.74 The offshore export cables will export energy from the OSPs to the Onshore Export Cables via the landfall interface between offshore and onshore settings. There will be up to four offshore export cables required for the Proposed Development (Offshore), with two supporting Caledonia North and two supporting Caledonia South. All offshore export cables will be located in separate trenches within the OECC, making landfall at Stake Ness on the Aberdeenshire coast via HDD. The offshore export cables will be multi-core HVAC cables, up to 290mm diameter (may vary depending on the voltage or material of the cable itself), with a maximum voltage of 275kV.

5.7.2.75 Despite EMF being emitted throughout the life cycle of the Proposed Development (Offshore), measures will be implemented to mitigate exposure to EMF emissions. These measures will include cable burial and/or the implementation of cable protection measures. These actions will be carried out in accordance with management plans, including the Cable Plan (CaP), to reduce the impact of EMF emissions on surrounding environments and organisms. In instances where cables cannot be buried, as such with inter-array cables between FWTG, measures can be put in place such as cables being monitored regularly for wear and tear or the use cable protection measures.

5.7.2.76 The impact of EMF is predicted to be of a highly localised spatial extent, long term duration, continuous but reversible, only occurring during the lifetime of the Proposed Development (Offshore). It is predicted that the impact will affect the fish and shellfish receptors indirectly. Due to the extremely localised spatial extent, the magnitude is therefore, considered to be **Low**.

Sensitivity of Receptor

5.7.2.77 The potential effects of EMF from offshore wind farms on marine organisms vary between taxa. EMF generated by inter-array cables and export cables associated with the Proposed development (Offshore) may have behavioural effects on marine organisms. While responses can vary depending on the species and the intensity of EMF exposure, some studies suggest that certain organisms, such as diadromous species and elasmobranchs use EMF detection for navigation, and for prey detection (elasmobranchs) (Hutchinson *et al.,* 2018[262]) and may exhibit avoidance behaviours or altered movement patterns in the vicinity of EMF sources (Gill and Kimber, 2005[278]; Tricas and Gill, 2011[288]). EMF exposure can also potentially affect the physiology of marine organisms. Research have explored the physiological responses of organisms to EMF, including changes in metabolic rates, reproductive processes, and stress responses. While research on the specific physiological effects of EMF on a broad range of fish and shellfish is limited, similar crustacean species have been shown to exhibit physiological responses to EMF exposure (Gill and Kimber, 2005[278]; Tricas and Gill, 2011[288]).

Pelagic and Demersal IEFs

5.7.2.78 Pelagic species, such as mackerel and sprat, are likely to encounter the EMF emitted by inter-array or connecting cables. However, due to their high mobility, they are not expected to remain near any heightened EMF associated with the Proposed Development (Offshore) for extended periods.

5.7.2.79 Demersal species such as sandeel, cod and sole and substrate spawning species such as herring are more likely to be impacted by EMF emitted from inter-array and interconnecting cables. Several demersal species utilise spawning and nursery grounds that overlap with the Caledonia OWF.

5.7.2.80 Cresci *et al.* (2019[264]; 2022a[265]; 2022b[263]) conducted research on the impact of electromagnetic field (EMF) exposure on haddock, herring, and lesser sandeel larvae. Haddock larvae were found to be magneto-sensitive according to Cresci *et al.* (2019[264]). Exposure to B-fields ranging from 50 to 150 μT in laboratory conditions did not induce significant changes in spatial distribution (i.e., no attraction effect) but did lead to slower swimming speeds, potentially affecting the dispersal ecology of this species (Cresci *et al.,* 2022a[265]). Atlantic herring larvae exposed to B-fields ranging from 48.8 to 50 μT both in situ and in laboratory settings did not exhibit any alterations in orientation due to EMF exposure, suggesting that this species does not employ magnetic compass orientation, at least during this life stage (Cresci *et al.,* 2019[264]). Similarly, lesser sandeel larvae exposed to B -fields ranging from 50 to 150 μT in laboratory conditions showed no changes in spatial distribution or modifications in swimming speed, acceleration, or distance travelled (Cresci *et al.,* 2022b[263]). It should be noted that EMF of this intensity would only occur in close proximity to the cables and have a very limited spatial impact. Notwithstanding this, fish are capable of being present in close proximity to the cables, however this is expected to only result in a behavioural effect, whereby they move away from the source of EMF.

5.7.2.81 Subsequently fish receptors within the study area regionally important, high recoverability and are considered to have a low vulnerability to potential impacts associated from EMF and are therefore assessed to be of a **Low** sensitivity.

Shellfish IEFs

5.7.2.82 Many marine invertebrates such as brown crab and lobster, are thought to be magneto-sensitive, with this often being used for navigational purposes (migration etc.). However, evidence for potential impacts from anthropogenic B fields is limited and can be contradictory even within the same species (Scott *et al.,* 2020[266]). Studies on the green shore crab (*Carcinus maenas*) have been directly contradictory, with one study demonstrating reduced aggression in response to AC and B fields which are likely to be emitted from those from a buried OWF cable (Gill *et al.,* 2014[267]). However, another study found no effects from static B fields (Bochert and Zettler, 2006[268]). Brown shrimp (*Crangon crangon*) were recorded as being attracted to B fields of the magnitude expected from offshore wind cabling (Love *et al.,* 2017[269]). One recent study (Hutchison *et al.,* 2020a[270]) has suggested potential changes to exploratory behaviour in American lobster (Homarus americanus) in response to B fields when in tanks placed near a DC subsea cable.

5.7.2.83 A study investigating the response of lobsters when exposed to static EMFs within enclosures positioned above a High Voltage Directional Current (HVDC) power cable found a behavioural response (Hutchison *et al.,* 2020a[270];2020b[260]). However, there was no indication that these responses were correlated with zones of high or low EMF, instead, they represented an overall reaction. It's noteworthy that this study investigated HVDC cables at 300 kV and 500 kV, where the magnetic fields observed were substantially greater than the cables voltage. Therefore, these results are not directly applicable to the proposed HVAC cables for the Proposed Development (Offshore).

5.7.2.84 Another study involving lobsters and brown crabs exposed to EMF found no significant impact on embryonic development time, larval release time, or vertical swimming speed for either species. However, when exposed throughout embryonic development, an increase in larval deformities was noted, along with a reduced swimming test success rate among lobster larvae (Harsanyi *et al.,* 2022[271]). It's important to highlight that this study examined exposure to 2.8 Millitesla (mT) of EMF, a significantly higher intensity compared to the proposed cables for the Proposed Development (Offshore), rendering direct comparisons invalid. Another recent laboratory investigation on brown crab (Scott *et al.,* 2018[272];2021[273]; Harsanyi *et al.,* 2022[271]) revealed no adverse physiological or behavioural effects at magnetic field strengths of 250 μT. However, adverse behavioural effects, such as attraction and reduced time spent roaming, as well as physiological impacts, were observed at 500 μT and higher. While responses were noted at these elevated levels, it's crucial to note that the proposed buried cables for the Proposed Development (Offshore) would be unlikely to attenuate EMF at such magnitudes (> 500 μT) and due to the demersal nature of shellfish, they will not be exposed to significant lengths of unprotected cables entering the into the seabed. These findings suggests that a working limit of a maximum of 250 μT could result in minimal physiological and behavioural changes within this species and should be considered (Scott *et al.,* 2021[273]).

5.7.2.85 Based on the above information, whilst it is possible that shellfish species present within the Caledonia OWF may be able to detect the iE or B fields generated by the cables, it is unlikely that the field strengths will disrupt feeding, spawning or migratory behaviours.

5.7.2.86 Subsequently, shellfish receptors within the study area of regional importance, high recoverability and are considered to have a low vulnerability to potential impacts associated from EMF and are therefore assessed to be of a **Low** sensitivity.

Elasmobranch IEFs

5.7.2.87 Elasmobranchs, such as sharks and rays, possess the ability to detect electro-magnetic fields directly and are known to be more responsive to electric fields compared to other species (Anderson *et al.,* 2017[274]; Hutchison *et al.,* 2020a[270]; Kempster *et al.,* 2013[275]).

5.7.2.88 A study by Gill and Taylor (2001[347]) investigates the potential effects of EMF generated by OWF cables on elasmobranch. Their study had several important findings, first of which was some elasmobranch species were found to detect EMFs at certain thresholds and exhibited avoidance behaviour when exposed to EMFs at higher intensities. This avoidance could impact their natural movements and habitat use, potentially leading to changes in distribution patterns. However, the degree of responsiveness varies depending on the species and the experimental setup. Gill *et al.* (2009[276]) demonstrated that thornback rays where more likely to move around in within EMF zones whereas spurdog restricted their movements in areas with magnetic field strengths of 8 μT and electric field strengths of 2.2 μV/m. However, there was no evidence to suggest any positive or negative effect on elasmobranchs as a result of encountering the EMF, only that at greater EMF strength (>52.6 μT) skates were shown to travel further compared to control groups (Gill *et al.,* 2014[267]; Hutchison *et al.,* 2020a[270]) also showed that the little skate (*Leucoraja erinacea*) exhibited increased exploratory or foraging behaviour in response to EMF exposure from a HVDC cable, with magnetic field strengths reaching up to 65.3 μT. For population-level effects to manifest, such responses would need to translate into reduced health, survival, or reproductive success (Gill and Desender, 2020[259]).

5.7.2.89 Species such as skates, rays, and sharks, have well-developed electrosensory systems are more susceptible to EMF exposure compared to fish with less sensitive systems. They have been found to exhibit avoidance behaviour, leading to altered foraging patterns and behaviour, which could impact local ecosystems and fishing areas (CSA Ocean Sciences Inc. and Exponent, 2019[256]).

5.7.2.90 Research by Kempster and Colin (2011[277]) explores the distribution of electrosensory pores in basking sharks and their potential role in the sharks' feeding behaviour. While the study focuses on electrosensory systems rather than the direct effects of EMFs, the findings offer insights that can help infer possible EMF impacts. Basking sharks might be sensitive to EMFs generated by sub-sea cables and experience disruption to navigation and feeding patters, however these are expected to be limited to EMF from dynamic cables which aren't protected and will have a greater attenuation of EMF (Kempster and Colin, 2011[277]).

5.7.2.91 In summary, several studies showed behavioural reactions in elasmobranchs due to iE-fields emitted from inter-array cable within offshore wind farms, with small changes in behaviour when near to the cable compared to when not (Gill and Kimber, 2005[278]). However, the behavioural changes appeared to be dependent on the individual and as such consequences for species populations are uncertain.

5.7.2.92 Therefore, on a precautionary basis, elasmobranchs are considered to be medium vulnerability and medium recoverability and overall of **Medium** sensitivity to EMF.

Diadromous Fish and Migratory IEFs

5.7.2.93 Unlike elasmobranch species, diadromous species such as Atlantic salmon and European Eel, lack specialised electro-magnetic receptor cells. Instead, they harbour magnetically sensitive material within their skeletal structure and utilise the Earth's magnetic field as a navigational aid for migration. Consequently, if the migratory routes of diadromous species intersect with the cable routes of the Proposed Development (Offshore), there exists the potential for EMFs emitted by the cables to influence the behaviour of individuals, particularly in shallower waters of 20 meters or less (Gill *et al.,* 2012[276]). Such effects could manifest as avoidance behaviour, potentially delaying the migration of salmonids and European eels. However, studies have produced widely variable results, indicating effects could vary from temporary change in swimming to potentially a more serious avoidance response or delay to migration, leaving the extent of EMF effects on migratory fish unclear (Gill and Bartlett, 2010[279]). Many diadromous species are of conservation significance, either as Annex II species (lamprey species and Atlantic salmon) or as Critically Endangered under the IUCN Red List (European eel).

5.7.2.94 Adult and juvenile Atlantic salmon primarily inhabit the upper 5 meters of the water column (Godfrey *et al.,* 2015[280]; Newton *et al.,* 2021[183]), meaning they are less likely to be affected by EMFs emitted from seabed cables. Eels traverse various depths throughout the water column and are more likely to encounter EMFs from both seabed and dynamic cables.

5.7.2.95 A laboratory study conducted by Marine Scotland (Armstrong *et al.,* 2015[281]) found no evidence of differences in eel movement due to EMFs, nor any observed changes in eel behaviour. Armstrong *et al.* (2015[281]) similarly concluded that there were no identifiable physiological or behavioural responses of Atlantic salmon to magnetic fields at intensities of 95 μT and below. While no field studies on the response of Atlantic salmon to EMFs are available, Wyman *et al.* (2018[282]) investigated the effect of EMFs from a 200kV subsea cable on Chinook salmon migratory success in San Francisco Bay, California. They observed a slight deviation from normal migratory routes and increased migration times due to EMF activation, but this did not diminish overall migration success (Wyman *et al.,* 2018[282]).

5.7.2.96 Studies on European eel have shown some deviation from migratory routes in response to low (5μT) DC B-fields; however, the effects were localised and of short-term duration and not thought to impact on overall migration (Öhman *et al.,* 2007[283]). Interestingly, no effects were seen in European eel from AC fields of 9.6μT (Armstrong *et al.,* 2015[281]), suggesting that there may be differences in effects between DC and AC cabling. A review of potential effects of EMF on migratory fish for Scottish Natural Heritage (Gill and Bartlett, 2010[279]) identified that there was insufficient evidence to be able to confirm whether any impacts would arise on migratory fish from the field strengths generated by OWF cabling.

5.7.2.97 While high levels of EMF emitted by the Proposed Development (Offshore) may have the potential to impact the migration of these diadromous fish, these effects are likely to be localised and temporary and are unlikely to affect their migratory patterns and behaviour.

5.7.2.98 Atlantic salmon and European eel are therefore deemed to have a low vulnerability to the levels of EMF being emitted due to swimming in surface waters, high recoverability of international importance and to be of **Medium** sensitivity to impacts from EMF.

5.7.2.99 Some migratory species may be sensitive to electric fields. Lampreys possess specialised ampullary receptors that are responsive to weak, low frequency E-fields (Bodznick and Northcutt, 1981[284]; Bodznick and Preston, 1983[285]), but information regarding what use they make of the electric sense is limited. Observations by Chung-Davidson *et al.* (2008[286]) suggest that weak E-fields may play a role in the reproduction of sea lamprey, with electric stimuli thought to be important in detecting potential mates, retaining lampreys in their nests or in regulating sexual behaviour. Others have suggested that adult sea lamprey may use their electric senses to locate prey over short distances or to navigate by using the electric fields induced in the water column by the Earth's magnetic fields (Bodznick and Preston, 1983[285]). Laboratory tests conducted on adult sea lamprey (i.e., individuals at their marine stage) showed strong reductions in swimming behaviour at electric fields strengths of 30μV/cm and above (Chung-Davidson *et al.,* 2004[287]). Overall, current evidence suggests that the threshold for behavioural response in sea lamprey lies within the range of electric field induced by subsea power cables (CMACS, 2003[341]; Normandeau Associates *et al.,* 2011[288]).

5.7.2.100 Taking this into consideration, these species are deemed to have medium vulnerability, high recoverability of international importance and to be of **Medium** sensitivity to impacts from EMF.

5.7.2.101 Information on the impact of EMFs on the other diadromous species (sea trout, twaite shad and allis shad) is limited. A broad scale study of fish aggregations and directional movement around subsea cables at the Nysted offshore wind farm in Denmark showed no evidence of any change in directionality or distribution of species as a result of the cable installation (Hvidt *et al.,* 2004[289]). Taking this into consideration, these species are deemed to have low vulnerability, high recoverability of regional importance and to be of **Low** sensitivity to impacts from EMF.

Significance of Effect

5.7.2.102 Taking in to account the **Low** sensitivity of fish and the **Low** magnitude of impact, the overall effect of EMF during operation and maintenance is considered to be **Negligible and Not Significant in EIA terms**.

5.7.2.103 Taking the **Medium** sensitivity of shellfish and the **Low** magnitude of impact, the overall effect of EMF during operation and maintenance is considered to be **Minor and Not Significant in EIA terms**.

5.7.2.104 Taking the **Medium** sensitivity of elasmobranchs and the **Low** magnitude of impact, the overall effect of EMF during operation and maintenance is considered to be **Minor and Not Significant in EIA terms**.

5.7.2.105 Taking the **Medium** sensitivity of diadromous fish and the **Low** magnitude of impact, the overall effect of EMF during operation and maintenance is considered to be **Minor and Not Significant in EIA terms**.

Impact 11: Effects Arising from Underwater Noise During Operation

5.7.2.106 The primary source of underwater noise from operational WTGs is the mechanically generated vibration from the rotating machinery within the WTGs, which transmits into the sea through the WTG tower and foundation structure (Nedwell *et al.,* 2003[290]; Tougaard *et al.,* 2020[291]). Noise levels above the water surface are sufficiently low that significant airborne noise does not transfer from air to water.

5.7.2.107 Underwater noise levels during the operational phase are predicted to be considerably lower than those of the construction phase, being limited to noise from operational turbines and maintenance vessel traffic.

Magnitude of Impact

5.7.2.108 Underwater noise from an operational turbine mainly originates from the gearbox and the generator and has tonal characteristics (Madsen *et al.,* 2005[292]; Tougaard *et al.,* 2009[293]). The radiated levels are low and the spatial extent of the potential impact of the operational windfarm noise on marine receptors is generally estimated to be small and thus unlikely to result in any injury to fish (Wahlberg and Westerberg, 2005[294]). Besides the sound source level, the potential for impact will also depend on the propagation environment, the receptor's hearing ability and the ambient sound levels.

5.7.2.109 UWN modelling in Volume 7, Appendix 6 (Underwater Noise Assessment) shows that operational UWN from WTGs is below the TTS threshold (>186 dB) and less than 100m impact range using this extrapolated level and the Popper *et al.* (2014[32]) criteria for continuous noise (Figure 5-22). The TTS threshold of 158 dB (Lp) would require an individual to be closer than 20 meters for 12 hours continuously to have any effect.

Table 5-31: Summary of the bottom-fixed foundation operational WTG noise impact ranges using the continuous noise criteria from Popper *et al.* (2014[32]) for fish (swim bladder involved in hearing).

Popper *et al.* (2014[32]) $L_{p,}$	Operational WTG (15 MW)	Operational WTG (25 MW)
Recoverable injury 170 dB (48 hours)	< 50 m	< 50 m
TTS 158 dB (12 hours)	< 50 m	< 50 m

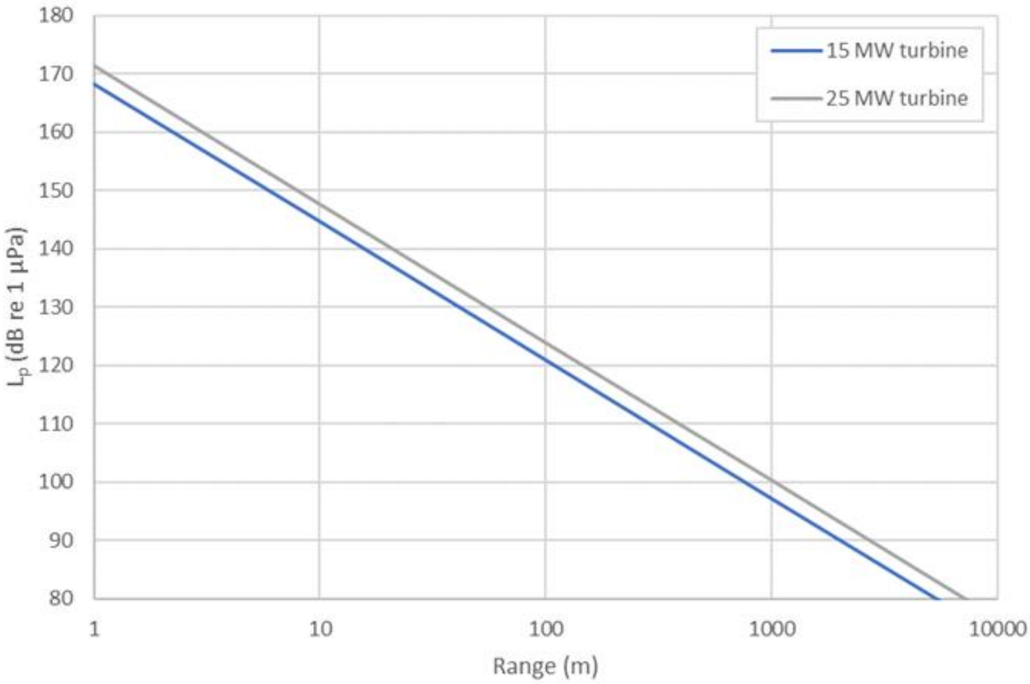


Figure 5-22: UWN Impact Ranges from Operational WTGs (Volume 7, Appendix 6: Underwater Noise Assessment).

5.7.2.110 The noise source for most operational WTGs is the radiating area of the foundation in the water. For a bottom-fixed monopile foundation, this is the surface area of the cylindrical pile in the water column. Other bottom-fixed foundations such as jacket or tripod foundations are more complex. Regarding floating WTGs, the radiating area source is limited to the weighted and buoyant section beneath the sea surface, a much smaller area compared to bottom-fixed WTGs. With a smaller submerged radiating area, the noise is expected to be lower, assuming equivalent sound generation within the WTG and transmission through the tower.

5.7.2.111 The particle acceleration resulting from an operational wind turbine has also been measured by Sigray and Anderson (2011[352]) with the resultant levels being considered too low to be of concern for behavioural reactions from fish. Furthermore, the particle acceleration levels measured at 10m from the turbine were comparable with hearing thresholds. Whilst limited, the available data provides an indicator that operational wind turbines are unlikely to result in disturbance of fish except within very close proximity of the turbine structure, as postulated by Wahlberg and Westerberg (2005[294]). However, the available measurement data is mostly for smaller turbines (up to 1.5MW), and it would be expected that larger wind turbines would result in different acoustic characteristics, with foundation type also having an influence on the acoustic characteristics of the noise radiated from the structure.

5.7.2.112 There is little empirical data exists for the operational noise produced by floating WTGs. For example, Tougaard *et al.* (2020[291]) and the study by Stöber and Thomsen (2021[295]) did not consider any floating designs and reliable noise thresholds are recommended to identify disturbances from rare or intermittent impulses of this type. Mooring lines have been described as producing a "snapping" noise related to tension release (Jasco *et al.,* 2011[296]). According to Xodus (2015[296]), up to 23 snaps were identified per day were identified at the Hywind Test site. Over two months of monitoring, fewer than 10 snaps exceeding 160 dB re 1 µPa (Lp) at 150 meters from the WTG were recorded on most days. Since any snapping occurs at an average rate of less than one snap per hour, disturbance leading to avoidance behaviour is considered unlikely. Additionally, this prediction includes WCS assumptions (e.g., all WTGs producing the maximum number of snaps daily, equivalent noise levels from multiple locations affecting a receptor equally) and is below any TTS or injury criteria for fish and shellfish IEFs. Refer to the magnitude of impact section of Impact 1 or further species-specific details regarding the magnitude of impacts for TTS.

5.7.2.113 Additional research on UWN measurements at the completed Hywind site found occurrence of transient noises was found to have a positive correlation with wave height, but only a limited correlation with wind speed (Martin *et al.,* 2011[350]). These noises were determined to originate near the turbines, with no evidence suggesting that the mooring noise was generated further down the mooring system (Baldachini *et al.,* 2024[297]). Further study at Kincardine and Hywind Scotland sites by Risch *et al.* (2023[298]) provided limited information on mooring line noise, it did note the presence of transients similar to those observed by Martin *et al.* (2011[350]) during periods of higher wind speeds and "significant wave height" though it did not define what was meant by "significant".

5.7.2.114 Considering the operational turbine noise of the windfarm and any associated service vessels, the ambient noise levels within the site would be expected to be lower than those present in the vicinity of nearby shipping lanes.

5.7.2.115 The impact is predicted to be of a highly localised spatial extent, long term duration, continuous and irreversible (during the 35-year lifetime of the Proposed Development (Offshore)). It is predicted that the impact will affect the fish and shellfish receptors indirectly. Due to the extremely localised spatial extent, the magnitude is therefore, considered to be **Negligible**.

Sensitivity of Receptor

5.7.2.116 Marine animals may perceive the radiated tonal components where they exist above the ambient noise levels, which may result in a behavioural response of the receptor or lead to a reduced detection of other sounds due to masking. Previous studies show that behavioural responses of fish are only likely at close ranges from the turbine, (i.e., a few metres) (Wahlberg and Westerberg, 2005[294]). Although effects on fish are difficult to establish given the lack of information available in the scientific literature, there is indicative evidence that fish would be unlikely to show significant avoidance to the noise levels radiating from the turbine. ICES has formulated recommendations for maximum radiated underwater noise from research vessels which are approximately 30dB above the hearing threshold of cod and herring (Mitson, 1995[185]). The implication of this is that the presence of continuous noise that is not significantly above the hearing threshold of fish is not thought to cause any significant movement of fish away from the source. Studies of very low frequency sound have indicated that consistent deterrence from the source is only likely to occur at particle accelerations equivalent to a free-field sound pressure level of 160dB re 1µPa (RMS) (Sand *et al.,* 2001[299]). This is higher than the noise levels reported in the open literature for operational windfarms measured at a number of ranges, all within a few hundred metres of the turbine (Nedwell *et al.,* 2007[173]; Betke *et al.,* 2004[300], see also Wahlberg and Westerberg, 2005[294]; Madsen *et al.,* 2005[292]).

5.7.2.117 Tougaard *et al.* (2020[291]) conducted a study on underwater noise data from 17 operational WTGs in Europe and the United States. The study used indicative power outputs to calculate impacts. For WTGs with bottom-fixed foundations, power outputs up to 25 MW were assumed, while floating WTGs with outputs up to 20 MW were considered. The findings indicate that for operational WTGs with bottom-fixed foundations, the risk of injury is minimal. Operational UWN is expected to be below TTS threshold, and not expected to have any significant effects on any of the receptor groups. Refer to the sensitivity assessment carried out under Impact 1 for TTS.

5.7.2.118 The sensitivities of group 3 fish and shellfish receptors were assessed as having a maximum sensitivity of **Medium**. All remaining groups of fish and shellfish IEFs are deemed as being of **Low** sensitivity to the effects of operational UWN.

Significance of effect

5.7.2.119 Operational UWN is expected to be below the TTS threshold for all groups of fish and shellfish IEFs, with a maximum magnitude being **Low**, and the maximum sensitivity of group 3 species considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.7.3 Decommissioning

Impact 12: Mortality, Injury, Behavioural Impacts and Auditory Masking Arising from Noise and Vibration

Magnitude of Impact

5.7.3.1 Decommissioning of offshore infrastructure for the Proposed Development (Offshore) may result in temporarily elevated underwater noise levels which may have effects on fish and shellfish species, with subsequent effects on spawning and nursery habitats. These elevated noise levels may be due to increased vessel movements and removal of the turbine foundations with the resulting noise levels dependant on the method used for removal of the foundation. The decommissioning sequence will generally be the reverse of the construction sequence and involve similar types and numbers of vessels and equipment. The maximum levels of underwater noise during decommissioning would be from underwater cutting required to remove structures, with piled foundations cut approximately 1m below the seabed. The noise levels from this process are expected to be much less than pile driving and, therefore, impacts would be less than as assessed during the construction phase.

5.7.3.2 Studies of underwater construction noise (decommissioning) reported source levels which are similar to those reported for medium sized surface vessels and ferries (Shadman *et al.,* 2023[301]). The noise resulting from wind turbine decommissioning employing abrasive cutting is unlikely to result in any injury, avoidance or significant disturbance of local marine animals. Some temporary minor disturbance might be experienced in the immediate vicinity of the decommissioning activity, for example, from dynamically positioned vessels.

5.7.3.3 The impact is predicted to be of highly local spatial extent, short-term duration, intermittent and reversible. Based on the information available at the time of writing, and due to the localised spatial extent, the expected magnitude is considered to be **Negligible** for all receptors.

Sensitivity of Receptor

5.7.3.4 Based of the full UWN impact assessment carried out under Impact 1, the maximum sensitivity of all receptors to underwater noise is medium taking this into account, the most sensitive receptor is considered to be of low vulnerability, with medium recoverability and of international importance. All other receptors are considered to be of low vulnerability, with medium recoverability and of regional to international importance, therefore their overall sensitivity is considered to be **Low**.

Significance of Effect

5.7.3.5 The magnitude of the impact was determined to be **Negligible**, with the maximum sensitivity of the receptors being **Medium**. Therefore, the significance of the effect of Mortality, injury, behavioural impacts and auditory masking arising from noise and vibration occurring as a result of decommissioning activities is a maximum of **Minor and Not Significant in EIA terms**.

Impact 13: Temporary Increase in SSC and Sediment Deposition

Magnitude of Impact

5.7.3.6 Increases in SSC and sediment deposition from the decommissioning works will be similar to that for construction and are of a similar magnitude. The magnitude of the impact on fish and shellfish to increased SSC and sediment deposition are described in detail under Impact 2: Temporary Increase in SSC. The magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptor

5.7.3.7 The sensitivity of fish and shellfish to increases in SSC and sediment deposition from the decommissioning works will be similar to that for construction and the same sensitivity. The sensitivities of fish and shellfish to increased SSC and sediment deposition are described in detail under Impact 2. Receptors are considered to be of low vulnerability, with medium recoverability and of regional to national importance, therefore their overall sensitivity is considered to be **Low**.

Significance of Effect

5.7.3.8 Overall, the magnitude of the impact has been assessed as **Low** with the maximum sensitivity of receptors assessed as **Medium**. Therefore, the significance of effect from changes in SSC and associated sediment deposition occurring as a result of decommissioning activities is considered to be **Minor and Not Significant in EIA terms**.

Impact 14: Temporary Habitat Loss

Magnitude of Impact

5.7.3.9 Temporary habitat loss and disturbance from the decommissioning works will be similar to that for construction and are of similar magnitude. The magnitude of temporary habitat loss on fish and shellfish are described in detail under Impact 3. The magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptor

5.7.3.10 The sensitivity of fish and shellfish to temporary habitat loss and disturbance from the decommissioning works will be similar to that for construction are described in detail under Impact 3. Receptors are considered to be of low vulnerability, with medium recoverability and of regional to national importance, therefore their overall sensitivity is considered to be **Low**.

Significance of Effect

5.7.3.11 The magnitude of the impact was determined to be **Low**, with the maximum sensitivity of the receptors being **Medium**. Therefore, the significance of the effect of temporary seabed habitat loss/disturbance occurring as a result of decommissioning activities is a maximum of **Minor and Not Significant in EIA terms**.

Impact 15: Direct and Indirect Seabed Disturbances Leading to the Release of Sediment Contaminants from Decommissioning Activities

Magnitude of Impact

5.7.3.12 Direct and indirect seabed disturbances leading to release of sediment contaminants from the decommissioning works will be similar to that for construction and are of a similar magnitude. The magnitude of the impact on fish and shellfish to the impact are detailed under Impact 4. The resuspension of contaminants as a result of sediment disturbance is predicted to occur on a small scale, with contaminants predicted to be rapidly dispersed by the tide. The magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.7.3.13 Direct and indirect seabed disturbances leading to release of sediment contaminants from the decommissioning works will be similar to that for construction and are of a similar magnitude. The sensitivities of fish and shellfish to the impact are detailed under Impact 4. Receptors are considered to be of low vulnerability, with medium recoverability and of regional to national importance, therefore their overall sensitivity is considered to be **Low**.

Significance of Effect

5.7.3.14 Overall, the magnitude of the impact is deemed to be **Negligible**, and the maximum sensitivity of receptors is considered to be **Medium**. The significance of the effect is therefore considered to be a maximum of **Minor and Not Significant in EIA terms**.

Basking Sharks

5.7.4 Construction

5.7.4.1 This section presents the assessment of impacts on basking shark receptors arising from the construction phase of the Proposed Development (Offshore). It is important to note that this assessment accounts for the WCS presented in Table 5-21, and that different construction programme scenarios were considered for different construction impacts scoped in.

Impact 1: Underwater Noise from Pile-driving

5.7.4.1 The assessment below focuses on the potential impacts of underwater noise (UWN) and its effects on basking sharks during construction of the Proposed Development (Offshore). These include, impacts of UWN and vibration from pile-driving for the installation of foundations for offshore structures within the Proposed Development (Offshore) (i.e., WTGs and OSPs).

5.7.4.2 Pile installation has the potential to generate underwater noise which could result in injury to basking sharks during the construction stage. To date there have been a limited number of studies that have examined the effects of exposure to anthropogenic sound sources in species of elasmobranch (Casper *et al.,* 2012[307]). Chapius *et al.* (2019[302]) investigated the effect of underwater sound on eight species of shark (excluding basking sharks), which showed less 'inquisitive' behaviour to baited test rigs when an orca call sequence and artificially generated sound were playing. Casper *et al.* (2012[307]) also recorded that sharks can have a startle response to loud, sudden onset sounds (20-30 dB above ambient noise), but noted that sharks would habituate to the stimuli after a few trials.

5.7.4.3 It is more likely that basking sharks would experience barotrauma as a result of the impulsive energy produced by a pile hammer strike. Halvorsen *et al.* (2012[303]) suggests that some of the barotrauma damage found in teleosts when exposed to pile-driving stimuli is focused in the liver, kidneys, and intestines, and while elasmobranchs were not used in that study, they have many similarities in morphology with those species (e.g., they have the same organs as teleosts). Therefore, we consider that this study is indicative of the potential impacts of barotrauma on basking sharks. However, as there are limited studies surrounding particle motion and the ability to predict the consequences of particle motion of a noise source and the sensitivity of fish to a specific particle motion value, the criteria proposed by Popper *et al.* (2014[32]) is most commonly used (Popper and Hawkins, 2019[304]).

5.7.4.4 Impact pile-driving modelling has been undertaken at four representative locations for various foundation types as illustrated in Table 5-32 and Table 5-33 (see Volume 7, Appendix 6: Underwater Noise Assessment). The greatest impact ranges are predicted for the multi-leg foundation scenario at the westernmost corner of the site, due to the deep water at, and surrounding this location.

Table 5-32: Modelling results of impact ranges considering single location piling at location 7, both stationary and fleeing receptors of basking sharks, under piling scenario of different foundation types within the Caledonia OWF.

Piling Scenario	Mortality and Potentially Mortal Injury			Recoverable Injury			TTS	
	Instantaneous (SPL_{peak})	Stationary (SEL_{cum})	Fleeing (SEL_{cum})	Instantaneous (SPL_{peak})	Stationary (SEL_{cum})	Fleeing (SEL_{cum})	Stationary (SEL_{cum})	Fleeing (SEL_{cum})
Monopile foundation impact area (sequential piling of two monopiles in a 24-hour period)	<140m	700m	<100m	<140m	1.1km	<100m	56km	46km
Pin-pile foundation impact area (sequential piling of up to four pin piles in a 24-hour period)	<130m	950m	<100m	<130m	1.5km	<100m	67km	48km
Anchor piles for floating foundation (up to one anchor pile in a 24-hour period)	100m	230m	<100m	<100m	350km	<100m	26km	20km

Table 5-33: Modelling results of in-combination impact ranges considering both stationary and fleeing receptors, under concurrent piling scenario of different foundation types within the Caledonia OWF.

Piling scenario	Mortality and Potentially Mortal Injury		Recoverable injury		TTS	
	Stationary (SEL_{cum})	Fleeing (SEL_{cum})	Stationary (SEL_{cum})	Fleeing (SEL_{cum})	Stationary (SEL_{cum})	Fleeing (SEL_{cum})
Monopile foundation in-combination impact area (sequential piling of two monopiles in a 24-hour period)	3.5km^2	-	8.3km^2	-	13,000km^2	9,400km^2
Pin-pile foundation in-combination impact area (sequential piling of two monopiles in a 24-hour period)	6.9km^2	-	16km^2	-	17,000km^2	9,700km^2
Anchor pile in combination impact area (up to one anchor pile in a 24-hour period)	0.4km2	-	1.3km^2	-	3,700km^2	2,600km^2
Note, '-' indicates no in-combination effect identified.						

Magnitude of Impact (Mortality and Mortal Injury)

5.7.4.5 Given the current lack of knowledge on the effects of high-intensity sound exposure on basking sharks, and limited data on species abundance within the study area, it is difficult to assess the likelihood of the impact and therefore a probable likelihood is used in the absence of any empirical data showing otherwise.

5.7.4.6 When considering a stationary receptor, the concurrent piling of pin-piles at modelling locations is estimated to result in the greatest cumulative (SEL_{cum}) onset impact range of mortality and mortal injury of 6.9km^2 in basking sharks during construction phase (Table 5-33). This is thought to be precautionary as basking sharks need to keep swimming to have water flow through their gills to enable them to absorb oxygen (e.g., obligate ram ventilation; Dolce and Wilga, 2013[305]).

5.7.4.7 When considering a fleeing receptor, the single location piling of all foundation types at modelling within the Caledonia OWF is estimated to result in cumulative onset impact ranges of mortality and mortal injury less than 100m in basking sharks during construction phase (Table 5-32).

5.7.4.8 The greatest instantaneous (SPL_{peak}) onset impact range of mortality and mortal injury, considering the piling of monopile foundation at location 7, is estimated to be 140m (Table 5-32).

5.7.4.9 The potential impact of mortality or mortal injury is anticipated to only occur when the shark receptor is very close to the noise source of pile driving activities, which is considered very unlikely as basking sharks are expected to move away from the noise sources before noise levels are high enough to cause irreversible injury. The impact is also estimated to be greatly reduced by the soft starts and ramp up procedure from the initiation of piling activity as embedded mitigation outlined in the Piling Strategy (M-11, Table 5-19). To mitigate and further reduce the risk of barotrauma from piling, it is suggested that prior to any piling activity, marine mammal observers (MMOs) will be used as required, in line with JNCC (2010[34]), to ensure that basking sharks are not present within the defined mitigation zone (as defined in the Marine Mammal Mitigation Protocol (MMMP); M-16). The impact is short-term duration as is restricted to active piling days (maximum 72 days for monopiles or 105 days for pin piles) during the construction phase.

5.7.4.10 With the implementation of the Piling Strategy (M-11, Table 5-19), mortality and mortal injury to basking sharks during pile driving is estimated to affect a very small proportion of the population, and is very unlikely to affect the population trajectory as any potential impact will be of short term duration, intermittent and reversible.

5.7.4.11 The magnitude is therefore assessed as **Negligible** to basking sharks during pile-driving activities for the construction phase of the Proposed Development (Offshore).

Magnitude of Impact (Recoverable Injury)

5.7.4.12 When considering a stationary receptor, the concurrent piling of pin-piles at modelling locations is estimated to result in the greatest cumulative (SEL_{cum}) onset impact range of recoverable injury of 16km^2 in basking sharks during construction phase (Table 5-33).

5.7.4.13 When considering a fleeing receptor, the single location piling of all foundation types at modelling location 7 is estimated to result in cumulative onset impact ranges of recoverable injury less than 100m in basking sharks during construction phase (Table 5-32).

5.7.4.14 The greatest instantaneous (SPL_{peak}) onset impact range of recoverable injury, considering the piling of monopile foundation at location 7, is estimated to be 140m (Table 5-32).

5.7.4.15 Similar to mortality and mortal injury, the potential impact of recoverable injury is anticipated to only occur when the shark receptor is close to the noise source of pile driving activities, which is considered very unlikely as basking sharks are expected to move away from the noise sources before noise levels are high enough to cause recoverable injury.

5.7.4.16 With the implementation of the Piling Strategy (M-11, Table 5-19), the piling impact of recoverable injury to basking sharks during the construction phase, is estimated to affect a very small proportion of the population, and is very unlikely to affect the population trajectory as any potential impact will be of short term duration, intermittent and reversible.

5.7.4.17 The magnitude is therefore assessed as **Negligible** to basking sharks during pile-driving activities for the construction phase of the Proposed Development (Offshore).

Magnitude of Impact (TTS)

5.7.4.18 When considering a stationary receptor, the concurrent piling of pin-piles at modelling locations is estimated to result in the greatest cumulative (SEL_{cum}) onset impact range of TTS of 17,000km^2 in basking sharks during construction phase (Table 5-33).

5.7.4.19 When considering a fleeing receptor, the concurrent piling of pin-piles at modelling locations is estimated to result in the greatest cumulative (SEL_{cum}) onset impact range of TTS of 9,700km^2 in basking sharks during construction phase (Table 5-33).

5.7.4.20 Given that basking sharks do not vocalise or rely on hearing to forage, the effect of TTS is thought to be of minor severity. The impact of TTS is expected to be greatly reduced by the soft starts and ramp up procedure to be implemented as embedded mitigation of Piling Strategy (M-11, Table 5-19). The relatively localised impact of TTS is estimated to have a short-term duration as is restricted to active piling days (maximum 105 days for pin piles) during the construction phase. The impact of TTS is anticipated to only affect a small proportion of the population and is unlikely to affect the population trajectory as any potential impact will be of short term duration, intermittent and reversible.

5.7.4.21 The magnitude is therefore assessed as **Low** to basking sharks during pile-driving activities of the construction phase of the Proposed Development (Offshore).

Magnitude of Impact (Masking or Behavioural Effects)

5.7.4.22 Popper *et al.* (2014[32]) suggest that high risk of masking or behavioural effects from pile driving activities on basking sharks would only occur within tens to hundreds of metres from the noise sources, with risk reducing to low at far distances (thousands metres) from the sources(Table 5-23). With the adoption of soft starts and ramp up as part of the Piling Strategy (M-11, Table 5-19), and consideration of the intermittent and short-term duration of the impact, masking or behavioural effects are estimated to only affect a very small proportion of the shark population and is unlikely to alter the population trajectory as any potential impact will be of short term duration, intermittent and reversible.

5.7.4.23 The magnitude is therefore assessed as **Negligible** to basking sharks during pile-driving activities of the construction phase of the Proposed Development (Offshore).

Species Sensitivity

5.7.4.24 There is very limited information on the behavioural responses of basking sharks to underwater noise from OWF development in general (Drewery, 2012[306]). Elasmobranchs including basking sharks lack a swim bladder and detect sound using inner ear end organs primarily (Casper *et al.,* 2012[307]). They may only detect particle motion (Popper *et al.,* 2014[32]) and are therefore considered less sensitive to underwater noise compared to other fish hearing groups with gas-filled organs, and teleost with otoliths. The hearing physiology and auditory capabilities of basking sharks are usually inferred from knowledge on other shark species due to the limited relevant knowledge available (Casper and Mann, 2010[46]; Popper *et al.,* 2014[32]). Studies on lemon shark (*Negaprion brevirostris*), scalloped hammerhead (*Sphyrna lewini*) and sharpnosed shark (*Rhisoprionodon terranovae*) reveal that elasmobranch species in general have higher sensitivity to low frequency sound (Casper and Mann, 2010[46]), and therefore low frequency noise may be detectable by basking sharks.

5.7.4.25 According to playback studies conducted by the US Navy, other coastal and oceanic shark species were found to avoid sudden onset of loud noise of low frequencies, but became habituated after a few trials (Myrberg, 2001[47]).

5.7.4.26 Basking sharks are therefore considered of low vulnerability, high recoverability and adaptability to underwater noise impact from pile driving during the construction phase. Basking sharks are highly mobile and have a wide distribution within Scottish waters; therefore, the sensitivity of basking sharks to underwater noise impact from pile driving during the construction phase of the Proposed Development (Offshore) is assessed as **Low**.

Significance of Effects

5.7.4.27 Taking the **Negligible** magnitude of mortal injury, recoverable injury, masking and behavioural effects and **Low** sensitivity of basking sharks, the significance of these impacts from underwater noise from pile driving during construction is considered **Negligible and Not Significant in EIA terms**.

5.7.4.28 Taking the **Low** magnitude of TTS and **Low** sensitivity of basking sharks, the overall significance of TTS from underwater noise from pile driving during construction is considered **Negligible and Not Significant in EIA terms**.

Impact 2: Underwater Noise from UXO Clearance

5.7.4.29 It is possible that UXO items with a range of charge weights (or quantity of contained explosive) are present within the boundaries of the Proposed Development, therefore there is potential for UXO clearance to be required prior to construction. If UXOs are found within the Caledonia OWF and/or Caledonia OECC, a risk assessment will be undertaken and items of UXO will be either avoided by equipment micro-siting, moved, or disposed of in situ. Whilst UXO clearance will be consented under a separate Marine Licence and will therefore not be part of the Project consenting process, it is considered to be reasonably foreseeable as a site-preparation activity and therefore has been included in this assessment. Until detailed pre-construction surveys are undertaken across the Caledonia OWF and Caledonia OECC, the exact number of potential UXO requiring clearance is unknown.

5.7.4.30 Methods of UXO clearance considered for the Proposed Development may include low-order detonation through deflagration. The number of UXO that may require clearance and duration of UXO clearance operations are currently unknown. Therefore, it is important to note that the assessments for UXO clearance presented within this chapter are, at this stage, illustrative.

5.7.4.31 The severity of the consequences of UXO detonation will depend on several variables, including, but not limited to, the charge weight and its proximity to the receptor. Potential effects of underwater detonation of UXOs on basking sharks include barotrauma or auditory injury from exposure to the shock and pressure wave, resulting in mortality or PTS/TTS in hearing sensitivity respectively.

5.7.4.32 The calculation of UXO noise propagation and associated modelling of impact ranges are detailed in Volume 7, Appendix 6: Underwater Noise Assessment.

5.7.4.33 The impact ranges of UXO detonation presented in Table 5-34 are highly precautionary as the underwater noise model did not account for any smoothing of the pulse over long ranges, which would reduce the pulse peak and other characteristics of the sound that cause injury. In addition, the water depth of receptor was not modelled, and noise exposure could be lower if the individual is near water surface (MTD, 1996[308]). Finally, UXOs at the Project site might be buried, deflagrated or subject to significant attenuation from its 'as-new' condition which would lead to a reduction in impact ranges.

Table 5-34: Modelled impact areas for UXO detonation using Group 1 fish threshold criteria from Popper *et al*. (2014[32]).

Charge Size	Threshold Criteria for Mortality and Potential Mortal Injury Arising from Explosions Considering Unweighted SPLpeak Source Level dB re 1 µPa @ 1 m	
	SPL 234dB re 1µPa	SPL 229dB re 1µPa
Low-order (0.25kg)	<50m	60m
25kg +donor	170m	290m
55kg + donor	230m	380m
120kg + donor	300m	490m
240kg + donor	370m	620m
525kg +donor	490m	810m
698kg + donor	530m	890m

5.7.4.34 High order UXO detonation is not being assessed in the EIAR as low order deflagration has been proved to be a viable and effective method of UXO clearance at a nearby OWF (Moray West).

Magnitude of Impact (Mortality and Mortal Injury)

5.7.4.35 When considering the low-order UXO clearance and the noise exposure criteria for UXO clearance of 229dB re 1µPa in basking sharks as the WCS, the SPL_{peak} onset impact area of mortality and mortal injury in basking sharks is estimated to be 60m respectively (Table 5-34).

5.7.4.36 The potential impact of mortality or mortal injury is anticipated to only occur when the basking shark is very close to the noise source during UXO clearance, which is considered very unlikely as basking sharks are expected to move away from the area before any UXO clearance works take place. The impact is also estimated to be greatly reduced by the MMO requirement, in line with JNCC (2021), from the initiation of UXO clearance activity as embedded mitigation outlined in the MMMP (M-16).

5.7.4.37 Taking into account the intermittent and localised nature of UXO clearance events, and the precautionary nature of underwater noise modelling of UXO impact ranges, it is very unlikely that basking sharks will experience mortal injury and, therefore, the impact is not likely to alter the population trajectory as any potential impact will be of short term duration, intermittent and reversible.

5.7.4.38 The impact magnitude is therefore assessed as **Negligible** to basking sharks, with respect to underwater noise as a result of UXO clearance during construction of the Proposed Development (Offshore).

Magnitude of Impact (Recoverable Injury, TTS and Behavioural Effects)

5.7.4.39 Popper *et al.* (2014[32]) suggest there is a high risk of recoverable injury, TTS, masking and behavioural effects of UXO clearance on basking sharks within tens to hundreds of metres from the sound source, with the risk reducing to low at greater distances (defined as thousands metres; Table 5-26). As basking sharks are expected to move away from the area before any UXO clearance works take place, the risks of recoverable injury, TTS and behavioural effects are highly greatly reduced.

5.7.4.40 Taking into account the intermittent and localised nature of UXO clearance events, and the precautionary nature of underwater noise modelling of UXO impact ranges, the impact of recoverable injury, TTS and behavioural effects to basking sharks is estimated to affect a very small proportion of the population and is very unlikely to affect the population trajectory as any potential impact will be of short term duration, intermittent and reversible.

5.7.4.41 The magnitude is therefore assessed as **Negligible** to basking sharks with respect to underwater noise as a result of UXO clearance during the construction phase of the Proposed Development (Offshore).

Sensitivity of Receptor

5.7.4.42 Basking sharks are of low vulnerability, high recoverability and adaptability to underwater noise impact. The consequence of barotrauma, however, is considered to be of major severity with limited ability for the animal to recover from any impact on vital rates. Therefore the sensitivity of basking sharks to underwater noise and vibration from UXO clearance during the construction phase of the Proposed Development (Offshore) is assessed as **High**.

Significance of Effects

5.7.4.43 Taking the **Negligible** magnitude of mortal injury, recoverable injury, TTS and behavioural effects and **high** sensitivity of basking sharks, the overall significance of these impacts from underwater noise from UXO clearance during the construction phase of the Proposed Development (Offshore) is considered to be **Negligible and Not Significant in EIA terms**.

Impact 3: Underwater Noise from Other Construction Activities

5.7.4.44 While impact piling will be the loudest noise source during the construction phase, there will also be several other construction activities that will produce underwater noise. General construction noise, arising from cable lying, dredging, drilling, rock placement, trenching and other seabed preparation and landfall works will generate low levels of continuous noise throughout the construction phase of the Proposed Development (Offshore):

- Cable laying: continuous noise from the cable laying vessel and any other associated noise during the offshore cable installation;
- Dredging: Dredging may be required on site for seabed preparation work for certain foundation options, as well as for the offshore export cables, inter-array cables and interconnector cable installation;
- Drilling/vibro piling: There is the potential for WTG foundations to be installed using drilling or vibro piling depending on seabed type or if a pile refuses during impact piling operations.
- Rock placement: Potentially required on site for installation of offshore cables (cable crossings and cable protection) and scour protection around foundation structures; and
- Trenching: Plough trenching may be required during offshore cable installation.

5.7.4.45 The Marine Management Organisation (MMO, 2015[309]) provided information on the acoustic properties of anthropogenic continuous noise sources including from dredging, drilling and shipping. For all these activities, the main energy is listed as being below 1kHz.

Cable Laying

5.7.4.46 Underwater noise generated during cable installation is generally considered to be unlikely to impact basking sharks due to its non-impulsive nature of the noise generated and the fact that any generated noise is likely to be dominated by the vessel from which installation takes place.

Dredging

5.7.4.47 Dredging is described as a continuous broadband sound source, with the main energy below 1kHz; however, the frequency and sound pressure level can vary considerably depending on the equipment, activity, and environmental characteristics (Todd *et al.,* 2015[310]). The frequency range of dredging varies between 45Hz and 7kHz (Evans, 1990[311]; Thompson *et al.,* 2009[312]; Verboom, 2014[313]).

Drilling/vibro-piling

5.7.4.48 The continuous sound produced by drilling has been likened to that produced by potential dredging activity; low frequency noise caused by rotating machinery (Greene, 1987[314]). Recordings of drilling at the North Hoyle OWF suggest that the sound produced has a fundamental frequency at 125Hz

(Nedwell, *et al*., 2003[290]) while for vibro piling, the main energy is also at low frequencies between 17 and 40Hz (Koschinski and Lüdemann, 2020[315]), with noise emissions in the order of 10 to 20dB below mitigated impact piling by monopiles (Gerke and Bellmann, 2012[316]).

Rock placement

5.7.4.49 Underwater noise generated by rock placement works is largely unknown. The study of rock placement activities in the Yell Sound in Shetland, Scotland found that this activity produced low frequency tonal noise from the machinery, and that the measured noise levels were within background levels (Nedwell and Howell, 2004[317]). Therefore, it is highly likely that any generated noise is likely to be dominated by the vessel from which activities take place.

Trenching

5.7.4.50 Underwater noise generation during cable trenching activities is highly variable and depends on the physical properties of the seabed that is being cut. Few empirical data exist, but recordings of sound levels at the North Hoyle OWF were generally low (10 to 15 dB above background levels) with frequencies ranging from 100 Hz to 1 kHz (Nedwell *et al*., 2003[290]).

Magnitude of Impact

5.7.4.51 The predicted impact ranges relating to recoverable injury and TTS for other construction activities on fish with swim bladder are estimated to be less than 50m (Volume 7, Appendix 6: Underwater Noise Assessment), which implies the risk of any injurious or disturbance effect to basking sharks is expected to be very minimal.

5.7.4.52 Whilst for masking and behavioural disturbance effects, Popper *et al.* (2014[32]) suggest that there is a moderate to high risk of impacts of continuous noise on basking sharks occurring within hundreds of metres from the source, with the risk reducing to low at far distances (defined as thousands of metres) from the source (Table 5-27). As a highly mobile species, with a wide distribution in Scottish waters, it is expected that basking sharks can use alternative suitable habitat and could move away from noise sources.

5.7.4.53 With the localised spatial extent and short-term duration, underwater noise from other construction activities is considered unlikely to affect basking shark population or alter the population trajectory as any potential impact will be of short-term duration, intermittent and reversible.

5.7.4.54 The magnitude is therefore assessed as **Negligible** to basking sharks with respect to underwater noise as a result of non-impulsive noise impacts other construction activities during the construction phase of the Proposed Development (Offshore).

Sensitivity of Receptor

5.7.4.55 Basking sharks are of low vulnerability, high recoverability and adaptability to underwater noise impact from other construction activities. Basking sharks are highly mobile and have a wide distribution within Scottish waters, therefore the sensitivity of basking sharks to non-impulsive noise from other construction activities during the construction phase of the Proposed Development (Offshore) is assessed as **Low**.

Significance of Effects

5.7.4.56 Taking the **Negligible** magnitude of underwater noise impact from non-impulsive noise from other construction activities and **Low** sensitivity of basking sharks, the overall significance of these impacts from underwater noise from other construction activities from the Proposed Development (Offshore) is considered to be **Negligible and Not Significant in EIA terms**.

Impact 4: Vessel Collisions

5.7.4.57 Increased vessel operation within the Proposed Development (Offshore) could potentially result in injury or death to basking sharks due to vessel collision. The three consequences of vessel collision can be defined as: direct (injuries as the immediate result of collision), long-term (a decline in individual fitness over time), and population consequences (Dyndo *et al.,* 2015[318]; Schoeman *et al.,* 2020[319]).

5.7.4.58 Within the Shipping and Navigation study area, there was an average of approximately 17 vessels recorded per day during winter survey period and 29 to 30 vessels during summer survey period, with approximately 11 and 15 vessels per day recorded respectively in winter and summer survey periods crossing the Caledonia OECC. In winter fishing vessels made up the largest percentage of vessel traffic, followed by cargo in both the Shipping and Navigation study area and Caledonia OECC. During summer cargos were mostly sighted followed by wind farm vessels in the Shipping and Navigation study area, and recreational vessels followed by fishing vessels within the Caledonia OECC (see Volume 2, Chapter 9: Shipping and Navigation for further information).

5.7.4.59 During the construction phase, a maximum of 25 vessels are estimated to be present within the Proposed Development (Offshore) at any one time, resulting in a maximum of 3,992 vessel return trips over the construction period.

Magnitude of Impact

5.7.4.60 Vessel collisions with basking sharks have been reported in the southwest of England during a yachting event, and with small boats off Carradale (Speedie *et al.,* 2009[324]). Basking sharks with propeller injuries and other injuries consistent with vessel collisions have been recorded on the west coast of Scotland, Wales and Ireland where higher basking shark numbers, as compared to the east coast of the UK are recorded (Speedie and Johnson, 2008[328])

5.7.4.61 The area surrounding the Proposed Development (Offshore) already experiences a relatively high level of vessel traffic due to the presence of ports and harbours, such as in Nigg, Wick, Buckie and Fraserburgh, ports in the Cromarty Firth, and their links to shipping routes. Therefore, the increase in vessel activity as a result of construction is not considered significant nor is vessel presence novel to the area around the Proposed Development (Offshore).

5.7.4.62 Vessel traffic associated with the Proposed Development (Offshore) has the potential to increase vessel operations within the study area. This increase could potentially lead to increased vessel-basking shark interactions during the construction phase. Vessels travelling at higher speeds pose greater collision risk to basking sharks due to the lower probability of detection of marine animals coupled with the greater speed at impact, should impact occur (Schoeman *et al.,* 2020[319]).

5.7.4.63 It is estimated that most construction vessels during the construction phase of the Proposed Development (Offshore) are likely to be large vessels travelling either at slower speeds (lower than 7m/s), or stationary for significant periods of time. Therefore, the actual increase in vessel traffic within and near the Proposed Development (Offshore) is expected to occur over short and intermittent periods of offshore construction activity. Smaller vessels, such as survey vessels and CTVs present during construction are more likely to be able to avoid surfacing basking sharks due to better manoeuvrability (Schoeman *et al.,* 2020[319]). In contrast, larger construction vessels such as JUVs, will have low manoeuvrability and may require longer distances to avoid an animal, but will be travelling at slower speeds, allowing sufficient time for vessel operators to move away from basking sharks nearby.

5.7.4.64 Although the Proposed Development (Offshore) will lead to an increase in vessel activity during the construction phase, associated vessel movements are likely to be largely restricted to within the Caledonia OWF and Caledonia OECC. The Vessel Management Plan (VMP, M-13, Table 5-19) will ensure that vessel traffic moves along predictable routes to/from ports, which will minimise the potential of collision risk (Nowacek *et al.,* 2001[320]; Lusseau 2003[321], 2006[322]). The VMP will also set out a Code of Conduct based on best practice vessel handing protocols such as the Scottish Marine Wildlife Watching Code (NatureScot, 2017[29]) and the Basking Shark Code of Conduct (The Shark Trust, 2024a[30]), to minimise vessel interactions with basking sharks, and define how vessels should behave in the presence of animals.

5.7.4.65 Based on the above, the impact of vessel collisions during the construction phase is anticipated to affect a very small proportion of the population, and the effect is likely to occur at a low frequency with the implementation of the VMP throughout the construction phase. The intermittent effect is unlikely to alter the population trajectory of basking sharks as any potential impact will be of short-term duration, intermittent and reversible.

5.7.4.66 Therefore, the magnitude of impact of vessel collision risk at construction phase of the Proposed Development (Offshore) is assessed as **Negligible** to basking sharks.

Sensitivity of Receptor

5.7.4.67 Slow-moving and large-sized basking sharks with limited manoeuvrability are susceptible to vessel collision risk (NatureScot, 2019[323]). This could be of particular concern in summer and early autumn months when basking sharks feed and display breeding behaviour at or near the water surface closer to the coast. In addition, basking sharks do not appear to respond to approaching vessels, although it is thought that younger sharks do react more readily to vessel presence (Speedie *et al.,* 2009[324]).

5.7.4.68 A total of 13 basking shark strandings were reported to the Cetacean Strandings Investigation Programme (CSIP) between 2018 and 2020 (CSIP, 2019[325], 2020[326], 2021[327]), with four of them reported on the east coast of Scotland. No sign of vessel interaction and/or collision was identified on stranded individuals investigated post-mortem. There is little evidence from basking sharks stranded in UK waters to suggest that injury from vessel collision is an important cause of shark mortality. As noted above, there is evidence that not all collision incidents are lethal (Speedie and Johnson, 2008[328]), and that elasmobranchs in general have the potential for recovery from wound injuries (Riley *et al.,* 2009[329]; Chin *et al.,* 2015[330]).

5.7.4.69 Camera footage of a collision between a boat and a basking shark has recently been captured off thro cast off Ireland. In the video the female basking shark can be seen feeding on the surface before making sudden evasive move and then colliding with a boat, causing the animal to rapidly dive to the seabed. When the tag had automatically released 7 hours after the event, the individual has not resumed feeding and video showed visible damage and abrasions (Sparkes, 2024[331]).

5.7.4.70 Basking sharks are of high vulnerability, reasonable recoverability and limited adaptability to vessel collisions impact the during construction phase of the Proposed Development (Offshore). They are assessed as having a **High** sensitivity to vessel collision impact during construction phase.

Impact significance

5.7.4.71 Taking the **Negligible** magnitude of vessel collisions impact during the construction phase and **High** sensitivity of basking sharks, the overall significance of collision impact with vessels during construction for the Proposed Development (Offshore) is considered **Negligible and Not Significant in EIA terms**.

Impact 5: Vessel Disturbance

5.7.4.72 In addition to the higher risk of vessel collisions, increased vessel movement during construction could potentially disturb basking sharks in the Proposed Development (Offshore), in the form of underwater noise and the physical presence of vessel.

5.7.4.73 Within the Shipping and Navigation study area, there was an average of approximately 17 vessels recorded per day during winter survey period and 29 to 30 vessels during summer survey period, with approximately 11 and 15 vessels per day recorded respectively in winter and summer survey periods crossing the OECC. In winter fishing vessels made up the largest percentage of vessel traffic, followed by cargo in both the Shipping and Navigation study area and OECC. During summer cargos were mostly sighted followed by wind farm vessels in the Shipping and Navigation study area, and recreational vessels followed by fishing vessels within the OECC (see Volume 2, Chapter 9: Shipping and Navigation for further information).

5.7.4.74 During the construction phase, a maximum of 25 vessels are estimated to be present within the area of Proposed Development (Offshore) at any one time, resulting in a maximum of 3,992 vessel return trips over the construction period.

5.7.4.75 The area surrounding the Proposed Development (Offshore) already experiences a relatively high level of vessel traffic, the increase in vessel activity as a result of construction is therefore not considered a novel impact for basking sharks present in the Proposed Development (Offshore).

Magnitude of Impact

5.7.4.76 The modelled impact ranges of recoverable injury and TTS from large- and medium-sized vessels on fish with swim bladder are estimated to be less than 50m (Volume 7, Appendix 6: Underwater Noise Assessment), which implies the risk of any recoverable injury or TTS effect to basking sharks is expected to be very minimal.

5.7.4.77 Whilst for masking and behavioural disturbance effects, Popper *et al.* (2014[32]) suggest that there is a moderate to high risk of impacts of continuous noise on basking sharks occurring within hundreds of metres from the source, with the risk reducing to low at far distances (defined as thousands of metres) from the source (Table 5-27). As a highly mobile species, with a wide distribution in Scottish waters, it is expected that basking sharks can use alternative suitable habitat and could move away from noise sources.

5.7.4.78 Field observations suggested that basking sharks react to approaching vessels at distances approximately 10m to 1km away (Bloomfield and Solandt, 2008[119]), and that engine noise and angle of vessel approach had very limited effect on behavioural disturbance of basking sharks (Speedie and Johnson, 2008[328]).

5.7.4.79 The adoption of a VMP (M-13, Table 5-19) will ensure that vessel traffic moves along predictable routes to/from ports, which will minimise the potential risk of disturbance imposed by vessel operations (Nowacek *et al.,* 2001[320]; Lusseau, 2003[321]; 2006[322]). The VMP will also set out a Code of Conduct based on best practice vessel handing protocols such as the Scottish Marine Wildlife Watching Code (NatureScot, 2017[29]) and the Basking Shark Code of Conduct (The Shark Trust, 2024a[30]) to minimise vessel interactions with basking sharks, and define how vessels should behave in the presence of the animals.

5.7.4.80 The impact of vessel disturbance at construction phase to basking sharks is anticipated to affect a very small proportion of the population, and the effect is likely to occur at a low frequency with the implementation of the VMP throughout the construction phase. The intermittent effect is unlikely to alter the population trajectory of basking sharks as any potential impact will be of short-term duration, intermittent and reversible.

5.7.4.81 Therefore, the magnitude of impact of vessel disturbance during the construction phase of the Proposed Development (Offshore) is assessed as **Negligible** to basking sharks.

Sensitivity of Receptor

5.7.4.82 As basking sharks lack swim bladder and may only detect particle motion (Popper *et al.,* 2014[32]), they are therefore considered less sensitive to underwater noise.

5.7.4.83 Broadly, basking sharks appear to be relatively tolerant of the physical presence of vessels (Compagno, 1984[332]; Speedie and Johnson, 2008[328]). However, avoidance behaviour in the presence of boats has been recorded, although disruption of behaviour was only reported when vessels were relatively close to the animals (within 10m to 1km; Bloomfield and Solandt, 2008[119]). Speed of vessel is likely to be a factor in behavioural responses, for example, Speedie and Johnson (2008[328]) reported no observable changes in basking shark behaviour towards slowly approaching vessels.

5.7.4.84 Basking sharks are of low vulnerability, high recoverability and adaptability to vessel disturbance impact during the construction phase. The sensitivity of basking sharks to vessel disturbance during the construction phase is assessed as **Low**.

Significance of Effects

5.7.4.85 Taking the **Negligible** magnitude of vessel disturbance and **Low** sensitivity of basking sharks, the overall significance of vessel disturbance during the construction phase of the Proposed Development (Offshore) is considered **Negligible and Not Significant in EIA terms**.

Impact 6: Indirect Impacts on Prey

5.7.4.86 During construction activities, there is the potential for impacts upon these fish species, including:

- Mortality, injury, behavioural impacts and auditory masking arising from noise and vibration;
- Temporary increase in SSC;
- Temporary habitat disturbance; and
- Direct and indirect seabed disturbance.

5.7.4.87 The basking shark is an obligate ram filter feeder primarily feeding upon zooplankton (Sims *et al.,* 2008[341]). Its preferred prey species in the UK includes copepod *Calanus helgolandicus* (Speedie, 1999[333]) and *Calanus finmarchicus* (Sims *et al.,* 1997[139]). Previous analysis of stomach contents indicated that basking sharks also consume fish eggs, fish larvae, fish post-larvae, mysid larvae, decapod larvae, chaetognaths, larvaceans, polychaetes, cladocerans, and decapod larvae (Sims and Merrett, 1997[139]).

5.7.4.88 Given that basking sharks feed primarily on copepods, there is the potential for indirect effects on basking sharks as a result of impacts upon crustacean and invertebrate species, and the fish eggs and larvae that support them. However, although it is suggested basking sharks use electroreception to find food patches (Sims & Quayle, 1998[346]; Kempster & Collin 2011[277]) the mechanisms controlling this are unclear and there are currently no published data that inform the impact of increased sediment suspension on electrosensitive species.

Magnitude of Impact

5.7.4.89 Due to the lack of any significant effect on prey species and the generalist nature of basking shark diet, the indirect impacts on prey during construction are anticipated to affect a very small proportion of basking shark population without altering population trajectory as any potential impact will be of short term duration, intermittent and reversible.

5.7.4.90 Therefore, the magnitude of indirect impacts on prey is assessed **Negligible** to basking sharks during the construction phase of the Proposed Development (Offshore).

Species sensitivity

5.7.4.91 Changes to prey availability could increase the energy expenditure required for feeding through increased effort. However, the prey species of basking sharks are typically present within wider Scottish waters. As basking sharks are highly mobile, it is reasonable to assume that they will be able to find nearby suitable habitat with sufficient, similar prey resources.

5.7.4.92 While the copepod *C. helgolandicus* and *C. finmarchicus* may be preferred prey species that comprise a high proportion of the diet, basking sharks are considered as generalist feeders, and therefore can exploit a variety of prey and are not reliant on few particular species.

5.7.4.93 Therefore, basking sharks are of low vulnerability, high recoverability and adaptability to indirect impacts on prey during the construction phase of the Proposed Development (Offshore). The sensitivity of basking sharks to indirect impacts on prey during the construction phase is assessed as **Low.**

Significance of Effects

5.7.4.94 Taking the **Negligible** magnitude of indirect impacts on prey during the construction phase and **Low** sensitivity of basking sharks, the overall significance of indirect impacts on prey during the construction phase of the Proposed Development (Offshore) is considered **Negligible and Not Significant in EIA terms**.

Impact 7: Water Quality Changes

5.7.4.95 The Proposed Development (Offshore) has the potential to increase sediment suspension in the marine environment through the generation of sediment plumes from seabed disturbance and smothering (Volume 2, Chapter 2: Marine and Coastal Processes), through seabed preparation for foundations, sandwave clearance for cable installation, cable trenching and drilling for foundation installation.

5.7.4.96 These activities can impact basking sharks directly (e.g., reducing the ability to forage by gill-raker clogging) and indirectly (e.g., reducing zooplankton abundance by light attenuation). However, studies have shown these effects are generally short-lived (with suspended sediment expected to disperse within a few tidal cycles) and are confined mainly to an area of a few hundred metres from the point of discharge (Newell *et al.,* 1998[334]; Hitchcock and Bell, 2004[335]).

Magnitude of Impact

5.7.4.97 Site-specific modelling of sediment plumes and deposition from seabed preparation and installation activities within Caledonia OWF and along Caledonia OECC has been undertaken to quantify the potential footprint of the plumes, their longevity and the SSC as well as the subsequent deposition of plume material on the seabed. The full assessment including assessment methodology is set out in Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report.

5.7.4.98 Based on the modelling results, both cable installation using jetting techniques and foundation drilling activities may produce sediment plumes, with SSCs up to thousands of mg/l. however these concentrations will be spatially restricted and short-lived. Elevated SSC may be advected by tidal currents up to 20km away, but only for the foundation installations, although these concentrations will be low. In the majority of cases, elevated SSC will be indistinguishable from background levels up to three days after the cessation of activities. The associated deposition from sediment plumes is generally in the order of tens of mm within several hundreds of metres from the point of disturbance, reducing to low tens of mm beyond this. Sediment deposition is generally not measurable beyond 1km away from the associated activities except during cable installation activities up to approximately 6km. This deposition is likely to become integrated into the local sediment transport regime and will be redistributed by tidal currents. The coast at the landfall (within the OECC) might be affected by increased of SSC during cable installation and HDD operations. However, model results only indicated increased of SSC between 1 and 4mg/l during a very short period (approximately seven hours).

5.7.4.99 The overall effect of water quality changes to basking sharks during the construction phase is therefore considered to be localised, temporary, and indistinguishable from background levels within the Caledonia OWF and Caledonia OECC. It is anticipated to affect a small proportion of the population, and is very unlikely to alter the population trajectory as any potential impact will be of short term duration, intermittent and reversible. Therefore, the magnitude of impact of water quality changes at construction phase of the Proposed Development (Offshore) is assessed as **Low** to basking sharks.

Sensitivity of Receptors

5.7.4.100 As a highly mobile species with wide distribution across Scottish waters, basking sharks are expected to experience exposure to naturally high variability of SSC within their distribution range, and are expected to move away from any localised changes in water quality due to increased SSC. In addition, the species has been recorded in turbid regions (Skomal *et al.,* 2009[336]) and might adopt the vortical cross-step filtration method of filter-feeding to avoid gill-raker clogging (Sanderson *et al.,* 2016[337]).

5.7.4.101 Basking sharks are therefore estimated to be of low vulnerability, high recoverability and adaptability to impact of water quality changes. The sensitivity of basking sharks to water quality changes during the construction phase of the Proposed Development (Offshore) is considered to be **Low.**

Significance of Effect

5.7.4.102 Taking the **Low** magnitude of water quality changes during the construction phase and **Low** sensitivity of basking sharks, the overall significance of water quality changes during the construction phase of the Proposed Development (Offshore) is considered **Negligible and Not Significant in EIA terms**.

5.7.6 Operation and Maintenance (O&M)

5.7.6.1 As mentioned in Volume 1, Chapter 3: Proposed Project Description (Offshore), the strategy of O&M will be finalised post-consent, depending on the location of O&M base and the final design parameters adopted for the Proposed Development (Offshore). It is anticipated that the operational lifespan of the Proposed Development (Offshore) would be 35 years.

Impact 8: Vessel Collisions

5.7.6.2 During O&M phase, a maximum of five vessels are estimated to be present within the area of Proposed Development (Offshore) at any one time, resulting in a maximum of 938 vessel movements annually throughout the O&M period of 35 years.

Magnitude of Impact

5.7.6.3 Given the lower number of vessels estimated for the O&M phase, the impact magnitude of vessel disturbance during the O&M phase would be similar or lower than that of the construction phase. Associated vessel movements are likely to be largely restricted to within the Caledonia OWF and Caledonia OECC. The VMP (M-13, Table 5-19) will ensure that vessel traffic moves along predictable routes to/from ports, which could effectively minimise potential risk imposed by vessel operations (Nowacek *et al.,* 2001[320]; Lusseau, 2003[321]; 2006[322]). The VMP will also set out a Code of Conduct based on best practice vessel handing protocols such as the Scottish Marine Wildlife Watching Code (NatureScot, 2017[29]) and the Basking Shark Code of Conduct (The Shark Trust, 2024a[30]) to minimise vessel interactions with basking sharks, and define how vessels should behave in the presence of the animals.

5.7.6.4 Given the lower number of vessels estimated for O&M phase, the impact magnitude of vessel collisions during O&M would be similar or lower than that of the construction phase and would not impact the population trajectory as any potential impact will be of short-term duration, intermittent and reversible. Therefore, the magnitude of vessel collision during the O&M phase of the Proposed Development (Offshore) has therefore been assessed as **Negligible** for basking sharks.

Sensitivity of Receptor

5.7.6.5 As detailed in Section 5.7.4.67 to 5.7.4.69, Basking sharks are of high vulnerability, reasonable recoverability and limited adaptability to vessel collision. Basking sharks are therefore assessed as having a **High** sensitivity to vessel collision risk during O&M phase of the Proposed Development (Offshore).

Significance of Effects

5.7.6.6 Taking the **Negligible** magnitude of vessel collision and the **High** sensitivity of basking sharks, the overall impact significance of vessel collisions during

O&M at the Proposed Development (Offshore) is considered **Negligible and Not Significant in EIA terms**.

Impact 9: Vessel Disturbance

5.7.6.7 During the O&M phase, a maximum of five vessels are estimated to be present within the area of Proposed Development (Offshore) at any one time, resulting in a maximum of 938 vessel movements annually throughout the O&M period of 35 years.

Magnitude of Impact

5.7.6.8 Given the lower number of vessels estimated for operation phase, the impact magnitude of vessel disturbance during the O&M phase would be similar or lower than that of the construction phase. With also considering the implementation of VMP (M-13, Table 5-19), the magnitude of vessel disturbance during the O&M phase of the Proposed Development (Offshore) has been assessed as **Negligible** for basking sharks.

Sensitivity of Receptors

5.7.6.9 As detailed above, Basking sharks are of low vulnerability, high recoverability and adaptability to vessel disturbance. The sensitivity of basking sharks to vessel disturbance during the O&M phase of the Proposed Development (Offshore) is assessed as **Low**.

Significance of Effects

5.7.6.10 Taking the **Negligible** magnitude of vessel disturbance during the O&M phase **Low** sensitivity of basking sharks, the overall effect of vessel disturbance during the O&M phase of the Proposed Development (Offshore) is considered **Negligible and Not Significant in EIA terms**.

Impact 10: Indirect Impacts on Prey

5.7.6.11 The assessment of Fish and Shellfish Ecology above identified that during the O&M phase for the Proposed Development (Offshore), there is the potential to negatively affect shellfish, invertebrates, fish eggs and/or fish larvae in ways including:

- Long-term habitat loss;
- Increased risk of introduction and/or release of invasive non-native species; and
- EMF.

Magnitude of Impact

5.7.6.12 Although zooplankton are found in areas of high-water turbidity, there appears to be an effect where changes in zooplankton composition are correlated with changes in turbidity (Hart 1988[338]). An increase in turbidity as a result of suspended sediment results in a decline in the feeding rates of zooplankton (Arruda *et al.,* 1983[339]; Hart 1988[338]). The extent of this decline, however, differs between species of zooplankton (Hart, 1988[338]). As all aspects of basking shark ecology are thought to be driven by their unique feeding mechanism (Sims 2008[340]), we would consider any aspect of the development with the potential to impact the distribution or abundance of zooplankton prey species to also have an impact on the presence of basking sharks.

5.7.6.13 The adoption of embedded mitigation measures listed for Fish and Shellfish Ecology will ensure that no significant effects to prey species arise from the Proposed Development (Offshore), and the indirect impacts on prey to basking sharks during O&M phase are minimised as far as reasonably practicable.

5.7.6.14 With also considering the generalist nature of basking shark diet, the indirect impacts on prey during the O&M phase are anticipated to affect a very small proportion of basking shark population without altering population trajectory as any potential impact will be of short term duration, intermittent and reversible.

5.7.6.15 Therefore, the magnitude of indirect impacts on prey is assessed as **Negligible** to basking sharks during the O&M phase of the Proposed Development (Offshore).

Sensitivity of Receptors

5.7.6.16 As detailed above, basking sharks are of low vulnerability, high recoverability and adaptability to indirect impacts on prey. The sensitivity of basking sharks to indirect impacts on prey during the O&M phase of the Proposed Development (Offshore) is assessed as **Low**.

Significance of Effect

5.7.6.17 Taking the **Negligible** magnitude of indirect impacts on prey during the O&M phase and the **Low** sensitivity of basking sharks, the overall significance of indirect impacts on prey during the O&M phase of the Proposed Development (Offshore) is considered **Negligible and Not Significant in EIA terms**.

Impact 11: Electromagnetic Fields (EMF)

5.7.6.18 The conduction of electricity through the inter-array, interconnector and export cables associated with the Proposed Development (Offshore) has the potential to emit localised EMF which could potentially affect the sensory mechanisms of electroreceptive fishes, which include basking sharks (CMACS, 2003[341]). While responses can vary by species and the intensity of EMF exposure, studies suggest that elasmobranchs may exhibit avoidance behaviours or altered movement patterns in the vicinity of EMF sources (Walker *et al.,* 1997[342]).

5.7.6.19 Within the Caledonia OWF, the inter-array cables will be multi-core HVAC cables (of up to 230mm in diameter, subject to the voltage or material of the cable itself) with a maximum voltage of 132 kV, and a fibre optic system (up to 48 fibres).

5.7.6.20 Within the Caledonia OECC, there will be up to four offshore export cables. All offshore export cables will be in separate trenches within the Caledonia OECC, making landfall at Stake Ness on the Aberdeenshire coast via HDD. The offshore export cables will be multi-core HVAC cables (up to 290mm in diameter, subject to the voltage or material of the cable itself) with a maximum voltage of 275kV.

Magnitude of Impact

5.7.6.21 EMF around subsea electricity cables has been shown to attenuate at an inverse square of vertical and horizontal distance from the cables, with the magnetic field typically dropping to zero within 10m from the cables (Normandeau Associates Inc. *et al.,* 2011[288]). Although shallow burial or protection of surface cables does not reduce EMF strength, it physically moves the cables further away from receptors, and as such the receptors are subject to reduced field strengths. The threshold of induced electric fields (iE fields) causing responses in elasmobranchs in general is estimated to be between 400 and 1,000μV/m (CMACS, 2012[343]), while these iE field levels are likely to only be found at or within 1 to 2m of the seabed for cables with burial depth of 1m.

5.7.6.22 While field studies have been conducted on EMFs from cables buried in the seabed (Hutchison *et al.,* 2018[258]), there is limited information on EMFs from dynamic cables suspended in the water column, as will be the configuration for dynamic inter-array cables (Gill and Desender, 2020[259]; Hutchison *et al.,* 2020a[270]).

5.7.6.23 A Cable Plan (CaP) (M-1, Table 5-19 refers) will be adopted to include relevant measures, such as cable burial and/or implementation of cable protection measures, to reduce EMF impact on surrounding environment and species from the Proposed Development (Offshore).

5.7.6.24 Based on the above, the impacts arising from EMF on basking sharks is anticipated to affect a small proportion of the population and is unlikely to alter the population trajectory as any potential impact will be of short term duration, intermittent and reversible. Therefore, the magnitude of impact of EMF during the O&M phase is assessed as **Low** to basking sharks.

Sensitivity of Receptors

5.7.6.25 Electromagnetic detection has been well documented in elasmobranchs for navigation and prey detection (Meyer *et al.,* 2005[344]; Hart and Colin, 2015[345]; Hutchison *et al.,* 2020a[270]). Shark species generally are able to detect voltage gradients (about 5 nanovolts per metre, nV/m) and biopotentials of their prey (0.001 to 0.5V) at distances of up to 0.5m (Hart and Collin, 2015[345]). For basking sharks, the species use ampullae of Lorenzini concentrated around the snout to detect electrical signals of their zooplankton prey (Sims and Quayle, 1998[346]).

5.7.6.26 Studies conducted on other elasmobranch species found the degree of responsiveness of elasmobranchs to EMF varies among species, sex, age classes, and depends on the strength of EMFs (Normandeau Associates Inc. *et al.,* 2011[288]). No conclusion can currently be drawn on the behavioural patterns of whether elasmobranchs respond positively, negatively or neutrally to EMF emissions (Gill *et al.,* 2001[347]; 2009[276]), particularly from dynamic cables on pelagic species (Taormina *et al.,* 2018[261]).

5.7.6.27 As the vulnerability, recoverability and adaptability of basking sharks to EMF impact during O&M phase of the Proposed Development (Offshore) is largely unknown, a precautionary approach has been adopted and the sensitivity of basking sharks to EMF is assessed as **High.**

Significance of Effect

5.7.6.28 Taking the **Low** magnitude of EMF during the O&M phase and the **High** sensitivity of basking sharks, the overall significance of EMF during the O&M phase of the Proposed Development (Offshore) is considered **Minor and Not Significant in EIA terms**.

Impact 12: Operational Noise

5.7.6.29 The main source of underwater noise from operating wind turbines comes from the mechanically generated vibration of the nacelle and wind-induced vibration of the turbine tower radiating to the foundations and surrounding water (Nedwell *et al.,* 2003[290]; Tougaard *et al.,* 2020[291]; Thomsen *et al.,* 2023[348]). The operational WTG noise is considered non-impulsive and continuous in nature, and its energy is primarily of low frequencies of below 1kHz (Thomsen *et al.,* 2006[349]). While underwater sound is expected to increase with increasing turbine size (Tougaard *et al.,* 2020[291]), WTGs with new direct drive technology will produce considerably less underwater noise compared to the older geared turbines. For instance, Stöber and Thomsen (2021[295]) have identified a noise reduction of around 10dB in newer WTGs using direct drive technology compared to the same size geared turbine.

5.7.6.30 In addition to WTG noise, it is estimated that floating WTGs (semi-submersible and tension leg platform foundations) and WTGs with FRP foundations in the Caledonia South site could potentially introduce another underwater noise source from the tension release in mooring-related structures and dynamic cables (Martin *et al.,* 2011[350]; Xodus, 2015[351]). The dynamic motion of moorings, in particular those in semi-taut or catenary configuration, may generate noise as dynamic inter-array cables connecting the turbines move through the water column, and as the anchors or mooring lines interact with the water. The noise from moorings is also expected to be non-impulsive and continuous in nature.

Magnitude of Impact

5.7.6.31 The spatial extent of underwater noise from operating wind turbines is estimated to be non-impulsive and continuous in nature, and relatively localised; therefore it is unlikely to result in any injury to fish (Wahlberg and Westerberg, 2005[294294]; Popper *et al.,* 2014[32]). Project specific underwater noise modelling, adopting the formula for underwater propagation of operational noise presented by Tougaard *et al.* (2020[291]), predicted impact ranges for recoverable injury and TTS of less than 50m for basking shark from WTGs with bottom-fixed foundations (Volume 7, Appendix 6: Underwater Noise Assessment). Therefore, the risk of recoverable injury and TTS as a result of operational noise is considered negligible.

5.7.6.32 Previous studies also indicate that behavioural responses in fish, such as avoidance, only likely occur very close to the noise source, ranging from a few metres to a few hundred metres from the operational wind turbine, and depends on the hearing sensitivity of the species (Sand *et al.,* 2001[299]; Wahlberg and Westerberg, 2005[294]; Sigray *et al.,* 2011[352]). However, these observations were made for smaller turbines (up to 1.5MW), and it would be expected that the larger turbines for the Proposed Development (Offshore) would result in different acoustic characteristics, with foundation type also impacting the acoustic characteristics of operational WTG noise.

5.7.6.33 The underwater sounds from wind turbines can be characterized as continuous sound sources that often have both broadband and tonal components with harmonics all below 1,000 Hz (Mooney *et al.,* 2020[353]). Noise measurements from floating WTGs off Stavanger, Norway indicated that WTG noise levels were below 110dB re 1 µPa at the monitoring location 150m from the operational WTGs, and that the ambient noise levels were dominated largely by vessel noise nearby (Martin *et al.,* 2011[350]). Mooney *et al.* (2020[353]) reported received levels of an operating turbine between 105-125 dB re 1 µPa (SPL) measured at 100m distance and −54 dB re 1 m s^{-2} (2–200 Hz) sound particle acceleration at 20m distance. The estimated TTS impact range of WTG noise from floating wind turbines, considering a power output of 2.3MW per WTG and the noise modelling formula presented by Tougaard *et al.* (2020[291]) is predicted to be less than 20m. The basking shark would also need to be very close to the operational turbine for 12 hours continuously for TTS onset to occur, which is considered unlikely.

5.7.6.34 While for snapping noise from moorings and dynamic cables, the impact ranges for injury are estimated to be small (a few hundred metres), with noise levels generally below the injury threshold criteria for fish species (Martin *et al.,* 2011[350]; Xodus, 2015[351]). There is currently no reliable noise threshold available for quantifying impacts of disturbance in fish; however, the effect is estimated to be minimal in elasmobranchs considering their low sensitivity to underwater noise.

5.7.6.35 Considering the relatively localised spatial extent and moderate duration of operational noise (35 years), this impact is considered to affect a very small proportion of the population and is very unlikely to affect the population trajectory of basking sharks as any potential impact will be of short term duration, intermittent and reversible. The magnitude of operational noise from WTGs and moorings is therefore assessed as **Negligible** to basking sharks during the O&M phase of the Proposed Development (Offshore).

Sensitivity of Receptors

5.7.6.36 Basking sharks are of low vulnerability, high recoverability and adaptability to underwater noise impacts. Basking sharks are highly mobile and have a wide distribution within Scottish waters, therefore the sensitivity of basking sharks to operational noise from WTGs during the O&M phase of the Proposed Development (Offshore) is assessed as **Low.**

Significance of Effect

5.7.6.37 Taking the **Negligible** magnitude of operational noise from WTGs during the O&M phase and the **Low** sensitivity of basking sharks, the overall significance of operational noise from WTGs during the O&M phase of the Proposed Development (Offshore) is considered **Negligible and Not Significant in EIA terms**.

Impact 13: Entanglement

5.7.6.38 Many of the newest marine renewable energy technologies, including floating OWFs, require mooring lines and/or anchors to ensure they maintain a fixed position within the development area (Garavelli, 2020[361361], Copping *et al.,* 2020[354]). In addition, conventional submarine cables, such as those used in bottom-fixed foundation OWFs, are unable to be installed for floating renewable energy developments and, as such, the cables (also known as dynamic cables) for floating offshore wind have floating components to enable them to move both with currents in the water column, and the floating structures they are attached to (Taninoki *et al.,* 2017[355]). The introduction of these new energy technologies, their mooring structures and dynamic cables into the marine environment introduces new potential risks of entanglement and thus, injury, to species such as basking sharks.

5.7.6.39 Moorings and dynamic cables associated with the operation of floating wind turbines (semi-submersible or tension leg foundations) and wind turbines with FRP foundation have the potential to entangle basking sharks within the Caledonia OWF. This could potentially result in respiratory distress through restricted gill mobility, increased drag and therefore less efficient foraging and movement in pelagic and ram filter-feeding basking sharks (Carlson *et al.,* 2004[356]).

5.7.6.40 Indirect entanglement could exacerbate primary entanglement effect of entanglement around moorings and dynamic cables if basking sharks are bycaught in drift nets and/or lost or discarded fishing gear snagged on moorings and dynamic cables (Benjamins *et al.,* 2014[37]). Derelict fishing gear and nets wrapped around the offshore wind structures could potentially increase spatial impact ranges (considering derelict nets could be tens of metres in width) and impact a variety of species, including marine mammals and sharks, resulting in relatively high bycatch rates locally.

5.7.6.41 Injuries and scars consistent with entanglement in ropes or nets associated with fishing gear have been regularly observed in basking sharks (Francis and Duffy, 2002[357]; Solandt and Chassin, 2013[117]; Gore *et al.,* 2016[358]). This could have disproportionate population impacts on shark species, such as basking sharks, which have long lifespans, late maturity and low reproductive output (Lewison *et al.,* 2004[359]).

5.7.6.42 The risks of entanglement of basking sharks within marine renewable technology structures are dependent upon both the physical characteristics of the mooring lines themselves and the amount of dynamic cable that is present in the water column (Harnois *et al.,* 2015[360]). For example, mooring configurations which have taut mooring lines are likely to present a lower risk of entanglement than catenary systems due to greater tension in the mooring line. However, catenary mooring systems are still considered to have too much tension on these lines to generate any loops big enough that could entangle marine mammals and basking sharks (Benjamins *et al.,* 2015[360], Copping *et al.,* 2020 Garavelli, 2020[361]). The same applies to dynamic cables in the water column, as these cables are designed to withstand mechanical forces to prevent cable failure and the creation of loops within the system (Young *et al.,* 2018[362]). Similarly, developments with shorter lengths of dynamic cable are also likely to present lower risks of entanglement (Benjamins *et al.,* 2014[37]). Depending on the number of new mooring lines and the length of dynamic cable present in the water column, the risks of derelict or ghost fishing gear being caught within marine renewable energy structures can also increase.

5.7.6.43 Three different mooring configurations are currently under consideration for the Offshore Development: catenary, semi-taut and taut. Since the risk of entanglement is higher for catenary moorings, these are considered as the realistic worst-case scenario. As such, the impact assessment for the risk of injury resulting from entanglement with mooring lines or cables, including secondary interactions with derelict fishing gears for the Proposed Development (Offshore), is based upon the following project characteristics for a catenary mooring system:

- Each WTG will have a catenary mooring line system with up to six mooring lines per WTG;
- Each WTG mooring line will be a maximum length of 1km, designed to withstand mechanical forces to prevent cable failure and the creation of loops within the system (Young *et al.,* 2006[111]) , and is made of:
  - Chain (top section), fibre rope (mid section) and chain (bottom section)
- Max mooring line swept area 45,000m^2.

Magnitude of Impact

5.7.6.44 According to the relative risk assessment of entanglement from offshore wind developments by Benjamins *et al.* (2014[37]) and other studies (Kropp, 2013[363]; Harnois *et al.,* 2015; Maxwell *et al.,* 2022[364]), entanglement with moorings and dynamic cables associated with offshore wind is estimated to be a low to moderate risk to basking sharks.

5.7.6.45 In addition to mooring configurations, entanglement risks associated with offshore wind development also vary substantially based on factors such as WTG spacing, array layout and diameters of mooring lines and/or dynamic cables (FERC, 2010[365]; Benjamins *et al.,* 2014[37]). Regardless of the mooring line designs, any mooring or dynamic cable structures for the Proposed Development (Offshore) will be set up to minimise the potential for creating any loop that could entangle large-sized marine wildlife like basking sharks.

5.7.6.46 Little is known about the distribution and abundance of derelict fishing gear in Scottish waters, and its extent being snagged and retained in mooring or cabling associated with offshore wind development. Therefore, the relative risk and likelihood of secondary entanglement of basking sharks under such conditions is largely unknown. Given the slow rate at which the snagged fishing gear (e.g., nets and lines) might decay, the secondary impact could be substantial, although further studies are required to quantify the level of risk.

5.7.6.47 The embedded mitigation includes the commitment to risk-based adaptive approach to the inspections of the mooring lines and cables present in the water column as part of the EMP (M-8, Table 5-19). Considering the localised spatial extent (within the Caledonia OWF only) and moderate duration of the potential impact (35 years), the entanglement impact, with the implementation of embedded mitigation as part of the EMP, is considered to affect a small proportion of the population, and is not likely to affect the population trajectory of basking sharks for all WTG foundation designs, as any potential impact will be of short term duration, intermittent and reversible.

5.7.6.48 The magnitude of entanglement to basking sharks during the O&M phase of the Proposed Development (Offshore) is assessed as **Low** when considering the mooring configuration resulting in the worst-case scenario (i.e., semi-submersible foundation with catenary moorings).

Sensitivity of Receptors

5.7.6.49 Based on a modelling study of relative entanglement risk from offshore renewable development by Benjamins *et al.* (2014[37]), basking sharks were estimated to have a moderate risk of entanglement.

5.7.6.50 With relatively poor eyesight and lateral eye placement on the head (McComb *et al.,* 2009[366]), it is visually difficult for basking sharks to detect mooring lines or cables, in particular in low-light conditions. Electroreceptive sharks however are able to detect metallic moorings or electrical elements of dynamic cables at close range by electroreceptors around their head (Haine *et al.,* 2001[367]), or turbulence in the water column generated by the movement of mooring and/or dynamic cables using their lateral line system, which consists of flow sensors for motion detection (Popper *et al.,* 2014[32]). There is however a possibility that filter-feeding sharks might swim through the water column with their mouth open and are entangled across the mouth when feeding on plankton (Knowlton and Kraus, 2001[368]; Johnson *et al.,* 2005[369]). The entanglement risk during feeding is estimated to be lower compared to that of lunge-feeding baleen whales (Benjamins *et al.,* 2014[37]).

5.7.6.51 Comparatively large body appendages in basking sharks also cause the species to be more susceptible to entanglement as are more likely to be entangled (e.g., dorsal and ventral fins), although basking sharks are flexible and therefore may be able to avoid entanglement more easily as compared with more rigid animals such as large whales and sea turtles (Benjamins *et al.,* 2014[37]).

5.7.6.52 Basking sharks are estimated to be of moderate vulnerability, limited recoverability and reasonable adaptability to entanglement impact during the O&M phase. Therefore, the sensitivity of basking sharks to entanglement risks during the O&M phase is considered to be **Medium**.

Significance of Effect

5.7.6.53 Taking the **Low** magnitude of entanglement during the operation of WTGs with semi-submersible foundation and catenary moorings and the **Medium** sensitivity of basking sharks, the overall effect of entanglement from of WTGs with semi-submersible foundation with catenary moorings during the O&M phase of the Proposed Development (Offshore) is considered **Minor and Not Significant in EIA terms**.

Impact 14: Long-term Displacement, Habitat Loss and Barrier Effects

5.7.6.54 The physical presence of array infrastructure at the Caledonia OWF has the potential to either displace basking sharks through an effective loss of habitat, and/or create barrier effects, whereby the regular movements of a particular species are impacted by the presence of the wind farm (Onoufriou *et al.,* 2021[370]). Mooring lines and dynamic cables used for floating WTGs in the Caledonia South site, which would move within the water column, could result in a strimming effect.

Magnitude of Impact

5.7.6.55 It is expected that basking sharks, with body lengths of about six to 12m, are able to move between and around the WTGs and OSP foundations (minimum distance of 944m between infrastructure) at all depths. Therefore, the Proposed Development (Offshore) is unlikely to result in significant displacement and/or barrier effects.

5.7.6.56 The impact area of long-term habitat loss and displacement/barrier effects is highly localised, considering the wider distribution of basking sharks throughout Scottish waters. The impacted habitat is also common and widespread within and near the Proposed Development (Offshore); therefore, if the habitat were important to basking sharks, similar suitable habitat is available nearby.

5.7.6.57 The impact of long-term habitat loss, displacement and barrier effects is considered to affect a very small proportion of the basking shark population, and is unlikely to affect its population trajectory during the O&M phase as any potential impact will be of short term duration, intermittent and reversible.

5.7.6.58 Therefore, the magnitude of long-term habitat loss, displacement and barrier effects on basking sharks during the O&M phase for the Proposed Development (Offshore) is assessed as **Negligible**.

Sensitivity of Receptors

5.7.6.59 Basking sharks have low dependency on benthic habitat and therefore are not considered vulnerable to long-term loss of areas of the seabed.

5.7.6.60 Basking sharks are highly mobile and have a wide distribution within Scottish waters, and their migratory pathways of basking sharks primarily span across the west coast of Scotland (such as around the Firth of Clyde), the Irish Sea including waters off the Isle of Man, and the western English Channel (Sims *et al.,* 2003[116]; Solandt and Chassin, 2013[117]; Cornwall Wildlife Trust, 2020[86]). It is important to note that basking sharks do not have a 'habitat' in the same sense as other taxa and instead the location of foraging patches drives the location of basking sharks. Therefore, habitat exclusion is not considered a significant impact.

5.7.6.61 Basking sharks are of low vulnerability, high recoverability and adaptability to long term habitat loss, displacement and barrier effects during the O&M phase. Therefore, the sensitivity of basking sharks to habitat loss, displacement and barrier effects during the O&M phase of the Proposed Development (Offshore) is considered **Negligible**.

Significance of Effect

5.7.6.62 Considering the **Negligible** magnitude of long-term habitat loss, displacement and barrier effects and the **Negligible** sensitivity of basking sharks, the overall impact significance of long-term habitat loss, displacement and barrier effects to basking sharks during the O&M phase of the Proposed Development (Offshore) is considered **Negligible and Not Significant in EIA terms**.

5.7.7 Decommissioning

5.7.7.1 The decommissioning phase of the Proposed Development (Offshore) is yet to be decided and will depend on the choice of turbine structure and the foundation type. As such a detailed assessment of potential impacts that may occur during the decommissioning phase or the mitigation strategies that may be implemented is not currently possible.

5.7.7.2 At the end of the operational lifetime of the Proposed Development (Offshore), it is anticipated that all structures above the seabed level will be completely removed, or left buried if removal would lead to greater in-situ environmental impacts. It is anticipated that piled wind turbine foundations would be cut at or below seabed level, and the protruding section will be removed during decommissioning. The final removal method will be dependent on the technologies available at the time of decommissioning, acknowledging the preferences stated in the latest guidance at the time of writing such as the Scottish Government's Guidance for the Decommissioning of Offshore Renewable Energy Installations in Scottish Waters (Scottish Government, 2022[371]). it is predicted that impact magnitude and significance of these decommissioning activities to basking sharks will be reduced as compared to the construction phase, as no pile driving will be involved, and mitigation measures will be in place as part of the Decommissioning Programme (M-10, Table 5-19).

5.7.7.3 A Decommissioning Programme (Volume 7, Appendix 11 and Volume 7, Appendix 12) will be developed and submitted for approval before pre-construction to address the principal decommissioning measures for the Proposed Development (Offshore); this will be written in accordance with applicable guidance and will detail the management, environmental management and schedule for decommissioning (see Volume 1, Chapter 2: Proposed Development (Offshore) Description for more details). Prior to the commencement of any decommissioning works, the Decommissioning Programme will be reviewed and revised as required in accordance with the industry practice at that time. The decommissioning activities are expected to take a similar duration as the construction and pre-construction programme.

5.7.7.4 It is unknown at this time what types of decommissioning vessels will be available on the market at the point of decommissioning. A worst-case assumption would be that the decommissioning sequence being the reverse of the construction sequence involving similar number of vessel movements/trips as during the construction/installation phase. However, it is expected that many more efficiencies would be achievable in more than 35 years' time.

5.7.7.5 Given the nature of the decommissioning activities, which will largely be a reversal of the installation process, the impacts during decommissioning are expected to be similar to or less than those assessed for the construction stage. Therefore, the magnitude of impacts assigned to basking shark receptors during the construction stage (including pre-construction) is also applicable to the decommissioning stage. It is also assumed that the receptor sensitivities will not materially change over the lifetime of the Proposed Development (Offshore). Therefore, the decommissioning effects are not expected to exceed those assessed for construction and pre-construction.

5.8 Cumulative Effects

5.8.1 Approach to Cumulative Impact Assessment

5.8.1.1 The Cumulative Impacts Assessment (CIA) assesses the impact associated with the Proposed Development (Offshore) together with other relevant plans, projects and activities. Cumulative effects are therefore the combined effect of the Proposed Development (Offshore) along with the effects from a number of different projects, on the same receptor or resource.

5.8.1.2 The developments relevant to the CIA for fish and shellfish ecology include plans, projects and activities considered alongside the Proposed Development (Offshore) falling into the following types of developments:

- OWFs;
- OWF Cables and OECCs;
- Subsea cables; and
- Other Energy Developments (Wave and tidal).

5.8.1.3 The approach to the CIA for fish and shellfish ecology follows the process outlined in Volume 7A, Appendix 7-1: Cumulative Impact Assessment Methodology. The projects and plans selected as relevant to the assessment of impacts to fish and shellfish ecology are based upon an initial screening exercise undertaken on a long list. Each project, plan or activity has been considered and scoped in or out on the basis of effect-receptor pathway, data confidence and the temporal and spatial scales involved. The short-list of relevant developments for inclusion within the CIA is outlined in Volume 7A, Appendix 7-1, Annex 2.

5.8.1.4 It is anticipated that offshore construction of the Proposed Development (Offshore) will at the earliest commence in 2028. After construction, the Proposed Development (Offshore) will be operational for 35 years. Projects included in the CIA have been categorised into tiers depending on their development status. Details of the projects, their associated tier, and a justification for inclusion within the CIA is included in Volume 7A, Appendix 7-1: Cumulative Impact Assessment Methodology.

5.8.1.5 Projects and developments included in tiers 1, 2 and 3 are considered to have sufficient data confidence to be included within the cumulative assessment. Projects and developments in tier 4 were scoped out of the cumulative impact assessment, as it is not possible to conduct a meaningful assessment of potential cumulative assessment for projects or plans where sufficient detail is not available on construction proposals or programme or timelines.

5.8.1.6 Due to the expected operational life of the Proposed Development (Offshore) (35 years), and a similarly long operational life for other developments in the vicinity, it is not possible to conduct a meaningful assessment of the potential for cumulative impact during decommissioning. As such, decommissioning is not considered further within this cumulative impact assessment.

Fish and Shellfish Ecology

5.8.1.7 For potential effects on fish and shellfish, planned projects were screened into the assessment based on a screening range that encapsulates the study area as defined by the secondary ZoI of 10km, which has been defined based on the expected maximum distance that sediment within the Project might be transported on a single mean spring tide, in the flood and/or ebb direction. The 10km secondary ZoI has been used to screen in developments which have the potential to result in a cumulative effect for SSC, habitat loss (short-term and long-term) and EMF. An additional screening range of 100km has also been applied to encapsulate cumulative impacts associated with UWN to encompasses any potential UWN originating from other projects in the vicinity. This screening area therefore encompasses the extent of impacts to fish and shellfish ecology associated with the project (Figure 5–23).

5.8.1.8 Operational projects included within Table 5-35 are included due to their completion/commissioning occurring subsequent to the data collection process for the Proposed Development (Offshore), and as such are not included within the baseline characterisation. Note that this table only includes the projects screened into the assessment for fish and shellfish ecology.

5.8.1.9 Impacts that are scoped into the assessment for the Proposed Development (Offshore) alone are not considered in the cumulative assessment, due to the following reasons:

- The highly localised nature of the impacts (i.e., they are generally spatially restricted to being within the Caledonia OWF and Caledonia OECC);
- Management measures in place for the Proposed Development (Offshore) will also be in place on other projects reducing the risk of impacts occurring; and/or
- Where the potential significance of the impact from the Project alone has been assessed as negligible.

5.8.1.10 However, certain potential impacts have the potential to affect the fish and shellfish communities over a larger area, and therefore have the potential to result in cumulative effects. For this reason, the following cumulative impacts on fish and shellfish receptors have been considered in the CIA (Table 5-36):

- Mortality, injury and behavioural changes resulting from underwater noise arising from construction activity;
- Temporary increase in suspended sediment and sediment deposition from cumulative construction activities;
- Temporary habitat loss and disturbance;
- Cumulative long-term habitat loss from operation; and

- Cumulative electromagnetic fields (EMF) effects arising from cables.

5.8.1.11 The specific projects scoped into the CIA are presented in Table 5-35 below. The full list of plans and projects considered, including those screened out, are presented in Volume 7A, Appendix 7-1: Cumulative Impact Assessment Methodology. The projects listed in Table 5-36 have been selected as those having the potential to result in a cumulative effect on an identified receptor group. The cumulative impacts presented and assessed in this section have been selected from the details provided in the project description for the Project, as well as the information available on other projects and plans in order to inform a cumulative WCS. Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the project design envelope to that assessed here, be taken forward in the final design scheme.

Table 5-35: Projects included within the Fish and Shellfish Ecology CIA.

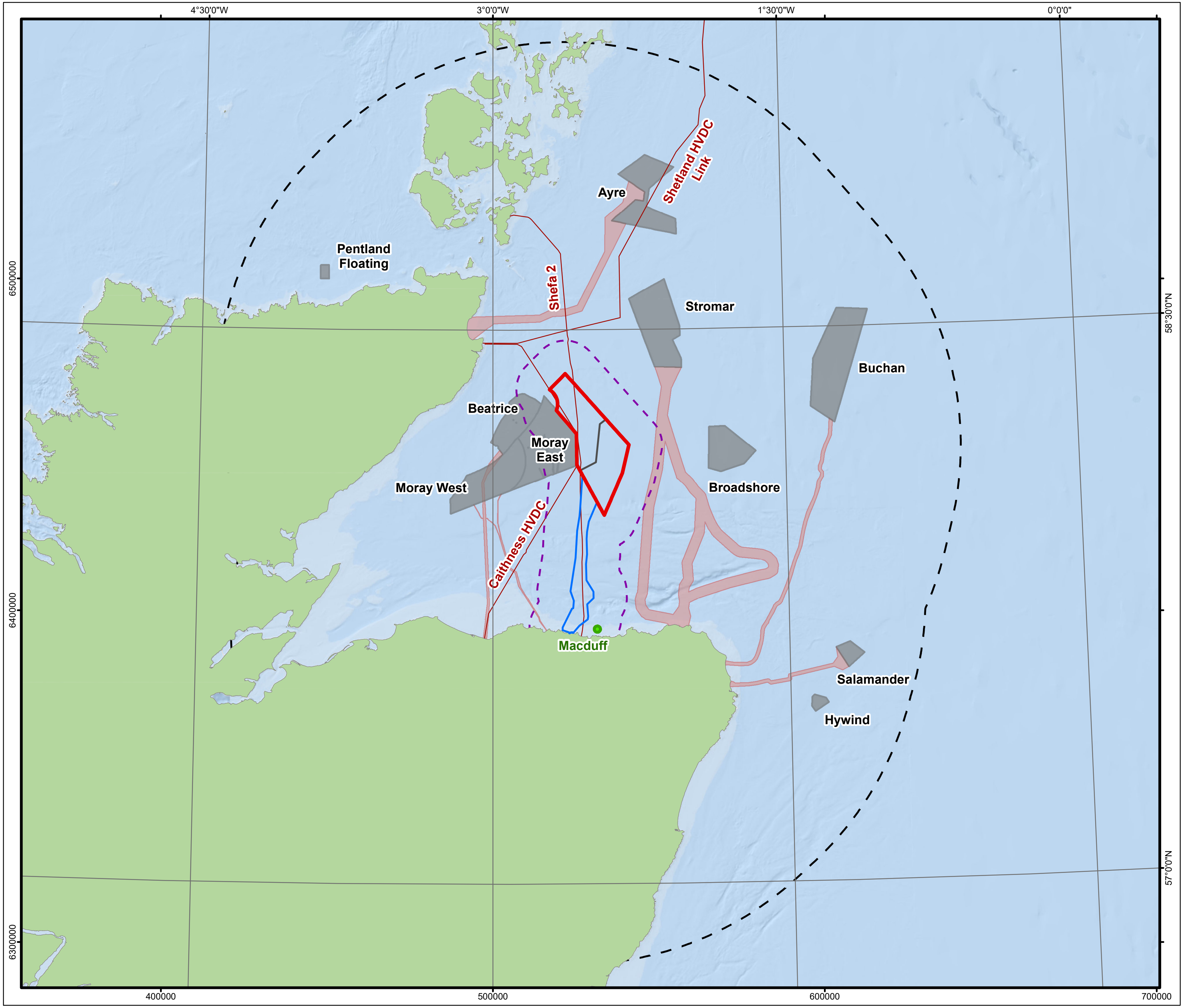
Development	Status	Tier	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Potential for Effect
OWF Developments					
Moray East OWF	Operational	1	0.00	3.4	Moray East borders the Proposed Development (Offshore). It is already operational so there is no potential for an overlap in cumulative impacts associated with construction activities. Instead, there is a potential for cumulative impacts arising from cumulative SSC and deposition and short term habitat loss and disturbance from construction works from the Proposed Development (Offshore). There is potential for operational and maintenance impacts associated long term habitat loss and cumulative EMF due to Moray East OWF being situated within the 10km secondary ZoI.
Beatrice OWF	Operational	1	4.9	22	Beatrice OWF is already operational so there is no potential for an overlap in cumulative impacts associated with construction activities. Instead, there is a potential for cumulative impacts arising from cumulative SSC and deposition and short term habitat loss and disturbance from construction works from the Proposed Development (Offshore). There is potential for operational and maintenance impacts associated long term habitat loss and cumulative EMF due to Beatrice OWF being situated within the 10km secondary ZoI.
Moray West OWF[v]	Under Construction	1	14.24	17.44	Moray West OWF is currently under construction however it is expected to be operational by 2024 and have no temporal overlap with construction activities at the Proposed Development (Offshore). There is however the potential for cumulative effects from operation and maintenance activities instead. There is potential for operational and maintenance impacts associated long

[v] Moray West Export Cable was commissioned after the CIA was undertaken, and therefore has been included as part of the longlist.

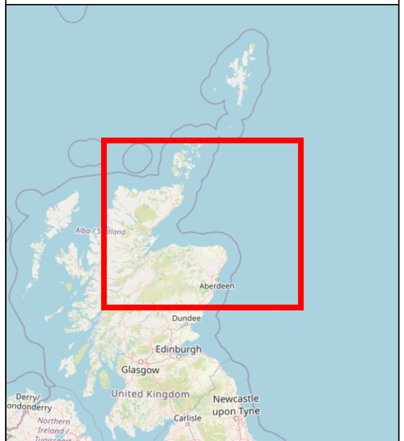
Development	Status	Tier	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Potential for Effect
					term habitat loss and cumulative EMF. Although the Moray West OWF is situated just outside the 10km secondary ZoI, due to the proximity to the Proposed Development (Offshore) it has been scoped into the cumulative assessment on a precautionary basis.
Pentland Floating OWF	In Planning	1	74.44	96.68	Pentland Floating OWF is located 74.52km from the Proposed Development (Offshore). Construction is expected to start in 2027 and the operational life of Pentland Floating OWF will be up to 30 years and therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Pentland Floating OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts of SSC and deposition, long term habitat loss and EMF have been scoped out.
Salamander OWF	Concept/Early Planning	1	80.33	74.52	Construction is expected to be completed by 2030 and therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Pentland Floating OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts of SSC and deposition, long term habitat loss and EMF have been scoped out.
Broadshore OWF	Concept/Early Planning	2	24.03	35.07	Broadshore OWF is anticipated to have a similar construction window ("late 2020's") and to be operational by the "early 2030's") and therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Broadshore OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts of SSC and deposition, long term habitat loss and EMF have been scoped out.

Development	Status	Tier	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Potential for Effect
Stromar OWF	Concept/Early Planning	2	21.56	39.33	Stromar OWF is anticipated to have a similar construction period (2029-2032) and therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Stromar OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts of SSC and deposition, long term habitat loss and EMF have been scoped out.
Ayre OWF	Concept/Early Planning	2	48.31	77.00	Construction of Ayre OWF is expected to take place in 2028 and last 3-5 years and therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Ayre OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts of SSC and deposition, long term habitat loss and EMF have been scoped out.
Buchan OWF	Concept/Early Planning	2	55.97	70.56	Buchan OWF is located 74.44km from the Proposed Development (Offshore). Construction is expected to take place through 2026, and the operational life of the Offshore Development will be up to 30 years, therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Buchan OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts of SSC and deposition, long term habitat loss and EMF have been scoped out.
Subsea Cables					
Caithness HVDC subsea cable	Operational	1	0.00	0.00	Caithness HVDC subsea cable is located within the 10km secondary ZoI and has the potential for operational activities overlap temporally with the construction and the O&M of the Proposed Development (Offshore). Therefore, cumulative increase

Development	Status	Tier	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Potential for Effect
					SSC and deposition, short term habitat loss and disturbance, long term habitat loss as well as EMF have been screened into the CIA.
Shefa 2 subsea cable	Operational	1	5.14	0.00	Shefa 2 subsea cable is located within the 10km secondary ZoI and has the potential for operational activities overlap temporally with the construction and the O&M of the Proposed Development (Offshore). Therefore, cumulative increase SSC and deposition, long term habitat loss as well as EMF have been screened into the CIA.
Moray West OECC	Under Construction	1	5.3	8.3	Moray West OECC is located within the 10km secondary ZoI and has the potential for operational activities overlap temporally with the construction and the O&M of the Proposed Development (Offshore). Therefore, cumulative increase SSC and deposition, short term habitat loss and disturbance, long term habitat loss as well as EMF have been screened into the CIA.
Shetland HVDC Link	Under Construction	1	12.6	43.4	Shetland HVDC Link subsea cable is located just outside the 10km secondary ZoI and has the potential for construction/operational activities to overlap temporally with the construction and the O&M of the Proposed Development (Offshore). Therefore, cumulative increase SSC and deposition, short term habitat loss and disturbance, long term habitat loss as well as EMF have been screened into the CIA.
Stromar OECC	Concept/Early Planning	2	7.69	12.49	Stromar OECC is anticipated to have a similar construction period (2029-2032) and therefore it is likely that there will be potential for an overlap in cumulative impacts associated SSC and deposition and short term habitat loss and disturbance from construction work at THE Proposed development (Offshore). long term habitat loss as well as EMF have been screened into the CIA.



- Caledonia OWF
- Caledonia North Site and Caledonia South Site Division Line
- Offshore Export Cable Corridor
- 10km Secondary Zone of Influence
- 100km CIA Zone of Influence
- Offshore Wind Development
- Export Cable Corridors
- Disposal Sites
- Telecommunications and Power Cables



0 10 20 30 40 50 km

REV	DATE	DOC STATUS	ORIGIN	REVIEW	APP
01	24/09/2024	Approved	EV	BB	DH

CALEDONIA Offshore Wind Farm | GoBe APEM Group

CONTRACTOR DRAWING NO: UKCAL1_GO_WNF_FAS_MAP_00173	CONTRACTOR REV: 01
GEODETIC PARAMETERS: WGS 84 / UTM zone 30N (EPSG: 32630)	
DRAWING TITLE: Figure 5-23:Offshore Developments Within the Cumulative Impact Assessment 100km ZoI	
STATUS: Approved	SCALE: 1:1,550,000
DRAWING NUMBER: N/A	SHEET NO: 01 of 01 / REV: N/A

Table 5-36 Summary of projects used to inform CIA for Fish and Shellfish

Potential Impact	Scoped in CIA Projects	Explanation
Construction		
Cumulative Mortality, injury and behavioural changes resulting from underwater noise arising from construction activity.	**Tier 1 Projects:** ▪ Construction of Salamander OWF ▪ Construction of Pentland Floating OWF **Tier 2 Projects:** ▪ Construction of Broadshore OWF ▪ Construction of Buchan OWF ▪ Construction of Ayre OWF ▪ Construction of Stromar OWF	Out of all the OWF developments included in the 100km ZoI for the CIA, Salamander OWF, Pentland OWF, Buchan OWF, Broadshore OWF, Ayre OWF and Stromar have the potential for cumulative impacts arising from UWN during construction activities. An overlap in construction of these developments could lead to cumulative UWN impacts from piledriving for foundation/ anchor piles. The spatial WCS for simultaneous construction of Caledonia OWF and Broadshore OWF construction period which could result in an overlap of pilling operations has been modelled and is presented in Volume 7, Appendix 6: Caledonia Offshore Wind Farm Underwater Noise Technical Note.
Cumulative temporary increase in suspended sediment and sediment deposition	**Tier 1 Projects:** ▪ O&M of Moray East OWF ▪ O&M of Beatrice OWF ▪ O&M Caithness HVDC subsea cable ▪ O&M Shefa 2 subsea cable ▪ Construction/O&M Shetland HVDC Link ▪ Construction/O&M Stromar OECC	All of these tier 1 projects occur within the 10km secondary ZoI have the potential for cumulative impacts arising from temporary increase in suspended sediment and sediment deposition. If these intermittent activities overlap temporally with either the construction or maintenance of the Proposed Development (Offshore), there is potential for cumulative SSC and sediment deposition to occur within the plume footprints.
Temporary Habitat Loss and Disturbance	**Tier 1 Projects:** ▪ O&M of Moray East OWF ▪ O&M of Beatrice OWF ▪ O&M of Moray West OWF and OECC ▪ O&M Caithness HVDC subsea cable ▪ O&M Shefa 2 subsea cable ▪ Construction/O&M Shetland HVDC Link ▪ Construction/O&M Stromar OECC	All of these tier 1 projects occur within the 10km secondary ZoI (or just outside the 10km secondary ZoI in the case of Moray West) have the potential for cumulative impacts arising from temporary habitat loss and disturbance. If these intermittent activities overlap temporally with either the construction or maintenance of the Proposed Development (Offshore), there is potential for cumulative temporary habitat loss and disturbance the respective developments footprints.

Potential Impact	Scoped in CIA Projects	Explanation
Operation		
Cumulative long-term habitat loss	**Tier 1 Projects:** ▪ O&M of Moray East OWF ▪ O&M of Beatrice OWF ▪ O&M of Moray West OWF and OECC ▪ O&M Caithness HVDC subsea cable ▪ O&M Shefa 2 subsea cable ▪ O&M Shetland HVDC Link ▪ O&M Stromar OECC	All of these tier 1 projects occur within the 10km secondary ZoI (or just outside the 10km secondary ZoI in the case of Moray West) have the potential for cumulative impacts arising from long-term habitat loss. An overlap in operation could result in cumulative effects of long term habitat lost from the presence of anchors, foundations, cables and sour protection.
Cumulative Impacts from EMF	**Tier 1 Projects:** ▪ O&M of Moray East OWF ▪ O&M of Beatrice OWF ▪ O&M of Moray West OWF and OECC ▪ O&M Caithness HVDC subsea cable ▪ O&M Shefa 2 subsea cable ▪ O&M Shetland HVDC Link ▪ O&M Stromar OECC	All of these tier 1 projects occur within the 10km secondary ZoI (or just outside the 10km secondary ZoI in the case of Moray West) have the potential for cumulative impacts arising from EMF. An overlap in operation could result in cumulative effects of EMF from the presence subsea cables.

Basking Sharks

5.8.1.12 For potential effects on basking sharks, planned projects were screened into the assessment based on a screening range within the basking shark study area as defined by a primary ZoI of 100km (Figure 5–23). This primary ZoI has been applied to encompass any potential cumulative impacts associated with underwater noise impacts originating from other projects in the vicinity. A secondary ZoI of 10km has been applied for developments that have the potential to result in a cumulative effect from risk of entanglement and EMF from offshore export cables. This precautionary secondary ZoI of 10km is defined based on expert opinion of the maximum impact ranges of these impact pathways. This screening area therefore encompasses the extent of impacts to basking sharks associated with the project (Figure 5–23).

5.8.1.13 Impacts that are scoped into the assessment for the Proposed Development (Offshore) alone are not considered in the CIA (Table 5-37), due to the following reasons:

- The highly localised nature of the impacts (i.e., they are generally spatially restricted to being within the Caledonia OWF and Caledonia OECC);
- Management measures in place for the Proposed Development (Offshore) will also be in place on other projects reducing the risk of impacts occurring; and/or

- Where the potential significance of the impact from the Project alone has been assessed as negligible.

5.8.1.14 However, certain potential impacts have the potential to affect basking shark communities over a larger area, and therefore have the potential to result in cumulative effects. The specific developments scoped into the CIA for basking sharks are presented in Table 5-38.

5.8.1.15 The following cumulative impacts on basking shark receptors have been considered in this CIA (Table 5-39):

- Construction:
  - Cumulative disturbance impact resulting from underwater noise arising from construction activity;
- Operation:
  - Cumulative disturbance from underwater noise from operational noise;
  - Risk of secondary entanglement; and
  - Cumulative EMF effects arising from cables.

Table 5-37: Description of impacts excluded considered within the basking shark CIA.

Impact	Justification
Auditory injury from pile-driving and other activities	As an EPS, legislation and suitable mitigation must be put in place to reduce auditory injury risk to basking sharks to negligible levels across all projects considered in the cumulative assessment. Similarly, any risk of auditory injury during decommissioning will be determined via appropriate decommissioning plans and if required, mitigated. Any non-piling construction noise sources will have a very local spatial extent and therefore represent a minimal risk of injury. Moreover, it is anticipated that underwater noise associated with vessel activity will deter animals from the injury zone. As such, assuming application of appropriate mitigation measures, any risk of injury it is considered highly unlikely and potential for cumulative effects on basking sharks due to auditory injury as a result of piling, UXO, other non-piling construction activities and decommissioning was not considered further.
Underwater noise from UXO clearance	In line with the DEFRA *et al.* (2022[36]) joint interim position statement, it is expected that, where feasible, across all projects, UXO clearance campaigns will be conducted using low-order deflagration techniques. Moreover, it is expected that the clearance of a UXO would elicit a startle response and potentially very short-duration behavioural responses and would therefore not be expected to cause widespread and prolonged displacement (JNCC, 2020[372]). Given that behavioural disturbance is considered negligible in the context of UXO clearance as the duration of the impact (underwater noise) is very short, the potential for cumulative effects is considered unlikely and this impact was not considered further.

Impact	Justification
Vessel collisions	It is expected that across all project’s vessel movements will be managed through the implementation of vessel codes of conduct (VMP) that will mitigate the negative impacts to basking sharks (e.g., limited vessel speeds, adherence to vessel transit routes), following relevant guidance to minimise the risks of injury to basking sharks. As such, the potential for significant cumulative effects is minimal and this impact was not considered further.
Vessel disturbance	Disturbance from other (non-piling) construction activities is anticipated to be highly localised and is closely associated with the disturbance from vessel presence required for the activity. As such, cumulative effects for vessel disturbance have been assessed and potential for cumulative effects due to other (non-piling) construction activities was not considered further.
Indirect impacts on prey	The changes in prey availability are expected to be highly localised across all Projects. As such, basking sharks have a generalised diet and therefore are not expected to be sensitive to potential changes in prey. As such, the potential for significant cumulative effects is minimal and therefore this impact was not considered further.
Water quality changes	The changes in water quality are expected to be highly localised across all Projects. As such, the potential for significant cumulative effects is minimal and therefore this impact was not considered further.
Long-term displacement/habitat loss/barrier effects	The potential risks associated with long term displacement and barrier effects are expected to be highly localised across floating projects. The habitat loss is considered to be temporary during construction only. As such, the potential for significant cumulative effects is minimal and therefore this impact was not considered further.

Table 5-38: Projects included within the basking shark CIA

Development	Status	Tier	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Potential for Effect
OWF Developments					
Moray East OWF	Operational	1	0.00	3.4	Moray East borders the Proposed Development (Offshore). It is already operational so there is no potential for an overlap in cumulative impacts associated with construction activities. There is potential for operational and maintenance impacts associated operational noise, secondary entanglement and cumulative EMF due to Moray East OWF being situated within the 10km secondary ZoI.
Beatrice OWF	Operational	1	4.9	22	Beatrice OWF is already operational so there is no potential for an overlap in cumulative impacts associated with construction activities. There is potential for operational and maintenance impacts associated operational noise, secondary entanglement and cumulative EMF due to Beatrice OWF being situated within the 10km secondary ZoI.
Moray West OWF[v]	Under Construction	1	14.24	17.44	Moray West OWF is currently under construction however it is expected to be operational by 2024 and have no temporal overlap with construction activities at the Proposed Development (Offshore). There is potential for operational and maintenance impacts associated operational noise, secondary entanglement and cumulative EMF. Although the Moray West OWF is situated just outside the 10km secondary ZoI, due to the proximity to the Proposed Development (Offshore) it has been scoped into the cumulative assessment on a precautionary basis.
Pentland Floating OWF	In Planning	1	74.44	96.68	Pentland Floating OWF is located 74.52km from the Proposed Development (Offshore). Construction is expected to start in 2027 and the operational life of Pentland Floating OWF will be up to 30 years and therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction

Development	Status	Tier	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Potential for Effect
					activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Pentland Floating OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts such operational noise, secondary entanglement and cumulative EMF have been scoped out.
Salamander OWF	Concept/Early Planning	1	80.33	74.52	Construction is expected to be completed by 2030 and therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Pentland Floating OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts therefore cumulative impacts such operational noise, secondary entanglement and cumulative EMF have been scoped out.
Broadshore OWF	Concept/Early Planning	2	24.03	35.07	Broadshore OWF is anticipated to have a similar construction window ("late 2020's") and to be operational by the "early 2030's") and therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Broadshore OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts such operational noise, secondary entanglement and cumulative EMF have been scoped out.
Stromar OWF	Concept/Early Planning	2	21.56	39.33	Stromar OWF is anticipated to have a similar construction period (2029-2032) and therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Stromar OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts such operational noise, secondary entanglement and cumulative EMF have been scoped out.

Development	Status	Tier	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Potential for Effect
Ayre OWF	Concept/Early Planning	2	48.31	77.00	Construction of Ayre OWF is expected to take place in 2028 and last 3-5 years and therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Ayre OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts such operational noise, secondary entanglement and cumulative EMF have been scoped out.
Buchan OWF	Concept/Early Planning	2	55.97	70.56	Buchan OWF is located 74.44km from the Proposed Development (Offshore). Construction is expected to take place through 2026, and the operational life of the Offshore Development will be up to 30 years, therefore it is likely that there will be potential for an overlap in cumulative impacts associated with construction activities. There is a potential for cumulative impacts arising from UWN. It should be noted that Buchan OWF lies outside of the 10km secondary ZoI and therefore cumulative impacts such operational noise, secondary entanglement and cumulative EMF have been scoped out.
Subsea Cables					
Caithness HVDC subsea cable	Operational	1	0.00	0.00	Caithness HVDC subsea cable is located within the 10km secondary ZoI and has the potential for operational activities overlap temporally with the construction and the O&M of the Proposed Development (Offshore). Therefore, cumulative increase of EMF have been screened into the CIA.
Shefa 2 subsea cable	Operational	1	5.14	0.00	Shefa 2 subsea cable is located within the 10km secondary ZoI and has the potential for operational activities overlap temporally with the construction and the O&M of the Proposed Development

Development	Status	Tier	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Potential for Effect
					(Offshore). Therefore, cumulative increase of EMF have been screened into the CIA.
Moray West OECC	Under Construction	1	5.3	8.3	Moray West OECC is located within the 10km secondary ZoI and has the potential for operational activities overlap temporally with the construction and the O&M of the Proposed Development (Offshore). Therefore, cumulative increase of EMF have been screened into the CIA.
Shetland HVDC Link	Under Construction	1	12.6	43.4	Shetland HVDC Link subsea cable is located just outside the 10km secondary ZoI and has the potential for construction/operational activities to overlap temporally with the construction and the O&M of the Proposed Development (Offshore). Therefore, cumulative increase of EMF have been screened into the CIA.
Stomar OECC	Concept/Early Planning	2	7.69	12.49	Stromar OECC is anticipated to have a similar construction period (2029-2032) and therefore it is likely that there will be potential for an overlap in cumulative impacts associated from construction and the O&M of the Proposed development (Offshore). Cumulative increase of EMF have been screened into the CIA.

Table 5-39: Summary of projects used to inform basking shark CIA.

Potential Impact	Scoped in CIA Projects	Explanation
Construction		
Cumulative disturbance resulting from underwater noise arising from construction activity.	**Tier 1 Projects:** ▪ Construction of Salamander OWF ▪ Construction of Pentland Floating OWF **Tier 2 Projects:** ▪ Construction of Broadshore OWF ▪ Construction of Buchan OWF ▪ Construction of Ayre OWF ▪ Construction of Stromar OWF	Out of all the OWF developments included in the 100km ZoI for the CIA, Salamander OWF, Pentland OWF, Buchan OWF, Broadshore OWF, Ayre OWF and Stromar have the potential for cumulative impacts arising from UWN during construction activities. An overlap in construction of these developments could lead to cumulative UWN impacts from pile-driving for foundation/anchor piles. The spatial WCS for simultaneous construction of Caledonia OWF and Broadshore OWF construction period which could result in an overlap of pilling operations has been modelled and is presented in Volume 7, Appendix 6: Underwater Noise Assessment.
Operation		
Cumulative disturbance from underwater noise arising from operational noise	**Tier 1 Projects:** ▪ O&M of Moray East OWF ▪ O&M of Beatrice OWF ▪ O&M of Moray West OWF and OECC ▪ O&M Caithness HVDC subsea cable ▪ O&M Shefa 2 subsea cable ▪ Construction/O&M Shetland HVDC Link	All of these tier 1 projects occur within the 10km secondary ZoI (or just outside the 10km secondary ZoI in the case of Moray West) have the potential for cumulative impacts arising from UWN from operational activity of the Proposed Development (Offshore). If these intermittent activities overlap temporally with either the construction or maintenance of the Proposed Development (Offshore), there is potential for cumulative operational noise.
Risk of secondary entanglement	**Tier 1 Projects:** ▪ O&M of Moray East OWF ▪ O&M of Beatrice OWF ▪ O&M of Moray West OWF and OECC ▪ O&M Caithness HVDC subsea cable ▪ O&M Shefa 2 subsea cable ▪ O&M Shetland HVDC Link	All of these tier 1 projects occur within the 10km secondary ZoI (or just outside the 10km secondary ZoI in the case of Moray West) have the potential for cumulative impacts arising from secondary entanglement. An overlap in operation could result in cumulative effects of secondary entanglement from the presence of

Potential Impact	Scoped in CIA Projects	Explanation
		anchors, foundations, cables and sour protection.
Cumulative Impacts from EMF	**Tier 1 Projects:** ▪ O&M of Moray East OWF ▪ O&M of Beatrice OWF ▪ O&M of Moray West OWF and OECC ▪ O&M Caithness HVDC subsea cable ▪ O&M Shefa 2 subsea cable ▪ O&M Shetland HVDC Link	All of these tier 1 projects occur within the 10km secondary ZoI (or just outside the 10km secondary ZoI in the case of Moray West) have the potential for cumulative impacts arising from EMF. An overlap in operation could result in cumulative effects of EMF from the presence subsea cables.

Fish and Shellfish

5.8.2 Construction

Cumulative Mortality, Injury and Behavioural Changes Resulting from Underwater Noise Arising from Construction Activity

5.8.2.1 UWN modelling has been undertaken to show the potential for cumulative impacts between the Proposed Development (Offshore) and other projects in the vicinity. Broadshore is located in close proximity to the Proposed Development (Offshore), potential cumulative effects of concurrent piling at Caledonia OWF and Broadshore have been modelled (Volume 7, Appendix 6: Underwater Noise Assessment). Modelling assumed that the piling operations at each location start at the same time.

5.8.2.2 Model outputs have shown that there is unlikely to be a risk of cumulative impacts associated with noise that can cause mortality, at 207 dB or higher. Figure 5-24 provides modelled outputs from modelling of impact piling at the Caledonia OWF and at Broadshore. The figure presented represents the largest areas of cumulative TTS impact (186 dB) that was modelled. The figure shows cross over in contours at the 203 dB and 186 dB levels; however, no cross over of contours for any of the lower noise levels, although there are also small increases in overall area of these higher noise level contours.

5.8.2.3 In general, if simultaneous piling operations from two different projects are closer together, it will result in an overall increase in the louder noise contours (mortality and recoverable injury) and potentially a reduction in the overall area in the TTS contour. Whereas if the operations are further apart, but still close enough for noise to interact, there is less likely to be any increase in the louder noise contours (mortality and recoverable injury), but the area of TTS contours may increase to a much larger area.

5.8.2.4 Although not the closest potential project (Stromer OWF is approximately 2km closer), the modelled outputs form Broadshore are considered to represent a reasonably foreseeable WCS for assessing cumulative impacts of UWN of the Proposed Development (Offshore).

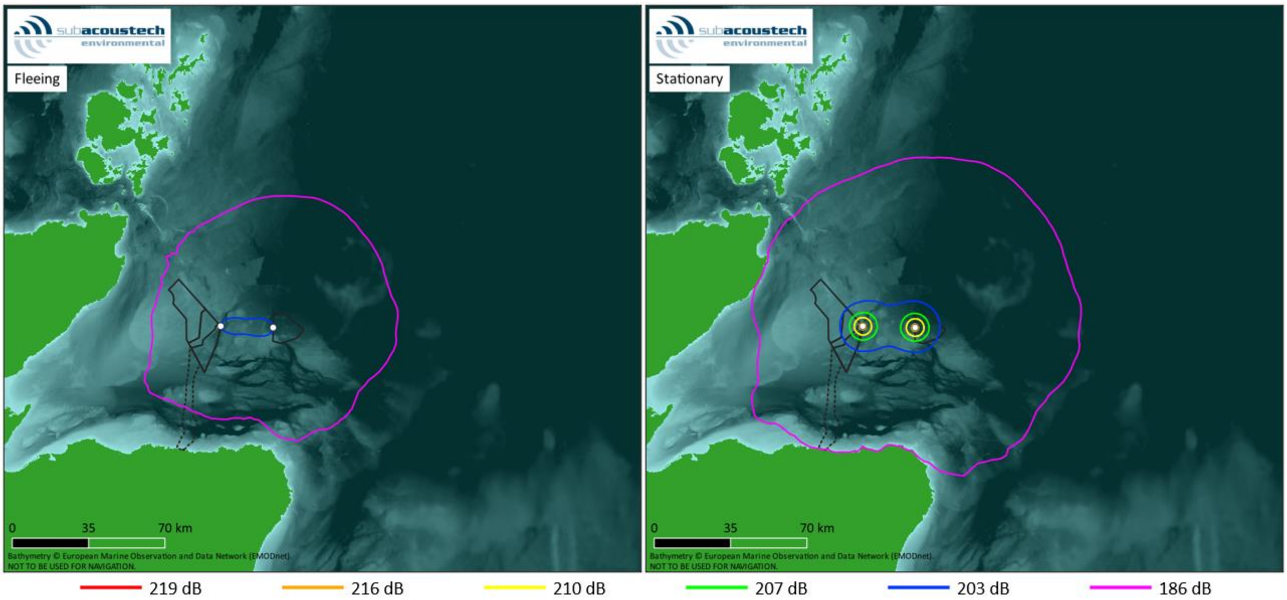


Figure 5-24: Contour plots showing the cumulative impacts of concurrent installation of multi-leg foundations at modelling location 7 at Caledonia South and another at the western edge of Broadshore OWF for fish using the pile driving Popper *et al.* (2014[32]) criteria assuming both fleeing and stationary animals.

5.8.2.5 The CIA for UWN has been informed by information and specific development environmental assessments which are available in the public domain. The full length of the anticipated construction periods of screened in developments has been considered when assessing the potential for cumulative effects. For these projects, it is therefore assumed that project parameters for the installation of foundations would be similar to those applied for the Proposed Development (Offshore) (i.e., installation of piles using impact piling and high hammer energies). Piling operations will likely represent intermittent occurrences at these OWF sites with each individual piling events likely to be similar in duration to those at Caledonia OWF.

5.8.2.6 Owing to the early stage of several of the proposed tier 2 OWF within the planning process, no site-specific information relating the scale of piling (e.g., number of piles to be piled and hammer energy used) is currently available for projects listed in Table 5-40.

5.8.2.8 It should be noted that OWFs which are already operational within the 100km UWN ZoI are anticipated to have very localised impacts associated with UWN. These include the Moray East OWF, Beatrice OWF, Hywind OWF, Aberdeen Offshore Wind Farm or European Offshore Wind Deployment Centre (EOWDC) and Green Volt OWF. None of these operational OWFs are scoped into the UWN cumulative impact assessment.

Table 5-40: OWF developments within the 100km cumulative study area.

Project	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Tier and Status	Temporal Scope	Justification
Pentland Floating OWF	74.44	96.68	Tier 1, In Planning	Construction expected to begin intake place between 2024, continuing for 18 months and 2026	Potential cumulative impacts associated with Mortality and potential mortal injury and TTS/Behavioural response during construction.
Salamander OWF	80.33	74.52	Tier 1, Concept/Early Planning	Construction anticipated to take place between 2028-2029 could take up to three years after consent awarded, no specific dates/years	Potential cumulative impacts associated with Mortality and potential mortal injury and TTS/Behavioural response during construction.
Broadshore	24.03	35.07	Tier 2, Concept/Early Planning	Scoping Report submitted in March 2024, Consent expected between Mid 2026 and mid 2027 according to Public Information Boards. Construction to take 2 – 4 years or longer so potential construction between mid 2028 and mid 2031, with commercial operation identified as early 2030s	Potential cumulative impacts associated with Mortality and potential mortal injury and TTS/Behavioural response during construction.
Stromar OWF	21.56	39.33	Tier 2, Concept/Early Planning	Scoping report suggests Stromar OWF will be commercially operational by 2030-33	Potential cumulative impacts associated with Mortality and potential mortal injury and TTS/Behavioural response during construction.

Project	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Tier and Status	Temporal Scope	Justification
Ayre OWF	48.31	77.00	Tier 2, Concept/Early Planning	Offshore construction to potentially take place between 2028-2033anticipated to take place between 2029-2033	Potential cumulative impacts associated with Mortality and potential mortal injury and TTS/Behavioural response during construction.
Buchan OWF	55.97	70.56	Tier 2, Concept/Early Planning	Scoping report suggests Buchan OWF construction will take place between 2028-20323	Potential cumulative impacts associated with Mortality and potential mortal injury and TTS/Behavioural response during construction.

5.8.2.9 There is potential for recoverable injury for group 2 and group 3 fish (203 dB SELcum, and TTS and behavioural changes and auditory masking for all fish groups, from noise and vibration as a result of construction activities associated with the Proposed Development (Offshore) and other projects. For the purposes of this CIA, other projects have been screened in based on their construction stage and location within the 100km study area.

5.8.2.10 Modelled outputs of simultaneous piling at the Caledonia OWF and at Broadshore OWF (Volume 7, Appendix 6: Underwater Noise Assessment) are presented in Table 5-41, which represent a reasonable WCS. Model outputs are shown for piling within the Caledonia OWF (CAL07) and concurrent piling at the western edge of the Broadshore OWF.

Table 5-41: Cumulative Impacts arising from UWN for concurrent pilling at both Caledonia OWF (CAL07) and Broardshore OWF.

Criteria	Noise Level (SEL_{cum})	Modelling location 07 (Caledonia OWF) – Impact area	Broadshore OWF Western Edge - Impact Area	Cumulative Impact Area
Mortality and Potentially Mortal Injury				
SEL_{cum} (static)	219 (Group 1)	2.8km^2	3.5km^2	6.9km^2
SEL_{cum} (fleeing)	219 (Group 1)	<0.1km^2	-	No cumulative effect
SEL_{cum} (static)	210 (Group 2)	45km^2	48km^2	100km^2
SEL_{cum} (fleeing)	210 (Group 2)	<0.1km^2	-	No cumulative effect
SEL_{cum} (static)	207 (Group 3)	110km^2	120km^2	250km^2
SEL_{cum} (fleeing)	207 (Group 3)	<0.1km^2	-	No cumulative effect
SEL_{cum} (static)	216 (Group 1)	7.1km^2	7.5km^2	16km^2
SEL_{cum} (fleeing)	216 (Group 1)	<0.1km^2	-	No cumulative effect
SEL_{cum} (static)	203 (Group 2 & 3)	320km^2	350km^2	910km^2
SEL_{cum} (fleeing)	203 (Group 2 & 3)	0.44km^2	0.8km^2	170km^2
SEL_{cum} (static)	186 (Group 1, 2 & 3)	10,000km^2	12,000km^2	17,000km^2
SEL_{cum} (fleeing)	186 (Group 1, 2 & 3)	4,500km^2	5,900km^2	9,700km^2

Mortality and Recoverable Injury

Magnitude of Impact

5.8.2.11 Given similar scales of development and technologies of the considered OWFs, it is anticipated that the impacts arising from these projects alone would be of similar magnitude to that predicted for Caledonia OWF. Therefore, it is considered that the maximum impact ranges for the onset of mortality and recoverable injuries for each individual project are unlikely to overlap.

5.8.2.12 As shown in Table 5-41, which presents modelled outputs of a reasonable WCS, there are slight increases in the total area of potential mortality and recoverable injury for stationary receptors, when compared to each project in isolation. For example, the SEL_{cum} contour of 219 dB (static) is 2.8km^2 for the Proposed Development (Offshore) and 3.5km^2 at the Broardshore OWF location. The cumulative impact is 6.9km^2, which is slightly over the combined total in isolation, by an additional 0.6km^2. Similar small increases (relative to the size of the in isolation contours) in the total combined area due to concurrent piling at the two projects, is also observed for the SEL_{cum} 210 dB (static) and SEL_{cum} 207 dB (static) contours. As such there is predicted to be small increases in the overall impact ranges for mortality and recoverable injury for the closest two OWF (Stromar OWF and Broadshore OWF) and no increase in predicted for all other projects. As such the magnitude of potential impact is of a similar nature and scale as the project alone assessment and is considered to be of **Low** magnitude.

Sensitivity of Receptors

5.8.2.13 As detailed under Impact 1, group 1 fish have mortality onset is at >213 dB SPL_{peak} or >219 dB SELc SEL_{cum} um and recoverable injury onset at > 216 dB SEL_{cum} and > 213 dB SPL_{peak}, they are of **Medium** sensitivity to both.

5.8.2.14 Group 2 have mortality onset at >207dB SPL_{peak} or 210dB SEL_{cum} and recoverable injury onset at 203dB SEL_{cum} and >207dB SPL_{peak}, they are of **Medium** sensitivity to both.

5.8.2.15 Group 3 fish and eggs and larvae have mortality onset at >207dB SPL_{peak} or >207dB SEL_{cum} and recoverable injury onset at 203dB SEL_{cum} and >207dB SPL_{peak} and are considered of **Medium** sensitivity to both.

Significance of Effect

5.8.2.16 The impact of mortality and recoverable injury on Group 1,2,3 receptors and eggs and larave is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

TTS and Behavioural Effects

5.8.2.17 Cumulative impacts for TTS (186dB SEL_{cum}) on fish and shellfish from pilling activities. Assuming similar noise propagation ranges for the other OWFs (Stromar, Salamander, Buchan, Ayre and Pentland Floating OWFs) compared to Caledonia OWF, noise emitted during piling may be sufficient to result in cumulative TTS or behavioural reactions in sensitive receptors. This may be sufficient to result in temporary avoidance of areas affected by UWN, with some temporary redistribution of fish in the wider area between the affected areas. Between piling events, fish may resume normal behaviour and distribution, as evidenced by work of McCauley *et al.* (2000[178]) which showed that fish returned to normal behavioural patterns within 14 to 30 minutes after the cessation of seismic airgun firing. However, there are some uncertainties over the response of fish to intermittent piling over a prolonged period and the extent that behavioural reactions will cause a negative effect in individuals.

Magnitude of Impact

5.8.2.18 The greatest risk of cumulative impacts of UWN on fish and shellfish species has been identified as being that produced by overlapping piling operations during the construction phase of other OWF sites within the 100km study area from the Proposed Development (Offshore). Table 5-40 identifies the projects that have the potential to contribute to TTS and behavioural changes resulting from UWN, including piling either in the form of concurrent piling at different wind farm sites or the long-term exposure of sensitive receptors due to sequential piling operations over prolonged periods of time.

5.8.2.19 Salamander OWF WCS piling scenario is represented by piling for anchor piles for up to 7 floating WTGs using for 1,500 kJ hammer energy across the site. Their assessment for UWN predicts no significant effect on fish and shellfish receptors. Their UWN modelling results for TTS (at 186 dB SEL_{cum}) has a maximum distance of TTS effect of 57km from the source. They concluded that based upon the temporary nature of the effect, the distance at which TTS is modelled to occur, the magnitude of disturbance from UWN generated by construction activities is considered **Low**.

5.8.2.20 Pentland Floating OWF has the potential of TTS for all fish species (186 dB SEL_{cum}) to occur up to 19km for fleeing receptors from the noise source and up to 34km for stationary receptors. Overall, they concluded the magnitude of TTS to be **Low**.

5.8.2.21 Furthermore, effects on receptors is likely to be reduced due to the implementation of soft-start and ramp-up procedures, which will allow mobile species to move away from the piling location prior to the use of highest hammer energies, thereby reducing the number of individuals at risk of mortal or recoverable injuries.

5.8.2.22 The mobile receptors are widely distributed within the region and would hence be able to move to nearby unimpacted areas. Therefore, while the concurrent or sequential piling of OWFs has the potential to result in cumulative TTS overlap, the adaptability of the receptors together with the implementation of good practice measures (i.e., soft-start procedures) is anticipated to minimise the risk of these effects occurring and they are deemed to be of **Low** magnitude.

5.8.2.23 TTS from pilling at Caledonia OWF and Broadshore has been modelled to with the WCS presented in Table 5-41. The TTS contour for the modelled scenario indicates a predicted area of 10,000km^2 for the Caledonia OWF and 12,000km^2 for Broadshore OWF for SEL_{cum} 186 dB (static). The cumulative area is predicted at 17,000km^2, which is significantly less than the sum of the two combined projects in isolation. This is expected where piling is closer together, as the areas in between the piling overlaps. As distances between piling increases, this overall area is expected to get closer to, and potentially slightly exceed the in isolation areas. Contour overlaps for this piling scenario are shown in Table 5-41.

5.8.2.24 Stromar OWF is a tier 2 development and there is limited information regarding the potential impacts associated with long term habitat loss as a result of operational activities. This impact has been included in the scoping report, however there are no details in the public domain to the extent of this impact. No significant impacts have been identified as a result of the Project.

5.8.2.25 As such there is predicted to be small increases in the overall impact ranges for TTS and behavioural effects for the closest two OWF (Stromar OWF and Broadshore OWF) and no increase in predicted for all other projects. As such the magnitude of potential impact is of a similar nature and scale as the project alone assessment and is considered to be of **Low** magnitude.

Sensitivity of Receptors

5.8.2.26 The proportions of fish spawning and nursery habitats predicted to be affected by cumulative impacts arising from underwater noise from construction activities such as piling operations are expected to be of relatively small spatial extent, particularly in the context of available spawning and nursery habitats within the North Sea. However, there will be overlap in cumulative UWN impacts with sandeel spawning and herring spawning grounds. Additionally, TTS and behavioural changes are likely to occur within thee magnitude ranges, with the relative risk of behavioural responses at far distances (<1,000m) considered to be low (Popper *et al.,* 2014[32]).

Group 1 IEFs

5.8.2.27 Considering the proximity to sandeel spawning grounds and their substrate dependency, the sensitivity of sandeel to TTS is considered to be **Low** to cumulative impacts from TTS and behavioural effects.

Group 2 IEFs

5.8.2.28 As discussed previously, diadromous species such as Atlantic salmon and sea trout are present throughout several of the rivers which flow into the Moray Firth (i.e., River Spey and River Deveron and are likely to migrate past the Caledonia OWF and other OWFs (such as Broadshore, Stromar) during their migration to and from these rivers. Please refer back to the Proposed Development (Offhore) alone assessment the potential barrier effects from TTS for migratory diadromous species. These receptors have been deemed to be of medium vulnerability and recoverability and are of regional (sea trout) to international (Atlantic salmon) importance. They have therefore been assessed as having **Medium** sensitivity to cumulative impacts from UWN.

Group 3 IEFs

5.8.2.29 Considering the overlap of the TTS noise contours with the historic Buchan and Orkney/Shetland herring spawning grounds (Coull *et al.,* 1998[94]) and of areas of low-density herring larvae, and the broadscale distribution of available spawning substrates for herring across the North Sea, underwater noise from piling is not anticipated to cause a population level effect, and therefore the sensitivity of cumulative impacts on spawning herring is considered to be **Low**.

Eggs and Larvae

5.8.2.30 Cod, herring, lemon sole, mackerel, plaice, sandeel, sole, sprat and whiting all have spawning grounds within the study. Eggs and larvae are considered organisms of concern by Popper *et al.* (2014[32]), due to their vulnerability, reduced mobility and small size. Taking this into consideration and given the broadscale nature of the spawning grounds, the sensitivity of eggs and larvae to cumulative TTS from underwater noise is considered to be **Medium**.

Shellfish IEFs

5.8.2.31 Shellfish do not possess swim bladders or other gas filled organs and are primarily sensitive to particle motion and disturbance from UWN rather than sound pressure (Popper and Hawkins, 2018[154]). Taking this into consideration, shellfish IEFs within the study area are deemed to be of local to international importance, medium vulnerability, and high recoverability. The sensitivity of these receptors is therefore considered to be **Low.**

Significance of Effect

Group 1 IEFs

5.8.2.32 Cumulative impact of TTS on sandeel is assessed as **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

5.8.2.33 Cumulative impact of TTS on fleeing Group 1 IEFs is considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Group 2 IEFs

5.8.2.34 Cumulative impact of TTS on Group 2 IEFs (Atlantic salmon and sea trout) are considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Group 3 IEFs

5.8.2.35 Cumulative impact of TTS on spawning adult herring are considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.8.2.36 Cumulative impact of TTS on Group 3 fleeing IEFs are considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Eggs and Larve

5.8.2.37 Cumulative impact of TTS on eggs and larvae are considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

Shellfish IEFs

5.8.2.38 Cumulative impact of TTS on shellfish are considered to be of **Low** magnitude, and the maximum sensitivity of the receptor is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

Summary of Effect

5.8.2.39 A summary of effects arising from cumulative UWN are presented in Table 5-42.

Table 5-42: Summary of Effects arising from Cumulative UWN.

Effect	Receptor Group	Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure Code	Residual Effect
Mortality and Potential Mortal Injury	Group 1	Low	Medium	Minor Adverse	M-11	Minor Adverse
	Group 2	Low	Medium	Minor Adverse		Minor Adverse
	Group 3	Low	Medium	Minor Adverse		Minor Adverse
	Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible
Recoverable Injury	Group 1	Low	Medium	Minor Adverse	M-11	Minor Adverse
	Group 2	Low	Medium	Minor Adverse		Minor Adverse
	Group 3	Low	Medium	Minor Adverse		Minor Adverse
	Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible
TTS	Group 1	Low	Medium	Minor Adverse	M-11	Minor Adverse
	Group 2	Low	Medium	Minor Adverse		Minor Adverse
	Group 3	Low	Medium	Minor Adverse		Minor Adverse
	Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible

Effect	Receptor Group	Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure Code	Residual Effect
Behavioural Effects	Group 1	Low	Low	Negligible	M-11	Negligible
	Group 2	Low	Medium	Minor Adverse		Minor Adverse
	Group 3	Low	Low	Negligible		Negligible
	Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible
UXO Clearance	Group 1	Low	Low	Negligible	M-96	Negligible
	Group 2	Low	Medium	Minor Adverse		Minor Adverse
	Group 3	Low	Low	Negligible		Negligible
	Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible

Cumulative Temporary Increase in Suspended Sediment and Sediment Deposition

5.8.2.40 Due to uncertainty associated with the exact timing of other projects and activities, there is insufficient data on which to undertake a quantitative or semi-quantitative assessment. As such, the discussion presented here is qualitative. It is considered unlikely that each of the identified projects would be undertaking major maintenance works, in particular asset reburial or repairs, as these are infrequent occurrences during the lifetime of developments.

5.8.2.41 Sediment plumes from O&M activities are generally short-lived, with major maintenance works infrequent. Any impacts from operational offshore windfarm export cables (and other subsea cables) activities are therefore likely to be short-lived and of localised extent, with limited opportunity to overlap with the Proposed Development (Offshore) activities. The Moray East OWF OECC is currently under construction and is expected to be fully operational by the end of 2025, therefore maintenance related impacts are similarly considered to be primarily short-lived and localised. Accordingly, the potential for cumulative interaction with these sites is limited and therefore has not been assessed further.

5.8.2.42 As detailed by the numerical modelling within Volume 2, Chapter 2: Marine and Coastal Processes (also see Volume 7B, Appendix 2-2: Marine and Coastal Processes Numerical Modelling Report), impacts for all construction activities (both in terms of SSCs and sedimentation) were predicted to mainly be confined to occur within the Caledonia OWF and/or along the Caledonia OECC. Given the short-lived nature of the sediment plumes, alongside the location of other infrastructure, there is not anticipated to be a notable overlap with concentrated sediment plumes created from other industry activities.

5.8.2.43 There is potential for cumulative temporary increases in SSC and sediment deposition as a result of construction of the Proposed Development (Offshore) and construction, operation and decommissioning activities associated with other projects. For the purposes of this assessment, this impact has been assessed from projects that fall within the 10km secondary ZoI, which is defined based on the expected maximum distance that sediments from within the Caledonia OWF and Caledonia OECC might be transported on a single mean spring tide, in the flood and/or ebb direction.

5.8.2.44 Table 5-43 identifies the projects that have the potential to contribute to cumulative temporary increases in SSCs and sediment deposition. This includes OWFs, marine sediment disposal sites and existing cables within the 10km secondary ZoI. Activities associated with these project that can give rise to increases in SSC and sediment deposition include seabed preparation works, sediment disposal, the drilling of foundations, and the installation and maintenance of cables.

Table 5-43: Projects with the potential to contribute to cumulative temporary increases in SSCs and sediment deposition.

Project	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Tier and Status	Temporal Scope	Justification
Moray East OWF	5.14	3.44	Tier 1 Operational	Operational	Potential for cumulative impacts from SSC and sediment deposition during intermittent maintenance activities.
Beatrice OWF	4.90	22.00	Tier 1 Operational	Operational	Potential for cumulative impacts from SSC and sediment deposition during intermittent maintenance activities.
Caithness HVDC subsea cable	0	2.83	Tier 1 Operational	Operational	Active power cable. Potential for cumulative impacts from SSC and sediment deposition during intermittent cable maintenance activities.
Shefa 2	0	0	Tier 1 Operational	Operational	Active telecommunication cable. Potential for cumulative impacts from SSC and sediment deposition during intermittent cable maintenance activities.
Shetland HVDC Link	12.6	43.4	Tier 1 Construction/ Operational	Construction expected to be complete by the end of 2024	Construction of subsea power cable. Potential to be operational by the time the Proposed Development (Offshore) undergoes construction for cumulative impacts from SSC and sediment deposition during intermittent cable maintenance activities.
Stromar OECC	7.69	12.49	Teir 2 Scoping	Scoping report suggests will be commercially operational by 2030-33	Potential for cumulative impacts from SSC and sediment deposition during construction and/or intermittent maintenance activities.

Magnitude of Impact

5.8.2.45 Sediment plumes and sediment deposition resulting from these activities are expected to be short-lived and of localised extent, with limited opportunity to overlap with the Proposed Development (Offshore) activities. The Moray East OWF is currently under construction and is expected to be in service by the end of 2025, therefore maintenance-related impacts are similarly considered to be primarily short-lived and localised. Accordingly, the potential for cumulative interaction with these projects is limited. Therefore, on account of the distance of the majority of these impacts from the zones of highest impact, the magnitude of the impact is predicated to be of small spatial extent, short term duration, intermittent and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptor

5.8.2.46 The fish and shellfish communities within the Caledonia OWF and Caledonia OECC are typical of the wider North Sea where relatively high levels of SSC occur naturally. Consequently, communities are exposed to and tolerant of variations in SSC and some degree of sediment deposition. The sensitivity rating assigned to each IEF, and associated justification is the same as evidenced for Impact 2. The maximum sensitivity of the fish and shellfish receptors within the region to increases in SSC and sediment deposition is **Medium**.

Significance of Effect

5.8.2.47 Based on the above the impact of cumulative temporary increases in SSC and sediment deposition is considered to be of **Low** magnitude, and the maximum sensitivity of receptors affected is considered to be **Medium** for fish and shellfish species. The significance of cumulative effects is therefore concluded to be **Minor and Not Significant in EIA terms**.

Cumulative Temporary Habitat Loss and Disturbance

5.8.2.48 Temporary habitat loss and disturbance because of activities associated with the construction of the Proposed Development (Offshore) and the other plans and projects. Temporary habitat loss and disturbance will be a likely occurrence from foundation seabed preparation, the use of jack-ups and anchored vessels and cable seabed preparation and installation works. These activities have the potential to impact on fish and shellfish ecology via direct loss/disturbance to individuals and the temporary removal of essential habitats for survival (e.g., spawning, nursery and feeding habitats).

5.8.2.49 Table 5-44 identifies the projects that have the potential to contribute to cumulative temporary habitat loss and disturbance. This includes OWFs, marine sediment disposal sites and existing cables within the 10km secondary ZoI.

Table 5-44: Projects with the potential to contribute to cumulative temporary habitat loss and disturbance.

Project	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Tier	Temporal Scope	Justification
Moray East OWF	5.14	3.44	Tier 1 Operational	Operational	Potential for cumulative impacts from temporary habitat loss and disturbance during intermittent maintenance activities.
Beatrice OWF	4.90	22.00	Tier 1 Operational	Operational	Potential for cumulative impacts from temporary habitat loss and disturbance during intermittent maintenance activities.
Moray West OWF and OECC	5.30	8.3	Tier 1 Under Construction	Construction expected to be complete by the end of 2024	Potential for cumulative impacts from temporary habitat loss and disturbance during intermittent maintenance activities.
Caithness HVDC subsea cable	0	2.83	Tier 1 Operational	Operational	Potential for cumulative impacts from temporary habitat loss and disturbance during intermittent maintenance activities.
Shefa 2	0	0	Tier 1 Operational	Operational	Potential for cumulative impacts from temporary habitat loss and disturbance during intermittent maintenance activities.
Shetland HVDC Link	12.6	43.4	Tier 1 Construction/ Operational	Construction expected to be complete by the end of 2024	Construction of subsea power cable. Potential to be operational by the time the Proposed Development (Offshore) undergoes construction for cumulative impacts from temporary habitat loss and disturbance during intermittent cable maintenance activities.
Stromar OECC	7.69	12.49	Teir 2 Scoping	Scoping report suggests will be commercially operational by 2030-33	Potential for cumulative impacts from temporary habitat loss and disturbance during construction and/or intermittent maintenance activities.

Magnitude of Impact

5.8.2.50 The maximum area of temporary habitat loss across Caledonia OWF and OECC due to JuVs and anchoring operations, cable preparation and installation, the presence of foundations and their scour protection and seabed preparation works (presented in Table 5-20) is 17.4km^2 which equates to 3.3% of the total seabed areas within the Proposed Development (Offshore). Comparable habitats and fish and shellfish species assemblages are present and widespread within the wider area.

5.8.2.51 Moray East OWF has a WCS temporary disturbance footprint of 0.71km^2 for the maintenance of infrastructure in the array area. The potential for disturbance from maintenance works in the OECC were not assessed. However, no significant effects were concluded on fish and shellfish receptors from temporary habitat loss and disturbance associated with associated with O&M activities for the Moray East OWF.

5.8.2.52 Moray West OWF is under construction until 2024. There is therefore the potential for cumulative effects during the operation of the OWF, from intermittent maintenance activities. The potential for habitat disturbance from maintenance works during the operation of the Moray West OWF were not assessed. However, no significant effects were concluded on fish and shellfish receptors from temporary habitat loss and disturbance.

5.8.2.53 The potential for habitat disturbance from maintenance works during the operation of the Beatrice OWF were not assessed. However, no significant effects were concluded on fish and shellfish receptors from temporary habitat loss and disturbance.

5.8.2.54 Any cable replacement works on the Caithness HVDC subsea cable will be done using a cable laying vessel and replacement cable section will be buried by post lay jet trenching (with a minimum target cover depth of 0.6m). The maximum footprint of this will be 3m wide. Where burial is not successful, there is the potential that some form of additional protection may be required. Additionally, the total footprint of temporary seabed disturbance via cable excavation/new cable installation equates to 1.1km^2.

5.8.2.55 Any replacement cable works on Shefa 2 subsea cables will be done using a cable laying vessel and replacement cable section will be buried by post lay jet trenching. Where burial is not successful, there is the potential that some form of additional protection may be required.

5.8.2.57 Maintenance activities for Shetland HCDV may include, but are not limited to (Shetland HCDV Inspection, Repair and Maintenance Plan (2021[373]):

- Maintaining designed cable protection levels through re-burial, or remedial rock placement;
- Maintaining rock berms at subsea asset crossings;
- Removing potential snagging risks;
- Rectification of free-spans;
- Remediation of threats to the cable system associated with mobile sediments; and
- Removal of other threats to the cable system

5.8.2.58 Stromar OECC is a tier 2 development and there is limited information regarding the potential impacts associated with long term habitat loss as a result of operational activities. This impact has been included in the scoping report, however there are no details in the public domain to the extent of this impact.

5.8.2.59 Taking the above into account, the cumulative temporary habitat loss and disturbance from construction activities at the Proposed Development (Offshore) and O&M activities of other nearby developments would therefore impact a very limited footprint. Any cumulative temporary habitat loss and disturbance is not expected to undermine regional ecosystem functions or diminish biodiversity. Therefore, the cumulative temporary habitat loss and disturbance associated with construction activities is predicted to be of local spatial extent, of short-term duration and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptors

5.8.2.60 The sensitivity rating assigned to each IEF, and associated justification is the same as evidenced for Impact 3.

5.8.2.61 Spawning herring are deemed to be of medium vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **Medium** to cumulative temporary habitat loss and disturbance.

5.8.2.62 Sandeel are deemed to be of medium vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is **Medium** to cumulative temporary habitat loss and disturbance.

5.8.2.63 All other IEFs (including all other fish, shellfish and elasmobranchs) are deemed to be of low vulnerability, high recoverability and of regional importance, and therefore the sensitivity of these receptor is **Low** to cumulative temporary habitat loss and disturbance.

Significance of Effect

5.8.2.64 The impact of cumulative temporary habitat loss and disturbance on sandeel is considered to be of **Low** magnitude, and the sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.8.2.65 The impact of cumulative temporary habitat loss and disturbance on spawning herring is considered to be of **Low** magnitude, and the sensitivity of the receptor is considered to be **Medium**. The significance of the effect is therefore concluded to be **Minor and Not Significant in EIA terms**.

5.8.2.66 The impact of cumulative temporary habitat loss and disturbance on all other fish and shellfish receptors is considered to be of **Low** magnitude, and the maximum sensitivity of the receptors is considered to be **Low**. The significance of the effect is therefore concluded to be **Negligible and Not Significant in EIA terms**.

5.8.2.67 Overall, the cumulative temporary habitat loss and disturbance during the construction phase will represent a short-term and localised effect. The magnitude of the impact was determined to be **Low**. The maximum sensitivity of the receptors was assessed as **Medium**. The significance of the effect is therefore considered to be a maximum of **Minor and Not Significant in EIA terms**.

5.8.3 Operation and Maintenance

Cumulative Long-term Habitat Loss

5.8.3.1 There is potential for cumulative long-term habitat loss as a result of operation and maintenance activities associated with the Proposed Development (Offshore) and other projects. For the purposes of this assessment, long term habitat loss been assessed from projects that fall within the 10km secondary ZoI.

5.8.3.2 Table 5-45 identifies the projects that have the potential to contribute to cumulative long-term habitat loss. This includes OWF projects and existing cables within the 10km secondary ZoI.

Table 5-45: Projects with the potential to contribute to cumulative long-term habitat loss.

Project	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Tier	Temporal Scope	Justification
Moray East OWF	5.14	3.44	Tier 1 Operational	Operational, but considered to have an ongoing impact	Contribution to cumulative long-term habitat loss due to placement of infrastructure and cable protection.
Beatrice OWF	4.9	22	Tier 1 Operational	Operational, but considered to have an ongoing impact	Contribution to cumulative long-term habitat loss due to placement of infrastructure and cable protection.
Moray West OECC	5.30	8.3	Tier 1 Operational	Construction expected to be complete by the end of 2024	Contribution to cumulative long-term habitat loss due to placement of infrastructure and cable protection.
Caithness HVDC subsea cable	0	2.83	Tier 1 Operational	Operational, but considered to have an ongoing impact	Potential contribution to cumulative long-term habitat loss due to existing cable protection.
Shefa 2	0	0	Tier 1 Operational	Operational, but considered to have an ongoing impact	Potential contribution to cumulative long-term habitat loss due to existing cable protection
Shetland HVDC Link	12.6	43.4	Tier 1 Construction/ Operational	Construction expected to be complete by the end of 2024	Potential contribution to cumulative long-term habitat loss due to existing cable protection.
Stromar OECC	7.69	12.49	Tier 2 Scoping	Scoping report suggests Stromar OWF will be commercially operational by 2030-33	Contribution to cumulative long-term habitat loss due to placement of infrastructure and cable protection.

Magnitude of Impact

5.8.3.3 The presence of infrastructure in the marine environment, including turbine foundations, scour protection and cable protection will cause long-term changes in the extent and distribution of sedimentary habitats. This may affect the distribution and abundance of sensitive fish and shellfish receptors that depend on the seabed for part of, or all of their life cycle, either directly or indirectly. The estimated long term habitat loss for the Proposed Development (Offshore) is expected to be 9.3km^2 and for this as a stand alone impact the magnitude has been assessed as low. The tier 1 and 2 projects screened into this assessment are already operational and expected to have cumulative impacts associated with long term habitat loss (Table 5-46).

5.8.3.4 Moray East OWF has a WCS of 3.76km^2 for long term habitat loss associated with gravity-based foundations, scour protection and cable protection.

5.8.3.5 Beatrice OWF has a WCS of 11.6km^2 for long term habitat loss associated with foundations, scour protection and cable protection.

5.8.3.6 The total footprint across the Moray West OWF and OECC which could be subject to habitat loss during operation is 6.3km^2.

5.8.3.7 The Caithness HVDC subsea cable is 260km long. Any replacement cable works will be done using a cable laying vessel and replacement cable section will be buried by post lay jet trenching (with a minimum target cover depth of 0.6m. The maximum footprint of this will be 3m wide. Where burial is not successful, there is the potential that some form of additional protection may be required.

5.8.3.8 Shefa 2 subsea cable is approximately 1,000km long. Any replacement cable works will be done using a cable laying vessel and replacement cable section will be buried by post lay jet trenching. Where burial is not successful, there is the potential that some form of additional protection may be required.

5.8.3.9 The Shetland HCDV link will be 260km long. Any replacement cable works will be done using a cable laying vessel and replacement cable section will be buried by post lay jet trenching. Where burial is not successful, there is the potential that some form of additional protection may be required.

5.8.3.10 Stromar OECC is a tier 2 development and there is limited information regarding the potential impacts associated with long term habitat loss as a result of operational activities. This impact has been included in the scoping report, however there are no details in the public domain to the extent of this impact. No significant impacts have been identified as a result of the Project.

Table 5-46: Total contribution to cumulative long-term habitat loss.

Project	Tier	Long-term Habitat Loss (km^2)
Moray East OWF	1	3.67
Moray West OWF and OECC	1	11.6
Beatrice OWF	1	6.3
The Proposed Development (Offshore)	1	9.3
Stromar OECC	2	No available
Caithness HVDC subsea cable	1	No available
Shefa 2	1	No available
Shetland HVDC Link	1	No available
Total		**30.87**

5.8.3.11 While temporary habitat loss will be locally impactful and comprise a permanent change in seabed habitat within the footprint of the structures and scour and cable protection, the footprint of the area affected is highly localised. The seabed habitats that would be affected are common and widespread both within the assessed ZoI and wider region. Likewise, the fish and shellfish species assemblages that rely on these habitats are common and widespread throughout the wider region and also use comparatively large areas for spawning in the context of the localised loss of substratum. Consequently, the magnitude of the impact is predicated to be of small spatial extent, long term duration, continuous and reversible, therefore the magnitude of the impact is deemed to be **Low**.

Sensitivity of Receptor

5.8.3.12 The maximum sensitivity of the fish and shellfish receptors within the study area to long-term habitat loss is **Medium**.

Significance of Effect

5.8.3.13 Overall, it is predicted that the cumulative impact of long-term habitat loss on fish and shellfish receptors is considered to be of **Low** magnitude, and the maximum sensitivity of receptors affected is considered to be **Medium**. The significance of cumulative effects is therefore concluded to be **Minor and Not Significant in EIAR terms**.

Cumulative Impacts from EMF

5.8.3.14 There is potential for cumulative impacts arising from EMF as a result of operation activities associated with the Proposed Development (Offshore) and other projects. For the purposes of this assessment, this cumulative impact has been assessed from projects that fall within the fish and shellfish ecology 10km secondary ZoI.

5.8.3.15 Table 5-47 identifies the projects that have the potential to contribute to cumulative impacts arising from EMF; this includes OWF projects and active power cables within the 10km secondary ZoI.

Table 5-47: Projects with the potential to contribute to cumulative impacts from EMF.

Project	Distance to Caledonia OWF (km)	Distance to Caledonia OECC (km)	Tier	Temporal Scope	Justification
Moray East OWF	5.14	3.44	Tier 1 Operational	Operational, but considered to have an ongoing impact	Contribution to cumulative operational EMF impacts.
Beatrice OWF	4.90	22.00	Tier 1 Operational	Operational, but considered to have an ongoing impact	Contribution to cumulative operational EMF impacts.
Moray West OECC	5.30	8.3	Tier 1 Operational	Construction expected to be complete by the end of 2024	Contribution to cumulative operational EMF impacts.
Caithness HVDC	0	2.83	Tier 1 Operational	Operational, but considered to have an ongoing impact	Contribution to cumulative operational EMF impacts.
SHEFA 2	0	0	Tier 1 Operational	Operational, but considered to have an ongoing impact	Contribution to cumulative operational EMF impacts.
Shetland HVDC Link	12.6	43.4	Tier 1 Construction/ Operational	Construction expected to be complete by the end of 2024	Contribution to cumulative operational EMF impacts.
Stromar OECC	7.69	12.5	Tier 2 Concept/Early Planning	Scoping report suggests Stromar OWF will be commercially operational by 2030-33	Contribution to cumulative operational EMF impacts.

Magnitude of Impact

5.8.3.16 The potential magnitude of effects from EMF during operation of the Proposed Development (Offshore) has been assessed as low, based on the rapid attenuation of EMF within the environment and the localised nature of behavioural changes in sensitive fish and shellfish IEFs. Based on similar technology and project designs, the extent of EMF emissions from other OWF projects considered in the cumulative impact assessment is also expected to be highly localised and restricted to areas within the immediate proximity of the cables. There is potential for cumulative effects from EMF between the Proposed Development (Offshore), Moray East OWF, Moray West OWF, Beatrice OWF, Stromar OECC, the Caithness HVDC subsea cable, Shefa 2 subsea cable and Shetland HVDC Link, leading to potential cumulative impacts arising from EMF (see Table 5-48).

5.8.3.17 The WCS for EMF from Moray West OWF & OECC has been derived from the maximum length of inter-array cables, OSP interconnector cables and offshore export cable circuits (total of 420km). It concluded a **Low** magnitude for EMF emissions effect on fish and shellfish receptors, as the emissions will be of limited strength and will be highly localised in terms of spatial extent.

5.8.3.18 The WCS for EMF from Moray East OWF of has been derived from the maximum length of inter-array (572km). It concluded a **Low** magnitude for EMF emissions effect on fish and shellfish receptors due to emissions will be of limited strength and will be highly localised in terms of spatial extent.

5.8.3.19 The WCS for EMF from Beatrice OWF has been derived from the maximum length of inter-array (350km) and an export cable corridor of 65km. It concluded a **Low** magnitude for EMF emissions effect on fish and shellfish receptors due to emissions will be of limited strength and will be highly localised in terms of spatial extent.

5.8.3.20 Stromar OECC is a tier 2 development and there is limited information regarding the potential impacts associated with EMF. This impact has been included in the scoping report for, however there are no details in the public domain to the extent of this impact.

5.8.3.21 EMF emitted from the Caithness HVDC subsea cable is of local spatial extent along its 260km length and EMF emitted from the cable are considered to be small in relation to the wider environment. The minimum burial depth for this cable is 0.6m. The magnitude of any potential impact is therefore expected to be **Low**.

5.8.3.22 EMF emitted from the Shefa 2 subsea cable is of local spatial extent along its 1000km length due to the attenuation EMF from the cable being small in relation to the wider environment. From an EIAR perspective, there is limited information regarding the potential impacts associated with EMF for this project.

5.8.3.23 EMF emitted from the Shetland HCDV link is of local spatial extent along its 260km length and EMF emitted from the cable are small in relation to the wider environment. From an EIAR perspective, there is limited information regarding the potential impacts associated with EMF for this project.

Table 5-48: Total cumulative length of subsea cabling.

Project	Tier	Total Cable Length (km)
Moray East OWF	1	572
Caledonia OWF	1	1,100
Beatrice OWF	1	415
Moray West OWF and OECC	1	420
Stromar OECC	2	No information available
Caithness HVDC	1	260
SHEFA 2	1	1,000
Shetland HVDC Link	1	260
Total		**4,072**

5.8.3.24 As such, as per the Proposed Development (Offshore) alone assessment, any cumulative behavioural responses of EMF-sensitive fish and shellfish receptors are deemed to be of local spatial extent, and the magnitude of cumulative emissions of EMF and their effects on sensitive receptors is assessed as **Low**.

Sensitivity of Receptors

5.8.3.25 The maximum sensitivity of the fish and shellfish receptors within the study area to cumulative impacts from EMF is **Medium**.

Significance of Effect

5.8.3.26 Taking the maximum **Medium** sensitivity of the fish and shellfish IEFs (i.e., diadromous fish) and the **Low** magnitude of the impact, the overall cumulative effect arising from EMF during operation and maintenance is considered to be **Minor and Not Significant in EIAR terms**.

Basking sharks

5.8.4 Construction

Cumulative Disturbance Resulting from Underwater Noise Arising from Construction Activity

5.8.4.1 UWN modelling has been undertaken to show the potential for cumulative impacts between the Proposed Development (Offshore) and other projects in the vicinity. Broadshore is located in close proximity to the Proposed Development (Offshore), potential cumulative effects of concurrent piling at Caledonia South Site and Broadshore have been modelled (Volume 7, Appendix 6: Underwater Noise Assessment). Although Broadshore is not the closest potential project (e.g., Stromer OWF is located 2km closer than Broadshore), the modelled outputs are considered to represent a foreseeable WCS for assessing cumulative impacts of UWN of the Proposed Development (Offshore). Modelling assumed that the piling operations at each location start at the same time.

5.8.4.2 In general, if simultaneous piling operations from two different projects are closer together, it will result in an overall increase in the louder noise contours (mortality and recoverable injury) and potentially a reduction in the overall area in the TTS contour. Whereas if the operations are further apart, but still close enough for noise to interact, there is less likely to be any increase in the louder noise contours (mortality and recoverable injury), but the area of TTS contours may increase to a much larger area.

5.8.4.3 Given similar scales of development and technologies of the considered OWFs within the ZoI, it is anticipated that the impacts arising from these projects alone would be of similar magnitude to that predicted for Caledonia South Site. Therefore, it is considered that the maximum impact ranges for the onset of mortality and recoverable injuries for each individual project are unlikely to overlap and are not assessed.

5.8.4.4 Whereas noise emitted from construction activities (such as piling) may result in cumulative TTS or behavioural changes in sensitive receptors. For basking sharks, this may be sufficient to result in temporary avoidance of areas, however, Popper *et al.* (2014[32]) suggest that high risk of masking or behavioural effects from pile driving activities on basking sharks would only occur within tens to hundreds of metres from the noise sources, with risk reducing to low at far distances (thousands metres) from the sources

Magnitude of Impact

5.8.4.5 Following the cumulative underwater noise from construction activity for fish and shellfish assessment above, basking sharks are highly mobile and have a wide distribution within Scottish waters and would hence be able to move to nearby unimpacted areas. Therefore, while the concurrent or sequential piling of OWFs has the potential to result in cumulative TTS overlap, the adaptability of the together with the implementation of good practice measures (i.e., soft-start procedures) is anticipated to minimise the risk of these effects occurring.

5.8.4.6 The potential impact of TTS is estimated to be greatly reduced by the soft-start with the adoption of soft starts and ramp up procedure from the initiation of piling activity as embedded mitigation outlined in the Piling Strategy (M-11, Table 5-19). Considering the intermittent and short-term duration of the impact of TTS, masking or behavioural effects are estimated to only affect a very small proportion of the shark population and is unlikely to alter the population trajectory as any potential impact will be of short-term duration, intermittent and reversible.

5.8.4.7 Whilst there is predicted to be small increases in the overall impact ranges for TTS and behavioural effects for the closest two OWF (Stromar and Broadshore OWFs), there are no increases in predicted impact ranges for all other projects. As such the magnitude of potential impact is of a similar nature and scale as the project alone assessment and is considered to be of **Low** magnitude.

Sensitivity of Receptor

5.8.4.8 As per the Proposed Development (Offshore) alone assessment (Section 5.7.4.24), basking sharks are of a low vulnerability, high recoverability and adaptability to underwater bouse impacts from construction activities. As a highly mobile species with a wide distribution within Scottish waters, the sensitivity of basking sharks as a result of cumulative TTS and behavioural effects has been concluded to be **Low**.

Significance of Effect

5.8.4.9 Considering the **Low** magnitude of TTS, masking and behavioural effects and the **Low** sensitivity of basking sharks, the overall significance of the cumulative effect of underwater noise from construction activities is therefore concluded to be **Negligible and Not Significant in EIA terms**.

5.8.5 Operation and Maintenance

Cumulative Disturbance Resulting from Underwater Noise from Operational Noise

5.8.5.1 The main source of underwater noise from operating wind turbines comes from the mechanically generated vibration of the nacelle and wind-induced vibration of the turbine tower radiating to the foundations and surrounding water (Nedwell *et al*., 2003[290]; Tougaard *et al.,* 2020[291]; Thomsen *et al.,* 2023[348]). The operational WTG noise is considered non-impulsive and continuous in nature, and its energy is primarily of low frequencies of below 1kHz (Thomsen *et al.,* 2006[349]). While underwater sound is expected to increase with increasing turbine size (Tougaard *et al.,* 2020[291]), WTGs with new direct drive technology will produce considerably less underwater noise compared to the older geared turbines. For instance, Stöber and Thomsen (2021[295]) have identified a noise reduction of around 10dB in newer WTGs using direct drive technology compared to the same size geared turbine.

5.8.5.2 In addition to WTG noise, it is estimated that floating WTGs (semi-submersible and tension leg platform foundations) and WTGs with FRP foundations in the Caledonia OWF could potentially introduce another underwater noise source from the tension release in mooring-related structures and dynamic cables (Martin *et al.,* 2011[350]; Xodus, 2015[351]). The dynamic motion of moorings, in particular those in semi-taut or catenary configuration, may generate noise as dynamic inter-array cables connecting the turbines move through the water column, and as the anchors or mooring lines interact with the water. The noise from moorings is also expected to be non-impulsive and continuous in nature.

Magnitude of Impact

5.8.5.3 The estimated TTS impact range of WTG noise from floating WTGs, considering a power output of 2.3MW per WTG for the Proposed Development and the noise modelling formula presented by Tougaard *et al.* (2020[291]) is predicted to be less than 20m. The basking shark would also need to be very close to the operational turbine for 12hours continuously for TTS onset to occur, which is considered unlikely.

5.8.5.4 Any effect from underwater noise during the operational phase of Proposed Development (Offshore) will be localised. It is also anticipated that any potential behavioural response arising from exposure to operational noise will be limited to the array area of respective projects, and will not result in complete exclusion of animals from the array. Therefore, despite an increase in the footprint of operational windfarms up to 2033, the cumulative impact of operational noise is anticipated to affect only a small proportion of the basking shark population and unlikely to alter the population trajectory as any potential impact will be of short term duration, intermittent and reversible.

5.8.5.5 Therefore, the magnitude of disturbance from operation noise has been assessed as **Negligible** to basking sharks**.**

Sensitivity of Receptor

5.8.5.6 As per the Proposed Development (Offshore) alone assessment, basking sharks are of low vulnerability, high recoverability and adaptability to underwater noise impacts. Basking sharks are highly mobile and have a wide distribution within Scottish waters, therefore the sensitivity of basking sharks to operational noise from WTGs and is assessed as **Low**.

Significance of Effect

5.8.5.7 Taking the **Negligible** magnitude of operational noise from WTGs and the **Low** sensitivity of basking sharks, the overall cumulative effect of disturbance from operational noise is considered to be **Negligible and Not Significant in EIA terms**.

Risk of Secondary Entanglement

5.8.5.8 There are a number of floating OWF projects being developed in Scottish waters, including Green Volt, Ossian, Pentland Floating, Salamander, Ayre, Bowdun, Broadshore, Buchan, Cenos, Culzean, Muir Mhor, Sinclair, Bellrock, Havbredey and Talisk.

5.8.5.9 It is expected that all projects considered in the cumulative impact assessment will commit to risk-based adaptive approach to the inspections of the mooring lines and cables present in the water column.

Magnitude of Impact

5.8.5.10 The risk of secondary entanglement is restricted to the respective array areas so is of local spatial extent and temporary (dynamic infrastructure will be removed from the water column at the end of the O&M phases of respective projects). There is a risk of entanglement to take place over the lifetime of the projects (long term). If the effect would occur, it is anticipated that it would affect a small proportion of the receptor population and is therefore unlikely to alter population trajectories. Risk is further reduced by the embedded mitigation within the EMP (M-8; Table 5-19) which includes the inspections of the mooring lines and cables present in the water column. The magnitude of entanglement to basking sharks is assessed as **Low**.

Sensitivity of Receptor

5.8.5.11 As per the Proposed Development (Offshore) alone assessment, basking sharks are estimated to be of moderate vulnerability, limited recoverability and reasonable adaptability to entanglement impact. Therefore, the sensitivity of basking sharks to secondary entanglement risks is considered to be **Medium**.

Significance of Effect

5.8.5.12 Taking the **Medium** sensitivity and the **Low** magnitude of entanglement to basking sharks, the overall cumulative effect of secondary entanglement during operation and maintenance is assessed as **Minor and Not Significant in EIA terms**.

Cumulative Impact from EMF

5.8.5.13 There is potential for cumulative impacts arising from EMF as a result of operation activities associated with the Proposed Development (Offshore) and other projects. For the purposes of this assessment, this cumulative impact has been assessed from projects that fall within the fish and shellfish ecology secondary ZoI.

5.8.5.14 Table 5-47 identifies the projects that have the potential to contribute to cumulative impacts arising from EMF; this includes OWF projects and active power cables within the 10km secondary ZoI.

Magnitude of Impact

5.8.5.15 There is potential for cumulative effects from EMF between the Proposed Development (Offshore), Moray East OWF, Moray West OWF, Beatrice OWF, Stromar OWF, Stromar OECC, the Caithness HVDC subsea cable, Shefa 2 subsea cable and Shetland HVDC Link, leading to potential cumulative impacts arising from EMF.

5.8.5.16 As such, any cumulative impacts arising from EMF on basking sharks are anticipated to affect a small proportion of the population and is unlikely to alter the population trajectory as any potential impact will be of short term duration, intermittent and reversible. Therefore, the magnitude of cumulative emissions of EMF and their effects on basking sharks is assessed as **Low**.

Sensitivity of Receptor

5.8.5.17 As per the Proposed Development (Offshore) alone assessment, recoverability and adaptability of basking sharks is largely unknown, using a precautionary approach, basking shark sensitivity to EMF is assessed as **High**.

Significance of Effect

5.8.5.18 Taking the **Low** magnitude of cumulative EMF during and the **High** sensitivity of basking sharks, the overall cumulative effect arising from EMF during operation and maintenance is considered to be **Minor and Not Significant in EIA terms**.

5.8.6 Summary of Cumulative Impacts

5.8.6.1 In conjunction with other developments and activities within the study area, the Proposed Development (Offshore) will have minor cumulative effects on fish and shellfish ecology as a result of the construction and operation and maintenance activities (Table 5-49 and Table 5-50). It should be noted that for all cumulative effects, no mitigation measures are required above and beyond embedded mitigation measures outlined in Table 5-19.

Table 5-49: Summary of fish and shellfish cumulative effects.

Potential Impact	Receptor	Magnitude Of Impact	Sensitivity of Receptor	Significance	Residual Effect
Cumulative Mortality, injury and behavioural changes resulting from underwater noise arising from construction activity	Group 1, Group 2, Group 3, and Eggs and Larvae	Low	Medium	Minor Adverse	Minor
	Shellfish	Low	Low	Negligible	Negligible
Cumulative temporary increase in suspended sediment and sediment deposition	All IEFs	Low	Medium	Minor	Minor
Cumulative Short term habitat loss and disturbance	All IEFs	Low	Medium	Minor	Minor
Cumulative long term habitat loss	All IEFs	Low	Medium	Minor	Minor
Cumulative impacts from EMF	All IEFs	Low	Medium	Minor	Minor

Table 5-50: Summary of basking shark cumulative effects.

Potential Impact	Magnitude Of Impact	Sensitivity of Receptor	Significance	Residual Effect
Cumulative disturbance resulting from underwater noise arising from construction activity	Low	Low	Negligible	Negligible
Cumulative disturbance resulting from underwater noise from operational noise	Negligible	Low	Negligible	No residual effects
Risk of secondary entanglement	Low	Medium	Minor	Minor
Cumulative impact from EMF	Low	High	Minor	Minor

5.9 In-combination Effects

5.9.1.1 In-combination impacts may occur through the inter-relationship with another EIAR topic that may lead to different or greater environmental effects than in isolation. There is also the potential for in-combination impacts resulting from onshore and offshore works.

Fish and Shellfish Ecology

5.9.1.2 The potential in-combination effects for fish and shellfish ecology receptors resulting from effects between the Proposed Development (Offshore) works are shown in Table 5-51. These include:

- Project lifetime effects: Assessment of the scope for effects that occur throughout more than one phase of the Proposed Development (Offshore) (construction, O&M and decommissioning); to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three key project stages (e.g., subsea noise effects from piling, operational WTGs, vessels and decommissioning); and
- Receptor-led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor. As an example, all effects on fish and shellfish ecology, such as UWN impacts, temporary habitat disturbance, long term habitat loss or temporary increases in SSC and deposition etc., may interact to produce a different, or greater effect on this receptor than when the effects are considered in isolation. Receptor-led effects might be short-term, temporary or transient effects, or incorporate longer term effects.

5.9.1.3 A summary of inter-relationships is as follows:

- Benthic Subtidal and Intertidal Ecology – impacts to benthic ecology receptors may affect prey resource for fish and shellfish ecology receptors;
- Marine Water and Sediment Quality – impacts on water quality (i.e., resuspension of contaminants) may affect fish and shellfish ecology receptors;
- Commercial Fisheries – changes to fishing intensity or gear types may affect fish and shellfish ecology receptors;
- Marine Mammal – impacts to fish and shellfish ecology receptors may affect prey resource for marine mammal receptors; and
- Offshore Ornithology - impacts to fish and shellfish ecology receptors may affect prey resource for ornithological receptors.

Table 5-51: In combination effects on fish and shellfish.

Project Phase(s)	Nature of Inter-related Effect	Assessment Alone	Inter-related Effects Assessment
Project Lifetime Effects			
Construction, O&M and decommissioning	Disturbance from underwater noise	Impacts were assessed as being Not Significant in the construction, O&M and decommissioning phases.	The impacts of underwater noise during the construction and decommissioning phases are expected to be short-term and intermittent. Impacts from underwater noise during the operational phase will be long term but of a very localised extent and at very low levels. The interaction of these impacts across construction, O&M and decommissioning stages of the development is not predicted to result in an effect of any greater significance than those assessed in the individual project phases.
Construction and decommissioning	Increase in SSC and sediment deposition	Impacts were assessed as being Not Significant in the construction and decommissioning phases.	The impacts of increased SSC and sediment deposition during the construction and decommissioning phases are expected to be short-term and intermittent, and of localised extent with any effects being reversible. The interaction of these impacts across construction and decommissioning stages of the development is not predicted to result in an effect of any greater significance than those assessed in the individual project phases.
Construction, O&M and decommissioning	Habitat loss and disturbance, and increased SSC and deposition	Impacts were assessed as being Not Significant in the construction and decommissioning phases.	The impacts of habitat loss and disturbance and increased SSC and deposition during the construction, O&M and decommissioning phases are expected to be short-term and intermittent, and of localised extent. The interaction of these impacts across construction, O&M and decommissioning stages of the development is not predicted to result in an effect of any greater significance than those assessed in the individual project phases.
Receptor-led effects			
No spatial or temporal interaction between the effects assessed above is expected during the project lifetime.			

Basking Sharks

5.9.1.4 In-combination impacts may occur through the inter-relationship with another EIAR topic that may lead to different or greater environmental effects than in isolation. There is also the potential for in-combination impacts resulting from onshore and offshore works. These are identified within Volume 6, Chapter 1: Introduction (Intertidal Interface) and are therefore not repeated here.

5.9.1.5 These effects are considered at two different levels:

- Project lifetime effects: Assessment of the scope for effects that occur throughout more than one phase of the Proposed Development (Offshore) (construction, O&M and decommissioning); to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three key project stages; and
- Receptor led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor. Effect may interact to produce different, or greater effect on this receptor than when the effects are considered in isolation. Receptor-led effects may be short-term, temporary or transient effects, or incorporate longer term effects.

5.9.1.6 The potential in-combination effects on basking sharks are presented and assessed in Table 5-52.

Table 5-52: In-combination effects on basking shark receptors.

Potential Impact	Project Phase(s)	In-combination Effect Assessment
Project Lifetime Effects		
Vessel collisions	Construction, O&M and decommissioning	Both the potential impacts of vessel collisions and disturbance are anticipated to arise throughout all project phases. However, it is not likely that these impacts would interact across project phases to result in combined effects of greater significance than those presented in Section 5.7 for each individual phase. With the adoption of VMP the impacts would more likely to be maintained at a similar significance level (which is Negligible and Not Significant in EIA terms) throughout the lifetime of the Proposed Development (Offshore).
Vessel disturbance	Construction, O&M and decommissioning	
Indirect impacts on prey	Construction, O&M and decommissioning	Indirect impacts on prey are estimated to arise throughout all key phases, but is not expected to result in an ongoing, additive loss of prey over the project lifetime. Rather there may be an initial and temporary decrease in prey availability during the construction phase followed by recovery of areas, leading to no large-scale and long-term loss of prey. The implementation of embedded mitigation listed in Table 5-19 will reduce the risk of significant effects on prey. Furthermore, due to the generalist nature of

Potential Impact	Project Phase(s)	In-combination Effect Assessment
		the basking shark diet, indirect prey species across the different phases are not anticipated to alter the population trajectory Therefore, the significance of this interaction between the effect across different phases is not predicted to be higher than that for individual project phases, which is assessed as Negligible and therefore Not Significant in EIA terms.
Changes in water quality	Construction, O&M and decommissioning	The impacts of changes in water quality during the construction, O&M and decommissioning phases are expected to be short-term and intermittent, reversible and of localised extent. The implementation of embedded mitigation listed in Table 5-19,will reduce any potential impacts of changes in water quality on basking sharks. The interaction of this impact across different key phases of Proposed Development (Offshore) is not anticipated to result in an effect of any greater significance than those assessed in Section 5.7.
Receptor-led Effects		
No spatial or temporal interaction between impacts assessed in Section 5.7 is expected during the project lifetime.		

5.10 Transboundary Effects

Fish and Shellfish Ecology

5.10.1.1 Transboundary impacts related to fish and shellfish ecology are not anticipated to arise from construction, O&M or decommissioning stages of the Proposed Development (Offshore). Any impacts on fish and shellfish receptors will be localised in nature (including those giving rise to the greatest footprint of effect such as underwater noise from piling), and any indirect effects will likely be limited to one tidal excursion from the impact source. The Proposed Development (Offshore) is a significant distance from the nearest adjacent EEZ of another member state, and therefore it is considered that transboundary impacts will not occur and will therefore be scoped out from further consideration within the EIAR. This is in line with the transboundary screening approach which concluded that no potentially significant transboundary effects are predicted for fish and shellfish receptors and therefore a transboundary effects assessment is not considered necessary in this chapter.

Basking Sharks

5.10.1.2 Transboundary impacts relating to basking sharks are not anticipated to arise from the construction, O&M or decommissioning phases of the Proposed Development (Offshore). Any impacts on basking sharks will be localised and short-term in nature. In addition, the Proposed Development (Offshore) is of a significant distance from the nearest adjacent EEZ of any other state. Following the transboundary screening approach, it is considered that transboundary impacts are unlikely to occur and are therefore scoped out from further consideration within the EIAR.

5.11 Mitigation Measures and Monitoring

Fish and Shellfish Ecology

5.11.1 Construction

5.11.1.1 No additional mitigation measures beyond those outlined in Table 5-19 are proposed for the construction phase.

5.11.2 Operation

5.11.2.1 No additional mitigation measures beyond those outlined in Table 5-19 are proposed for the operation phase.

5.11.3 Decommissioning

5.11.3.1 No additional mitigation measures beyond those outlined in Table 5-19 are proposed for the decommissioning phase.

Basking Sharks

5.11.4 Construction

5.11.4.1 No additional mitigation measures beyond those outlined in Table 5-19 are proposed for the construction phase.

5.11.5 Operation

5.11.5.1 No additional mitigation measures beyond those outlined in Table 5-19 are proposed for the operation phase.

5.11.6 Decommissioning

5.11.6.1 No additional mitigation measures beyond those outlined in Table 5-19 are proposed for the decommissioning phase.

5.12 Residual Effects

5.12.1.1 As no project-alone impact has been assessed as significant in EIA terms and that secondary mitigation is not considered necessary for fish and shellfish ecology, it can be concluded that there is no residual effect on fish and shellfish ecology and basking sharks identified for the Proposed Development (Offshore).

5.13 Summary of Effects

5.13.1.1 Table 5-53 and Table 5-54 presents a summary of the effects assessed for fish and shellfish ecology and basking sharks, respectively. Any mitigation measures required, and the residual effects are provided.

Table 5-53: Summary of effects for fish and shellfish ecology.

Potential Impact			Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
Construction							
Impact 1: Mortality, injury, behavioural impacts and auditory masking arising from noise and vibration	Mortality and Potential Mortal Injury	Group 1	Low	Medium	Minor Adverse	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor Adverse
		Group 2	Low	Medium	Minor Adverse		Minor Adverse
		Group 3	Low	Medium	Minor Adverse		Minor Adverse
		Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
		Shellfish	Low	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
	Recoverable Injury	Group 1	Low	Medium	Minor Adverse		Minor Adverse
		Group 2	Low	Medium	Minor Adverse		Minor Adverse
		Group 3	Low	Medium	Minor Adverse		Minor Adverse
		Eggs and Larvae	Low	Medium	Minor Adverse	No mitigation required above and beyond embedded mitigation	Minor Adverse
		Shellfish	Low	Low	Negligible		Negligible

Potential Impact			Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
	TTS	Group 1	Low	Medium	Minor Adverse	measures outlined in Table 5-19	Minor Adverse
		Group 2	Low	Medium	Minor Adverse		Minor Adverse
		Group 3	Low	Medium	Minor Adverse	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor Adverse
		Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
		Shellfish	Low	Low	Negligible		Negligible
	Behavioural Effects	Group 1	Low	Low	Negligible		Negligible
		Group 2	Low	Medium	Minor Adverse	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor Adverse
		Group 3	Low	Low	Negligible		Negligible
		Eggs and Larvae	Low	Medium	Minor Adverse		Minor Adverse
		Shellfish	Low	Low	Negligible		Negligible
	UXO	Group 1	Low	Low	Negligible	No mitigation required above and beyond embedded mitigation	Negligible
		Group 2	Low	Medium	Minor Adverse		Negligible

Potential Impact		Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
	Group 3	Low	Low	Negligible	measures outlined in Table 5-19	Minor Adverse
	Eggs and Larvae	Low	Medium	Minor Adverse		Negligible
	Shellfish	Low	Low	Negligible		Minor Adverse
Impact 2: Temporary Increases in suspended sediment concentrations (SSCs) and sediment deposition	Pelagic Spawning IEFs	Low	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
	Demersal Spawning IEFs	Low	Medium	Minor Adverse		Minor Adverse
	Diadromous IEFs	Low	Low	Negligible		Negligible
	Elasmobranch IEFs	Low	Low	Negligible		Negligible
	Shellfish	Low	Medium	Minor Adverse		Minor Adverse
Impact 3: Temporary Habitat Disturbance	Herring	Low	Medium	Minor Adverse	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor Adverse
	Sandeel	Low	Medium	Minor Adverse		Minor Adverse

Potential Impact		Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
	Pelagic & Diadromous IEFs	Low	Low	Negligible		Negligible
	Demersal IEFs	Low	Low	Negligible		Negligible
	Elasmobranch IEFs	Low	Medium	Minor Adverse		
	Shellfish	Low	Low	Negligible		Negligible
Impact 4: Direct and indirect seabed disturbance leading to release of sediment contaminants	Fish and Elasmobranch IEFs	Negligible	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
	Diadromous IEFs	Negligible	Low	Negligible		Negligible
	Eggs and Larvae	Negligible	Medium	Minor Adverse		Minor Adverse
	Shellfish	Negligible	Medium	Minor Adverse		Minor Adverse
Impact 5: Increased risk of introduction and/or spread of Invasive Non-Native Species (INNS)	Demersal Fish	Low	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor Adverse
	Pelagic Fish	Low	Low	Negligible		Negligible
	Diadromous IEFs	Low	Medium	Minor		Negligible

Potential Impact		Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
	Elasmobranch IEFs	Low	Low	Negligible		Negligible
	Shellfish	Low	Low	Negligible		Negligible
Operation						
Impact 6: Temporary Habitat Loss and Disturbance	Herring	Low	Medium	Minor Adverse	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor Adverse
	Sandeel	Low	Medium	Minor Adverse		Minor Adverse
	Pelagic & Diadromous IEFs	Low	Low	Negligible		Negligible
	Demersal IEFs	Low	Low	Negligible		Negligible
	Elasmobranch IEFs	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible
Impact 7: Long-term Habitat Loss	Sandeel	Low	Medium	Minor Adverse	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor Adverse
	Herring	Low	Medium	Minor Adverse		Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible

Potential Impact		Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
	All other IEFs	Low	Negligible	Negligible		Negligible
Impact 8: Colonisation of Hard Substrates	Pelagic and Demersal IEFs	Low	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
	Elasmobranch IEFs	Low	Low	Negligible		Negligible
	Diadromous IEFs	Low	Low	Negligible		Negligible
	Shellfish	Low	Low	Negligible		Negligible
Impact 9: Increased risk of introduced and/or spread of Invasive Non-Native Species (INNS)	Pelagic and Demersal Fish IEFs	Low	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
	Shellfish	Low	Low	Negligible		Negligible
	Elasmobranchs	Low	Low	Negligible		Negligible
	Diadromous	Low	Medium	Minor Adverse		Minor Adverse
Impact 10: Electromagnetic fields (EMF) effects arising from cables during decommissioning phase	Pelagic and Demersal Fish IEFs	Low	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
	Shellfish	Low	Low	Negligible		Negligible
	Elasmobranchs	Low	Medium	Negligible		Negligible

Potential Impact			Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
		Diadromous	Low	Medium	Minor Adverse		Minor Adverse
Impact 11: Effects arising from underwater noise during operation	TTS/ Behaviour	Group 3 fish	Negligible	Medium	Negligible	No additional mitigation measures have been proposed as of yet.	Negligible
		Shellfish	Negligible	Medium	Negligible		Negligible
		Elasmobranchs	Negligible	Low	Negligible		Negligible
		Diadromous	Negligible	Low	Negligible		Negligible
		Shellfish	Negligible	Low	Negligible		Negligible
Decommissioning							
Impact 12: Mortality, injury and behavioural changes resulting from underwater noise arising from decommissioning activity		All IEFs	Low	Medium	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor
Impact 13: Temporary Increases in suspended sediment concentrations (SSCs) and changes to seabed levels from decommissioning activities		All IEFs	Low	Medium	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor
Impact 14: Temporary Habitat Disturbance due to decommissioning activities		All IEFs	Low	Medium	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor adverse

Potential Impact		Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
Impact 15: Direct and indirect seabed disturbance leading to release of sediment contaminants from decommissioning activities	All IEFs	Low	Medium	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor adverse
Cumulative						
Cumulative Mortality, injury and behavioural changes resulting from underwater noise arising from construction activity	Group 1, Group 2, Group 3, and Eggs and Larvae	Low	Medium	Minor Adverse	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor Adverse
	Shellfish	Low	Low	Negligible		Negligible
Cumulative temporary increase in suspended sediment and sediment deposition	All IEFs	Low	Medium	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor adverse
Cumulative Short term habitat loss and disturbance	All IEFs	Low	Medium	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor adverse
Cumulative long term habitat loss	All IEFs	Low	Medium	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor adverse

Potential Impact		Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
Cumulative impacts from EMF	All IEFs	Low	Medium	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor adverse

Table 5-54: Summary of effects for basking shark receptors.

Potential Impact		Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
Construction						
Impact 1: Underwater noise from pile-driving	Mortality and mortal injury, recoverable injury, masking and behavioural effects	Negligible	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
	TTS	Low	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
Impact 2: Underwater noise from UXO clearance		Negligible	High	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
Impact 3: Underwater noise from other construction activities		Negligible	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
Impact 4: Vessel collisions		Negligible	High	Negligible	No mitigation required above and beyond embedded mitigation	Negligible

Potential Impact	Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
				measures outlined in Table 5-19	
Impact 5: Vessel disturbance	Negligible	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
Impact 6: Indirect impacts on prey	Negligible	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
Impact 7: Water quality changes	Low	Low	Negligible	Embedded mitigation listed in Volume 2, Chapter 2: Marine and Coastal Processes	Negligible
Operation					
Impact 8: Vessel collisions	Negligible	High	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
Impact 9: Vessel disturbance	Negligible	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible

Potential Impact	Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
Impact 10: Indirect impacts on prey	Negligible	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
Impact 11: EMF	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor
Impact 12: Operational noise	Negligible	Low	Negligible	No embedded or secondary mitigation required	Negligible
Impact 13: Entanglement	Low	Medium	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor
Impact 14: Long-term displacement/ habitat loss/barrier effects	Negligible	Negligible	Negligible	No embedded or secondary mitigation required	Negligible
Decommissioning					
Impact 15: Underwater noise from decommissioning activities	Negligible	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible

Potential Impact	Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
Impact 16: Vessel collisions	Negligible	High	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
Impact 17: Vessel disturbance	Negligible	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
Impact 18: Indirect impacts on prey	Negligible	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible
Impact 19: Water quality changes	Low	Low	Negligible	Embedded mitigation listed in Volume 2, Chapter 2: Marine and Coastal Processes	Negligible
Cumulative					
Cumulative disturbance resulting from underwater noise from operational noise	Low	Low	Negligible	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Negligible

Potential Impact	Magnitude	Sensitivity of Receptor	Significance	Mitigation Measure	Residual Effect
Cumulative disturbance resulting from underwater noise from operational noise	Negligible	Low	Negligible	No embedded or secondary mitigation required	Negligible
Risk of secondary entanglement	Low	Medium	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor
Cumulative impact from EMF	Low	High	Minor	No mitigation required above and beyond embedded mitigation measures outlined in Table 5-19	Minor

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Caledonia Offshore Wind Farm
5th Floor, Atria One
144 Morrison Street
Edinburgh
EH3 8EX

www.caledoniaoffshorewind.com

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