Bowdun Offshore Wind Farm, Offshore EIA Report

Volume 2, Chapter 23: Inter-Related Effects

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Glossary

Defined term	Definition
Applicant (the)	Bowdun Offshore Wind Farm Limited (BOWFL).
Array Area	The Array Area is the area in which the Offshore Generation Assets will be located.
Bowdun Offshore Wind Farm Limited (BOWFL)	A Special Purpose Vehicle (SPV) (legal entity) for the purpose of developing the Project. BOWFL are the Applicant for the Offshore Application.
Cumulative Effects	The effects of the Proposed Development assessed together with effects from the Onshore Infrastructure forming the Project as well as one or more different projects on the same receptor/resource.
Designated Landscape	Areas of landscape identified as being of importance at international, national or local levels, either defined by statute or identified in development plans or other documents.
Effect	Term used to express the consequence of an impact (i.e. the result of change or changes) on specific environmental resources or receptors. The significance of an effect is determined by correlating the magnitude of the impact with the importance, or sensitivity of the receptor or resource in accordance with defined significance criteria.
Environmental Impact Assessment (EIA)	Process for the assessment of likely significant environmental effects of a project on the physical, biological and human environment during construction, Operation and Maintenance (O&M) and decommissioning.
Environmental Impact Assessment Regulations (EIA Regulations)	Terminology used in this Offshore EIA Report to refer to three sets of regulations: • The Electricity Works (Environmental Impact Assessment) (Scotland) Regulations 2017; • The Marine Works (Environmental Impact Assessment) (Scotland) Regulations 2017; and • The Marine Works (Environmental Impact Assessment) Regulations 2007
Export Cable Corridor	The area seaward of Mean High Water Springs (MHWS), which connects the Array Area with the Landfall within which the Offshore Export Cables will be installed.
Impact	A change caused by an action that occurs during a project's lifetime.
Inter-Array Cables (IAC)	Cables which link the Wind Turbines to each other and with the OSPs.
Interconnector Cables	Cables which will connect individual OSPs to each other to provide redundancy against cable failure elsewhere.
Inter-Related Effects	The potential effects of multiple impacts from the construction, O&M and decommissioning of the Project, affecting one receptor.
Lifetime Effects	Assessment of effects that may occur throughout more than one phase (construction, O&M and decommissioning) which interact to potentially create a more significant effect on a receptor than if just assessed in isolation in each of the three key phases (e.g. underwater sound effects from construction piling, operational Wind Turbines, vessels and decommissioning activities).

Defined term	Definition
Maximum Design Scenario (MDS)	The scenario within the design envelope likely to result in the greatest impact on a particular topic receptor, and therefore the one that should be assessed for that topic receptor.
Offshore Environmental Impact Assessment (EIA) Report (hereafter, 'Offshore EIA Report')	Document prepared to report the findings of the EIA for the Proposed Development and produced in accordance with the EIA Regulations. The Offshore EIA Report is submitted to support the Offshore Application for the Proposed Development, and to comply with EIA Regulations.
Offshore Export Cables	Subsea cables used to transmit electricity generated offshore by the Wind Turbines from the OSPs to shore. The Transition Joint Bay (TJB) is the location where the Offshore Export Cables terminate, and the onshore cabling begins.
Offshore Generation Assets	The infrastructure of the Proposed Development required to generate electricity comprising of the Wind Turbines, Wind Turbine foundations and associated infrastructure (e.g. IACs).
Offshore Infrastructure	All of the Offshore Infrastructure associated with the Proposed Development that is located seaward of MHWS, comprising the Offshore Generation Assets and the Offshore Transmission Assets.
Offshore Substation Platform(s) (OSPs)	OSPs comprise the support structure, topside and electrical components used for collecting and/or converting electricity generated by the Wind Turbines for transmission by the Offshore Export Cables.
Offshore Transmission Assets	The infrastructure of the Proposed Development required to transmit the generated electricity comprising of the OSPs, Offshore Export Cables and associated infrastructure up to MHWS.
Onshore Transmission Assets	The transmission infrastructure associated with the Project above MLWS which is subject to the Planning Permission in Principle (PPP) Application submitted to Aberdeenshire Council (REF: APP/2025/1952).
Operation and Maintenance (O&M)	The phase of the Proposed Development following completion of construction. This phase of development includes routine inspections, repairs and replacement of infrastructure and equipment (including Interconnector Cables and IACs), Scour Protection replenishment or replacement, major component replacement, painting and/or other coating works, removal of marine growth, and replacement of access ladders.
Pathway	Describes the means or route by which a receptor (such as the seabed) can be affected by an identified impact source (such as Wind Turbine foundations).
Pre Application Consultation (PAC)	Pre-Application Consultation with communities and stakeholders with regard to the consent applications for the Project that meets the requirements of Marine Licensing (Pre-application Consultation) (Scotland) Regulations 2013.
Project (the)	An overarching term for the Bowdun Offshore Wind Farm (Bowdun OWF) comprising the offshore and onshore infrastructure required to generate and transmit electricity from the Array Area to the onshore Grid Connection Point (GCP). The Project includes the Offshore Generation Assets, the Offshore Transmission Assets and the Onshore Transmission Assets.

Defined term	Definition
Project Design Envelope (PDE)	A description of the range of possible elements that make up the design options for the Proposed Development under consideration when the exact engineering parameters are not yet known.
Proposed Development	Term used to define the Offshore Infrastructure associated with the Project seaward of MHWS for which consent is being sought. Further details of the parameters are included in Volume 1, Chapter 3: Project Description.
Receptor-led Effects	Assessment of multiple effects which interact to create inter-related effects on a receptor. Receptor-led Effects might be short term, temporary or transient effects, or incorporate longer-term effects.
Study Area	For each environmental topic, the baseline environment will be characterised, and the potential environmental impacts will be described within a topic-specific study area. Specific study areas are defined for each topic and are based on the maximum spatial extent across which potential impacts of the Project may be experienced by the relevant receptors (i.e. Zone of Influence).
Temporal Overlap	The time period during which the effects of multiple projects occur simultaneously.
Thistle Wind Partners (TWP)	Company established for the development of the Project.
Tidal Ellipse	The illustration of the variance of tidal currents in horizontal space.
Wasp-waist	The term Wasp-waist refers to a specific structure in marine ecosystems where a few abundant short lived species occupy an intermediate trophic level, forming a narrow 'waist' through which energy flow from low to high trophic levels is controlled.
Wind Turbines	Structures comprising of a tubular tower, rotor blades, and a nacelle which houses the Wind Turbine generator.
Zone of Influence	The geographical area within which the Proposed Development may have environmental effects.

Acronyms

Acronym	Definition
ADD	Acoustic Deterrent Device
ATC	Air Traffic Control
AUD INJ	Auditory Injury
BOWFL	Bowdun Offshore Wind Farm Limited
CBD	Convention on Biological Diversity
DAS	Digital Aerial Surveys
DEFRA	Department for Environment Food and Rural Affairs
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
FMMCP	Fisheries Mitigation Monitoring and Communication Plan
GVA	Gross Value Added
IAC	Inter-Array Cable
IAMMWG	Inter-Agency Marine Mammal Working Group
ICES	International Council for the Exploration of the Seas
IEF	Important Ecological Feature
IEMA	Institute of Environmental Management and Assessment
IFP	Instrument Flight Procedure
INNS	Invasive Non-Native Species
LAT	Lowest Astronomical Tide
LMP	Lighting and Marking Plan
MD-LOT	Marine Directorate – Licensing Operations Team
MDS	Maximum Design Scenario
MoD	Ministry of Defence
MPA	Marine Protected Area
MU	Management Unit
NATS	National Air Traffic Services
NBN	National Biodiversity Network
NEQ	Net Explosive Quantity
NRA	Navigational Risk Assessment
NSVMP	Navigational Safety and Vessel Management Plan
NtM	Notice to Mariners
O&M	Operation and Maintenance
OSP	Offshore Substation Platform
OWEC	Offshore Wind Evidence and Change
OWF	Offshore Wind Farm
PrePARED	Predators and Prey Around Renewable Energy Developments
PSR	Primary Surveillance Radar

Acronym	Definition
SAC	Special Area of Conservation
SAR	Search and Rescue
SMU	Seal Management Unit
SSC	Suspended Sediment Concentration
TTS	Temporary Threshold Shift
UK	United Kingdom
UXO	Unexploded Ordnance

Table of Units

Units	Definition
%	Percent
°C	Degree Celsius
dB	Decibel
kJ	KiloJoule
km	Kilometre
km²	Square kilometre
m	Metre
m/s	Metre per second
m²	Square metre
MW	Megawatt
nm	Nautical mile
s	Second
µPa	Micro Pascal (10^{-6})

23 Inter-Related Effects

23.1 Introduction

23.1.1 This chapter of the Offshore Environmental Impact Assessment (EIA) Report presents the assessment of the likely significant environmental effects on the environment in relation to inter-related effects as a result of the Proposed Development during the construction, Operations and Maintenance (O&M) and decommissioning phases.

23.1.2 The assessment presented has been informed by the individual chapters' relevant assessment of effects and conclusions, and their associated technical report, including:

- Volume 2, Chapter 7: Physical Processes;
- Volume 2, Chapter 8: Benthic Ecology;
- Volume 2, Chapter 9: Fish and Shellfish Ecology;
- Volume 2, Chapter 10: Marine Mammals;
- Volume 2, Chapter 11: Offshore Ornithology;
- Volume 2, Chapter 12: Offshore Bats;
- Volume 2, Chapter 13: Commercial Fisheries;
- Volume 2, Chapter 14: Shipping and Navigation;
- Volume 2, Chapter 15: Aviation and Radar;
- Volume 2, Chapter 16: Infrastructure and Other Users;
- Volume 2, Chapter 18: Socio-economics, Tourism and Recreation;
- Volume 2, Chapter 19: Marine Archaeology;
- Volume 2, Chapter 20: Seascape, Landscape and Visual Impacts; and
- Volume 2, Chapter 21: Cultural Heritage.

23.1.3 The following chapters have not been included within the assessment:

- Volume 2, Chapter 17: Major Accidents and Disasters - No specific major accidents and disasters receptors were identified and therefore, to avoid duplication of receptors listed under other topic chapters, the chapter has not been included in this assessment; and
- Volume 2, Chapter 22: Climatic Change - Inter-related effects specific to climatic effect receptors are discussed in Volume 3, Technical Appendix 22.3: In-Combination Climate Impacts Assessment.

23.1.4 The purpose of this chapter is to describe:

- the receptor groups considered within the inter-related effects assessment;
- the potential for impacts and consequent likely significant environmental effects on receptor groups across the three key phases of the Proposed Development (construction, O&M, and decommissioning);
- the potential for multiple impacts and consequent likely significant environmental effects on a receptor group, as presented within the topic-specific chapter, to interact to create inter-related effects; and
- the inter-related effects across different trophic levels of the ecosystem, affecting the environment.

23.1.5 This chapter follows the ecosystem-based approach, which is defined as *"a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way"* (Convention on Biological Diversity (CBD), 2023). The purpose of the ecosystem-based approach is to assess how the Proposed Development may interact at the ecosystem-level, affecting the environment.

23.1.6 This chapter is broken down into two assessment sections:

- Part One: Inter-related Effects Assessment – This section aims to assess how receptors are affected by the inter-related effects between topics from the Proposed Development; and
- Part Two: Ecosystem-Based Effects Assessment - This section aims to qualitatively assess the potential impacts of the Proposed Development on the ecosystem relevant to it, focusing on changes in predator-prey relationships and overall ecosystem functioning.

23.1.7 Inter-related effects were presented to the Marine Directorate and NatureScot in the Offshore EIA Scoping Report (Bowdun Offshore Wind Farm Limited (BOWFL), 2024). Section 23.4 describes how comments raised by the regulator and stakeholders were considered within this chapter.

23.2 Inter-Related Effects Study Area

23.2.1 Due to the varying spatial extent of effects experienced by different offshore receptors, the Inter-Related Effects Study Area differs according to topic and receptor. The significant inter-related effects evaluated in Part One of this chapter are therefore limited to the study areas defined in each of the topic-specific chapters outlined in Paragraph 23.1.2. Since the largest study area pertains to offshore ornithology, it represents the maximum limit of the Inter-Related Effects Study Area.

23.3 Policy and Legislative Context

23.3.1 The overarching policy and legislation applicable to the Proposed Development is presented in Volume 1, Chapter 2: Policy and Legislation. A summary of the legislative provisions relevant to inter-related effects are provided in Table 23.1, with other relevant policy provisions set out in Table 23.2.

Table 23.1: Summary of Legislation Relevant to Inter-Related Effects

Summary of Relevant Legislation	How and Where Considered in the Offshore EIA Report
EIA Directive (2011/92/EU) as transposed into the EIA Regulations. The environmental impact assessment shall identify, describe and assess in an appropriate manner, in the light of each individual case, the direct and indirect significant effects of the Proposed Development on the following factors: (a) population and human health; (b) biodiversity; (c) land, soil, water, air and climate; (d) material assets, cultural heritage and the landscape; and (e) the interaction between the factors referred to in points (a) to (d).	Assessment of likely significant environmental effects due to inter-related effects arising from the Proposed Development has been undertaken and is outlined in Sections 23.7 and 23.8.

Table 23.2: Summary of Marine Policy Relevant to Inter-Related Effects

Summary of Relevant Policy	How and Where Considered in the Offshore EIA Report
Scottish National Marine Plan (2015) GEN 9 (Natural Heritage) requires development to comply with legal requirements for protected areas; not to result in significant impact on the national status of Priority Marine Features (PMFs) (which includes geodiversity features); and to protect, and, where appropriate, enhance the health of the marine area.	Whilst the Scottish National Marine Plan – GEN 9 does not specifically consider inter-related effects, it does give credence to ecosystem services and to the role of biodiversity and geodiversity in ensuring the marine environment is healthy, biologically diverse, resilient and productive, and in providing social, economic and wider benefits. Assessments of impacts have been discussed in the chapters described in Paragraph 23.1.2, and the assessment of likely significant environmental effects due to inter-related effects arising from the Proposed Development has been undertaken and is outlined in Sections 23.7 and 23.8.
National Planning Framework 4 Policy 3 - Any potential adverse impacts, including cumulative impacts, of development proposals on biodiversity, nature networks and the natural environment will be minimised through careful planning and design. This will take into account the need to reverse biodiversity loss, safeguard the ecosystem services that the natural environment provides, and build resilience by enhancing nature networks and maximising the potential for restoration.	Assessments of impacts have been discussed in the chapters described in Paragraph 23.1.2, and the assessment of likely significant environmental effects on ecosystem services arising from the Proposed Development has been undertaken and is outlined in Sections 23.7 and 23.8.
Sectorial Marine Plan General Policy - The potential adverse effects on other marine users, economic sectors and the environment resulting from further commercial scale offshore wind development should be reduced.	Assessments of impacts have been discussed in the chapters described in Paragraph 23.1.2, and the assessment of likely significant environmental effects due to inter-related effects arising from the Proposed Development has been undertaken and is outlined in Sections 23.7 and 23.8.

Summary of Relevant Policy	How and Where Considered in the Offshore EIA Report
United Kingdom (UK) Marine Policy Statement (2011) Sets out high-level objectives for the marine space, including achieving a sustainable marine economy and identifies a wide range of relevant marine uses. Requires the use of the marine environment is spatially planned where appropriate and based on an ecosystems approach which takes account of climate change and recognises the protection and management needs of marine cultural heritage according to its significance.	Similar to the Scottish National Marine Plan, the UK Marine Policy Statement doesn't specifically consider inter-related effects, however, it requires that marine planning considers impacts and is based on an ecosystem approach. Assessments of impacts have been discussed in the chapters described in Paragraph 23.1.2, and the assessment of likely significant environmental effects due to inter-related effects arising from the Proposed Development has been undertaken and is outlined in Sections 23.7 and 23.8.

23.4 Consultation

23.4.1 The approach to consultation for the Proposed Development is set out in Volume 1, Chapter 5: Consultation and Engagement. A summary of the issues raised during consultation activities undertaken to date, specific to inter-related effects, is presented in Table 23.3, together with how these issues have been considered in the production of this assessment. Further details are presented in Volume 1, Chapter 5: Consultation and Engagement.

Table 23.3: Summary of Key Consultation Issues Raised During Consultation Activities Undertaken for the Proposed Development Relevant to Inter-Related Effects

Date	Consultee and Type of Consultation	Summary of Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
25/11/2024	NatureScot Scoping Opinion	NatureScot raised that 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 predator-prey interactions. Enabling a better understanding of the consequences (positive or negative) of any potential changes in prey distribution and abundance from the Proposed Development on bird and mammal (and other top predator) interests and what influence this may have on population-level impacts.	The effects on predator species (marine mammals and birds) in relation to prey availability, key spawning and nursery grounds for the key prey species and the likely significant environmental effects of the Proposed Development on these grounds are discussed in Section 23.7. The assessment of changes in prey availability has drawn on the fish and shellfish ecology assessment, which is presented in Volume 2, Chapter 9: Fish and Shellfish Ecology.
		NatureScot supported the approach to be undertaken for physical processes whereby information on physical processes will be used to inform other receptors.	Where physical processes have been used to inform other receptors, this is stated at the start of those chapters described in Paragraph 23.1.2. Furthermore, an assessment of likely significant environmental effects due to inter-related effects arising from the Proposed Development has been undertaken and is outlined in Sections 23.7 and 23.8.
	Marine Directorate – Licensing Operations Team (MD-LOT) and NatureScot Scoping Opinion	In regard to fish and shellfish, the Offshore EIA Report should clearly assess how the Proposed Development—alone and cumulatively—affects key prey species (e.g. sandeel, herring, mackerel, sprat) and their habitats, with ecosystem scale consideration across trophic levels to understand potential consequences for top predators like marine mammals. It should also evaluate how habitat loss or disturbance may impact the recruitment of these prey species through effects on spawning and nursery grounds. Predators and Prey Around Renewable Energy Developments (PrePARED) – An offshore renewables science project https://owecprepared.org/ was provided by the Marine Directorate to support this assessment.	This chapter includes an Ecosystem Effects Assessment (Section 23.8) whereby the potential changes across key trophic levels, potential habitat loss, disturbance, changes in trophic interactions, community and effects on prey species and their spawning and nursery grounds are assessed. The provided data source has been used in this Offshore EIA Report.

23.5 Data Sources

23.5.1 The data sources and baseline environment for each receptor group are detailed in their respective chapters (see Paragraph 23.1.2). This chapter assesses the significance of effects on receptor groups based on conclusions from those technical chapters. Furthermore, the data source recommended for use by the Marine Directorate has been used:

- PrePARED - various reports available and referenced in text where applicable.

PrePARED Project

23.5.2 Following consultation, detailed in Table 23.3, the PrePARED project (PrePARED, 2024) has been used to assist in the understanding of predator-prey relationships in and around Offshore Wind Farms (OWFs).

23.5.3 Funded by the Offshore Wind Evidence and Change (OWEC) Programme and Crown Estate Scotland, the PrePARED project seeks to better understand how seabirds and marine mammals respond to offshore wind developments and the mechanisms underpinning their responses, particularly changes in prey distribution. An increased certainty on the magnitude of cumulative impacts will facilitate deployment of OWFs at the pace and scale required to help meet the UK government's renewable energy targets and reach net-zero emissions (PrePARED, 2024).

23.5.4 Part of the project activities included fish, seabird and marine mammal data collection in and around OWFs in the Firth of Forth and Tay and the Moray Firth. Examples of tasks conducted as part of the project include:

- surveying fine-scale fish response to OWFs;
- collating historical data to determine large-scale fish distribution;
- collating historical data to develop seabird spatial distribution models;
- designing acoustic telemetry arrays to track fish and marine mammal movement; and
- collating historical data from various methods to develop marine mammal distribution models.

23.6 Methodology for Assessment

Overview

23.6.1 The inter-related effects assessment has followed the methodology set out in Volume 1, Chapter 4: Environmental Impact Assessment Methodology:

- Part One: Receptor-Based Inter-Related Effects Assessment outlines the assessment required as part of the EIA Regulations, and
- Part Two: Ecosystem Effects Assessment aims to address the comments (Table 23.3) raised by MD-LOT and NatureScot for a wider ecosystem scale assessment.

Part One: Inter-Related Effects Assessment Method

23.6.2 The following sections present the approach used for the project lifetime and receptor-led inter-related effects assessments of the Proposed Development.

23.6.3 The following guidance documents have been followed relating to the assessment of inter-related effects:

- The Guidelines for the Assessment of Indirect and Cumulative Impacts as well as Impact Interactions (European Commission, 1999); and
- Institute of Environmental Management and Assessment (IEMA, now known as the Institute of Sustainability and Environmental Professionals (ISEP)) Environmental Impact Assessment Guide to Shaping Quality Development (IEMA, 2016).

23.6.4 The approach for assessing the potential inter-related effects on each receptor or receptor group follows the steps summarised in Table 23.4 and outlined.

Table 23.4: Staged Approach to Assessing Inter-Related Effects

Stage	Description
1	Assessment of effects undertaken for individual topic areas within Volume 2, Chapters 7 to 21 (with the exception of Chapters 17[1] and 22[2])
2	Review of assessments undertaken within Volume 2, Chapters 7 to 21 (with the exception of Chapters 17 and 22) to identify 'receptor groups' requiring assessment.
3	Identification of potential inter-related impacts on receptor groups through review of topic-specific assessments in the chapters.
4	An assessment was undertaken on how individual effects may combine to create inter-related effects on each receptor group for: • project lifetime effects (i.e. during construction, O&M and decommissioning phases); and • receptor-led effects (i.e. multiple effects on a single receptor).

[1] No specific major accidents and disasters receptors were identified and therefore to avoid duplication of receptors listed under other topic chapters, the chapter has not been included in this assessment.

[2] Inter-related effects specific to climatic effect receptors are discussed in Volume 3, Technical Appendix 22.3: ICCI Assessment.

Stage 1: Topic-Specific Assessment

23.6.5 The first stage of the assessment of inter-related effects is presented in each of the topic chapters and comprises the individual assessments of effects on receptors across the construction, O&M and decommissioning phases.

Stage 2: Identification of Receptor

23.6.6 The second stage involved a review of the assessments undertaken in the topic-specific chapters to identify the 'receptor groups' requiring assessment within this chapter. The term 'receptor group' is used to highlight that, for the purposes of the assessment, the potentially sensitive receptors have been grouped together (e.g. marine mammals). The receptor groups assessed can be broadly categorised as those relating to the physical environment, the biological environment and the human environment, as follows (see Paragraph 23.1.2 for references to chapters):

- physical environment:
  - physical processes;
- biological environment:
  - benthic ecology;
  - fish and shellfish ecology;
  - marine mammals;
  - offshore ornithology;
  - offshore bats;
- human environment:
  - commercial fisheries;
  - shipping and navigation;
  - aviation and radar;
  - infrastructure and other users;
  - socio-economics, tourism and recreation;
  - marine archaeology;
  - seascape, landscape and visual impacts; and
  - cultural heritage.

Stage 3: Identification of Potential Inter-Related Impacts on Receptor Groups

23.6.7 After identifying receptor groups, the potential inter-related impacts on those groups were determined by reviewing the assessment sections of each relevant topic chapter. Professional judgement regarding which impacts may result in inter-related effects on receptors associated with the Proposed Development was used.

23.6.8 It is important to recognise potential linkages between the topic-specific chapters, where effects and receptor groups assessed in each chapter may have secondary effects on other receptors, such as in Volume 2, Chapter 8: Benthic Ecology addresses effects on benthic habitats and species arising from changes to the physical environment (as described in Volume 2, Chapter 7: Physical Processes).

23.6.9 Where such linked relationships arise, they have been fully assessed within the individual topic chapters. This chapter on inter-related effects summarises the consideration of these inter-related effects on linked receptors already set out in the topic-specific chapters.

Stage 4: Assessment of Inter-Related Effects on Each Receptor Group

23.6.10 Individual effects on each of the key receptor groups have been identified across the construction, O&M, and decommissioning phases (i.e. lifetime effects) as well as the interaction of multiple effects on a receptor (i.e. receptor-led effects).

23.6.11 The significance of the individual effects is presented in the summary of effects, Embedded and Additional Mitigation measures and monitoring tables for each receptor group within the relevant topic chapters (all conclusions for significance of effect defined in the topic chapters assume successful implementation of Embedded and Additional Mitigation measures where appropriate). A descriptive assessment of the scope for these individual effects to interact to create a different or greater effect is then undertaken (Section 23.7). This assessment incorporates qualitative and, where possible, quantitative assessments. Each topic-specific assessment, outlined in Table 23.5 to Table 23.14, presents an assessment of the significance of effect to any such inter-related effect.

23.6.12 The assessment of inter-related effects considers the Maximum Design Scenarios (MDSs), including the successful implementation of Embedded and Additional Mitigation measures incorporated into the Proposed Development, where appropriate. It is recognised that while individual effects may not be significant within their respective topic-specific assessments, they could become significant when considered together. In some cases, effects of Moderate significance or above may occur only during a specific phase of the Proposed Development's lifecycle (e.g. during construction but not during O&M or decommissioning). Where this applies, it is clearly stated that no inter-related effects are expected across the full lifetime of the Proposed Development.

Part Two: Ecosystem-Based Effects Assessment Method

23.6.13 The ecosystem-based assessment aims to qualitatively assess the potential impacts of the Proposed Development on the ecosystem, focusing on changes in predator-prey relationships and overall ecosystem functioning.

23.6.14 This structure of Part Two: Ecosystem-Based Effects Assessment Method is as follows:

- overview;
- ecosystem baseline;
- the marine food web;
- the key predator species;
- the key prey species;
- how the food system works;
- future ecosystem baseline;
- existing pressures on prey species;
- effects of the Proposed Development on prey species; and
- effects of the Proposed Development on predator species.

23.6.15 Information and conclusions from the relevant chapters of this Offshore EIA Report and their corresponding technical reports have been used to build up a picture of the marine ecosystem in the locality of the Proposed Development and inform the baseline for the ecosystem assessment. This information has also been used to inform the assessments within these sections to ultimately conclude whether the Proposed Development alone, and cumulatively with other projects, is likely to result in changes to prey species, which in turn will result in changes to predator species and therefore result in likely significant ecosystem effects.

23.7 Part One: Inter-Related Effects Assessment

Assessment of Inter-Related Effects

23.7.1 For all of the receptor groups that have been listed in Paragraph 23.6.6, the scope for impact to these receptors to create project lifetime effects over all phases and/or receptor-led effects through interacting together on a particular group has been explored and discussed below.

23.7.2 The sections below have been divided into the categories that are listed in Paragraph 23.6.6.

Physical Environment

Physical Processes

23.7.3 For physical processes, the following potential impacts have been considered within the inter-related effects assessment:

- project lifetime effects: potential changes to Suspended Sediment Concentration (SSC), bed levels and sediment type;
- project lifetime effects: potential impacts to seabed morphology in designated sites;
- project lifetime effects: potential impacts to coastal morphology;
- project lifetime effects: potential changes to the tidal regime;

- project lifetime effects: potential changes to the wave regime;
- project lifetime effects: potential changes to the sediment transport regime;
- project lifetime effects: potential changes to stratification and frontal systems; and
- project lifetime effects: scour.

23.7.4 Table 23.5 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for physical processes receptors.

23.7.5 Physical processes receptors have the potential to have secondary effects on other receptors and these effects are fully considered in the topic-specific chapters and elsewhere in this chapter. These receptors and effects are:

- benthic ecology:
  - potential changes to SSCs;
  - potential changes to bed levels;
  - potential impacts so seabed morphology;
- fish and shellfish ecology:
  - potential changes to SSCs;
  - potential changes to bed levels;
  - potential changes to stratification and frontal systems;
- marine mammals:
  - potential changes to SSCs;
  - potential changes to bed levels;
  - potential changes to stratification and frontal systems;
- offshore ornithology:
  - potential changes to SSCs;
  - potential changes to stratification and frontal systems;
- infrastructure and other users:
  - potential changes to SSCs;
  - potential changes to bed levels;
  - potential impacts so seabed morphology;
- marine archaeology:
  - potential changes to SSCs;
  - potential changes to bed levels; and
  - potential impacts so seabed morphology.

Table 23.5: Summary of Likely Significant Potential Inter-Related Effects for Physical Processes from Individual Effects Occurring across the Construction, O&M and Decommissioning Phases of the Proposed Development (Project Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Potential changes to SSC, bed levels and sediment type	✓	×	✓	**This change relates to a pathway, rather than an impact on a receptor. Accordingly, no statement is made with regards to the likelihood of Significant Inter-Related Effects** The effects of increased SSC caused by seabed disturbance will primarily occur during the construction and decommissioning phases of the Proposed Development. The spatial extent of meaningful seabed disturbance and associated increase of SSC and deposition is expected to be localised, mainly within the near-field and intermediate impact zones of the activity (up to 500 m). The cumulative effects of the impact over the project lifetime are not expected to result in greater significance than those assessed separately.
Potential impacts to seabed morphology in designated sites	✓	✓	✓	**No Likely Significant Inter-Related Effects** The morphology of designated areas of seabed and the coast could theoretically be subject to the project lifetime inter-related effects, with direct seabed disturbance occurring in the construction and decommissioning phases and indirect disturbance occurring during the O&M phase due to hydrodynamic, wave and sediment transport blockage related effects. However, in all cases the extent of change is expected to be negligible and even if combined over the project lifetime, the magnitude of change (and therefore overall significance of effect) would be no greater than if assessed in isolation.
Potential impacts to coastal morphology	✓	✓	✓	
Potential changes to the tidal regime	✓	✓	✓	**This change relates to a pathway, rather than an impact on a receptor. Accordingly, no statement is made with regards to the likelihood of Significant Inter-Related Effects** Changes to the tidal, wave and sediment regime will be greatest when all Offshore Infrastructure is in place. Although some change may occur during the construction and decommissioning phases (when the Proposed Development is partially built/decommissioned), the cumulative effects of the impact over the project lifetime are not expected to result in greater significance than those assessed separately.
Potential changes to the wave regime	✓	✓	✓	
Potential changes to the sediment transport regime	✓	✓	✓	

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Potential changes to stratification and frontal systems	✓	✓	✓	**This change relates to a pathway, rather than an impact on a receptor. Accordingly, no statement is made with regards to the likelihood of Significant Inter-Related Effects** Changes to stratification will be greatest when all Offshore Infrastructure is in place. Although some change may occur during the construction and decommissioning phases (when the Proposed Development is partially built/decommissioned), the cumulative effects of the impact over the project lifetime are not expected to result in greater significance than those assessed separately.
Scour	✓	✓	✓	**This change relates to a pathway, rather than an impact on a receptor. Accordingly, no statement is made with regards to the likelihood of Significant Inter-Related Effects** The greatest scour footprint will likely occur when all Offshore Infrastructure is in place. Although scour may occur during the construction and decommissioning phase (when the Proposed Development is partially built/decommissioned), the cumulative effects of the impact over the project lifetime are not expected to result in greater significance than those assessed separately.
Receptor-led Effects				
[None identified]	N/A	N/A	N/A	The different physical processes studied are already inter-related; in particular, sediment transport is dependent on currents and waves and therefore these linked processes have already been considered within the assessment. In turn, this information on changes to physical processes has been used to inform other EIA Report topics. Assessments have been undertaken separately within these individual topic chapters and are not reported here as additional inter-relationships.

*Proposed Development phase refers to construction (C), O&M (O) and decommissioning (D).

Biological Environment

Benthic Ecology

23.7.6 For benthic ecology, the following potential impacts have been considered within the inter-related effects assessment:

- temporary habitat loss and/or disturbance;
- long term habitat loss and/or disturbance;
- introduction of artificial structures and subsequent colonisation;
- changes to SSC, bed levels and sediment type;
- changes in physical processes;
- increased risk of introduction and spread of Invasive Non-Native Species (INNS);
- removal of hard substrates; and
- impacts to benthic ecology due to Electromagnetic Fields (EMF).

23.7.7 Table 23.6 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for benthic ecology receptors.

23.7.8 Effects on benthic ecology also have the potential to have effects on other receptors, and these effects are fully considered in the topic-specific chapters. These receptors and effects are:

- fish and shellfish ecology:
  - temporary (during construction, O&M and decommissioning phases), long term (during O&M phase only) and permanent habitat alteration (post-decommissioning), habitat loss and disturbance (see Volume 2, Chapter 9: Fish and Shellfish);
- marine mammals:
  - effects on marine mammals due to altered prey availability (see Volume 2, Chapter 10: Marine Mammals);
- offshore ornithology:
  - changes to prey availability (see Volume 2, Chapter 11: Offshore Ornithology).

Table 23.6: Summary of Likely Significant Inter-Related Effects for benthic ecology from Individual Effects Occurring Across the Construction, O&M and Decommissioning Phase of the Proposed Development (Project Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Temporary habitat loss and/or disturbance	✓	✓	✓	When habitat loss or disturbance is considered additively across all phases, the total area of habitat affected is larger than when considered across an individual phase (i.e. just construction). However, temporary and long term loss and/or disturbance will be highly localised to the vicinity of the activities during each phase of the Proposed Development. Individual activities resulting in temporary habitat loss and disturbance will occur intermittently throughout this time with only a small proportion of the total area of habitat being impacted at any one time. The predominantly sand and coarse sediment habitats that are most likely to be affected are typical of, and widespread throughout, the Regional Benthic Ecology Study Area and North Sea. Further, all benthic habitats are predicted to recover. There is the potential for repeat disturbance to occur during the O&M phase, although it was predicted that the communities will have fully recovered from construction impacts by this time. Therefore, across the lifetime of the project, the effects on benthic ecology receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase. As a result, the inter-related effects are of **Minor** adverse significance which is not significant in EIA terms.
Long term habitat loss and/or disturbance	✓	✓	✓	
Introduction of artificial structures and subsequent colonisation	✓	✓	✓	Introduction of hard substrate and subsequent colonisation will be highly localised to the vicinity of the introduced hard substrate during each phase of the Proposed Development. The predominantly sand and coarse sediment habitats that are most likely to be affected are typical of, and widespread throughout, the Regional Benthic Ecology Study Area and North Sea. Therefore, across the lifetime of the Proposed Development, the effects on benthic ecology receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase. As a result, the inter-related effects are of **Minor** adverse significance which is not significant in EIA terms.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Changes to SSC, bed levels and sediment type	✓	✓	✓	The majority of seabed disturbance (resulting in highest SSC/deposition) will occur during the construction and decommissioning phases, with any effects being short lived and intermittent across each phase. Benthic Important Ecological Features (IEFs) potentially affected by increased SSC and deposition are likely to have recovered in the intervening period between phases. Due to this and the low sensitivity (and/or high recoverability) of the species and habitats in question, the interaction of these impacts across the stages of the Proposed Development is predicted to result in an effect of Minor significance. Therefore, across the lifetime of the Proposed Development, the effects on benthic ecology receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance then the assessments presented for each individual phase. As a result, the inter-related effects are of **Minor** adverse significance which is not significant in EIA terms.
Changes in physical processes	×	✓	✓	Any effects due to changes in physical processes across the phases of the Proposed Development are likely to be highly localised (i.e. largely within the Array Area), with benthic ecology receptors having low sensitivity (and/or high recoverability) to the scale of changes predicted. Therefore, across the lifetime of the Proposed Development, the effects on benthic ecology receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance then the assessments presented for each individual phase. As a result, the inter-related effects are of **Minor** adverse significance which is not significant in EIA terms.
Increased risk of introduction and spread of INNS	✓	✓	✓	Although vessels associated with all phases of the Proposed Development (potentially from countries of origin other than the UK) may facilitate the spread of INNS, this effect will predominantly arise during the O&M phase as many INNS will require the hard substrate to be in place to provide substrate on which to settle. It should be noted that infaunal INNS may occur. However, the Embedded Mitigation includes the implementation of a Marine Invasive Non-native Species Biosecurity Plan as part of the EMP. This will require that the risk of potential introduction and spread of INNS will be reduced as far as practicable across all phases. Therefore, across the lifetime of the Proposed Development, the effects on benthic ecology receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase. As a result, the inter-related effects are of **Minor** adverse significance which is not significant in EIA terms.
Removal of hard substrates	×	×	✓	This effect will arise during the decommissioning phase only; therefore, no likely significant inter-related effects are anticipated across the lifetime of the project.
Impacts to benthic ecology due to EMFs	×	✓	×	This effect will arise during the O&M phase only; therefore, no likely significant inter-related effects are anticipated across the lifetime of the project.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Receptor-led Effects				
There is the potential for spatial and temporal interactions between the effects arising from temporary and long term habitat loss and/or disturbance, and increased SSCs and associated deposition effects on benthic habitats during the lifetime of the Proposed Development. Based on **best available evidence, published guidance**, and **professional judgement of experienced marine ecologists (Volume 2, Chapter 8: Benthic Ecology)**, the greatest potential for inter-related impacts is predicted to arise through the interaction of the following: • direct (both temporary and permanent) habitat loss and/or disturbance from the activities and Offshore Infrastructure detailed in the MDS; and • indirect habitat disturbance due to increased SSCs and associated deposition, and changes to physical processes. These individual impacts were assigned a significance of Negligible to Minor as standalone impacts and although the potential inter-related impacts may arise (i.e. spatial and temporal overlap of direct habitat disturbance), It was predicted that this will not be any more significant than the individual impacts in isolation. This is because the combined area of habitat potentially affected would typically be restricted to the Site Boundary, the habitats affected are widespread across the Regional Benthic Ecology Study Area and, where temporary disturbance occurs, full recovery of the benthos is predicted. In addition, any effects due to changes in physical processes are likely to be limited, both in extent (i.e. largely within the Array Area) and also in magnitude, with benthic ecology receptors having low sensitivity to the scale of changes predicted. As such, these interactions are predicted to be no greater than the individual effects assessed in isolation. As a result, the receptor-led effects are of a **Minor** adverse significance which is not significant in EIA terms.				

* Proposed Development Phase refers to construction (C), O&M (O) and decommissioning (D).

Fish and Shellfish Ecology

23.7.9 For fish and shellfish ecology the following potential impacts have been considered within the inter-related assessment:

- temporary habitat loss and/or disturbance;
- long term habitat loss and/or disturbance;
- introduction of artificial habitat and subsequent colonisation of hard structures;
- increased SSCs and associated deposition;
- subsea noise impacting fish and shellfish receptors; and
- impacts to fish and shellfish receptors due to EMF.

23.7.10 Table 23.7 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M phase, and decommissioning phases of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for fish and shellfish receptors.

23.7.11 Effects on fish and shellfish ecology also have the potential to lead to secondary effects on other receptors and these effects are fully considered in the topic-specific chapters. These receptors and effects are:

- Marine mammals:
  - changes to the fish and shellfish community within the Fish and Shellfish Ecology Study Area resulting from impacts associated with the Proposed Development may lead to changes in prey availability for marine mammals (see Volume 2, Chapter 10: Marine Mammals);
- Offshore ornithology:
  - changes in prey availability, as above for marine mammals (see Volume 2, Chapter 11: Offshore Ornithology);
- Commercial fisheries:
  - changes to the fish and shellfish community within the Fish and Shellfish Ecology Study Area resulting from impacts associated with the Proposed Development may affect the commercial fisheries industry (see Volume 2, Chapter 13: Commercial Fisheries).

Table 23.7: Summary of Likely Significant Inter-Related Effects for Fish and Shellfish Ecology from Individual Effects Occurring Across the Construction, O&M and Decommissioning Phase of the Proposed Development (Project Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Temporary habitat loss and/or disturbance	✓	✓	✓	If considered additively across the construction, O&M, and decommissioning phases, the total area of temporary habitat loss and disturbance is larger than for each individual stage. It should be noted, however, that across the three phases of the Proposed Development, there is potential for the same areas to be repeatedly disturbed, as the footprints of impact are localised to the various Offshore Infrastructure on the seabed. Repeated disturbance could occur at single Wind Turbines, the Offshore Substation Platforms (OSPs), and specific sections of the cables. Therefore, a total footprint of impact across all three phases would likely be an overestimation, with overlap in footprints across phases. Further, the seabed habitats potentially disturbed within the Site Boundary are widespread across the Fish and Shellfish Ecology Study Area. Therefore, project lifetime effects will be proportionally small in this wider context. This is further bolstered by the recoverability of temporarily disturbed seabed, and the high potential for fish and shellfish receptors to return to affected areas. Therefore, across the lifetime of the Proposed Development, the effects of this impact are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase (e.g. **Minor** adverse throughout). Overall, no likely significant inter-related effects anticipated across the lifetime of the Proposed Development.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Long term habitat loss and/or disturbance	✓ (combined as one phase in the assessment of significance: Volume 2, Chapter 9: Fish and Shellfish)		✓	In the assessment of significance for this impact, the construction and O&M phases were combined as the Offshore Infrastructure resulting in long term habitat loss and disturbance installed throughout the construction phase will persist into the O&M phase (i.e. the footprints of long term habitat loss in the construction phase will be in the same locations as in the O&M phase). The MDS for the decommissioning phase considered that the Scour Protection and cable protection will be left *in situ,* and the footprints of which will be in the same locations as they were in the combined construction and O&M phases. Therefore, the footprint of long term habitat loss and disturbance will not differ if considered additively across the combined construction and O&M phase, and the decommissioning phase (i.e. the total area of long term habitat loss and disturbance over all three phases will not be larger than described for the individual phases). Further, the seabed habitats (i.e. the offshore subtidal sands and gravels, and offshore muddy and mixed sediments IEFs as defined in Volume 2, Chapter 8: Benthic Subtidal Ecology) potentially disturbed within the Site Boundary are widespread across the Fish and Shellfish Ecology Study Area. Therefore, project lifetime effects will be proportionally small in this wider context. Therefore, across the lifetime of the Proposed Development, the effects of this impact are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase (e.g. **Minor** adverse throughout). Overall, no likely significant inter-related effects anticipated across the lifetime of the Proposed Development.
Introduction of artificial habitat and subsequent colonisation of hard structures	✓ (combined as one phase in the assessment of significance: Volume 2, Chapter 9: Fish and Shellfish)		✓	As above for 'long term habitat loss and/or disturbance'.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Increased SSCs and associated deposition	✓	✓	✓	Effects from increased SSCs and associated deposition in each phase of the Proposed Development will be short lived and intermittent. Fish and shellfish receptors potentially affected by this impact in each phase are likely to have recovered in the intervening period between both: • individual activities resulting in increased SSCs and associated deposition (such as seabed preparation); and • phases. Further, the fish and shellfish IEFs (except herring and sandeel) were considered to be of low sensitivity and/or high recoverability to this impact. Therefore, across the lifetime of the Proposed Development, the effects of this impact are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase (e.g. **Minor** adverse throughout). Overall, no likely significant inter-related effects anticipated across the lifetime of the Proposed Development.
Subsea noise impacting fish and shellfish receptors	✓	✓	✓	Subsea noise could occur during all phases of the Proposed Development, however those with the highest impact ranges would only occur in the construction phase (e.g. piling and Unexploded Ordnance (UXO) clearance). However, subsea noise produced as a result of piling during construction is likely to reach over a larger area compared to other noise producing activities associated. Therefore, it is considered unlikely that piling would act additively with other noise producing activities occurring at the same time, as the noise produced during piling is likely to mask other noise sources. Piling noise, although occurring during construction phase only, would contribute to the overall duration of noise impacts throughout all phases of the Proposed Development. Significance was considered to be **Minor** adverse and therefore not significant in EIA terms for all fish and shellfish receptors except herring, which was **Moderate** adverse and therefore significant in EIA terms. However, the effects of this noise source are not anticipated to interact in such a way with other noise sources as to result in inter-related effects of greater significance than the assessments presented for each individual phase (e.g. **Minor** adverse throughout and **Moderate** adverse for herring). Increased subsea noise during UXO clearance could interact with other noise sources. However, UXO clearance is planned using low order techniques which has the potential to result in localised disturbance only. For each UXO clearance event, the duration of the impact

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
				– including mitigation techniques - will be very short (i.e. hours). Subsea noise from UXO clearance, although occurring during construction phase only, could contribute to the overall duration of noise impacts throughout all phases of the Proposed Development. Significance was considered to be **Minor** adverse and therefore not significant in EIA terms. The effects of this noise source are not anticipated to interact in such a way with other noise sources as to result in inter-related effects of greater significance than the assessments presented for each individual phase (e.g. **Minor** adverse throughout). Elevated subsea noise during site-investigation surveys and construction activities could be additive over all phases of the Proposed Development, with sequential noise from site-investigation surveys leading to an extended effect on fish and shellfish receptors. However, these noise producing activities will occur intermittently, during short term events with cessation of noise in between events. Therefore, these impacts will be highly localised. Additive effects are possible (though unlikely given intermittency of these noise producing activities) and the duration of elevated subsea noise from all activities could be extended. Significance was considered to be **Minor** adverse and therefore not significant in EIA terms. The effects of these noise sources are not anticipated to interact in such a way with other noise sources as to result in inter-related effects of greater significance than the assessments presented for each individual phase (e.g. **Minor** adverse throughout).
Impacts to fish and shellfish receptors due to EMF	×	✓	×	This impact will only occur during the O&M phase, and will not overlap with other phases, therefore no likely significant inter-related effects are anticipated across the lifetime of the Proposed Development.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Receptor-led Effects				
• **Temporary habitat loss and/or disturbance;** • **Long term habitat loss and/or disturbance;** • **Introduction of artificial habitat and subsequent colonisation;** • **Increased SSCs and associated deposition;** • **Subsea noise impacting fish and shellfish receptors; and** • **Impacts to fish and shellfish receptors due to EMF.**	✓ (all impacts except EMF)	✓ (all impacts)	✓ (all impacts except EMF)	There is potential for temporal and spatial interactions between the impacts listed across all phases of the Proposed Development. However, these individual impacts were largely assigned as negligible to **Minor** adverse significance as standalone impacts. Although potential receptor-led effects may arise, it is important to recognise that the individual activities will not necessarily occur simultaneously or in the same physical areas of the Site Boundary. For example, the activities considered in the MDS for multiple impacts associated with the construction phase may not temporally overlap (such as UXO clearance, sandwave clearance, piling, and cable laying). Therefore, across the phases of the Proposed Development, receptor-led effects are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for individual impacts in isolation (e.g. **Minor** adverse throughout). Overall, no likely significant inter-related effects are anticipated across the lifetime of the Proposed Development.

* Proposed Development Phase refers to construction (C), O&M (O) and decommissioning (D).

Marine Mammals

23.7.12 For marine mammals the following potential impacts have been considered within the inter-related assessment:

- injury and disturbance from subsea noise generated during piling;
- injury and disturbance from subsea noise generated during UXO clearance;
- injury and disturbance from subsea noise generated during site-investigation surveys;
- injury and disturbance from subsea noise generated by vessel use and other noise producing activities;
- injury to marine mammals due to collision with vessels;
- injury and disturbance from subsea noise generated by Wind Turbine operation; and
- effects on marine mammals due to altered prey availability.

23.7.13 Table 23.8 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M, and decommissioning phases of the Proposed Development and the inter-related effects (receptor-led effects) that are predicted to arise for marine mammal receptors.

23.7.14 As noted above, effects on marine mammals have the potential to have secondary effects on other receptors and these effects are fully considered in the topic-specific chapters. These receptors and effects are:

- fish and shellfish ecology: Changes in the marine mammal community could have indirect effects on fish and shellfish populations.

Table 23.8: Summary of Likely Significant Inter-Related Effects for Marine Mammals from Individual Effects Occurring Across the Construction, O&M and Decommissioning Phase of the Proposed Development (Project Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Injury and disturbance from subsea noise generated during piling	✓	×	×	Whilst subsea noise could occur during all phases of the Proposed Development, subsea noise generated during piling is limited to the construction phase only and therefore no likely significant inter-related effects across multiple phases of the Proposed Development from piling (project lifetime effects) are therefore predicted. Increased subsea noise during piling activities associated with construction of the Proposed Development has the potential to interact with other sources of underwater noise associated with the construction phase of the Proposed Development (such as UXO clearance). However, the subsea noise produced as a result of piling during construction of the Proposed Development is likely to reach over a larger area (e.g. up to 17.40 km for minke whale *Balaenoptera acutorostrata* during the concurrent piling of two monopile foundations; Volume 2, Chapter 10: Marine Mammals) compared to other subsea noise producing activities associated with the Proposed Development. Therefore, during this phase it is considered unlikely that piling would act additively with other noise producing activities occurring at the same time, as the noise produced during piling is likely to mask other noise sources. Although piling itself occurs during only the construction phase, it would contribute to the overall duration of subsea noise impacts (other noise generating activities) across all phases of the Proposed Development and is discussed below in receptor-led effects Significance is considered to be **Minor** adverse and therefore not significant in EIA terms.
Injury and disturbance from subsea noise generated during UXO clearance	✓	×	×	Whilst subsea noise could occur during all phases of the Proposed Development, increased subsea noise generated during UXO clearance is limited to the construction phase only and therefore no likely significant inter-related effects across multiple phases of the Proposed Development from UXO clearance (project lifetime effects) are therefore predicted. Whilst subsea noise could occur during all phases of the Proposed Development, increased subsea noise generated during UXO clearance is limited to the construction phase only and therefore no likely significant inter-related effects across multiple phases of the Proposed Development from UXO clearance (project lifetime effects) are therefore predicted. Increased subsea noise during UXO clearance during pre-construction activities could interact with other sources of subsea noise in the construction phase. This has the potential to contribute to an increase in the subsea noise which in turn could affect marine mammals. Low order clearance methods are the default, which has the potential to result in auditory injury (AUD

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
				INJ) ranges of up to 1.27 km (Volume 2, Chapter 10: Marine Mammals) and localised disturbance out to 2.48 km (Volume 2, Chapter 10: Marine Mammals). However, the MDS assumes that high order clearance may occur, with potential for AUD INJ out to 14.23 km for the maximum assumed UXO size (720 kg Net Explosive Quantity (NEQ)) and out to 9.69 km for the most realistic maximum UXO size (227 kg NEQ). Disturbance (Temporary Threshold Shift (TTS) as a proxy) may occur out to 34.28 km for the maximum assumed UXO size (720 kg NEQ) and out to 23.21 km for the most realistic maximum UXO size (227 kg NEQ). Additional disturbance is possible due to use of Acoustic Deterrent Devices (ADDs) and soft start charges. It should be noted however, that for each UXO clearance, the duration of the impact - including mitigation techniques - will be very short, and there will be breaks between UXO clearance events to allow periods of recovery. It has however been concluded on a precautionary basis that temporally UXO clearance could add to the overall duration of elevated subsea noise from other activities during pre-construction (e.g. site-investigation surveys) (during the construction phase) and will contribute to the overall duration of subsea noise impacts throughout all phases of the Array Area and is discussed below in receptor-led effects. Significance is considered to be **Minor** adverse and therefore not significant in EIA terms.
Injury and disturbance from subsea noise generated during site-investigation surveys	✓	✓	×	Elevated subsea noise during site-investigation surveys could be additive over the construction and O&M phases of the Proposed Development with sequential noise from site-investigation surveys leading to extended effect on marine mammals. However, this impact will occur as short term events with cessation of noise in between events allowing periods of recovery, and the impact is localised, maximum auditory injury range of 0.25 km and disturbance of 9.15 km (Volume 2, Chapter 10: Marine Mammals). Additive effects are possible (though unlikely given intermittency of surveys) and the duration of elevated underwater noise from all activities could be extended. Significance is considered to be **Minor** adverse and therefore not significant in EIA terms.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Injury and disturbance from subsea noise generated by vessel use and other noise producing activities	✓	✓	✓	Elevated underwater noise during vessel use and other non-piling construction activities could occur across all three phases of the Proposed Development. Vessels will be used throughout all stages of the Proposed Development and could cause additional disturbance to marine mammals. Other construction activities include drilling (foundation installation) and could also lead to disturbance effects in this phase. Auditory injury was not exceeded for all species, and disturbance effects are likely to be localised for non-piling construction activities and during vessel movements (e.g. out to maximum of 5.6 km) with breaks in activity within phases, however, temporally these effects could occur over all phases of the Array Area and lead to additive effects. Significance is considered to be **Minor** adverse and therefore not significant in EIA terms.
Injury to marine mammals due to collision with vessels	✓	✓	✓	Over the lifetime of the Proposed Development there will be an ongoing risk of collision associated with vessels throughout all phases. If injury to marine mammals from collisions did occur this could lead to losses of individuals, but it is unlikely to lead to population-level effects. The risk of mortality is likely to be low due to vessels moving at low speed, particularly by adopting good practice code of conduct for vessel operators (Outline Navigational Safety and Vessel Management Plan (NSVMP)) (Volume 4, Appendix 29: Outline Navigational Safety and Vessel Management Plan) and therefore the risks will be reduced. It is important to consider that, to some extent, the subsea noise from the vessels themselves would act antagonistically with this impact by deterring animals away from vessels and thereby further reducing the risk of injury due to collision. Significance is considered to be **Minor** adverse and therefore not significant in EIA terms.
Injury and disturbance from subsea noise generated by Wind Turbine operation	×	✓	×	This impact occurs during the O&M phase only, therefore no likely significant inter-related effects across multiple phases of the Proposed Development (project lifetime effects) are therefore predicted.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Effects on marine mammals due to altered prey availability	✓	✓	✓	Fish and shellfish communities may be affected through all phases of the Proposed Development and therefore could present a long term effect on marine mammals through changes/reductions to prey availability. Inter-related effects on fish and shellfish receptors are described in more detail in Volume 2, Chapter 9: Fish and Shellfish Ecology. Volume 2, Chapter 9: Fish and Shellfish Ecology concluded that for all potential impacts and at all phases of the Proposed Development the effects were unlikely to lead to significant effects on fish and shellfish communities, and therefore unlikely to lead to significant effects on marine mammals (see Volume 2, Chapter 10: Marine Mammals). Even in the context of longer term impacts there is unlikely to be an additive effect as marine mammals can exploit a suite of prey species and only a small area will be affected when compared to available foraging habitat in the northern North Sea. Significance is considered to be **Minor** adverse and therefore not significant in EIA terms.
Receptor-led Effects				
Stressor 1: injury or disturbance from elevated underwater noise (from piling, UXO clearance, site-investigation surveys, vessels, operational noise from Wind Turbines)	✓	✓	✓	During the pre-construction phase, activities resulting in elevated subsea noise includes piling, UXO clearance, site-investigation surveys, vessel use and other noise producing activities. These activities are likely to result in disturbance to marine mammals which may be additive in nature if activities are synchronised, as it could lead to a larger area disturbed at any one time. Disturbance is likely to occur as short term, localised events for each activity within the construction phase. Prior to piling, for example, UXO clearance could result in no more than 40 single clearance events (Volume 2, Chapter 10: Marine Mammals), with disturbance occurring mainly during the implementation of Additional Mitigation (ADDs and soft start) rather than the UXO clearance event itself which would be no more than seconds for each. There is also a small potential that animals could experience injury during UXO clearance (if high order detonation is used). Site-investigation surveys will occur intermittently during the pre-construction phase, whilst disturbance during vessel activity will occur intermittently with timings linked to the pre-construction activities (UXO and site-investigation surveys). During the construction phase, activities resulting in elevated subsea noise include piling, other construction activities and vessel movements could occur. Since injury to marine mammals will be reduced through the Outline Marine Mammal Mitigation Protocol (MMMP) (Volume 4, Appendix 27: Outline Marine Mammal Mitigation Protocol), the key focus is on disturbance effects. Disturbance due to impact piling could occur intermittently on a total of 268 days over the construction phase of 60 months (five years). Other construction activities (e.g. drilling and cable laying) and vessel movements would occur intermittently within the

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
				five-year construction phase. When piling occurs the disturbance effects are likely to be greater than for any of the other activities contributing to elevated subsea noise so there is less likely to be an additive or synergistic effect during piling. Benhemma-Le Gall *et al.* (2021) found that piling was the main cause of displacement during construction with observed responses at distances of up to 10 km to 15 km at Beatrice and Moray East OWFs and without piling, there was still a disturbance response due to vessel activity and other construction, but that the effect ranges (up to 4 km) were less compared to piling. This demonstrates that the main driver for disturbance will be piling and that there would be less potential for additive or synergistic, inter-related effects from other activities during this time. Indeed, the effect of piling may be antagonistic with effects from other sound-producing activities as it dominates the soundscape and therefore may 'cancel out' any other effects that could occur. There may, however, be an additive effect spatially where two or more noise producing activities occur in different parts of the Proposed Development (though this is highly unlikely), or temporally due to ongoing disturbance from activities throughout the construction phase (e.g. if they occur consecutively). During the O&M phase, activities resulting in elevated underwater noise include vessel activity, geophysical surveys and operational noise from Wind Turbines. These activities have the potential to result in disturbance to marine mammals which may be additive if activities are synchronised, as it could lead to a larger area disturbed at any one time. Disturbance is likely to occur as short term, localised events for vessel activity (and it is likely other non-service vessels will be excluded from the OWF during maintenance activity) and geophysical surveys and the disturbance from operational noise is expected to be highly localised and minimal. There may be a slight additive effect spatially where two or more noise producing activities occur in different parts of the Array Area, or temporally due to ongoing disturbance from activities throughout the O&M phase (e.g. if they occur consecutively). During decommissioning, vessel movements associated with decommissioning activities, as well as removal of foundations, cables and cable protection, will result in elevated underwater noise which could lead to disturbance to marine mammals. Disturbance is likely to occur as short term, localised events and there may be an additive effect spatially where vessels are operating in different parts of the Array Area, or temporally due to ongoing disturbance throughout the decommissioning phase.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
				Therefore, marine mammal receptors have the potential to experience ongoing disturbance due to elevations in underwater noise from different sources across all phases of the Proposed Development. The sensitivity of marine mammal species will be linked to their ability to tolerate the stressor such that their ability to function normally (e.g. forage, reproduce, communicate and avoid predators) is not impeded. The assessment in Volume 2, Chapter 10: Marine Mammals, which adopts a highly precautionary, maximum design scenario approach, whereby multiple conservative assumptions are compounded. This has demonstrated that for all impacts, considered in isolation, the residual effects will not be significant, as either the spatial scale is very localised or where larger scale effects do occur (i.e. during piling or UXO) these will be highly reversible with marine mammals returning to baseline levels rapidly. There are, however, uncertainties as to how all activities interact to contribute to an additive effect from underwater noise as a stressor. It is highlighted that the impact assessment adopted a precautionary approach assuming the maximum extent of effects throughout each phase with no allowance for any acclimatisation to, or compensation for elevated levels of sound. Whilst it is acknowledged that this approach is appropriate due to inherent uncertainties in undertaking such assessments, it may lead to overestimates of the effects. To some extent it is anticipated that animals will acclimatise to or compensate for such increases in underwater noise. Graham *et al.* (2019), for example, demonstrated acclimatisation in harbour porpoise *Phocoena phocoena*, showing that the proportional response of harbour porpoise to piling noise decreased over the piling phase, with the proportion of animals disturbed at a received level of 160 dB re 1 µPa decreased from 91.5% to 49.2% from the first pile to the last pile. Kastelein *et al.* (2019) suggest that harbour porpoise (a species with high daily energy requirements) may be able to compensate for period of disturbance as they can dramatically increase their food intake in a period following fasting without any detriment to their health. In the Moray Firth, buzzing activity of harbour porpoise (representing foraging) was higher compared to baseline levels during the construction of Moray East offshore wind farm, possibly in relation to increased prey availability as a result of introduction of hard substrates (e.g. jacket foundations and scour protection). (Benhemma-Le Gall *et al.*, 2021). Russell *et al.* (2014) demonstrated pinnipeds anthropogenic structures at sea, with three animals concentrating their foraging effort in the wind farms. Similarly, Rose *et al.* (2025) found significantly higher detection rates within OWFs than in their vicinity

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
				(surrounding 2.5 km), and suggested OWFs in operation may attract rather than deter harbour porpoise (due to reef and/or refugium effects). Therefore, significance is considered to be **Minor** adverse and therefore not significant in EIA terms.
Stressor 2: injury due to collisions with vessels	✓	✓	✓	Injury due to collisions with vessels is associated with increased vessel movement, the impact of which was assessed from different types of vessels and at different phases of the Proposed Development. Over the lifetime of the Proposed Development there will be an increased temporal risk to marine mammal receptors. However, with Embedded Mitigation such as the outline NSVMP (Volume 2, Chapter 10: Marine Mammals) the potential risk of injury due to collision is likely to be reduced and therefore it is not anticipated that an additive effect will occur. Additionally, to some extent the noise from the vessels themselves would act antagonistically with this impact by deterring animals away from vessels and thereby further reducing the risk of injury due to collision. Furthermore, marine mammals in this area are already accustomed to high-level of vessel activity (see Volume 2, Chapter 10: Marine Mammals). For example, Buckstaff (2004) demonstrated that bottlenose dolphins *Tursiops truncatus* increased their rate of whistle production at the onset of a vessel approach, and then decreased production during and after it had passed. This increased whistle production may be a tactic to reduce signal degradation to ensure that information is being communicated in elevated noisy environment, but it also demonstrates that animals are aware of approaching vessel from a distance. This corroborates previous research of Nowacek *et al.* (2001), which found that bottlenose dolphins swim in tighter aggregated groups during vessel approaches, therefore if a vessel is loud enough to be detected by an animal for which it adjusts its behaviour, the likelihood of collision decreases. Furthermore, not all collisions that do occur are lethal (e.g. dependent depth of laceration, anatomical site of injury, health of animal (Combs, 2018; Conn and Silber, 2013; Rommel *et al.*, 2007; Vanderlaan and Taggart, 2007; Wiley *et al.*, 2016) and is highly species dependent, and therefore the assessment precautionarily considered recovery potential to be medium from vessel collisions. Therefore, significance is considered to be **Minor** adverse and therefore not significant in EIA terms.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Stressor 3: changes in prey communities	✓	✓	✓	The EIA considered overall effect on fish and shellfish communities from multiple stressors (see in Volume 2, Chapter 9: Fish and Shellfish Ecology) and therefore, in this respect, has taken an ecosystem-based approach. For some impacts stressors will be over the same timescales as marine mammals (such as subsea noise effects on fish and shellfish) while for others, such as temporary habitat loss, timescales may be different to those assessed for marine mammals (e.g. low mobility or sessile species may recover much more slowly). The assessment of effects (see Volume 2, Chapter 10: Marine Mammals) demonstrated that due to the high mobility of marine mammals, generalist feeding strategy and ability to exploit different prey species, combined with the small scale of potential changes in context of wider available foraging habitat for marine mammals, the changes to fish and shellfish communities are unlikely to have an effect even from multiple stressors. A recent study by Watson *et al.* (2024) reviewed the global impact of OWFs on ecosystem services and showed operational phase impacts were variable and detailed investigations into fish and shellfish recorded a net beneficial effect of wind farm operations on these species groups. Studies have found that the foundations of OWFs act as artificial reefs and fish aggregation devices (Degraer *et al.*, 2020; Langhamer, 2012) by providing space for the settlement, shelter and foraging (including pelagic and demersal fish and marine mammals). Equally, OWFs can act as an de-facto Marine Protected Areas (MPAs) by limiting activities that can adversely affect the environment, which can potentially enhance both biodiversity and fisheries in surrounding areas (Ashley *et al.*, 2014; Buyse *et al.*, 2022). Therefore, significance is considered to be **Minor** adverse and therefore not significant in EIA terms.
Multiple stressors: inter-related effect of all stressors	✓	✓	✓	The inter-related effect of all stressors is discussed in detail in Paragraph 23.7.15 *et seq*. The significance is considered to be **Minor** adverse and therefore not significant in EIA terms.

* Proposed Development Phase refers to construction (C), O&M (O) and decommissioning (D).

Multiple Stressors: Inter-Related Effect of all Stressors

23.7.15 It is possible that multiple stressors interact across the lifetime of the Proposed Development. Arrigo *et al.* (2020) suggests that large organisms at higher trophic levels, such as marine mammals, may be generally adversely impacted by increasing interaction strength between stressors from different activities, but the variability in the response to such interactions is small and therefore unlikely to lead to population-level effects.

23.7.16 For elevated underwater noise there is the potential for marine mammals to forage in different habitats and to compensate for reduced foraging time. As such the ability of displaced animals will depend on the availability of prey resources in the habitat to which the animals are displaced. Studies have shown that for small, localised marine mammal populations with high site fidelity, there may be biological risks posed by displacement (Forney *et al.*, 2017). For example, due to the importance of the areas for survival (i.e. areas of high resource availability), animals may be highly motivated to remain in an area despite adverse impacts which may increase stress (Rolland *et al.*, 2012). Thus, the inter-related effects of underwater noise (Stressor 1) and changes in fish and shellfish prey resources (Stressor 3) needs to be considered. Impacts on fish and shellfish prey resources were predicted to be localised and short term and therefore unlikely to contribute to an inter-related effect where animals are displaced beyond the Site Boundary. Within the Site Boundary however, there may be short term inter-related effects of noise disturbance and reduced fish and shellfish prey resources. For marine mammals remaining in proximity to the Proposed Development, a substantial disruption in foraging may not be as easy to compensate for where there are shifts in the species composition or localised reductions of fish and shellfish communities. Gordon *et al.* (2003) suggested it may be possible that damaged or disoriented prey could attract marine mammals to an area of impact due to providing short term feeding opportunities (but increasing levels of exposure), however, there is currently little evidence available to investigate such indirect effects on marine mammals.

23.7.17 Therefore, whilst the assessment has largely described potential adverse effects, there is also potential for some beneficial effects on marine mammal receptors. Construction of OWFs can lead to the introduction of hard substrates which can lead to the establishment of new species and new fauna communities, and this may in turn attract marine mammals (Fowler *et al.*, 2018; Lindeboom *et al.*, 2011; Raoux *et al.*, 2017). Thus, even where there is potential for an inter-related effect from ongoing vessel noise during the O&M phase this may be compensated for, to some extent, by an increase in available prey resources. Russell *et al.* (2014) and Russell and McConnell (2014) demonstrated that harbour seal *Phoca vitulina* and grey seal *Halichoerus grypus* moved between hard structures at two operational OWFs and used space-state models to predict where animals were remaining at these locations to actively forage and where they were travelling to the next foundation structure.

23.7.18 Similarly, Rose *et al.* (2025) utilised 13 years of data from Cetacean Porpoise Detector (C-POD) monitoring between 2010 and 2023, to carry out a comparison of harbour porpoise detection rates measured within OWFs in operation (positioned in the German Bight) to those in the vicinity of the same wind farm (2.5 km buffer). Results showed significantly higher detection rates within OWFs than in their vicinity, with an increase of 10.6% in the factor model. Rose *et al.* (2025) suggested operational OWFs may attract rather than deter harbour porpoises due to reef effects (offshore foundations and piles serve as a hard substrate and attract fish and other hard substrate-related fauna), as well as refugium effects (within the areas of German OWFs fishing is prohibited). Even though service vessels still operate within OWFs, and intrinsic ambient noise is present around the Wind Turbines, these impacts apparently did not deter harbour porpoises. Lindeboom *et al.* (2011) studied the ecological effects of the Egmond aan Zee OWF and found that even though the fish community was highly dynamic in time and space, with only minor effects upon fish assemblages observed during the O&M phase, some fish species (e.g. cod) benefited from the 'shelter' within the OWF. This is likely due to reduced fishing activity and the new hard substratum with associated fauna which attracts predator species. Lindeboom *et al.* (2011) suggested the observed increase in echolocation activity of harbour porpoise within the OWF may be correlated with presence of additional increased food sources compared to reference areas.

23.7.19 The potential inter-related effects between subsea noise and collision risk have been discussed in Table 10.64 of Volume 2, Chapter 10: Marine Mammals, and it is considered likely that marine mammals will move away from moving vessels in response to engine noise, therefore reducing the risk of collision (classed as an antagonistic interaction). Alternatively, marine mammals may tolerate and persist in a highly stressed state (as a result of injury caused by underwater noise) while the vessels are approaching (Muto *et al.*, 2018). Animals could also become habituated to vessel noise and not move away from the vessel (McWhinnie *et al.*, 2018) which would result in a synergistic interaction (Wright and Weilgart, 2011). Therefore, the outcome will depend on the degree of habituation and prior experience and a number of acoustical properties that allow an approaching vessel to be detected by a marine mammal species (Gerstein *et al.*, 2005). However, as described in the impact assessment, with Embedded Mitigation in place (Table 10.30 of Volume 2, Chapter 10: Marine Mammals) it is likely that any risk of injury from collision with vessels will be negligible.

23.7.20 Aerial survey Haul-Out counts were conducted before, during and after the construction phases at Scroby Sands OWF, off the coast of Norfolk, to monitor harbour and grey seal counts at haul-out site, located less than 2 km away from the OWF array (Skeate *et al.*, 2012). A decline in harbour seal numbers was reported during construction, with numbers remaining lower over several subsequent years. However, the numbers of grey seal increased dramatically year after year throughout the construction and early operational periods. It has been suggested that it is possible that changes in harbour seal numbers may be linked to rapid colonisation of competing grey seal (Skeate *et al.*, 2012). It was

noted regional changes in patterns of haul-outs of harbour seal in the Wash coincided with the construction of the Scroby Sands OWF, but such changes in harbour seal number could have been part of wider regional dynamics (Verfuss *et al.*, 2016). It should be noted that Scroby Sands OWF is located 2.5 km off the coast of Great Yarmouth whereas the Proposed Development is located further offshore (40.4 km from Firth of Tay and Eden Estuary Special Area of Conservation (SAC), designated for harbour seal) and therefore a greater distance from Haul-Out sites. As a part of marine mammal monitoring at Robin Rigg OWF, boat-based surveys for cetaceans were conducted before, during, and after construction (Canning *et al.*, 2013). The monitoring data suggested that harbour porpoise were displaced from the wind farm site during the construction phase and operation period when compared to the pre-construction numbers. However, because there was only one year of pre-construction survey, natural variation cannot be ruled out as the reason for the observed change, especially since control survey locations outside of the wind farm also appeared to experience declines in harbour porpoise density.

23.7.21 With the rapid expansion of OWFs, post-construction monitoring programmes are being implemented at various developments in Europe. Tougaard *et al.* (2003) studied short term effects of the construction of Wind Turbines on harbour porpoises at Horns Rev OWF and showed a decrease in harbour porpoise acoustic activity within the wind farm at the onset of piling operations, but subsequent recovery to higher levels a few hours after each piling operation was completed. Tougaard *et al.* (2003) also showed that over the entire construction phase at Horns Rev there was no significant change in the abundance of harbour porpoise in the wind farm area compared to reference areas. Teilmann *et al.* (2008) also reported that during the O&M phase harbour porpoise activity was higher in both the wind farm and reference area compared to baseline levels. As a result of monitoring at Nysted OWF, it was demonstrated initially during construction and the first two years of operation that there were lower acoustic detections of harbour porpoises in the wind farm area, with recovery starting to occur within two years after the end of construction (Teilmann *et al.*, 2006). Teilmann *et al.* (2006) suggested that harbour porpoise were gradually habituating and returning to the wind farm area.

23.7.22 Nabe-Nielsen *et al.* (2011) suggested, using simulations of the response of harbour porpoise to wind farm construction, that wind farms already existing off Danish coast do not have impact on harbour porpoise population dynamics and that the construction of new wind farms is not expected to cause any changes in the long term dynamics of the population. Likewise, Edrén *et al.* (2010) and McConnell *et al.* (2012) investigated possible interactions between seals and Danish OWFs (Nysted Wind Farm and Rødsand II) and found that although there was a temporary reduction in the number of seals hauled out during construction operations (i.e. piling), there was no long term effect on haul-out behaviour trends.

23.7.23 Therefore, the examples of monitoring studies suggest marine mammal receptors can quickly recover and return to the impacted area, despite the potential effects from multiple stressors associated with OWFs. As such, the significance of multiple inter-related stressors is considered to be **Minor** adverse and therefore not significant in EIA terms.

Offshore Ornithology

23.7.24 For offshore ornithology, the following potential impacts have been considered within the inter-related assessment:

- collision risk mortality due to collision with rotor blades;
- distributional responses, displacement and barrier effects from Offshore Infrastructure;
- disturbance to birds from vessel movements;
- disturbance to prey species and their habitats;
- temporary habitat loss and/or habitat disturbance;
- attraction to light;
- direct impacts from UXO clearance; and
- indirect impacts from construction/decommissioning noise.

23.7.25 Table 23.9 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for ornithological receptors.

23.7.26 As highlighted in the other receptor sections, it is not expected that effects on ornithological receptors will have the potential to lead to secondary effects on other receptors. However, the impacts discussed in the following chapters of this Offshore EIA Report are expected to have secondary effects on ornithological receptors:

- Physical Processes - Impacts to the SSCs and changes to the stratification and frontal systems can indirectly impact ornithological receptors due to changes in prey species and their habitats (Volume 2, Chapter 7: Physical Processes);
- Benthic Ecology - Impacts to benthic habitats and species can indirectly impact ornithological receptors due to changes in prey species availability and their habitats (Volume 2, Chapter 8: Benthic Ecology); and
- Fish and Shellfish Ecology - Impacts to fish and shellfish ecology can indirectly impact offshore ornithological receptors, as changes to the distributional and abundance of fish and shellfish may lead to changes in prey availability for offshore ornithology (Volume 2, Chapter 9: Fish and Shellfish Ecology).

Table 23.9: Summary of Likely Significant Inter-Related Effects for Offshore Ornithology from Individual Effects Occurring Across the Construction, O&M and Decommissioning Phase of the Proposed Development (Project Lifetime Effects)

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Collision with Wind Turbines	×	✓	×	This effect will only arise during the O&M phase. Therefore, no inter-related project lifetime effects will occur.
Distributional responses, displacement and barrier effects from Offshore Infrastructure	✓	✓	✓	During construction, O&M and decommissioning, activities will be highly localised and only occur at any given time over a short period of time within the Proposed Development or beyond. Therefore, across the project lifetime, the effects on seabird receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase.
Disturbance to birds from vessel movements	✓	✓	✓	The impacts to seabirds from vessel movements will be highly localised and temporary. Therefore, across the project lifetime, the effects on seabird receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase.
Disturbance to prey species and their habitats	✓	✓	✓	The changes to prey availability during all phases are expected to be temporary, with prey availability recovering rapidly. Therefore, across the project lifetime, the effects on seabird receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase.
Temporary habitat loss and/or habitat disturbance	✓	×	✓	The majority of the disturbance during construction and decommissioning activities will be highly localised. The affected habitats are predicted to recover quickly following completion of construction and decommissioning activities with prey species for seabirds recovering into the affected areas. Therefore, across the project lifetime, the effects on seabird receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Attraction to light	✓	✓	✓	The impacts from artificial light attraction are predicted to be highly localised. Therefore, due to the small area impacted at a given time across the project lifetime, the effects on seabird receptors are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase.
Direct impacts from UXO clearance	✓	×	×	This effect will only arise during the construction phase. Therefore, no inter-related project lifetime effects will occur.
Indirect impacts from construction/ decommissioning noise	✓	×	✓	The indirect impacts from construction/decommissioning noise on seabirds will be highly localised and temporary. Therefore, across the project lifetime, the effects on seabird receptors are not anticipated to result in inter-related effects of greater significance than the assessments presented for each individual phase.
Receptor-led Effects				
• **Impact 1 – Collision with Wind Turbines; and** • **Impact 2 – Distributional responses, displacement and barrier effects from Offshore Infrastructure.**	✓ (Only Impact 2)	✓	✓ (Only Impact 2)	There is potential for spatial and temporal interactions between the effects arising from collision risk and distributional responses. Given both impacts are expected to have the highest impacts during the O&M phase of the Proposed Development, the Zone of Influence (Array Area only and Array Area plus a 2 km buffer for collision risk and distributional responses respectively) for both impacts overlap, and have the potential to result in direct or indirect mortality of seabirds an assessment of the combined effect of both impacts has been carried out and presented in Volume 2, Chapter 11: Offshore Ornithology.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
• **Impact 4 – Disturbance to prey species and their habitats;** • **Impact 5 – Temporary habitat loss and/or disturbance;** • **Impact 7 – Direct impacts from UXO clearance; and** • **Impact 8 – Indirect impacts from construction/ decommissioning.**	✓	✓ (Only Impact 4)	✓ (Excluding Impact 7)	There is potential for spatial and temporal interactions between the effects arising from Impact 4, Impact 5, Impact 7 and Impact 8, as all impacts are expected to contribute to the disturbance of prey species, which will have indirect effects on ornithological receptors. The effect is expected to be highest during the construction phase of the Proposed Development as this is the only phase where all four impacts have the potential to occur. It is expected that the combined area within the Site Boundary impacted at any given time is expected to be small, and the impacts are only expected to occur intermittently in a given area. Additionally, due to the temporary nature of these impacts it is expected that any effects will be reversible. Therefore, it is determined that the combined impact is expected to be no greater than the individual effects assessed in isolation and therefore the receptor-led effects are of a **Minor** adverse significance, which is not significant in EIA terms.

* Proposed Development Phase refers to construction (C), O&M (O) and decommissioning (D).

Offshore Bats

23.7.27 For Offshore Bats the following potential impacts have been considered within the inter-related assessment:

- Collision risk.

23.7.28 There are no roosts in or around the Site Boundary. Therefore, there are no inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M, and decommissioning phases of the Proposed Development and also no inter-related effects (receptor-led effects) that are predicted to arise for Offshore Bat receptors.

Human Environment

Commercial Fisheries

23.7.29 For commercial fisheries, the following potential impacts have been considered within the inter-related effects assessment:

- reduction in access to, or exclusion from established fishing grounds within the Array Area;
- reduction in access to, or exclusion from established fishing grounds within the Export Cable Corridor;
- displacement leading to gear conflict and increased fishing pressure on adjacent grounds;
- disturbance of commercially important fish and shellfish resources leading to displacement or disruption of fishing activity;
- increased vessel traffic associated with the Proposed Development within fishing grounds leading to interference with fishing activity;
- additional steaming to alternative fishing grounds for vessels that would otherwise fish within the Proposed Development; and
- increased snagging risk, which could result in loss or damage to fishing gear.

23.7.30 Project lifecycle and receptor-led inter-related effects from commercial fisheries are presented in Table 23.10.

23.7.31 Effects on commercial fishing also have the potential to have a secondary effect on other receptors and these effects are fully considered in the topic-specific chapters and elsewhere in this chapter. These receptors and effects are:

- fish and shellfish ecology:
  - displacement of fishing activities into other areas could increase fishing pressure in these areas and affect fish and shellfish receptors.
- benthic subtidal ecology:
  - displacement of fishing activities into other areas could increase fishing pressure in these areas and affect benthic subtidal ecology receptors.

- socio-economics, tourism and recreation:
  - reduced value of fish caught by commercial fisheries with potential downstream impacts, for example on fish processors.

Table 23.10: Summary of Likely Significant Inter-Related Effects for Commercial Fisheries from Individual Effects Occurring Across the Construction, O&M and Decommissioning Phase of the Proposed Development (Project Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Reduction in access to, or exclusion from established fishing grounds within the Array Area	✓	✓	✓	Loss or restricted access to fishing grounds is considered to be temporary during construction and decommissioning. A buoyed construction area around the Array Area during installation and decommissioning activities will temporarily restrict access to fishing grounds. In the O&M phase it is assumed fishing can resume in the Proposed Development. Loss or restriction of access to fishing grounds within the Export Cable Corridor is expected to be temporary during construction and decommissioning of Offshore Export Cables. During the O&M phase, fishing activity will be able to resume once construction works are complete. The effects on commercial fisheries across the construction, O&M and decommissioning phases are not anticipated to interact in such a way as to result in combined effects of greater significance than those identified for each phase individually. This is because the majority of impacts (e.g. temporary restriction of access to fishing grounds, increased vessel traffic) are short term and localised to specific construction or decommissioning activities, while operational effects are limited primarily to the presence of Offshore Infrastructure within the Array Area. As such, there is limited spatial or temporal overlap between the impacts arising in different phases, and the magnitude of each impact has been assessed as low adverse. Consequently, when considered across the project lifetime, these impacts would not combine to increase the overall level of significance beyond **Minor** adverse, which is not significant in EIA terms.
Reduction in access to, or exclusion from established fishing grounds within the Export Cable Corridor	✓	✓	✓	
Displacement leading to gear conflict and increased fishing pressure on adjacent grounds	✓	✓	✓	Fishing activity may be disrupted and displaced to adjacent fishing grounds surrounding the Array Area and Export Cable Corridor due to the loss of access effects described immediately above. For the reasons set out above, the effects on commercial fisheries across the phases are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase and are therefore **Minor** adverse and not significant in EIA terms.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Disturbance of commercially important fish and shellfish resources leading to displacement or disruption of fishing activity	✓	✓	✓	Inter-related effects across the project lifetime are unlikely as the nature of potential impacts differs during construction (underwater noise) and O&M phases (EMF, loss of habitat and increased SSCs and suspended sediments). Temporary and long-term habitat loss which occurs across all phases is expected to be proportionally small in relation to habitat availability in the Local and Regional Commercial Fisheries Study Areas. Temporary and long term habitat loss which occurs across all phases is expected to be proportionally small in relation to habitat availability in the Regional Commercial Fisheries Study Area (see Volume 2, Chapter 9: Fish and Shellfish Ecology) and therefore is unlikely to result in measurable reductions in the availability of commercially exploited species. The effects on commercial fisheries across the phases are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase and are therefore **Minor** adverse and not significant in EIA terms.
Increased vessel traffic associated with the Proposed Development within fishing grounds leading to interference with fishing activity	✓	✓	✓	With the successful implementation of Embedded Mitigation (i.e. issue of Notices to Mariners (NtMs)), preparation of a Fisheries Mitigation Monitoring and Communication Plan (FMMCP) (Volume 4, Appendix 28: Fisheries Mitigation Monitoring and Communication Plan), close liaison with the local vessels), no significant effects are predicted for the construction, O&M, and decommissioning phases of the Proposed Development. The majority of vessel traffic with potential to interfere with fishing activity is predicted to peak during construction and decommissioning with reduced potential for interference during the O&M phase. The effects on commercial fisheries across the phases are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase and are therefore **Minor** adverse and not significant in EIA terms.
Additional steaming to alternative fishing grounds for vessels that would otherwise fish within the Proposed Development	✓	✓	✓	Impacts on steaming and transit times are expected to be highest during construction and decommissioning when areas undergoing installation/decommissioning activities will be avoided. Vessels may also choose to avoid transiting through the Proposed Development during the O&M phase, though transit is deemed possible based on Wind Turbine spacing. For the reasons set out in the first row of the table, the effects on commercial fisheries across the phases are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase and are therefore **Minor** adverse and not significant in EIA terms.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Increased snagging risk, which could result in loss or damage to fishing gear	✓	✓	✓	Impacts due to gear snagging may occur during the construction and O&M phases due to the presence of the Proposed Development's seabed infrastructure. At the end of the operational lifetime, it is expected that all structures above the seabed (with the exception of Scour Protection and cable protection/crossings) will be fully removed where feasible. Environmental conditions and sensitivities will also be considered since removal of structures may result in greater environmental impacts in comparison to leaving *in situ*. Loss or restricted access to fishing grounds is considered to be temporary during construction and decommissioning. A buoyed construction area around the Array Area during installation and decommissioning activities will temporarily restrict access to fishing grounds. In the O&M phase it is assumed fishing can resume in the Proposed Development. Loss or restriction of access to fishing grounds within the Export Cable Corridor is expected to be temporary during construction and decommissioning of Offshore Export Cables. During the O&M phase, fishing activity will be able to resume once construction works are complete. For these reasons, the effects on commercial fisheries across the phases are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase and are therefore **Minor** adverse and not significant in EIA terms.
Receptor-led Effects				
An inter-related receptor-led effect may occur from the combination of the reduction in access to fishing grounds and the subsequent displacement and increased pressure on adjacent grounds.	✓	✓	✓	While these two effects may act together, given the proposed Additional Mitigation (Volume 2, Chapter 13: Commercial Fisheries), it is considered that any inter-related effect will not be of any greater significance than those already assessed in isolation. Consequently, although these effects may occur together, the resulting inter-related effect is not anticipated to increase the overall magnitude of impact beyond that assessed for the individual effects, and the significance therefore remains **Minor** adverse and not significant in EIA terms.

* Proposed Development Phase refers to construction (C), O&M (O) and decommissioning (D).

Shipping and Navigation

23.7.32 The impacts and effects identified for shipping and navigation to interact with each other, which could give rise to synergistic impacts as a result of that interaction.

23.7.33 Table 23.11 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M, and decommissioning phases of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for shipping and navigation receptors.

23.7.34 Given the nature of shipping and navigation, project lifetime effects are uncommon because impacts occur at different times and do not typically build up across phases. No project lifetime effects with respect to shipping and navigation are predicted during construction, O&M, and decommissioning that are not already considered within the impact assessment undertaken within this chapter. None of the likely significant environmental effects considered will be worsened through interactions across different phases of the Proposed Development.

23.7.35 As noted above, effects on shipping and navigation also have the potential to have secondary effects on other receptors and these effects are fully considered in the topic-specific chapters. These receptors and effects are:

- Commercial Fisheries (Volume 2, Chapter 13):
  - potential impact on small vessel activity;
- Socio-Economics, Tourism and Recreation (Volume 2, Chapter 18):
  - potential impact on small vessel activity;
- Aviation and Radar (Volume 2, Chapter 15):
  - interference with Radar, communications, and positioning systems; and
  - potential impact to Search and Rescue (SAR) capability;
- Infrastructure and Other Users (Volume 2, Chapter 16):
  - potential impact to SAR capability.

Table 23.11: Summary of Likely Significant Inter-Related Effects for Shipping and Navigation from Individual Effects Occurring Across the Construction, O&M and Decommissioning Phase of the Proposed Development (Project Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Impact of floating mooring and cable systems and interactions with vessels at risk of snagging	✓	✓	✓	The Navigation Risk Assessment (NRA) conducted (Volume 3, Technical Appendix 14.1: Shipping and Navigation Navigational Risk Assessment) was of sufficient detail that interactions between effects were considered from different phases. This identified that impacts are temporally distinct and do not produce increasingly higher impacts over multiple project phases. No impacts with respect to shipping and navigation are predicted to compound during construction, O&M, and decommissioning. None of the likely significant effects considered will be worsened through interactions across different phases of the Proposed Development. Therefore, across the project lifetime, the effects on shipping and navigation receptors are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase.
Deviation of commercial vessels	✓	✓	✓	
Increased collision risk	✓	✓	✓	
Increased contact/allision risk	✓	✓	✓	
Increased grounding risk	✓	✓	✓	
Impact to SAR capability	✓	✓	✓	
Interference with Radar, communications and positioning systems	✓	✓	✓	
Reduction in Under Keel Clearance (UKC) due to subsurface Offshore Infrastructure	✓	✓	✓	
Towage operations	✓	✓	✓	
Breakout or loss of station of a floating Wind Turbine	✓	✓	✓	
Impact on port/harbours and nearshore operations	✓	✓	✓	
Impact on small vessel activity (fishing/recreational)	✓	✓	✓	

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Receptor-led Effects				
Displacement of fishing activity and displacement of commercial vessels leading to fishing in higher density traffic areas	✓	✓	✓	Potential exists for interactions between impacts to shipping and navigation and commercial fishing in respect of displacement of fishing activity from the Array Area. This displacement of fishing activity can be further displaced or disrupted in areas of dense commercial shipping caused by changes in commercial shipping routes. Alternatively, displacement of fishing away from the Array Area can lead to reduction in impacts of allision and snagging as less fishing would occur in these areas. These impacts are assessed in Volume 2, Chapter 14: Shipping and Navigation and within Volume 2, Chapter 13: Commercial Fisheries. The NRA conducted for shipping and navigation (Volume 3, Technical Appendix 14.1: Shipping and Navigation Navigational Risk Assessment) was of sufficient detail that interactions between effects to marine receptors were considered, both from different phases and different receptors, and therefore the assessment captures these effects on marine receptors. Embedded Mitigation for the appointment of a Fisheries Liaison Officer (FLO) (defined within the FMMCP), advance notification (via NtMs and Kingfisher Bulletins), and the NSVMP resulted in the assessment of each on any single receptor to be captured. Therefore, with the presence of Embedded Mitigation, these receptor-led effects on Shipping and Navigation receptors are considered to be of no greater significance than those already assessed in isolation.
Displacement of fishing activity leading changes to contact/allision risk	✓	✓	✓	
Impact on small vessel activity (fishing/recreational) leading to changes in commercial fishing	✓	✓	✓	
Impact on vessel routing causing delays and cancellations for local operators in normal and adverse conditions	✓	✓	✓	Potential exists for interactions between impacts to shipping and navigation and socio-economics, tourism and recreation in respect of deviations leading to delays of sailing, or cancellations. The NRA conducted for Shipping and Navigation (Volume 3, Technical Appendix 14.1: Shipping and Navigation Navigational Risk Assessment) identified that regular running ferry services would not be impacted by the presence of the Proposed Development in normal or adverse weather and therefore the inter-related effects of this impact is considered to be of no greater significance than that already assessed in isolation.

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Impact to SAR capability from marine and aviation responders	✓	✓	✓	Potential exists for interactions between impacts to shipping and navigation and aviation and radar in respect of: • lighting and marking; • impact to radar, communications and positioning systems; and • SAR requirements. The need for SAR assets to enter the Array Area has impacts upon marine (lifeboat) and aviation (SAR helicopter) receptors. These impacts are assessed in Volume 2, Chapter 14: Shipping and Navigation and within Volume 2, Chapter 15: Aviation and Radar. The NRA conducted for Shipping and Navigation (Volume 3, Technical Appendix 14.1: Shipping and Navigation Navigational Risk Assessment) was of sufficient detail that interactions between effects to marine receptors were considered, both from different phases and different receptors, and therefore the assessment captures these effects on marine receptors. Embedded Mitigation for joint Lighting and Marking Plan (LMP) (outline shown in Volume 4, Appendix 31: Outline Lighting and Marking Plan), NSVMP (outline shown in Volume 4, Appendix 29: Outline Navigational Safety and Vessel Management Plan)) and Emergency Response Cooperation Plan (ERCoP) to be developed in consultation with the relevant maritime and aviation authorities resulted in the assessment of each on any single receptor to be captured. Therefore, the receptor-led effects on shipping and navigation receptors are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each receptor.
Interference with Radar, communications and positioning systems for marine and aviation receptors	✓	✓	✓	
Breakout or loss of station of a floating Wind Turbine leading to changes in marine and aviation or SAR	✓	✓	✓	

* Proposed Development Phase refers to construction (C), O&M (O) and decommissioning (D).

Aviation and Radar

23.7.36 For aviation and radar, the following potential impacts have been considered within the inter-related assessment:

- Aberdeen Airport Instrument Flight Procedures (IFPs) due to presence of obstacles (Wind Turbines in construction);
- National Air Traffic Services (NATS) Allanshill and Perwinnes Air Traffic Control (ATC) Primary Surveillance Radars (PSRs) due to operation of Wind Turbines;
- Ministry of Defence (MoD) Buchan Air Defence PSR due to operation of Wind Turbines; and
- Military low flying and UK SAR helicopter operations due to presence of obstacles (Wind Turbines in construction).

23.7.37 Table 23.12 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for aviation and radar receptors.

23.7.38 As noted above, effects on aviation and radar also have the potential to have secondary effects on other receptors and these effects are fully considered in the topic-specific chapters. These receptors and effects are:

- Shipping and Navigation (Volume 2, Chapter 14):
  - Aviation lighting and marking requirements differ from those of maritime operators; consequently, it has been necessary to interact with Volume 2, Chapter 14: Shipping and Navigation assessment in order to ensure that the requirements of both aviation and maritime operators are taken into account.

Table 23.12: Summary of Likely Significant Inter-Related Effects for Aviation and Radar from Individual Effects Occurring Across the Construction, O&M and Decommissioning Phase of the Proposed Development (Project Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Aberdeen Airport IFPs due to presence of obstacles (Wind Turbines in construction)	✓	×	×	The scale of effects to aviation and radar receptors progressively increases during construction as the Wind Turbines and ancillary structures are installed. Once installed, the Offshore Infrastructure causing physical obstacles to air traffic will remain constant until the decommissioning phase. The effects of aviation and radar will not interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase. Therefore, across the project lifetime, the effects on aviation and radar receptors are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase.
NATS Allanshill and Perwinnes ATC PSRs due to operation of Wind Turbines	×	✓	×	
MoD Buchan Air Defence PSR due to operation of Wind Turbines	×	✓	×	
Military low flying and UK SAR helicopter operations due to presence of obstacles (Wind Turbines in construction)	✓	×	×	
Receptor-led Effects				
Potential exists for interactions between impacts to aviation and radar in respect of the lighting and marking requirements for the Proposed Development's Wind Turbines. As aviation lighting and marking requirements differ from those of maritime operators, it has been necessary to interact with the Volume 2, Chapter 14: Shipping and Navigation assessment in order to ensure that the requirements of both aviation and maritime operators are taken into account. As a result, an outline LMP has been developed which outlines the lighting and marking mitigation measures which are designed to avoid confliction between aviation and maritime operators. With the committed outline LMP measures in place, the receptor-led effects from aviation and radar lighting and marking are not likely to be significant. No other inter-relationships exist with the potential to alter or introduce significant effects.				

* Proposed Development Phase refers to construction (C), O&M (O) and decommissioning (D).

Infrastructure and Other Users

23.7.39 For infrastructure and other users, the following potential impacts have been considered within the inter-related assessment:

- physical restriction on space for recreational craft and recreational fishing vessels;
- physical restriction on space for recreational activities/recreational fishing; and
- physical impact or loss of access to early development cables and existing cables and pipelines.

23.7.40 Table 23.13 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for infrastructure and other users receptors.

23.7.41 As noted above, receptor-led effects have the potential to result in secondary effects upon other infrastructure and other users receptors and these effects are fully considered within this chapter. These receptors and effects are:

- displacement of recreational activities (including recreational sailing, cruising and recreational fishing):
  - physical restriction on space for recreational craft and recreational fishing vessels;
  - displacement of recreational sailing and motor cruising, recreational fishing (boat angling);
  - physical restriction on space for recreational activities/recreational fishing; and
  - displacement of recreational fishing (shore angling) and other recreational activities (kayaking, coasteering, surfing and paddleboarding).
- impacts to early development cables or pipelines or restrictions on access to cables or pipelines:
  - physical impact to development cables and pipelines or loss of access to existing cables and pipelines.

Table 23.13: Summary of Likely Significant Inter-Related Effects for infrastructure and other users from Individual Effects Occurring Across the Construction, O&M and Decommissioning Phase of the Proposed Development (Project Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Displacement of Recreational Activities (Including Recreational Sailing, Cruising and Recreational Fishing)	✓	✓	✓	The presence of Offshore Infrastructure, Safety Zones and/or advisory safety distances during the construction and decommissioning phases, and the presence of Offshore Infrastructure, operational Safety Zones and temporary Safety Zones and/or advisory safety distances during the O&M phase, may result in the displacement of recreational craft and recreational fishing vessels from the Array Area and along the Export Cable Corridor. The level of recreational activity within the Array Area is low. There is low recreational vessel activity in nearshore areas of the Export Cable Corridor, with boating and angling also taking place closer to shore, however any displacement along the Export Cable Corridor will be temporary. Therefore, across the project lifetime, the effects on recreational craft users and recreational fishing vessels are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase.
Impacts to early development cables or pipelines or restrictions on access to cables or pipelines	✓	✓	✓	Cables and pipelines may be affected where they are crossed by Offshore Infrastructure. In addition, the presence of Offshore Infrastructure, Safety Zones and/or advisory safety distances may restrict access to existing cables and pipelines during construction, O&M and decommissioning activities. Cable and pipeline crossing agreements will be developed and implemented with each relevant cable and pipeline operator to minimise the potential for any impact. Crossing agreements will include the ability of a cable/pipeline operator to access their infrastructure as far as practical during the Proposed Development construction, O&M and decommissioning phases and the crossing agreements will ensure close communication and planning between the affected parties to ensure disruption of activities is minimised. Therefore, across the project lifetime, the effects on Infrastructure and Other Users are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase.
Receptor-Led Effects				
Potential exists for spatial and temporal interactions between direct and indirect impacts to Infrastructure and Other Users receptors. Based on current understanding and expert knowledge, there is scope for potential inter-related impacts to arise from the physical restriction on space for recreational craft and recreational fishing vessels interacting with the displacement of recreational sailing and motor cruising, recreational fishing (boat angling) and other recreational activities. Where both impacts overlap spatially and temporally, there is potential for inter-related effects as the restriction/displacement on movements of recreational activity may cover a larger area. However, as a vast extent of alternative resource for recreational activities will remain available, and the impacts initially identified were of **Minor** adverse significance, these impacts are not likely to interact in a way that results in a significant inter-related effect.				

* Proposed Development Phase refers to construction (C), O&M (O) and decommissioning (D).

Socio-economics, Tourism and Recreation

23.7.42 For socio-economics, tourism and recreation, as assessed in Volume 2, Chapter 13: Commercial Fisheries there is potential for impacts on commercial fishing activities, which could result in a reduced value of the fish and potential associated downstream impacts, for example on fish processors. This is relevant for socio-economics, as there could be an adverse impact on Gross Value Added (GVA) and employment, should this have a discernible impact on the fishing industry. Additionally, adverse wellbeing impacts for local fishermen could arise should their livelihoods be impacted. However, as assessed in Volume 2, Chapter 13: Commercial Fisheries, with the Embedded Mitigation in place, including commitment to Disruption Agreements where relevant, the Proposed Development is expected to result in effects of Negligible or Minor (adverse) significance, which is not significant. No synergistic impacts are expected on GVA and employment as a result.

23.7.43 In relation to receptor-led inter-related effects, tourism and recreation receptors and associated impacts have been identified with consideration of the following related environmental assessments:

- Volume 2, Chapter 14: Shipping and Navigation;
- Volume 2, Chapter 16: Infrastructure and Other Users;
- Volume 2, Chapter 20: Seascape, Landscape and Visual Impacts; and
- Volume 2, Chapter 21: Cultural Heritage.

23.7.44 As the project-wide effects and inter-related receptors identified from these chapters have already been assessed in the relevant sections of Section 23.7, additional assessment of inter-related effects for socio-economics, tourism and recreation is not considered necessary.

Marine Archaeology

23.7.45 For marine archaeology, the following potential impacts have been considered within the inter-related assessment:

- sediment disturbance and deposition leading to indirect impacts on marine archaeology receptors; and
- alteration of sediment transport regimes leading to indirect impacts on marine archaeology receptors.

23.7.46 Table 23.14 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for marine archaeology receptors.

Table 23.14: Summary of Likely Significant Inter-Related Effects for Marine Archaeology from Individual Effects Occurring Across the Construction, O&M and Decommissioning Phase of the Proposed Development (Project Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Sediment disturbance and deposition leading to indirect impacts on marine archaeology receptors	✓	✓	✓	When SSC and sediment deposition are considered additively across all phases, the volume of sediment deposited is larger than when considered across an individual phase (i.e. just construction). The majority of seabed disturbance (resulting in highest SSC and deposition) will occur during the construction and decommissioning phases, with effects being short lived and intermittent across each phase. Meaningful sediment plume interaction generally only has the potential to occur at the same time. Due to this, and the medium vulnerability and medium recoverability of marine archaeology receptors to indirect impacts from sediment disturbance and deposition, the interaction of these impacts across the stages of the Proposed Development are not anticipated to interact in such a way as to result in inter-related effects of greater significance than the assessments presented for each individual phase. As a result, the inter-related effects are of **Minor** adverse significance, which is not significant in EIA terms.
Receptor-led Effects				
• **Sediment disturbance and deposition leading to indirect impacts on marine archaeology receptors; and** • **Alteration of sediment transport regimes leading to indirect impacts on marine archaeology receptors.**	×	✓	×	Potential exists for spatial and temporal interactions between the effects arising from increased SSC and sediment deposition and alteration of sediment transport regimes on marine archaeology receptors during the O&M phase of the Proposed Development. Due to the impacts of sediment disturbance and deposition being short lived and intermittent, particularly in the O&M phase (the majority of seabed disturbance resulting in the highest SSC and deposition will occur during the construction and decommissioning phases), and the impact of the alteration of sediment transport regimes having negligible magnitude of impact in the O&M phase, it is predicted that any inter-related effect will not be of any greater significance than those impacts already assessed in isolation (i.e. **Minor** adverse). Furthermore, the impacts of the alteration of sediment transport regimes may expose or bury marine archaeology receptors, and sediment deposition could only bury them. In general, burial can be seen as a beneficial impact, as it slows the physical, chemical and biological deterioration of marine archaeology receptors (Björdal and Nilsson, 2008). The receptor-led impact would therefore likely be burial and therefore beneficial in nature. As a result, the receptor-led effects are of **Minor** adverse significance which is not significant in EIA terms.

* Proposed Development Phase refers to construction (C), O&M (O) and decommissioning (D).

Seascape Landscape Visual Impact

23.7.47 For seascape, landscape and visual receptors, the following potential impacts have been considered within the inter-related assessment:

- changes to the perceived seascape (coastal) character of coastal areas;
- changes to the perceived landscape character and qualities of Designated Landscapes; and
- changes to views experienced by people from specific and representative viewpoints and from visual receptors.

23.7.48 Table 23.15 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for seascape, landscape and visual receptors.

23.7.49 As noted above, effects on seascape, landscape and visual receptors also have the potential to have secondary effects on other receptors, and these effects are fully considered in the topic-specific chapters. These receptors and effects are:

- Cultural Heritage (Volume 2, Chapter 21):
  - temporary (during construction and decommissioning phases), long term (during O&M phase only) and reversible (post-decommissioning) addition of the Proposed Development resulting in direct effects on views from, and indirect effect to, perceived character of Gardens and Designed Landscapes (GDLs); and
- Socio-Economics, Tourism and Recreation (Volume 2, Chapter 18):
  - temporary (during construction and decommissioning phases), long term (during O&M phase only) and reversible (post-decommissioning) addition of the Proposed Development resulting in indirect effects to visitor and tourist use of the coast including receptors on beaches, recreational routes and visitor attractions.

Table 23.15: Summary of Likely Significant Inter-Related Effects for Seascape, Landscape and Visual Receptors from Individual Effects Occurring Across the Construction, O&M and Decommissioning Phase of the Proposed Development (Project Lifetime Effects) and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase*			Likely Significant Inter-Related Effects
	C	O	D	
Project Lifetime Effects				
Temporary, indirect and direct seascape, landscape and visual effects arising because of the works associated with the Offshore Export Cable, Interconnector Cables and Landfall connection site	✓	×	✓	No greater than the individually assessed impacts. Although impacts are broken down into different receptors based upon physical and perceived characteristics (coastal character areas) the actual receptor is the same in each case (i.e. the people or person perceiving the effect on coastal character). Therefore, these people will only perceive the effect one way (visually) at one point in time, and will not experience the construction, O&M and decommissioning phases simultaneously, or across multiple pathways.
Temporary effects arising because of the construction and decommissioning works associated with the installation of Wind Turbines and OSPs	✓	×	✓	No greater than the individually assessed impacts. Although impacts are broken down into different receptors based upon physical and perceived characteristics (Landscape Character Types) and planning policies (landscape designations) the actual receptor is the same in each case (i.e. the people or person perceiving the effect on landscape or character within which the designation sits). Therefore, these people will only perceive the effect one way (visually) at one point in time, and will not experience the construction, O&M and decommissioning phases simultaneously, or across multiple pathways.
Long term effects (daytime) of the O&M of the offshore elements of the Proposed Development on visual receptors/views	×	✓	×	No greater than the individually assessed impacts. Although impacts are broken down into different receptors (viewpoints and visual receptors) the actual receptor is the same in each case (i.e. the people or person perceiving the effect). Therefore, these people will only perceive the effect one way (visually) at one point in time, and will not experience the construction, O&M and decommissioning phases simultaneously, or across multiple pathways.
Receptor-led Effects				
Receptor-led effects (i.e. those that interact, spatially and temporally, to create inter-related effects on a receptor) will not occur on seascape, landscape and visual receptors, since changes are experienced by the same receptor in each case (people and or person) and in **one** way (visually) at one point in time, therefore effects on views and on perceived character are inter-linked, and do not interact to produce a different, or greater effect, on a receptor or receptors than when effects are considered in isolation.				

* Proposed Development Phase refers to construction (C), O&M (O) and decommissioning (D).

Cultural Heritage

23.7.50 Across the Project's lifetime, the effects on cultural heritage receptors are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase or when considered in conjunction with other topics addressed in this Offshore EIA Report.

23.7.51 Construction and decommissioning phase impacts on cultural heritage receptors have been scoped out because any changes in setting during these phases would be transitory and short-lived. Consequently, there is no realistic pathway by which the three project phases combined would produce greater long-term effects on cultural heritage than those assessed for the operational phase.

23.7.52 The assessment of setting has been carried out holistically and therefore accounts for the aggregate visual changes that could arise from the Proposed Development. No plausible mechanism has been identified by which the Project could cause physical harm to the fabric of cultural heritage assets, and receptors are not exposed to multiple, compounding physical impacts.

23.7.53 Although the SLVIA and the cultural heritage assessment both consider visual change, they address different receptors and use distinct assessment endpoints. For this reason, the SLVIA findings do not give rise to additional or greater impacts on cultural heritage receptors beyond those already considered in the cultural heritage assessment.

23.8 Part Two: Ecosystem-Based Effects Assessment

Overview

23.8.1 An ecosystem comprises a community of living (biotic) organisms interacting with the non-living (abiotic) components of their environment. These biotic and abiotic elements are connected through nutrient cycles and energy flows (LibreTexts, 2022). In marine ecosystems, biotic factors include plankton, seaweed, benthic communities, fish, seabirds, and marine mammals, while abiotic factors encompass air, salt water, seabed materials, and rock.

23.8.2 Biodiversity refers to the variety of genomes, species, and ecosystems present within a defined geographic area (National Research Council, 1995). Biodiversity within an ecosystem serves as an indicator of its overall health. Ecosystems containing a broader range of species typically demonstrate greater resilience to external pressures compared to those with fewer species present in large populations (Oliver *et al.* 2015, Folke *et al.* 2004). If certain species experience changes due to climate or human impacts, the ecosystem may be able to adapt and persist (European Commission, 2022).

23.8.3 This ecosystem-based assessment aims to qualitatively evaluate potential impacts of the Proposed Development at the ecosystem-level. This includes examining possible modifications to predator-prey relationships and the subsequent effects on ecosystem functioning. Furthermore, this assessment seeks to address advice raised by NatureScot during consultation in the Offshore EIA Scoping Opinion (MD-LOT, 2024) (Table 23.3).

Ecosystem Baseline

23.8.4 This section provides an overview of the abiotic and biotic components of the marine ecosystem relevant to the Proposed Development, based on the topic-specific Study Areas assessed in Volume 2, Chapters 7 to 12. Where necessary, supplementary information from these chapters is included to support and strengthen the assessment in subsequent sections.

Abiotic Environment

23.8.5 The Site Boundary comprises the Array Area and the Export Cable Corridor. The Array Area is located 38 km off the Aberdeenshire coast. The Export Cable Corridor extends from the Array Area and will reach Landfall at Benholm, Aberdeenshire (Volume 1, Chapter 3: Project Description).

Array Area

23.8.6 The seabed in the Array Area is characterised by a mix of sand and silty sand, muddy (silty) sand is also widely distributed. Boulders are present across approximately 20% of the Array Area, with the northern and central parts, extending southwards up to the southern boundary, containing the largest boulder–covered surfaces. The Array Area is located within a complex geological setting with six stratigraphic units identified. Residual rates of sediment transport are generally low, notwithstanding this, where sand is present net bedload transport is expected to be in a southerly direction.

23.8.7 Bathymetrically, the Array Area ranges from approximately -54 m to -91 m Lowest Astronomical Tide (LAT), with generally flat terrain and steeper gradients where bedforms occur. Active bedforms (namely sandwaves and megaripples) comprising mobile Holocene sediments are also present, where they can exceed 6 m in height. Ripple and smaller megaripple features are known to be mobile within the Array Area (Volume 2, Chapter 7: Physical Processes).

Export Cable Corridor

23.8.8 The Export Cable Corridor is primarily characterised by the presence of sand and silty sand, with areas of outcropping glacial till and boulders. Nearshore areas at and immediately adjacent to the Landfall have exposed bedrock outcrops (of Silurian or Devonian age). Glacial outwash sediments are also locally present further offshore. Residual sediment transport rates are generally higher along the Export Cable Corridor in comparison to the Array Area.

23.8.9 Bathymetry along the corridor ranges from 0 m nearshore to -113 m LAT offshore. In the nearshore areas, bedrock outcrops create a complex terrain with significant slope variations, reaching up to 83° in some areas. Further offshore, average slopes are generally below 5°.

23.8.10 For further information on the abiotic environment, see Volume 2, Chapter 7: Physical Processes and the associated technical report.

Biotic Environment

Benthic Ecology

23.8.11 The Local Benthic Ecology Study Area includes the Site Boundary and a buffer equivalent to one Spring Tidal Ellipse to capture the full Zone of Influence for benthic impacts, while the Regional Study Area extends into the Northern North Sea to provide a broader ecological context (see Volume 3, Technical Appendix 8.1: Benthic Ecology Technical Report). Site-specific surveys using grab sampling, underwater video (Volume 3, Technical Appendix 8.2: Bowdun OWF Benthic Characterisation Survey 2024: Survey Report), and intertidal walkovers (Appendix E, BOWFL, 2024) revealed a diverse range of benthic fauna. Subtidal habitats supported species such as annelid worms, sea urchins *Echinus esculentus*, and bivalves, with sparse overlying assemblages including colonial jellyfish, and crustaceans like hermit crabs *Pagurus bernhardus*. In Benholm Bay, the intertidal area featured a rocky shore, with 17 biotopes identified overall (Volume 2, Chapter 8: Benthic Ecology).

Fish and Shellfish Ecology

23.8.12 The fish and shellfish baseline for the Proposed Development was established through a comprehensive desktop review of existing studies and datasets (Volume 2, Chapter 9: Fish and Shellfish Ecology, and Volume 3, Technical Appendix 9.1: Fish and Shellfish Ecology Technical Report). Fish and shellfish ecology within the Proposed Development area encompasses a diverse range of species, including marine fish such as teleosts (e.g. cod *Gadus morhua*, Atlantic herring *Clupea harengus*, and sandeel *Ammodytes* spp.) and elasmobranchs (e.g. basking shark *Cetorhinus maximus* and the flapper and common blue skate complex). Data indicates that diadromous species, those migrating between freshwater and seawater, such as salmonids, lampreys, shads, and European eel *Anguilla anguilla* are likely to be present alongside freshwater pearl mussel *Margaritifera margaritifera*, which relies on salmonids to complete its life cycle. Shellfish species include commercially important crustaceans like lobsters and crabs, and molluscs such as scallops, whelks, and cephalopods. These communities were characterised within a broad Fish and Shellfish Ecology Study Area, defined as a 100 km buffer around the Array Area and Export Cable Corridor, including the Firth of Forth and Firth of Tay. Site-specific surveys and desktop reviews confirmed that the assemblage is typical of the Northern North Sea, with spawning and nursery grounds identified for key species such as herring and sandeel (Volume 2, Chapter 9: Fish and Shellfish Ecology).

Marine Mammals

23.8.13 The marine mammal baseline for the Proposed Development was established through a comprehensive desktop review of existing studies and datasets, complemented by 24 months of site-specific Digital Aerial Survey (DAS) data (Volume 2, Chapter 10: Marine Mammals and the associated technical reports). This assessment confirmed that the Northern North Sea supports a diverse range of marine mammal species, several of which have internationally important populations occurring near the development area. Species with robust density data suitable for quantitative assessment include harbour porpoise, bottlenose dolphin, white-beaked dolphin *Lagenorhynchus albirostris*,

minke whale, grey seal, and harbour seal. Humpback whale *Megaptera novaeangliae,* killer whale *Orcinus orca* and Risso's dolphin *Grampus griseus*, were also included qualitatively (Volume 2, Chapter 10: Marine Mammals).

Offshore Ornithology

23.8.14 The offshore ornithology baseline for the Proposed Development was established through a comprehensive desktop review of existing studies, surveys and datasets, complemented by 24 months of site-specific DAS data (Volume 2, Chapter 11: Offshore Ornithology and the associated technical reports). Offshore ornithology for the Proposed Development encompasses seabirds and migratory birds that may transit through and within the Site Boundary. Key species identified include fulmar *Fulmarus glacialis*, gannet *Morus bassanus*, kittiwake *Rissa tridactyla*, great black-backed gull *Larus marinus*, herring gull *Larus argentatus*, Arctic tern *Sterna paradisaea*, guillemot *Uria aalge*, razorbill *Alca torda*, puffin *Fratercula arctica*, Manx shearwater *Puffinus puffinus*, European storm petrel *Hydrobates pelagicus*, oystercatcher *Haematopus ostralegus*, lapwing *Vanellus vanellus*, curlew *Numenius arquata*, common gull *Larus canus*, and black-headed gull *Chroicocephalus ridibundus*. These species were identified as key receptors due to their potential sensitivity to the Proposed Development (Volume 2, Chapter 11: Offshore Ornithology).

Offshore Bats

23.8.15 The Offshore Bats baseline for the Proposed Development was established through a desktop literature review presented in Volume 3, Technical Appendix 12.1: Offshore Bats Literature and Data Review. Nathusius' pipistrelle *Pipistrellus nathusii* is increasingly being recorded in the UK, possibly due to a westward expansion in its range. Sightings are scattered across the UK, with most from southern England. Evidence suggests that Nathusius' pipistrelle undertakes long-distance migrations, crossing large water bodies like the North Sea, with numbers peaking in autumn and spring.

23.8.16 Leisler's bat *Nyctalus leisleri* is most common in Ireland and parts of southern and central England, less frequent in Wales, and scarce in Scotland, where records are mainly from the south-west (e.g. Arran, Bute and Dumfries and Galloway). It is absent from the far north and most of the Highlands. The evidence for Leisler's bat suggests they prefer to migrate along the coastline and their hibernation habitat is further south than Scandinavia, therefore, suggesting it is unlikely they will interact with the Array Area (Volume 3, Technical Appendix 12.1: Offshore Bats Literature and Data Review).

23.8.17 Records from North-Eastern Scotland, including Aberdeenshire, show terrestrial occurrences of Nathusius' pipistrelle. These could be speculated to be related to migratory observations. Observations on Offshore Infrastructure further support the migratory behaviour of this species (Volume 3, Technical Appendix 12.1: Offshore Bats Literature and Data Review).

23.8.18 The presence of records on Offshore Infrastructure is suggestive of Nathusius' pipistrelle migration; however, it cannot be definitively ruled out that they are migratory records. Only one confirmed record of Nathusius' pipistrelle has been recorded on National Biodiversity Network (NBN) in 2010 (Highland Biological Recording Group, 2026). The data suggests that Nathusius' pipistrelle migrates from Scandinavia to avoid harsh winters and overwinters in the British Isles. The records from remote areas like Shetland and Orkney suggests that these regions may support overwintering or migratory populations.

23.8.19 Volume 3, Technical Appendix 12.1: Offshore Bats Literature and Data Review describes how the Southern North Sea provides contextual evidence of Nathusius' pipistrelle migrating between England and the Dutch and Belgian coasts, and the distances they travel.

23.8.20 Overall, the evidence suggests that Nathusius' pipistrelle are present in northern Scotland during the autumn and spring due to peaks in records during the migration season. They move to and from their breeding grounds in the mainland UK with the closest confirmed maternity roost being located in north-east England. However, it should be noted that insufficient data is available to ascertain the exact route of this migration across the Northern North Sea, and where bats might make landfall along the Scottish coastline. Furthermore, the is insufficient evidence to support bats in the marine ecosystem and their function. Therefore, offshore bats have not been taken further forward for discussion within the assessment.

The Marine Food Web

23.8.21 Trophic levels represent the hierarchical positions organisms occupy within a marine food web, reflecting their roles in energy transfer and ecological interactions. At the base are primary producers such as phytoplankton and seaweed, which convert sunlight into energy through photosynthesis. These producers are consumed by primary consumers, including zooplankton, copepods, clams, snails, and mussels, which feed directly on plant material. Secondary consumers occupy the next level, feeding on both primary producers and consumers; this group includes fish larvae, species like Atlantic herring and sandeel, as well as crabs and shrimp. Tertiary consumers, such as larger fish and cephalopods like octopus and squid, prey on secondary consumers and play a crucial role in regulating population dynamics. At the top of the trophic hierarchy are apex predators, including humans, seabirds, marine mammals, large fish, sharks, skates, and rays, which exert significant influence over the structure and stability of the marine ecosystem. These interconnected levels illustrate the complex and dynamic nature of marine food webs, where energy flows 'upward' and ecological balance is maintained through predator-prey relationships. Figure 23.1 shows the relationships among these trophic levels.

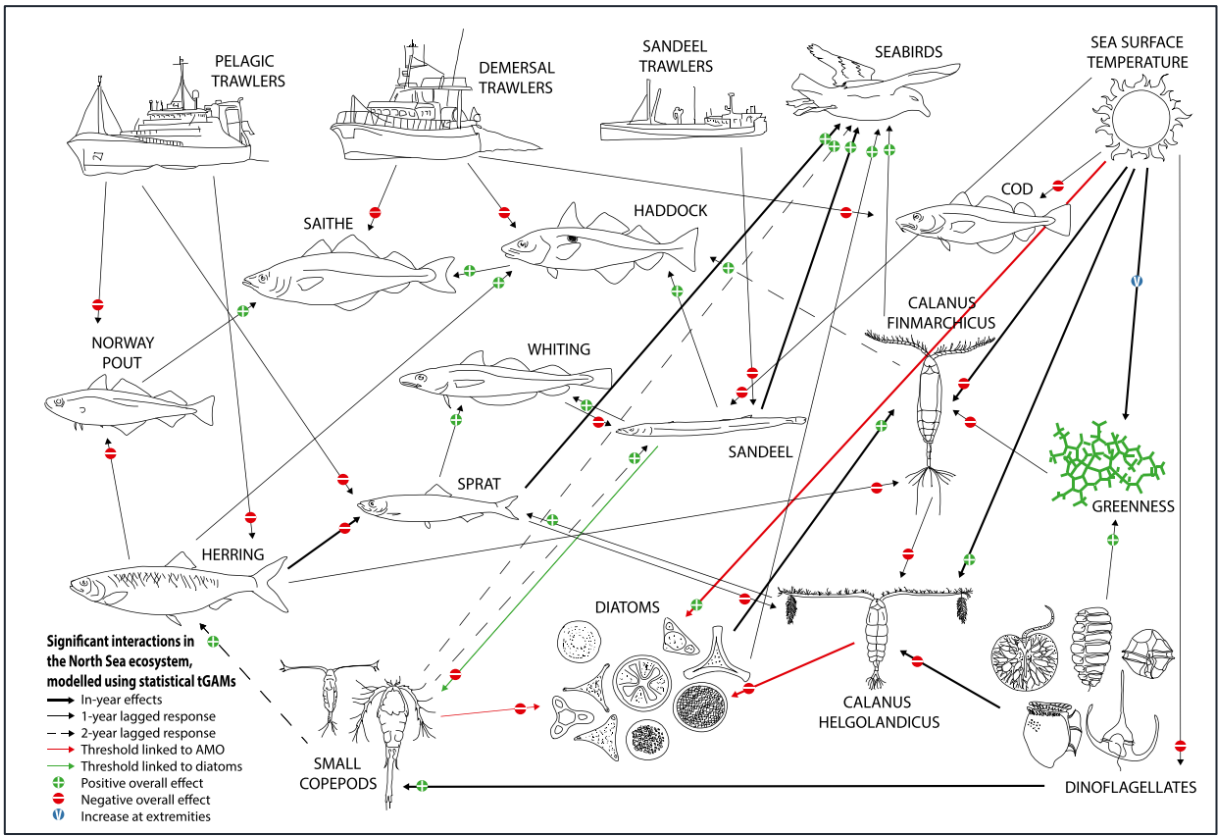

Figure 23.1: Significant Interactions Between Functional Groups and Drivers (from Lynam *et al.*, 2017)

The Key Predator Species

23.8.22 Volume 2, Chapter 9: Fish and Shellfish Ecology, Volume 2, Chapter 10: Marine Mammals, and Volume 2, Chapter 11: Offshore Ornithology provide in-depth information on the most abundant and ecologically significant species within their respective study areas. These chapters identify the key receptor groups (fish, marine mammals, and seabirds) that are most likely to be affected by the construction, O&M, and decommissioning phases of the Proposed Development. By analysing the species composition and ecological roles of these receptors, it is possible to determine which species function as key predators within the marine ecosystem surrounding the Proposed Development. A high-level summary of the biotic baseline environment is presented in Paragraph 23.8.4 *et seq.*, offering an overview of biotic baseline.

Piscivorous Fish

23.8.23 Piscivorous fish primarily feed on other fish species. Table 23.16 presents a detailed overview of piscivorous marine species relevant to the Proposed Development and identified from the IEFs in Table 9.14 of Volume 2, Chapter 9: Fish and Shellfish Ecology, highlighting their ecological roles within the marine food web. The prey profiles have been expanded to include specific examples of fish species commonly consumed, offering insight into the type of predator-prey dynamics and trophic interactions in the Proposed Development.

Table 23.16: Key Predatory Fish Species and their Prey

Species	Typical Prey Species
Teleost fish	
Anglerfish *Lophius piscatorius*	Ambush predator feeding on small fish, cephalopods, and crustaceans using a modified dorsal spine as a lure.
Atlantic bluefin tuna *Thunnus thynnus*	Fast-swimming predator consuming schooling fish such as herring, mackerel, and squid; plays a key role in pelagic food webs.
Blue whiting *Micromesistius poutassou*	Feeds on small fish like sprat and Norway pout, crustaceans, and zooplankton.
Cod	Young demersal cod - small benthic crustacea; adults feed on pelagic fish such as sandeel, whiting, haddock and squid. Demersal feeding includes annelids, crustacea and molluscs.
European hake *Merluccius merluccius*	Predator of small fish such as blue whiting and horse mackerel, along with cephalopods and crustaceans.
Haddock *Melanogrammus aeglefinus*	Small invertebrates, shellfish, worms and crabs make up the majority of its diet. They may occasionally hunt small fish such as sandeel and sprats, but this is not thought to be a major part of their diet until haddock are fully grown.
Horse mackerel *Trachurus trachurus*	Consumes small fish such as sprat and anchovy, crustaceans, and planktonic organisms.
Ling *Molva molva*	Demersal predator feeding on fish such as cod and whiting, crustaceans, and cephalopods.
Mackerel *Scomber scombrus*	Feeds on plankton, small fish such as sprat and sandeel, and squid.
Norway pout *Trisopterus esmarkii*	Consumes small fish like sprat and goby, zooplankton, and benthic invertebrates.
Plaice	Feeds on benthic organisms such as crustaceans, annelids, and sandeel.
Poor cod *Trisopterus minutus*	Feeds on small fish such as sandeel and goby, crustaceans, and benthic organisms.
Saithe *Pollachius virens*	A young saithe eats crustaceans and small fish, such as sandeel, while the mature saithe eats krill and small fish, such as Norway pout and blue whiting.
Whiting *Merlangius merlangus*	Worms, crustaceans and shellfish and small fish.
Elasmobranch	
Blue shark *Prionace glauca*	Pelagic predator feeding on fish such as mackerel and herring, squid, and occasionally seabirds.
Porbeagle shark *Lamna nasus*	Feeds on mackerel, cod, squid, and other fish.
Tope shark *Galeorhinus galeus*	Consumes fish like whiting and mackerel, cephalopods, and crustaceans.
Spurdog *Squalus acanthias*	Feeds on fish such as herring and sandeel, crustaceans, and cephalopods.
Nursehound *Scyliorhinus stellaris*	Demersal predator feeding on fish such as whiting and poor cod, molluscs, and crustaceans.

Species	Typical Prey Species
Small-spotted catshark *Scyliorhinus canicula*	Feeds on small fish such as sandeel and goby, crustaceans, and benthic invertebrates.
Cuckoo ray *Leucoraja naevus*	Consumes small fish such as sandeel and goby, crustaceans, and worms.
Thornback ray *Raja clavata*	Feeds on small fish such as sandeel and whiting, crabs, and shrimp.
Thorny skate *Amblyraja radiata*	Predator of fish such as whiting and poor cod, and benthic invertebrates.
Common skate *Dipturus batis*	Feeds on fish such as cod and haddock, crustaceans, and molluscs.
Flapper skate *Dipturus intermedius*	Consumes fish such as whiting and haddock, and invertebrates.
Diadromous fish	
Atlantic salmon *Salmo salar*	Feeds on fish such as sandeel and sprat, aquatic invertebrates, and crustaceans during marine phase.
Sea trout *Salmo trutta*	Predator of fish such as sprat and goby, insects, and crustaceans.
Sea lamprey *Petromyzon marinus*	Parasitic feeder attaching to fish such as cod and haddock, feeding on blood and tissue.

Marine Mammals

23.8.24 These species correspond to the marine mammal IEF identified in Table 10.17, Volume 2, Chapter 10: Marine Mammals. The sensitivity of marine mammals to prey availability within the Site Boundary will be affected by how important this area is to each species and how sensitive they are to prey availability. A summary of the typical prey species of the marine mammal species that could occur within the Proposed Development is presented in Table 23.17. Density information can be found within Volume 2, Chapter 10: Marine Mammals and in Volume 3, Technical Appendix 10.1: Marine Mammal Technical Report.

Table 23.17: Diet and Abundance of Key Marine Mammal Species

Species	Distribution in the Proposed Development	Typical Prey Species
Odontocetes		
Harbour porpoise	Harbour porpoise are present in the North Sea Management Unit (MU) with a density of 0.635 animals per km² in the Local Marine Mammal Study Area, based on a design-based (absolute) density estimate from the DAS campaign. The estimated population within this MU is 346,601 individuals, of which 159,632 are found in the UK portion (Inter-Agency Marine Mammal Working Group (IAMMWG), 2022). The Southern North Sea Special Area of Conservation (SAC) is a key designated site for this species.	Small fish such as herring, cod, haddock, gobies and sandeel. Dominant prey in North Sea in summer are sandeel and whiting; During the winter season dominant prey are sprat and herring. Harbour porpoise distribution shifts in the North Sea in the last 20 years have been linked to changing sandeel distributions (Paxton *et al.,* 2016).
Bottlenose dolphin	Bottlenose dolphins occur at a density of 0.007 animals per km² within the Local Marine Mammal Study Area. The total population is estimated at 2,248 individuals within the Coastal East Scotland and Greater North Sea MU, with 2,111 found in the UK portion (IAMMWG, 2022; Arso Civil *et al.,* 2021). The Moray Firth SAC is a key designated site for this species.	Benthic and pelagic fish (both solitary and schooling species), squid and octopus (Scottish Government, 2021) Typical prey items in Scottish waters include cod, saithe, whiting, salmon and haddock.
Risso's dolphin	During the two years of Proposed Development DAS campaign, Risso's dolphin were sighted in five survey months, with a total of 11 animals recorded. No specific designated sites are currently listed for this species.	Risso's dolphins primarily feed on cephalopods, especially squid, octopus, and cuttlefish. Their diet also includes fish such as anchovies, krill, and crustaceans (NatureScot, 2023). They are known to forage in deep offshore waters near the continental shelf edge and slope, often diving to depths of -600 to -800 m. Feeding typically occurs at night when prey migrates closer to the surface.
White-beaked dolphin	White-beaked dolphins have a relatively high density of 0.155 animals per km² within the Local Marine Mammal Study Area. The total population is estimated at 43,951 individuals in the Celtic and Greater North Sea MU, with 12,293 in the UK portion (IAMMWG, 2022). No specific designated sites are currently listed for this species.	Small schooling pelagic fish (e.g. mackerel, herring, and sprat), haddock, as well as crustaceans, octopus and squid (Scottish Government, 2021). Main prey species in Scottish waters is whiting, but also clupeids *Clupeidae* (e.g. herring), gadoids (e.g. haddock and cod) and shad (*Alosa* spp.) (Canning *et al*., 2008; Santos *et al*., 1994).

Species	Distribution in the Proposed Development	Typical Prey Species
Mysticetes		
Minke whale	Minke whales are present in the Celtic and Greater North Sea MU with a density of 0.030 animals per km² in the Local Marine Mammal Study Area. The population is estimated at 20,118 individuals in the Celtic and Greater North Sea MU, with 10,288 in the UK portion (IAMMWG, 2022). The Southern Trench MPA is a relevant designated site for this species.	Minke whales have a varied diet, feeding on smaller fish: sandeel, herring, sprat, haddock, saithe, whiting and small cod, as well as krill and other animals of the plankton (NatureScot, 2024). Sandeel are the key food resource throughout the North Sea, with sprat, shad and herring also preferred prey items (Robinson and Tetley, 2005).
Humpback whale	Humpback whale travel long annual migration distances and individuals in Scottish waters have been matched with both recovering (western North Atlantic) and non-recovering (Cape Verde) breeding populations. No humpback whale were observed during the two years of DAS and no density estimates are currently available for this region.	Humpback whales are believed to be largely opportunistic foragers. They have been documented feeding on krill, hake and small schooling fish (e.g. herring) (Reidy, 2022).
Fin Whale	More typical of the deep waters to the north and west of Scotland rather than the North Sea, small numbers reported in the Northern North Sea. No fin whale were observed during the two years of Proposed Development DAS and no density estimates are currently available for this region.	Fin whale are lunge feeders and feed by engulfing large volumes of water rich in prey. Fin whale diet includes small schooling fish, squid, and zooplankton (Watkins *et al.*, 1984; Løviknes *et al.*, 2021). There is limited data on prey availability in Scottish waters, but fin whale have been observed foraging on herring and other small pelagic species in the North Sea (Evans and Waggitt, 2020).
Pinnipeds		
Grey seal	Grey seals show a high density of 0.56 animals per km² in the Local Marine Mammal Study Area. The combined population is 52,355 individuals in the North Coast and Orkney Seal Management Unit (SMU), Moray Firth SMU, and East Scotland SMU. The Berwickshire and North Northumberland Coast SAC is a relevant designated site for this species.	Grey seal have a selective diet, mostly comprised of flatfish and sandeel. A study on the diet of grey seals in Scottish waters found that 50% of prey items were plaice and sole *Solea solea* and 46% of prey items were sandeel (Damseaux *et al.*, 2021). Gosch (2017) reported that there are significant regional and temporal differences in the diet of grey seal. Seals in shallow waters show a preference for demersal and groundfish species such as cephalopods and flatfish, while seals foraging in deeper waters, over sandy substrates, will target pelagic and bentho pelagic species such as blue whiting and sandeel (Gosch, 2017).
Harbour seal	Harbour seals occur at a density of 0.009 animals per km² in the Local Marine Mammal Study Area, with a population of 1,322 individuals in the North Coast & Orkney and Moray Firth MU. The Dornoch Firth and Morrich More SAC is a relevant designated site for this species.	Harbour seals are generalist predators feeding on a wide range of fish species, including sandeel, cod, whiting, herring, and flatfish. They also consume cephalopods and crustaceans. Their diet varies seasonally and regionally, often reflecting local prey availability (Oakley, 2008).

Seabirds

23.8.25 Seabird species diet and foraging behaviour determine the extent to which individual species are impacted and can respond to changes in prey availability. Table 23.18 provides an overview of the key seabird species associated with the Proposed Development. These species were identified from IEFs detailed in Table 11.7 of Volume 2, Chapter 11: Offshore Ornithology. The table outlines their roles within the marine food web, summarising typical feeding strategies and prey species for seabirds that may be affected by the Proposed Development.

Table 23.18: Diet and Feeding Strategies of Key Seabird Species

Species	Primary Feeding Strategy	Primary Feeding Location	Typical Prey Species
Arctic tern	Surface feeding and plunge diving	Water surface and upper water column (~1 m)	Sandeel, herring, sprat, and small crustaceans
Fulmar	Surface feeding and pursuit diving	Water surface, up to 1 m depth	Sandeel, cod, pollock, herring and small crustaceans
Gannet	Plunge diving	Water column - intermediate depths up to -30 m	Mackerel, sandeel and fisheries discards
Great black-backed gull	Opportunistic surface feeding	Coastal and pelagic zones, including intertidal	Fish (including sandeel and herring), crustaceans and molluscs
Guillemot	Pursuit diving[3]	Water column - up to -150 m depth	Sandeel, herring and shad, small marine crustaceans, squid and octopus.
Herring Gull	Surface feeding and scavenging	Coastal zones, estuaries, and urban areas	Fish (e.g. herring, sprat) and invertebrates
Kittiwake	Surface feeding	Water surface - up to -1 m depth	Sandeel, herring and sprat
Puffin	Pursuit diving	Water column – up to -60 m depth	Sandeel and sprats, supplemented by crustaceans, molluscs *Mollusca* sp. and polychaetes during the breeding season
Razorbill	Pursuit diving	Upper water column – up to -120 m depth	Sandeel, sprat and herring

[3] Plunge divers dive into the sea from a height to catch prey, whereas pursuit divers dive and can then swim underwater in pursuit of prey.

23.8.26 It is important to note that ornithological species exhibit strong seasonal patterns, with significantly higher numbers present during certain times of the year. This includes:

- Breeding season: During this period, birds are closely associated with their nesting sites, engaging in activities such as nest building, egg laying, and feeding their young.
- Non-breeding season: Although birds are not tied to nesting sites during this time, they can still occur in large numbers within Scottish marine areas.

23.8.27 This seasonal variation can influence the structure and dynamics of the ecosystem, as the presence of more individuals, including dependent young, may alter species interactions and ecological processes. Table 23.19 describes the seasonal variation.

Table 23.19: Seasonal Definitions of IEFs Recorded in the Array Area (Volume 2, Chapter 11: Offshore Ornithology)

Species	Breeding Season	Non-Breeding Season
Fulmar	April to mid-September	Mid-September to March
Gannet	Mid-March to September	October to mid-March
Kittiwake	Mid-April to August	September to mid-April
Great black-backed gull	April to August	September to March
Herring gull	April to August	September to March
Arctic tern	May to August	September to April
Guillemot	April to mid-August	Mid-August to March
Razorbill	April to mid-August	Mid-August to March
Puffin	April to mid-August	Mid-August to March

Key Prey Species

23.8.28 Key prey species and their predators have been identified in Table 23.20 by cross-referencing the predator information outlined in the preceding section with the IEF listed in Table 9.14 of Volume 2, Chapter 9: Fish and Shellfish. Detailed species accounts, including distribution and life history strategies, are available in Volume 3, Technical Appendix 9.1: Fish and Shellfish Ecology Technical Report and are not repeated here for brevity.

Table 23.20: Key Prey Species

Prey	Predators
Teleosts	
Blue whiting	European hake, saithe, white-beaked dolphin, grey seal (in deeper waters)
Cod	Porbeagle shark, bottlenose dolphin, harbour porpoise, sea lamprey (parasitic), harbour seal
Haddock	Harbour porpoise, minke whale, bottlenose dolphin, white-beaked dolphin, harbour seal
Herring	Atlantic bluefin tuna, blue shark, white-beaked dolphin, minke whale, Arctic tern, kittiwake, puffin, guillemot, razorbill, herring gull
Horse mackerel	European hake, blue shark, gannet, great black-backed gull
Mackerel	Blue shark, porbeagle shark, white-beaked dolphin, gannet, great black-backed gull
Norway pout	Saithe, puffin, razorbill, guillemot
Poor cod	Nursehound, thorny skate, great black-backed gull, herring gull, harbour seal
Saithe	Bottlenose dolphin, minke whale, killer whale
Sprat	Atlantic salmon, sea trout, harbour porpoise, minke whale, kittiwake, puffin, razorbill, arctic tern, herring gull, guillemot
Whiting	Harbour porpoise, bottlenose dolphin, grey seal, white-beaked dolphin, razorbill, guillemot, great black-backed gull, herring gull
Diadromous fish	
Sea trout	Bottlenose dolphin
Shellfish	
Crabs	Haddock, thornback ray, great black-backed gull, herring gull, fulmar
Squid	Risso's dolphin, bottlenose dolphin, white-beaked dolphin, guillemot, puffin, razorbill, fulmar

How the Food System Works

23.8.29 Understanding the structure and dynamics of marine ecosystems is essential for assessing the potential impacts of offshore developments. This section outlines how energy flows through trophic levels and the ecological significance of mid-trophic species.

23.8.30 Energy transfer within marine food webs begins with primary producers such as phytoplankton and algae, which convert solar energy into biomass via photosynthesis. This energy is passed to primary consumers like zooplankton, and then up through successive trophic levels.

23.8.31 Marine ecosystems often exhibit a 'Wasp-waist' trophic structure (Fauchald *et al.* 2011), characterised by high species diversity at both the lower and upper trophic levels, but relatively low diversity among mid-trophic species. These mid-level species, particularly sandeel, herring, mackerel, and sprat, play a pivotal role in linking primary producers to apex predators such as marine mammals and seabirds.

23.8.32 Phenology, the timing of biological events, shapes how species interact within the food web. Many marine organisms have evolved life history strategies that align reproduction and growth with favourable seasonal conditions. Climate induced shifts in phenology can disrupt these patterns, affecting species at the base of the food chain and triggering cascading effects (Maron *et al.,* 2015). For example, changes in sandeel populations from climate induced shifts can significantly impact seabirds like kittiwake, which rely heavily on this prey.

23.8.33 Paragraph 23.8.23 *et seq*. outlines key predator species including fish, seabirds, and marine mammals, while Paragraph 23.8.28 *et seq*. identifies their typical prey. Although many predators share common prey species, their reliance on specific prey varies. For instance, kittiwake are particularly dependent on sandeel, making them more vulnerable to changes in its distribution and abundance.

23.8.34 Mid-trophic species, such as greater and lesser sandeel, herring, and rays, are often grouped into broader ecological categories because they share similar functional roles. Although they may not always be individually recognised as IEFs, their collective role as key links in energy flow is vital to maintaining ecosystem integrity. The low diversity among mid-trophic species means there is little functional redundancy, few species can substitute for one another. Consequently, the loss or decline of a single species can trigger significant cascading effects throughout the food web. Ecosystems with limited redundancy are less resilient to disturbances, making the conservation of these species essential for preserving trophic stability.

Future Ecosystem Baseline

23.8.35 The EIA Regulations require that '*a description of the relevant aspects of the current state of the environment (baseline scenario) and an outline of the likely evolution thereof without implementation of the Proposed Development as far as natural changes from the baseline scenario can be assessed with reasonable effort'*. While this has been undertaken for this Offshore EIA Report, this approach can be applied to a future ecosystem baseline scenario.

23.8.36 This section summarises the future baseline scenario in relation to the abiotic and biotic environment, as described in Volume 2, Chapter 7, Physical Processes, Volume 2, Chapter 8: Benthic Ecology, Volume 2, Chapter 9: Fish and Shellfish Ecology, Volume 2, Chapter 10: Marine Mammals, and Volume 2, Chapter 11: Offshore Ornithology. In addition, this section aims to synthesise this information into a future ecosystem baseline scenario specific to the Proposed Development.

23.8.37 The future ecosystem baseline presents a dynamic and evolving picture of the marine environment, shaped by both natural processes (e.g. changing sea temperatures, storm frequency and intensity, and seabed morphology) and anthropogenic influences (e.g. marine pollution, existing and planned marine developments, and commercial fishing). This scenario outlines how the abiotic and biotic components of the ecosystem are likely to change over time in the absence of the Proposed Development.

23.8.38 Physical processes are expected to undergo gradual but significant shifts due to climate variability and long term trends such as rising sea temperatures, changes in storm frequency and intensity, and sea level rise. Sea level rise is projected to reach approximately 0.25 m above 2025 levels by 2065, driven primarily by increases in mean sea level rather than storminess. Thermal stratification in UK shelf seas is anticipated to extend by approximately two weeks by 2100, with intensified surface-to-bottom temperature differences in the Northern North Sea. While tidal patterns and sediment transport regimes offshore are unlikely to change substantially, increased wave energy reaching the coast may alter erosion rates and the equilibrium of coastal features. However, projections of future wave climates remain uncertain.

23.8.39 Benthic ecology will be influenced by these physical changes, as well as by ongoing anthropogenic pressures such as pollution, seabed disturbance, and Offshore Infrastructure development. Climate change is expected to affect benthic communities both directly, through temperature increases and indirectly, via changes in hydrographic conditions and nutrient availability. These shifts may alter species composition and ecological functions like nutrient cycling and larval supply. Despite these pressures, substrate types are expected to remain stable, limiting the extent of biotope reclassification.

23.8.40 Fish and shellfish populations are similarly subject to natural cycles and climate-driven changes. Rising sea temperatures, documented at rates of 0.05°C to 0.07°C per decade in Scottish waters (Volume 2, Chapter 9: Fish and Shellfish), are likely to affect species at all biological levels. Cold-adapted species such as cod and herring may spawn earlier or shift their ranges northward, while warm-adapted species may expand into newly suitable habitats. Changes in weather patterns, particularly increased spring storms, could disrupt water column stratification and primary production, impacting food availability across trophic levels. Fisheries management measures, such as the 2024 ban on sandeel fishing in Scottish and English waters, are expected to yield direct benefits for sandeel populations and indirect benefits for their predators, including fish, seabirds, and marine mammals.

23.8.41 Marine mammals face a complex array of pressures, both direct and indirect. Anthropogenic threats, such as bycatch, pollution, vessel activity, and habitat degradation, continue to affect their abundance and distribution. Climate change compounds these impacts, prompting shifts in species ranges, altering prey availability, and influencing reproductive success and survival rates. Rising sea levels and changing weather patterns may further degrade coastal habitats. Monitoring gaps, such as infrequent Small Cetaceans in European Atlantic waters and the North Sea (SCANS) and Special Committee on Seals surveys, limit the ability to predict future population trajectories with confidence. While some populations (e.g. bottlenose dolphin and grey seal) show signs of stability or growth, others (e.g. harbour seal) exhibit regional declines, underscoring the uncertainty of future outcomes.

23.8.42 Offshore ornithology reveals a troubling trend of seabird population decline, with over a third of UK species experiencing significant reductions in breeding abundance since the early 1990s. Climate change is identified as the primary driver, affecting prey availability and increasing the frequency of extreme weather events. Invasive species and bycatch in fisheries also pose substantial threats, though these are more amenable to direct management. Conservation efforts, including predator eradication and the closure of sandeel fisheries, aim to mitigate these impacts and support seabird recovery. However, the long term effectiveness of these measures remains uncertain, particularly in the face of global climate pressures. The discard ban (the Landing Obligation introduced under the Common Fisheries Policy) requires fishers to land quota species rather than discard them at sea, reducing the availability of discards that scavenging seabirds have used as a food source, adding further stress to already vulnerable populations.

23.8.43 Taken together, these summarised topic-specific insights form an overview of the future marine ecosystem. The baseline is characterised by increased variability, shifting species distributions, and evolving community structures. Climate change emerges as the dominant force shaping both abiotic and biotic components, influencing everything from sea level and stratification to species behaviour and ecological interactions.

23.8.44 While pressures, such as invasive species and fishing impacts, can be managed through targeted interventions, the pervasive nature of climate change presents a more formidable challenge. The absence of the Proposed Development would mean foregoing its potential contribution to greenhouse gas reductions, thereby exacerbating climate-related impacts on marine biodiversity. In this context, the future ecosystem baseline underscores the need for proactive, integrated management strategies that address both local and global drivers of change, ensuring the resilience and sustainability of marine ecosystems over the coming decades.

Existing Pressures on Prey Species

23.8.45 Before assessing the potential ecosystem-level effects of the Proposed Development on prey species, it is essential to first understand the existing selection pressures, both anthropogenic and natural, that influence their populations, distributions, and ecological roles. These pressures shape the structure and function of marine food webs and determine the resilience of prey species to additional stressors introduced by the Proposed Development.

23.8.46 The North Sea is recognised as one of the most anthropogenically impacted marine ecosystems globally (Halpern *et al.*, 2015; Emeis *et al.*, 2015). Mid-trophic level shoaling fish, such as sandeel, herring, and sprat, are subject to intense top-down pressure from commercial fisheries. These species are also affected by bottom-up processes, particularly those driven by climate change. Since the 1960s, temperature-driven changes have significantly altered planktonic communities, which form the base of the marine food web. These pressures propagate both upward and downward through the trophic hierarchy, with mid-trophic fish acting as ecological intermediaries that link changes in primary production to impacts on higher predators (Lynam *et al.*, 2017).

23.8.47 Globally, forage fish landings represent approximately one-third of all marine fish landings, excluding losses from bycatch and discards (Alder *et al.*, 2008). In the North Sea, sandeel have historically been exploited for their oil and use in animal feed and fertiliser. Despite management efforts, many sandeel stocks have experienced severe declines due to a combination of overfishing and climate-related stressors, such as warming sea temperatures and altered stratification patterns (NatureScot, 2022). In response to these pressures, the Scottish government introduced a prohibition on sandeel fishing within waters of International Council for the Exploration of the Seas (ICES) Area 4 (North Sea) in March 2024 (Scottish Government, 2024 and Department for Environment Food and Rural Affairs (DEFRA), 2024), marking a significant shift in fisheries policy aimed at ecosystem recovery.

23.8.48 Herring, another key prey species, has also faced substantial anthropogenic pressure. Once abundant in the North Sea, herring stocks collapsed in the 1970s due to overfishing (Scottish Herring, 2023). A recovery plan was implemented in 1996 and further supported by the 2015 discard ban for pelagic fisheries (DEFRA, 2015), including herring. While stocks have shown signs of recovery, they remain vulnerable to environmental variability and require continued active management to prevent future collapse (Dickey-Collas *et al.*, 2010).

23.8.49 The key prey species present within the marine ecosystem surrounding the Proposed Development are not only ecologically significant but also serve as primary food sources for a wide range of larger predatory fish. Species such as plaice, cod, haddock, whiting, saithe, tope shark, and spurdog rely heavily on prey fish like sandeel, herring, sprat, and mackerel. Additionally, diadromous fish species, including Atlantic salmon, sea trout, sea lamprey, European eel, allis shad, and twaite shad, are likely to migrate through the Proposed Development and utilise these prey resources during key life stages.

23.8.50 As described in Paragraph 23.8.35 *et seq.,* climate change is expected to exert significant influence on marine fish species across all trophic levels. Prey species such as sandeel and herring are particularly vulnerable due to their sensitivity to changes in sea temperature, ocean acidification, and stratification. These environmental shifts can disrupt spawning cycles, alter distribution patterns, and reduce prey availability, with cascading consequences for predator populations and overall ecosystem stability.

23.8.51 In summary, the prey species within the North Sea ecosystem are subject to a complex interplay of pressures, including overfishing, habitat degradation, pollution, and climate change. Understanding these existing stressors is critical to accurately assessing the potential impacts of the Proposed Development and to ensuring that mitigation strategies are ecologically informed and effective.

23.8.52 Table 23.21 describes the existing pressures on those prey species identified in Table 23.20 (Volume 3, Technical Appendix 9.1: Fish and Shellfish Ecology Technical Report).

Table 23.21: Prey Species Selection pressures

Prey	Selection Pressures
Teolosts	
Blue whiting	Climate change (temperature shifts), overfishing, and changes in ocean currents
Cod	Overfishing, habitat degradation, climate change (warming waters), and pollution
Haddock	Fishing pressure, climate change, and seabed disturbance
Herring	Overfishing, climate change (temperature and acidification), prey availability, and pollution
Horse mackerel	Fishing pressure, climate change, and habitat changes
Mackerel	Overfishing, climate change, and ocean acidification
Norway pout	Fishing pressure, climate variability, and habitat disturbance
Poor cod	Habitat degradation, pollution, and climate change
Saithe	Fishing pressure, climate change, and prey competition
Sprat	Climate change (temperature and stratification), overfishing, and pollution
Whiting	Fishing pressure, climate change, and habitat degradation
Diadromous fish	
Sea trout	Climate change, habitat fragmentation, pollution, and fishing pressure
Shellfish	
Crabs	Habitat disturbance, pollution, climate change, and harvesting pressure
Squid	Climate change (temperature and oxygen levels), overfishing, pollution

Effects of the Proposed Development on Prey Species

23.8.53 This section assesses the potential likely significant environmental effects of the Proposed Development on prey species and any impacts on physical processes which may impact prey species indirectly by altering their availability to food sources such as plankton and zooplankton.

23.8.54 Information to support this assessment has been extracted from the relevant receptor topic Offshore EIA Report chapters. Conclusions on likely significant environmental effects have also been extracted from these chapters. Each assessment of an effect focuses on the prey species most vulnerable to the impact and therefore represents the greatest potential impact.

Potential Impacts on Prey Species

23.8.55 Volume 2, Chapter 8: Benthic Ecology and Volume 2, Chapter 9: Fish and Shellfish identify several potential impacts from the Proposed Development that may affect both fish and shellfish, as well as benthic ecology:

- temporary habitat loss and/or disturbance;
- long term habitat loss and/or disturbance;
- introduction of artificial structures and subsequent colonisation of hard structures;

- changes to SSCs, bed levels and sediment type;
- removal of hard substrates;
- subsea noise impacting fish and shellfish receptors; and
- impacts to benthic ecology, and fish and shellfish ecology due to EMF.

23.8.56 The significance of effects on benthic ecology from the Proposed Development was assessed as Negligible to Minor adverse, both for the Proposed Development alone and cumulatively with other projects. These levels are considered not significant in EIA terms, indicating that the Proposed Development is unlikely to affect the identified benthic receptors.

23.8.57 Similarly, the significance of effects on fish and shellfish was assessed as negligible to Minor adverse for all but one impact 'subsea noise impacting fish and shellfish receptors', specifically in relation to herring, again both for the Proposed Development alone and cumulatively. These effects are also not significant in EIA terms where Additional Mitigation is applied, suggesting the Proposed Development is unlikely to affect the identified fish and shellfish receptors.

23.8.58 However, the chapter highlights that the impact 'subsea noise impacting fish and shellfish receptors' could significantly affect the herring receptor if no Additional Mitigation is implemented for both the Proposed Development alone and cumulatively during the piling activity of the construction phase, resulting in a decrease in assessment of significance to Minor adverse effect.

23.8.59 The following section provides a summary and detailed discussion of this impact during the construction phase, focusing on the herring receptor that has the potential to be significantly affected by the Proposed Development. The analysis considers the ecosystem context both prior to and following the implementation of Additional Mitigation.

Subsea Noise Impacting Fish and Shellfish Receptors

Proposed Development Alone

Magnitude of the Impacts

23.8.60 Piling of Wind Turbine foundations and OSP foundations could lead to injury and disturbance for fish and shellfish IEFs during the construction phase of the Proposed Development. For piling, the subsea noise modelling considered three potential foundation options and a concurrent piling scenario (Table 9.15 of Volume 2, Chapter 9: Fish and Shellfish):

- Fixed foundation monopile – 25 MW option:
  - 40 foundations;
  - 40 piles;
  - maximum pile diameter of 15 m;
  - maximum pile length of 123 m, with final pile penetration of 45 m;
  - maximum hammer energy of 6,250 kilojoules (kJ); and

    - maximum piling duration of 8.6 hours.
- Fixed foundations – 25 MW 3-legged jacket:
    - 40 foundations;
    - 120 piles;
    - maximum pile diameter of 5 m;
    - maximum pile length of 90 m, with final pile penetration of 85 m;
    - maximum hammer energy of 4,500 kJ; and
    - maximum piling duration of 16.2 hours.
- Realistic scenario – 25 MW fixed foundation monopile with the average hammer energy and average piling duration, instead of the maximums modelled for the scenarios above:
    - 40 foundations;
    - 40 piles;
    - maximum pile diameter of 15 m;
    - maximum pile length of 123 m, with final pile penetration of 45 m;
    - maximum hammer energy of 6,000 kJ; and
    - maximum piling duration of 4.3 hours.
- Concurrent piling – all three scenarios:
    - up to two vessels piling concurrently; and
    - minimum of 1 km and maximum of 20 km distance between concurrent piling events.

23.8.61 The subsea noise modelling and the MDS, therefore, considers the greatest potential impact from subsea noise on fish and shellfish IEFs, based on the greatest hammer energy, alongside a more realistic scenario (using the average hammer energies and piling durations). The subsea noise modelling of concurrent piling (i.e. piling at more than one location simultaneously) ensures a precautionary assessment has been undertaken, alongside the single piling scenarios. The results of the subsea noise modelling are discussed in Volume 2, Chapter 9: Fish and Shellfish to define the 'sensitivity of the receptor' in relation to injury and behavioural impacts upon the fish and shellfish IEFs.

23.8.62 The impact is predicted to be of local spatial extent, short term duration (in terms of piling hours), intermittent over the construction phase and high reversibility, with the soundscape returning to near baseline conditions upon completion of piling. It is predicted that the impact will affect the receptor directly. The magnitude is therefore considered to be low.

Sensitivity of the Receptor

23.8.63 Paragraph 9.10.166 *et seq.* of Volume 2, Chapter 9: Fish and Shellfish, describes the criteria used to evaluate the fish and shellfish IEFs, with Paragraph 9.10.177 *et seq.* describing the modelling approach taken and the sensitivities of fish and shellfish receptors.

23.8.64 This section summarises the predicted impacts of subsea noise, from Volume 2, Chapter 9: Fish and Shellfish, in relation to piling activities on herring, a species classified under Group 1 hearing sensitivity (see Paragraph 9.10.167 *et seq.* of Volume 2, Chapter 9: Fish and Shellfish for further information). The modelling approach considered both moving and static receptors, using two acoustic metrics: Cumulative Sound Exposure Level and Peak Sound Pressure Level (SPLpk). Moving receptors were assigned a conservative swim speed of 0.5 m/s, while static receptors represent a precautionary MDS where fish are assumed to remain stationary throughout the piling event.

Single Monopile Installation

23.8.65 For single monopile installation, herring modelled as moving receptors were not predicted to experience mortality or recoverable injury (Table 23.22). However, TTS, a reversible reduction in hearing sensitivity, was predicted to occur up to 22.27 km from the piling source. In contrast, static receptor modelling indicated greater vulnerability, with mortality predicted up to 1,436 m, recoverable injury up to 1,993 m, and TTS extending to 25.0 km.

Table 23.22: Injury Ranges for Herring Under Single Monopile Installation

Response	Threshold (SPLpk)	First Strike (m)	Highest Energy (m)
Mortality	213 dB re 1 µPa	180	888
Recoverable Injury	213 dB re 1 µPa	180	888

Jacket Pile Installation

23.8.66 Under the jacket pile installation scenario, herring modelled as moving receptors were again not predicted to exceed thresholds for mortality or injury, with TTS modelled out to 20.98 km (Table 23.23). Static receptor modelling showed increased risk, with mortality predicted up to 1,026 m, recoverable injury up to 1,495 m, and TTS extending to 25.0 km.

Table 23.23: Injury Ranges for Herring under Jacket Pile Installation

Response	Threshold (SPLpk)	First Strike (m)	Highest Energy (m)
Mortality	213 dB re 1 µPa	211	544
Recoverable Injury	213 dB re 1 µPa	211	544

Realistic Piling Scenario

23.8.67 The realistic piling scenario, based on average hammer energy and duration, represents the most likely operational conditions. For moving herring, no exceedance of mortality or injury thresholds was predicted (Table 23.24), with TTS extending to 22.15 km. Static receptor modelling indicated mortality up to 909 m, recoverable injury up to 1,349 m, and TTS up to 25.0 km.

Table 23.24: Injury Ranges for Herring Under Realistic Scenario

Response	Threshold (SPLpk)	First Strike (m)	Highest Energy (m)
Mortality	213 dB re 1 µPa	180	872
Recoverable Injury	213 dB re 1 µPa	180	872

Concurrent Piling Scenarios

23.8.68 Concurrent piling, involving two vessels operating simultaneously, increased the impact ranges for static herring (Table 23.25).

Table 23.25: Injury Ranges for Herring Under Concurrent Piling Scenario

Scenario	Mortality (m)	Recoverable Injury (m)	TTS (m)
Monopile	1,261	1,759	25,000
Three-legged Jacket	1,612	2,286	25,000
Realistic Scenario	N/E	N/E	22,852

23.8.69 These results highlight the precautionary nature of static receptor modelling, which assumes fish remain stationary throughout the piling event, an unlikely real-world behaviour for herring.

Behavioural Disturbance

23.8.70 Behavioural disturbance was assessed using a threshold of 150 dB re 1 µPa (rms), with ranges extending up to 70.36 km for all hearing groups. However, this threshold is considered highly conservative for Group 1 species like herring, which are less sensitive to subsea noise. Literature in Volume 2, Chapter 9 Fish and Shellfish suggests that herring are unlikely to exhibit strong behavioural responses below 160 dB re 1 µPa (SPLpk). Therefore, the mapped 160 dB contour likely overestimates the actual disturbance range.

23.8.71 Studies (Volume 2, Chapter 9: Fish and Shellfish) have shown that behavioural responses such as avoidance are more likely to occur at higher sound levels and vary based on individual condition, age, and environmental context. These findings support the conclusion that while herring may experience temporary hearing effects or behavioural changes during piling, the risk of mortality or long term harm under realistic conditions is low.

Spawning Grounds

23.8.72 Figure 23.2 shows the 160 dB re 1 µPa (SPL_{pk}) contour in relation to the spawning grounds for herring alongside cumulative larval densities. This figure illustrates that the 160 dB re 1 µPa (SPL_{pk}) contour associated with piling at the south of the Array Area does not extend to the hotspot of herring larval density, while piling at the north does. Therefore, the herring IEF is deemed to be of high vulnerability, medium recoverability, and national importance. The sensitivity of the receptor is, precautionarily, considered to be high.

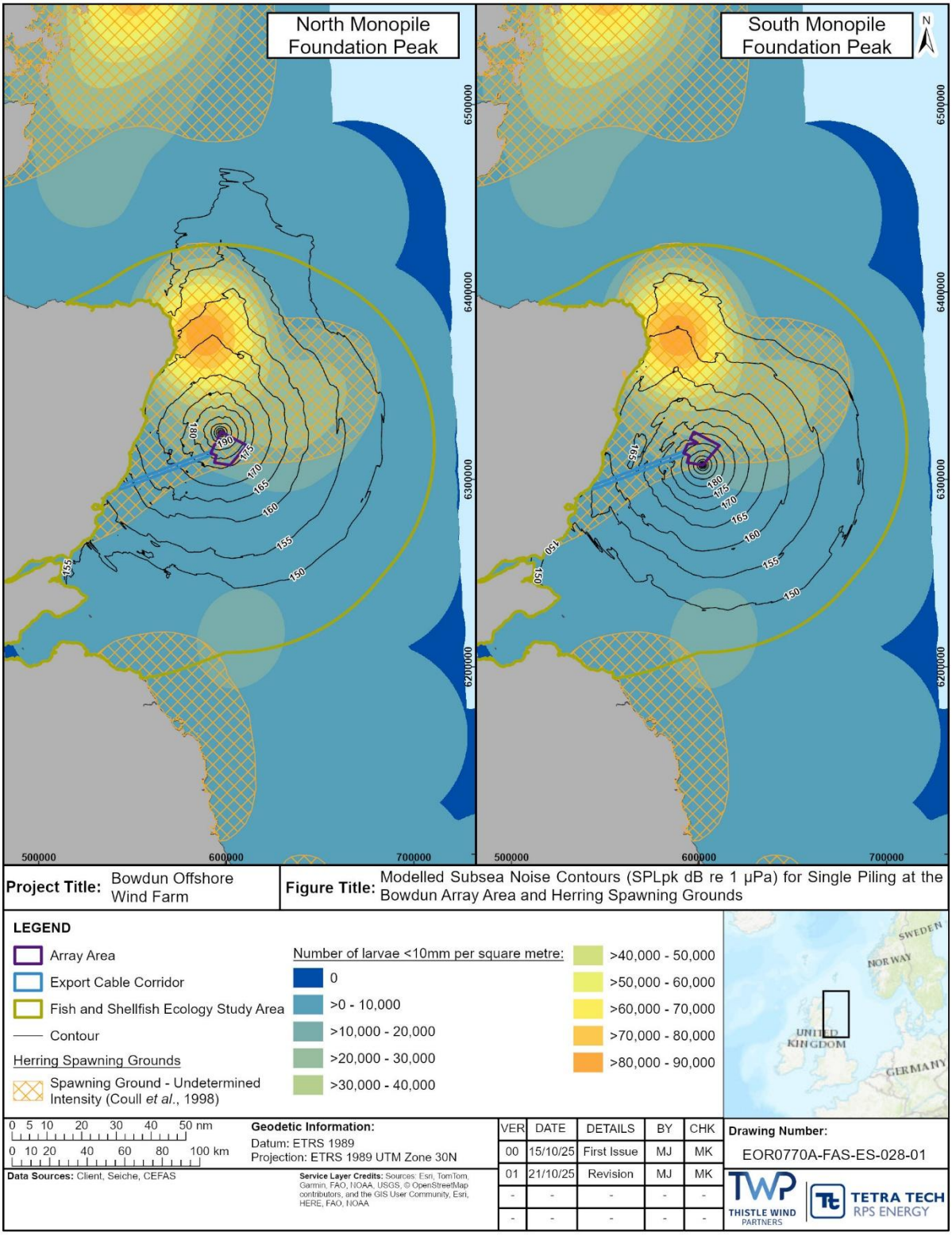

Figure 23.2: Modelled Subsea Noise Contours (SPL_{pk} dB re 1 µPa) for Single Piling at the Bowdun Array Area and Herring Spawning Grounds

Significance of Effect

23.8.73 Overall, for the herring IEF, the magnitude of impact is deemed to be low and the sensitivity of the receptor is considered, precautionarily, to be high. The cumulative effect will, therefore, be of **Moderate** adverse significance, which is significant in EIA terms.

Additional Mitigation and Residual Effect

23.8.74 A likely significant environmental effect (Moderate adverse) has been concluded for the herring IEF resulting from piling during the construction phase. Therefore, prior to the commencement of piling, appropriate Additional Mitigation measures will be discussed with NatureScot and other relevant stakeholders. These will be detailed and secured through the Piling Strategy developed post consent. Measures included in the Piling Strategy will be dependent on the final design of the Proposed Development and may include the use of mitigation measures such as noise abatement systems, or site-specific surveys to determine key herring spawning periods. Mitigation measures within the Piling Strategy will be agreed as part of a stepped strategy post consent and will follow the mitigation hierarchy – avoid, reduce, mitigate. It is expected that the measures secured within the Piling Strategy will reduce the significance of this impact to **Minor** adverse for herring, which is not significant in EIA terms

Cumulative Effects

Magnitude of Impact

23.8.75 Volume 2, Chapter 9: Fish and Shellfish describes in detail the magnitude of impacts and is summarised here.

23.8.76 During the construction phase of the Proposed Development, 14 Tier 2 offshore wind projects were identified as having potential for cumulative impacts from subsea noise. These include Kincardine OWF, Seagreen 1 OWF, Seagreen 1A Project, Seagreen Phase 1 OFTO, Seagreen Phase 1A OFTO, Hywind Scotland OWF, Berwick Bank OWF, Berwick Bank OFTO, Green Volt, Ossian OWF, Aspen OWF, Salamander OWF, Aberdeen OWF, and Muir Mhòr OWF. Subsea noise modelling results, where available, indicated that injury and disturbance effects were not significant for fish and shellfish species assessed in their respective EIAs. The modelling outputs were generally comparable in scale to those of the Proposed Development, and the species assessed were similar to the fish and shellfish IEFs considered in the Proposed Development alone. UXO clearance impacts for Berwick Bank OWF and Ossian OWF were also modelled, with limited spatial overlap predicted due to timing and geographic separation.

23.8.77 Importantly, most Tier 2 projects will be constructed prior to the Proposed Development, significantly reducing the likelihood of cumulative effects, as piling noise during construction poses the greatest risk. Only the construction phases of the Berwick Bank OWF (up to eight years; 2025 to 2032) and Ossian OWF (up to eight years; 2031 to 2038) overlap with that of the Proposed Development (2031 to 2036). The cumulative impact is predicted to be of local spatial extent, medium duration (over the construction phase), intermittent and

high reversibility. It is predicted that the impact will affect the receptor directly. The magnitude of impact is therefore, considered to be low.

Sensitivity of the Receptor

23.8.78 The sensitivity is as described in Paragraph 23.8.63.

Significance of Effect

23.8.79 Overall, for the herring IEF, the cumulative magnitude of impact is deemed to be low and the sensitivity of the receptor is considered, precautionarily, to be high. The cumulative effect will, therefore, be of **Moderate** adverse significance, which is significant in EIA terms.

Additional Mitigation and Residual Effect

23.8.80 A Moderate adverse significance was concluded for the herring IEF due to piling in the construction phase. Therefore, prior to the commencement of piling for the Proposed Development alone, appropriate Additional Mitigation measures will be developed following engagement with stakeholders; stakeholder feedback will be sought and measures will be finalised in discussion with the relevant statutory authorities. These may include the use of noise abatement systems or site-specific surveys to determine key herring spawning periods. Appropriate mitigation will be secured through the Piling Strategy as a condition of the Marine Licence. It is anticipated that following tailoring of Additional Mitigation measures as described above, the cumulative significance of this impact will be reduced to Minor adverse for herring, which is not significant in EIA terms.

Ecosystem Effects Assessment

Subsea Noise Impacting Fish and Shellfish Receptors

23.8.81 Subsea noise modelling for the Proposed Development indicates that herring, as a Group 1 hearing sensitivity species, are unlikely to experience mortality or permanent injury under realistic piling scenarios. While TTS and behavioural disturbances may occur, particularly when modelled as static receptors, the ranges are precautionary and reversible. For example, TTS was modelled up to 22.27 km for moving herring and up to 25.0 km for static individuals, but actual exposure is expected to be lower due to avoidance behaviours. Given herring's ecological role as a forage fish supporting higher trophic levels (e.g. seabirds, marine mammals and predatory fish), temporary displacement or hearing disruption could affect local predator-prey dynamics. Without Additional Mitigation, there could be a short term effect on the spawning population; however, this would have to occur during the spawning season. As Additional Mitigation has been proposed, the impact is unlikely to affect spawning success or population viability. Therefore, the Proposed Development alone is not expected to cause ecosystem-level disruption, especially considering the high reversibility and low magnitude of predicted impacts.

23.8.82 When considering cumulative impacts from 14 Tier 2 offshore wind projects, Kincardine OWF, Seagreen 1 OWF, Seagreen 1A Project, Seagreen Phase 1 OFTO, Seagreen Phase 1A OFTO, Hywind Scotland OWF, Berwick Bank OWF, Berwick Bank OFTO, Green Volt, Ossian OWF, Aspen OWF, Salamander OWF, Aberdeen OWF, and Muir Mhòr OWF, the potential for significant ecosystem-level effects on herring remains low. Most of these projects will be constructed prior to the Proposed Development, reducing the likelihood of concurrent piling noise. Where overlap does exist, such as with Berwick Bank OWF and Ossian OWF, subsea noise modelling shows limited spatial and temporal coincidence. Given herring's mobility, schooling behaviour, and relatively low sensitivity to impulsive noise, cumulative impacts are predicted to be localised, short term, and highly reversible. As such, the broader ecosystem functions supported by herring, such as nutrient cycling and food web stability, are unlikely to be compromised by cumulative subsea noise exposure.

Introduction of Artificial Habitat and Subsequent Colonisation of Hard Structures

23.8.83 Although the impact was assessed as having a Minor adverse significance and is therefore not significant in EIA terms, Paragraph 9.10.85 *et seq.* of Volume 2, Chapter 9: Fish and Shellfish highlights the potential for beneficial effects arising from the introduction of hard structures. These benefits merit further discussion, particularly in relation to how the Proposed Development may support prey species.

23.8.84 Artificial hard structures introduced during the construction phase can offer a range of ecological benefits for marine fish and shellfish throughout the O&M phase. Acting as artificial reefs, these structures create new habitats that attract a wide variety of species across different trophic levels, from biofouling organisms to larger predators such as cod, horse mackerel and mackerel. Some species are drawn to these areas for feeding, while others seek shelter or social interaction (Karlsson *et al.*, 2022; Inger *et al.*, 2009; Petersen and Malm, 2006), which can lead to the formation of larger schools and enhance survival and reproductive success.

23.8.85 Over time, these structures become colonised, forming stable populations that contribute to local biodiversity. Research (Volume 2, Chapter 9: Fish and Shellfish) indicates that fish abundance is often higher around Wind Turbine foundations than in surrounding areas. Cod, for example, have been observed to associate closely with these structures during parts of its life cycle (Bergström *et al.*, 2013; Reubens *et al.*, 2014). The increased availability of prey in these habitats can improve predator settlement, survival and growth, while also helping conserve energy. Additionally, OWF infrastructure has been shown to provide refuge for species such as cod and plaice, with plaice exhibiting significantly higher abundance on sandy scour protection patches due to enhanced food and shelter availability.

23.8.86 Crustaceans like crabs and lobsters also benefit from the presence of hard structures, which offer refuge and novel habitats in areas previously dominated by sandy or gravelly sediments. These environments may extend the habitat range of species such as the edible crab and serve as nursery grounds, as demonstrated by post-construction monitoring at sites like Horns Rev OWF in the North Sea. Rapid colonisation by crustacean larvae and juveniles has also been observed (Vattenfall, 2006).

23.8.87 While there remains some uncertainty about whether these structures contribute to recruitment into local populations or simply concentrate existing biomass, the overall evidence points to a neutral to beneficial effect on marine fish and shellfish. Although there is a potential risk of colonisation by INNS, which could impact native shellfish through competition or habitat loss, this risk is considered manageable with appropriate mitigation measures (Volume 2, Chapter 9: Fish and Shellfish).

23.8.88 The introduction of artificial hard structures in OWFs may have some beneficial effect for marine fish and shellfish (Paragraph 9.10.85 of Volume 2, Chapter 9: Fish and Shellfish). These structures enhance habitat complexity, support biodiversity, and contribute beneficially to the wider ecosystem food web. By increasing habitat availability, prey abundance, and shelter opportunities, they help strengthen ecological interactions and promote more resilient and productive marine ecosystems.

Effects of the Proposed Development on Predator Species

23.8.89 The assessment of the Proposed Development on prey species (Paragraph 23.8.53 *et seq.*) examined the impacts as a result of the Proposed Development which could have either beneficial or adverse effects on the distribution of key prey species. This section assesses the sensitivity of fish, marine mammal and seabird predator species to prey availability and draws on the conclusions of the assessment of the Proposed Development on prey species to determine if there are any potential likely significant environmental effects on predators as a consequence of changes in prey availability. The likelihood of increased predation of key prey species as a result of the Proposed Development is considered highly unlikely due to the mobile nature of both prey and predator species and therefore has not been assessed further.

Piscivorous Fish

23.8.90 The typical prey species of the key predators (piscivorous fish) are listed in Table 23.16 which shows these fish species have broad diets comprising not only of small fish but also benthic species including invertebrates, molluscs and crustaceans. This suggests, the fish predator species are likely to be less sensitive to the availability of the key prey species of those defined in Table 23.20.

23.8.91 As outlined in the assessment of the 'effects of the Proposed Development on prey species' (Paragraphs 23.8.73 to 23.8.80), the Proposed Development is expected to have both a potential adverse (subsea noise impacting fish and shellfish), albeit a Minor (not significant) impact following Embedded and Additional Mitigation, and some beneficial effect (introduction of artificial

habitat and subsequent colonisation of hard structures) on marine fish (including prey species). However, these impacts are not predicted to cause significant changes in prey species populations.

Marine Mammals

23.8.92 Marine Mammals are likely to benefit from locally increased food availability and/or shelter (as discussed in Volume 2, Chapter 10: Marine Mammals) and therefore have the potential to be attracted to forage within an OWF. While species such as harbour porpoise, minke whale, white-beaked dolphin, harbour porpoise and grey seal have been frequently recorded around offshore oil and gas structures, little is known about how their distribution is linked to the reef effect or sheltering effect (Todd *et al.,* 2016; Delefosse *et al.,* 2018; Lindeboom *et al.,* 2011). Acoustic results from a Towed Passive Acoustic Monitoring Device (T- POD) measurement within a Dutch OWF found that relatively more harbour porpoises were found in the wind farm area compared to the two reference areas (Lindeboom *et al*., 2011; Scheidat *et al*., 2011). This study concluded that the presence within the wind farm area was due to increased food availability as well as the exclusion of fisheries and reduced vessel traffic in the wind farm (shelter effect).

23.8.93 Further evidence suggesting that wind farms are used for foraging includes a study by Russell *et al*. (2014) where the movements of tagged harbour seals commonly exhibited grid-like movement patterns within two active wind farms in the North Sea. However, other studies have detected no statistical differences in the presence of harbour porpoises inside and outside a Danish OWF (Brandt *et al*., 2009). Brandt *et al*. (2009) suggested, however, that a small increase in detections during the night at hydrophones deployed in close proximity to single Wind Turbines may indicate increased foraging behaviour near the monopiles. While there is some mounting evidence of potential benefits of man-made structures in marine environment (Coolen, 2017), the statistical significance of such benefits and details about trophic interactions in the vicinity of artificial structures and their influence on ecological connectivity remain largely unknown (Elliott and Birchenough, 2022; Inger *et al*., 2009; McLean *et al*., 2022; Rouse *et al*., 2020).

23.8.94 Marine mammals exploit a range of different prey items and can forage widely, sometimes covering extensive distances. As the potential impacts of construction on prey resources will be localised and largely restricted to the Site Boundary, only a small area will be affected when compared to the available foraging habitat in the North Sea. The fish and shellfish communities found within the Fish and Shellfish Ecology Study Area are characteristic of fish and shellfish assemblages in the Northern North Sea. It is therefore reasonably to assume that, due to the highly mobile nature of marine mammals, there will be similar prey resources available in the wider area surrounding the Site Boundary.

23.8.95 Despite this, foraging over greater distances could result in an energetic cost with the associated increased travel with this effect being particularly pertinent for harbour porpoise. Harbour porpoise have a high metabolic rate and only a limited energy storage capacity, which limits their ability to buffer against diminished food. Despite this, if animals do have to travel further to alternative

foraging grounds, the impacts are expected to be largely short term in nature and reversible (i.e. elevated underwater noise would occur during site-investigation surveys, geophysical surveys, vessel activity, UXO clearance, piling and other noise producing activities) and are likely to return to the area after the noise activity has ceased. While the impact of elevated subsea noise from the operation of the Proposed Development is long term it is of highly local spatial extent and therefore of Minor adverse significance.

23.8.96 In Volume 2, Chapter 10: Marine Mammals it was identified that minke whale have the potential to be particularly vulnerable to potential impacts on sandeel, particularly if there is potential for reduced abundance. Studies analysing the stomach contents of minke whale found that in the North Sea this species is their key food resource, followed by clupeids *Clupeidae* and to a lesser extent mackerel (Robinson and Tetley, 2005; Tetley *et al.,* 2008). However, Volume 2, Chapter 9: Fish and Shellfish Ecology concluded that all impacts to sandeels would be of minor adverse significance, which is not significant in EIA terms, therefore minke whale are not considered to be affected indirectly through impacts to sandeel.

Seabirds

23.8.97 Prey availability is one of the most important controls of species abundance and distribution in the higher trophic levels, including birds (Mitchell *et al.,* 2020). Reduced availability or shifts in the distribution of prey species means seabirds are having to travel further distances to forage for food. Fayet *et al.* (2021) conducted a study comparing the foraging behaviour of puffin populations across the north-east Atlantic and found that puffins from declining populations had to cover greater distances for foraging and had less energy-dense diets. Low prey availability close to the colonies, potentially resulting from climate or commercial fisheries effects, is also amplified by increased intra-specific and inter-specific competition which forces birds to forage further from their colonies.

23.8.98 The extent to which seabirds respond to changes in prey availability is dependent on species. Generalist species, such as gulls, feed on a range of prey types and are therefore more resilient to these changes whereas specialist species, such as kittiwake, predominantly prey on small fish and struggle to adapt to changes in prey availability as easily.

23.8.99 Changes to prey distribution within the water column resulting from changes to stratification or temperature, will affect surface feeding species (e.g. kittiwake and terns) differently to water column feeding species (e.g. auks). Typically, water column feeding species can adapt better to changes in prey availability as they are not restricted to prey available in the upper 1 m to 2 m of the sea surface, as is the case for surface feeding species. The primary feeding strategies for key seabird species that have the potential to be impacted by the Proposed Development are detailed in Table 23.26.

23.8.100 The presence of sandeel has been linked to the reproductive success and survival of kittiwakes (Frederiksen *et al*., 2004, 2008; Carroll *et al*., 2017). During April and May, adult kittiwakes predominantly consume older sandeel (1+ year group), transitioning to juvenile sandeel (0 year group) in June and July while rearing chicks. This dietary pattern aligns with the annual cycle of sandeel as 1+ year group sandeel are active in the water column during spring and 0 year group, having newly metamorphosed from larvae to juveniles, are available from June. Both year groups then bury themselves over winter, surviving on the lipids they have accumulated during the spring months (Wright and Bailey, 1996). Sandeel stock levels have seen significant reductions as a result of climate change and commercial fisheries which may contribute to kittiwake declines (Carroll *et al.,* 2017).

23.8.101 In the Firth of Forth region, a decline in the average length-at-age of both the 0 year group and 1+ year group sandeel brought to puffin chicks on the Isle of May indicated a considerable decline in prey quality between 1973 and 2015. This trend is associated with reductions in kittiwake populations. It is estimated that the energy content of sandeel decreased by around 70% and 40% for 0 and 1+ year sandeel groups, respectively, potentially leading to a significant change in the diet or behaviour of seabirds that rely on sandeel species (Walness *et al.,* 2018). The diet of chick-rearing kittiwakes, puffins, razorbills and shags was predominantly sandeel between 1973 and 2015 in the North Sea. More recently, a shift to sprat and herring has been observed in guillemots, razorbills and kittiwakes (Walness *et al.,* 2018). Sprat feed and spawn repeatedly throughout spring and summer in coastal and offshore waters and are therefore more readily available, which could account for this shift. As plunge divers, gannet predominantly feed on pelagic fish such as mackerel and sandeel or fisheries discards (Le Bot *et al.,* 2019).

23.8.102 Overall, the construction and operation of Wind Turbines may lead to changes in the behaviour, availability or distribution of prey species for seabirds. However, the majority of seabird species have large foraging ranges and a variety of target species (Table 23.18) meaning they are able to adapt to short temporal changes in prey availability due to construction activities.

23.8.103 The majority of marine fish species are expected to avoid habitat loss effects due to their greater mobility and recoverability post-construction. Sandeel are particularly vulnerable to long term habitat and disturbance. Furthermore, Volume 2, Chapter 9: Fish and Shellfish describes the 90 site-specific grab samples collected across the Site Boundary, the Particle Size Analysis (PSA) results indicate that 15 sites comprised of sediments unsuitable for sandeel spawning (16.6%). These samples had mud compositions that were over 10%, with an average of 23.8% mud. Higher mud content prevents sandeel from maintaining their burrows as the burrows are more likely to collapse and can also reduce respiration due to fine particulate clogging their gill tissues. There were 41 out of 90 samples classified as sub-prime (therefore a preferred sediment habitat), representing 45.5% of the dataset. There were 34 samples classified as suitable (therefore a marginal sediment habitat preference), representing 37.7% of the dataset. There were no samples that met the Latto *et*

al. (2013) classification of 'prime'. The effects are unlikely to result in a measurable impact on fish and shellfish receptors.

23.8.104 During the construction phase, construction works will be spatially and temporally restricted, covering only a small portion of the Proposed Development at any given time. Construction impacts are restricted to the duration of the construction phase, and once construction has finished, the adverse impacts will cease and any change on prey species will likely be reversed.

23.8.105 During the O&M phase, temporary habitat loss will occur as a result of the cable reburial for O&M activities, and also due to disturbance caused by reburial of Inter-Array Cables (IACs) and Interconnector Cables. The MDS is for up to 11,688,813 m^2 of temporary habitat loss/disturbance during the O&M phase. This equates to 4.01% of the total Site Boundary and therefore this represents a relatively small proportion of the Fish and Shellfish Ecology Study Area. It should also be noted that only a small proportion of the total habitat loss/disturbance is likely to be occurring at any one time over the O&M phase of the Proposed Development. During the O&M phase, changes to prey availability are expected to be minimal. The sensitivity of the IEF is considered to range between low to medium (Table 23.26).

Table 23.26: Sensitivity of Receptors

IEF	Vulnerability to changes in prey availability	Recoverability	Conservation Value	Sensitivity
Arctic tern	Medium	Low	International	High
Fulmar	Low	Low	International	High
Gannet	Low	Low	International	High
Herring Gull	Medium	Low	International	High
Guillemot	Medium	Low	International	High
Herring gull	Low	Low	International	High
Kittiwake	Medium	Low	International	High
Puffin	Medium	Low	International	High
Razorbill	Medium	Medium	International	High

23.8.106 It is challenging to separate the effects of different pressures, due to the complexity of how they interact and the combined impact they have on seabird populations, their environment and their prey at all scales. Although OWFs can impact local seabird populations directly through displacement and collision, there may also be beneficial indirect impacts, such as the creation of artificial reefs and the resulting potential of an increase in prey availability (Coolen, 2017).

23.8.107 Overall, gannet, herring gull and lesser black-backed gull are thought to be buffered from the impacts of climate change, mostly relating to their ability to access a wider variety of prey, but they may be sensitive to controls on fisheries discards (Johnston *et al.,* 2021). Guillemot, kittiwake, puffin and razorbill abundances have been more closely linked to the success of their prey, which

may make them more vulnerable to bottom-up climate change impacts (Burthe *et al.,* 2014; Johnston *et al.,* 2021). A reduction in prey quality and availability may also reduce the resilience of these species against storm events, which could lead to an increase in large-scale wrecks as climate change leads to an increase in extreme weather (Anker-Nilssen *et al.,* 2017; Camphuysen *et al.,* 1999; Heubeck *et al.,* 2011; Morley *et al.,* 2016). Cliff nesting species, such as kittiwake and razorbill, may also be sensitive to nest failure in high winds and storm surges (Newell *et al.,* 2015).

23.8.108 Climate change is considered to be the likely primary cause of decline in seabird populations in the future. It is believed that the absence of the Proposed Development would further delay the transition of the UK from reliance on fossil fuels and therefore further contribute towards climate change impacts and declining seabird populations.

Conclusions

23.8.109 The assessment has considered the potential implications of the Proposed Development on the availability and distribution of key prey species and the subsequent effects on predator species across multiple trophic levels. While both adverse and beneficial impacts on prey species were identified, such as minor subsea noise effects and the introduction of artificial habitats respectively, these are not expected to result in significant changes to prey populations.

23.8.110 Piscivorous fish, which exhibit broad dietary preferences including small fish, benthic invertebrates, molluscs, and crustaceans, are considered less sensitive to fluctuations in specific prey species. Their dietary flexibility and mobility suggest a low likelihood of significant adverse effects due to changes in prey availability.

23.8.111 Marine mammals, particularly species such as harbour porpoise and minke whale, may experience localised benefits from increased food availability and shelter effects associated with Offshore Infrastructure. Although some species, like harbour porpoise, have high metabolic demands and limited energy reserves, the spatially restricted and temporary nature of construction-related disturbances implies that any energetic costs incurred from altered foraging patterns would be short term and reversible. Long term operational noise impacts are expected to be of Minor adverse significance due to their limited spatial extent.

23.8.112 Seabirds exhibit varied sensitivities to prey availability depending on their feeding strategies and dietary specialisation. Generalist species such as gulls are more resilient, whereas specialists like kittiwake and puffin are more vulnerable to reductions in prey quality and abundance, particularly sandeel, which has shown declining energy content and availability due to climate change and fisheries pressure. Nonetheless, most seabird species possess extensive foraging ranges and dietary adaptability, enabling them to buffer short term changes in prey distribution during construction and O&M phases.

23.8.113 Overall, the Proposed Development is not predicted to result in significant adverse effects on predator species due to changes in prey availability. The mobile nature of both prey and predator species, combined with Embedded and Additional Mitigation measures and the spatially and temporally limited nature of construction and O&M activities, supports the conclusion that impacts will be negligible to minor and reversible. Furthermore, the transition to renewable energy infrastructure may contribute beneficially to climate mitigation efforts, indirectly supporting the resilience of marine ecosystems and predator populations in the long term.

23.9 Summary

23.9.1 This chapter presents a comprehensive inter-related effects assessment of the Proposed Development across multiple receptor groups, including physical processes, benthic ecology, fish and shellfish ecology, marine mammals, offshore ornithology, offshore bats, commercial fisheries, shipping and navigation, aviation and radar, infrastructure and other users, socio-economic, and marine archaeology receptors. It also includes an ecosystem-based effects assessment focusing on predator-prey dynamics and ecosystem functioning.

Part One: Receptor-Based Inter-Related Effects Assessment

- **Physical Processes:** Across all phases of the Proposed Development, changes to SSC, bed levels, tidal and wave regimes, and scour are considered pathways rather than direct receptor impacts. These impacts, when considered across the project lifetime, do not interact in a way that increases their significance. No receptor-led effects were identified, as each receptor relates to a single impact pathway. Therefore, no significant inter-related effects are anticipated.
- **Benthic Ecology:** Temporary and long term habitat loss, changes to SSC, and the introduction of artificial structures are predicted to be highly localised and recoverable. These impacts, when considered across the project lifetime, do not interact in a way that increases their significance. Receptor-led effects may arise from overlapping habitat disturbance and SSC changes, but these are also predicted to be of **Minor** adverse significance and not significant in EIA terms.
- **Fish and Shellfish Ecology:** Impacts such as habitat loss, SSC changes, subsea noise, and EMF exposure are expected to be short term, intermittent, and recoverable. The cumulative footprint across phases is proportionally small, and no significant inter-related effects are anticipated. Although multiple impacts may interact spatially and temporally, they are not expected to result in greater significance than when considered individually.
- **Marine Mammals:** Subsea noise from piling, UXO clearance, vessel activity, and operational infrastructure were assessed across all phases. These impacts are considered **Minor** adverse and reversible. Receptor-led effects, including cumulative noise exposure and prey availability changes, may occur but are mitigated and not expected to result in significant effects. Overall, no significant inter-related effects are predicted.

- **Offshore Ornithology**: Impacts such as collision risk, displacement, vessel disturbance, prey changes, and light attraction are expected to be temporary and localised. These do not interact across phases in a way that increases their significance. While receptor-led effects from collision and displacement are acknowledged, no other significant interactions are identified. All effects are considered **Minor** adverse and not significant in EIA terms.
- **Offshore Bats**: Collision risk has been considered within the inter-related assessment. There are no known roosts in or around the Site Boundary; consequently, no project-lifetime inter-related effects (construction, O&M, decommissioning) or receptor-led inter-related effects are predicted for Offshore Bat receptors.
- **Commercial Fisheries:** Loss of access to fishing grounds, displacement, gear conflict, and vessel interference are mitigated and expected to be temporary or long term but not cumulative. Receptor-led effects from combined access loss and displacement are considered, but do not exceed the significance of individual impacts. No significant inter-related effects are anticipated across the project lifetime.
- **Shipping and Navigation:** No project lifetime effects are predicted, as impacts such as snagging, deviation, collision risk, and radar interference are assessed comprehensively in the NRA. Receptor-led effects are considered within the NRA, and no additional significance arises from interactions across phases or with other receptors.
- **Aviation and Radar:** Effects on aviation receptors increase during construction but remain constant during operation. These do not interact across phases to create greater significance. Receptor-led effects related to lighting and marking requirements are coordinated with maritime needs, and no other significant inter-relationships are identified.
- **Infrastructure and Other Users:** Recreational displacement and access restrictions to cables and pipelines are temporary and mitigated through agreements. These impacts do not interact across phases to increase significance. Receptor-led effects from overlapping recreational restrictions are possible but are Minor and not significant in EIA terms.
- **Socio-economics, Tourism and Recreation:** Tourism and recreation impacts depend on changes in other environmental factors and are not significant when considered cumulatively. Socio-economic impacts, such as employment and GVA, are beneficial and do not interact in a way that multiplies effects. No significant inter-related effects are anticipated.
- **Marine Archaeology:** SSC and sediment transport changes may interact to further bury archaeological receptors, but these effects are short term and potentially beneficial. Receptor-led effects are predicted to be **Minor** adverse and not significant in EIA terms. No significant project lifetime effects are identified.

Part Two: Ecosystem-Based Assessment

23.9.2 The ecosystem assessment highlights the importance of mid-trophic species (e.g. sandeel, herring and sprat) in maintaining food web stability. These species are vulnerable to climate change and commercial fisheries pressure.

23.9.3 Subsea noise from piling is the only impact predicted to have a likely significant effect on herring, with potential ecosystem-level implications. However, Embedded and Additional Mitigation are expected to reduce this risk to non-significant levels.

23.9.4 Artificial structures may enhance habitat complexity and support biodiversity, offering potential ecosystem benefits.

23.9.5 Climate change is identified as the dominant pressure shaping future ecosystem baselines, affecting species distributions, prey availability, and ecological resilience.

Conclusion

23.9.6 This assessment concludes that the Proposed Development is unlikely to result in significant adverse effects across receptor groups or at the ecosystem-level. Most impacts are localised, temporary, and reversible, with Embedded and Additional Mitigation measures in place to manage risks.

23.9.7 The only significant effect identified is subsea noise on herring during piling, which is expected to reduce to **Minor** adverse effect with Embedded and Additional Mitigation. Predator species, including piscivorous fish, marine mammals, and seabirds, are generally resilient due to their mobility and dietary flexibility.

23.9.8 The transition to renewable energy infrastructure is expected to contribute beneficially to climate mitigation, indirectly supporting marine ecosystem resilience. Overall, the Proposed Development is not predicted to cause significant ecological disruption and may offer some beneficial effects through habitat creation and reduced reliance on fossil fuels.

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