Morven South Offshore Wind Array Project

Environmental Impact Assessment Report

Volume 2, Chapter 21: Inter-related and Ecosystem Effects

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21.1 Introduction

21.1.1.1 This chapter of the Morven South Offshore Wind Array Project (hereafter "Morven South") Environmental Impact Assessment (EIA) Report (hereafter, the EIA Report) presents the assessment of the Likely Significant Effects (LSE[1]) (as per the EIA Regulations as defined in Volume 1, Chapter 2: Policy and Legislation) on the environment in relation to inter-related effects as a result of Morven South. Specifically, this chapter considers the inter-related effects during the construction, operation and maintenance (O&M) and decommissioning phases.

21.1.1.2 The assessment presented in this chapter has relied upon, or informed the following technical chapters:

- Volume 2, Chapter 7: Physical Processes;
- Volume 2, Chapter 8: Benthic Subtidal 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: Commercial Fisheries;
- Volume 2, Chapter 13: Shipping and Navigation;
- Volume 2, Chapter 14: Marine Archaeology;
- Volume 2, Chapter 15: Aviation (Military and Civil);
- Volume 2, Chapter 16: Other Sea Users and Communications;
- Volume 2, Chapter 17: Socio-Economics;
- Volume 2, Chapter 19: Major Accidents and Disasters;
- Volume 2, Chapter 20: Human Health.

21.2 Purpose of the chapter

21.2.1.1 The Morven South EIA Report provides the Scottish Ministers, statutory and non-statutory stakeholders with adequate information to determine LSE[1] of Morven South on the receiving environment. This is further outlined in Volume 1, Chapter 1: Introduction.

21.2.1.2 The purpose of this Inter-Related Effects Chapter is to describe:

- the receptor groups considered within the inter-related effects assessment;
- the potential for effects on receptor groups across the lifetime of Morven South (construction, O&M and decommissioning);
- the potential for multiple effects on a receptor group, as presented within the topic specific chapter, to interact to create inter-related effects;
- the inter-related effects across different trophic levels of the ecosystem.

21.2.1.3 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, 2023). The purpose of the ecosystem-based approach is to assess how Morven South may impact the ecosystem as a whole. This assessment has been carried out following stakeholder advice received during the Scoping process (Marine Directorate – Licensing Operations Team (MD-LOT), 2023).

21.2.1.4 An assessment of the LSE[1] of climate change and projected climate risks on environmental receptors is provided separately in Volume 3, Annex 18.3: In-Combination Climate Change Impact (ICCI) Assessment and is not repeated here.

21.2.1.5 It should be noted that this chapter does not consider that there are likely to be any cumulative receptor led effects from offshore and onshore activities associated with Morven South. This is primarily due to this project not including an export cable corridor, which will instead be assessed separately as part of a standalone Environmental Impact Assessment (EIA) and Environmental Statement (ES) submitted for the Morven Hawthorn Pit Grid Connection and an EIA for the Morven Branxton Area Grid Connection Project application.

21.3 Structure of the chapter

21.3.1.1 This chapter is structured in two parts:

- Part One – Provides the inter-related effects assessments for each of the topics in Volume 2 of the EIA. These assessments consider the potential for multiple effects upon receptors arising from Morven South, occurring either where a single effect acts upon a receptor over time to produce a potential additive effect or where a number of separate effects affect a single receptor group.
- Part Two – Provides an overarching assessment of the potential impact of Morven South on the ecosystem of the North Sea by bringing together the ecological assessments presented in Volume 2 of the EIA to determine the likely impacts across trophic levels.

21.4 Study areas

21.4.1.1 Due to the differing spatial extent of effects potentially experienced by the different offshore receptors, the study area for potential inter-related effects varies according to topic and receptor. The likely significant inter-related effects assessments in Part One of this chapter (Section 21.9) are, therefore, also limited to the study area defined in each of the topic specific chapters outlined in Section 21.1.

21.4.1.2 As the largest study area relates to offshore ornithology, this is the maximum spatial extent of potential inter-related effects.

21.5 Legislative and policy context

21.5.1.1 Volume 1, Chapter 2: Policy and Legislation, presents the policy and legislation of relevance to renewable energy infrastructure.

21.5.1.2 Of relevance to the inter-related effects chapter, Article 3(1) for the EIA Directive requires that the interaction between the environmental factors (e.g. human health, biodiversity, land, soil, water, air and climate etc) must be identified, described and assessed in the Morven South EIA Report. Under the EIA Regulations, there is a requirement to consider inter-relationships between topics that may lead to environmental effects. There is no policy relevant to inter-related effects in Scotland, thus this chapter has been compiled following the examples of previously consented projects (such as Ossian Offshore Windfarm (Ossian OWFL, 2024), Berwick Bank Offshore Windfarm (SSE Renewables, 2022), Ayre Offshore Windfarm (Ayre OWF Ltd, 2024) and Salamander Offshore Windfarm (Salamander OWF, 2024)) and advice from stakeholders as detailed in Table 21.1.

21.6 Consultation

21.6.1.1 Table 21.1 presents a summary of the key issues raised during consultation activities during pre-application specific to inter-related effects for Morven South and in the Morven Scoping Opinion (MD-LOT, 2023) along with how these have been considered in the development of this Morven South EIA Report chapter. Further detail is presented within Volume 1, Chapter 5: Consultation.

Table 21.1: Summary of key consultation issues raised during consultation activities undertaken for Morven South of relevance to inter-related effects

Date	Consultee and type of consultation	Summary of issue(s) raised	Applicant's response to issue raised and, if applicable, where considered in this chapter
April 2023	NatureScot and MD-LOT: Scoping Workshop	NatureScot recommended including links to predator/prey with other fish, birds and marine mammals. Sandeels present throughout the year with limited movement should also be considered.	Predator and prey relationships are discussed in various sub-sections of paragraph 21.9.1.1. The presence and impacts on key prey species, such as sandeels, are discussed in Section 21.10.4 and the potential effects of Morven South on these grounds is discussed in Section 21.10.8.
August 2023	NatureScot: Scoping Opinion	NatureScot highlighted there is a need to understand potential impacts of offshore wind farms holistically at a wider ecosystem scale. This assessment should focus on potential impacts across key trophic levels particularly in relation to the availability of prey species. This will enable a better understanding of the consequences (positive or negative) of any potential changes in prey distribution and abundance from the development of the wind farm on seabird and marine mammal (and other top predator) interests and what influence these may have on population level impacts.	The Ecosystem Based Assessment provided in paragraph 21.9.1.1 addresses these concerns regarding the wider scale impacts of Morven South. The impact on prey species is considered in Section 21.10.9 and the impact on predator species in considered in paragraph 21.10.10.
		Consideration should be taken of how habitat loss and/or disturbance may affect the recruitment of key prey (fish) species through impacts to important spawning or nursery ground habitats should also be assessed.	Consideration for the impacts of Morven South on key prey species, including their spawning and nursery grounds, have been considered in Section 21.10.9 of this report.
	The Royal Society for the Protection of Birds (RSPB): Scoping Opinion	The RSPB also noted the potential indirect impacts of offshore wind farms included wider ecosystem impacts such as changes in stratification. Ecosystem wide impacts that can change, for example, the abundance and availability of prey.	The Ecosystem Based Assessment provided in paragraph 21.9.1.1 addresses these concerns regarding the wider scale impacts of Morven South.

Date	Consultee and type of consultation	Summary of issue(s) raised	Applicant's response to issue raised and, if applicable, where considered in this chapter
September 2023	Marine Directorate-Science Evidence Data and Digital (MD-SEDD): Scoping Opinion	MD-SEDD advised that the potential changes to water column structure, including timing and extent of seasonal stratification should be assessed within the EIA. The link between stratification and fronts to primary productivity and higher trophic levels and ecosystem services should be noted.	The link between stratification and primary productivity has been outlined in Section 21.10.6. The potential impact of changes in stratification has been considered in Section 21.10.9, which highlights the minimal impact of Morven South on these processes.
November 2023	MD-LOT: Scoping Opinion	The Scottish Ministers note that the Developer should be directed to the NatureScot representation on 'the need to understand the potential impacts holistically at a wider ecosystem scale rather than only a set of discrete individual receptor assessments. The Scottish Ministers therefore advise that potential impacts should be considered across key trophic levels, particularly in relation to the availability of prey species'.	The effects on a wider ecosystem scale are discussed in paragraph 21.9.1.1 and the specific impact of Morven South on prey species is assessed in Section 21.10.9.
		The Scottish Ministers note that 'clear links between the benthic and the fish and shellfish assessments in relation to potential impacts on birds should be made within the ornithology assessment in the EIA Report as recommended in the NatureScot representation'.	Key spawning and nursery grounds for the key prey species are discussed in Section 21.10.9 and the potential effects of Morven South on these grounds is discussed in Section 21.10.8. 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. The effects on predator species (marine mammals and birds) in relation to prey availability are discussed in paragraph 21.10.10.
		The Scottish Ministers also advised that the potential changes to water column structure including timing and extent of seasonal stratification, and potential impacts on productivity and high trophic levels, should be assessed within the EIA Report.	The link between stratification and primary productivity has been outlined in Section 21.10.6. Primary production has subsequently been linked to prey abundance, with the exploration of the impact of prey abundance on higher trophic levels discussed in Section 21.10.10. The potential impact

Date	Consultee and type of consultation	Summary of issue(s) raised	Applicant's response to issue raised and, if applicable, where considered in this chapter
			of changes in stratification has been considered in Section 21.10.9, which highlights the minimal impact of Morven South on these processes.
		Scottish Ministers advised that the cumulative assessment, that it is premature to scope out cumulative impacts and inter-related effects and that these must be scoped in to the EIA Report unless HES provides written agreement that these can be scoped out prior to submission.	Inter-related effects have been included within the Marine Archaeology EIA assessment and are considered in Section 21.9.1 paragraph 21.9.1.45.

21.7 Data sources

21.7.1.1 The baseline environments for the receptor groups considered in Section 21.9 of this chapter are specific to each receptor group and are, therefore, set out in detail in the relevant topic chapters (Volume 2, Chapters 7 to 20) (see Section 21.1).

21.7.1.2 This chapter draws on the conclusions made within the technical chapters (Volume 2, Chapters 7 to 20) for the assessment of impacts acting in isolation on the receptor groups.

21.7.1.3 It should be noted that the inter-related effects impact assessment assesses the LSE from Morven South only as set out in Volume 2, Chapters 7 to 20. Inter-related effects from other projects are considered in the cumulative effects sections of the relevant chapters (Volume 2, Chapters 7 to 20).

21.7.1.4 Specific guidance relevant to the approach to the assessment in each part of this chapter has been stated in Section 21.8.

21.8 Assessment methodology

21.8.1.1 NatureScot highlighted that "the need to understand the potential impacts holistically at a wider ecosystem scale rather than only a set of discrete individual receptor assessments' (Table 21.1). In response, the assessment presented in this chapter has been split into two parts, Part One: Receptor Based Inter-Related Effects Assessment outlines the assessment required as part of the EIA Regulations, and Part Two: Ecosystem Effects Assessment looks to address the request from NatureScot for a wider ecosystem scale assessment

21.8.2 Part one: Inter-related effects assessment method

21.8.2.1 The following sections present the approach used for the inter-related effects assessment of Morven South. For the purpose of this assessment, the following definition has been used for the term inter-related effect:

- An "Inter-Related Effect" is when there are multiple effects upon the receptor arising from Morven South, occurring either where a single effect acts upon a receptor over time to produce a potential additive effect or where a number of separate effects, such as underwater noise and habitat loss, affect a single receptor (e.g. marine mammals).

21.8.2.2 Table 21.2 presents full definitions of the terms used in this assessment.

Table 21.2: Definitions of Morven South lifetime and receptor-led inter-related effects

Stage	Description
Morven South lifetime effects	Assessment of effects that may occur throughout more than one phase of Morven South, (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 of Morven South (e.g. long-term habitat loss which begins in the construction phase and persists in the O&M and decommissioning phases).
Receptor-led effects	Assessment of multiple impacts which interact to create inter-related effects on a receptor. As an example, multiple impacts on a given receptor such as benthic habitats (e.g. direct habitat loss or disturbance, sediment plumes, scour, jack-up vessel use etc.) may interact to produce a different or greater effect on this receptor than when the impacts are considered in isolation. Receptor-led effects might be short-term, temporary or transient effects, or incorporate longer term effects.

Approach to assessment

21.8.2.3 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);
- Institute of Environmental Management and Assessment (IEMA) Environmental Impact Assessment Guide to Shaping Quality Development (IEMA, 2016).

21.8.2.4 The approach for assessing the potential inter-related effects on each receptor or receptor group follows the four stages outlined in Table 21.3.

Table 21.3: Staged approach to assessing inter-related effects

Stage	Description
1	Assessment of effects undertaken for individual Morven South EIA Report topic areas within Volume 2, Chapters 7 to 20.
2	Review of assessments undertaken within Volume 2, Chapters 7 to 20 to identify ‘receptor groups’ requiring assessment.
3	dentification of potential inter-related impacts on receptor groups through review of topic specific assessments in the Morven South EIA Report chapters.
4	Assessment undertaken on how individual effects may combine to create inter-related effects on each receptor group for: • Morven South lifetime effects (i.e. during construction, O&M and decommissioning phases); • Receptor-led effects (i.e. multiple effects on a single receptor).

Stage 1: Topic specific assessment

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

Stage 2: Identification of receptors

21.8.2.6 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 use of a 'receptor group' approach has been agreed with stakeholders via the Morven Scoping Opinion (MD-LOT, 2023). 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 21.1.1.2 for references to chapters):

- physical environment:
  - physical processes.
- biological environment:
  - benthic subtidal ecology;
  - fish and shellfish ecology;
  - marine mammals;
  - offshore ornithology.
- human environment
  - commercial fisheries;
  - shipping and navigation;
  - aviation, military and communications;
  - infrastructure and other users;
  - socio-economics;
  - marine archaeology;
  - major accidents and disasters;
  - human health.

Stage 3: Identification of potential inter-related impacts on receptor groups

21.8.2.7 Following the identification of receptor groups, the potential inter-related impacts on those receptor groups were identified via a review of the assessment sections for each relevant topic chapter. The judgement to which impacts may result in inter-related effects upon receptors associated with Morven South was based on the professional judgement and experience.

21.8.2.8 It is important to recognise potential linkages between the topic-specific chapters, whereby effects and receptor groups assessed in each chapter have the potential for secondary effects on any number of other receptors. Examples include:

- Volume 2, Chapter 8: Benthic Subtidal Ecology addresses effects on benthic habitats and species arising from changes to the physical environment (as described in Volume 2, Chapter 7: Physical Processes);
- Volume 2, Chapter 9: Fish and Shellfish Ecology addresses effects on fish and shellfish receptors arising from the impacts on benthic habitats;
- Volume 2, Chapter 10: Marine Mammals and Volume 2, Chapter 11: Offshore Ornithology assess the effects on marine mammal and seabird receptors, respectively, arising from potential changes in benthic habitats and the distribution of fish, which form their principal prey (as described in Volume 2, Chapter 9: Fish and Shellfish Ecology);
- Volume 2, Chapter 16: Other Sea Users and Communications assess the effects on infrastructure and other user receptors arising from potential impacts on aggregate resource

as a result of potential increase in Suspended Sediment Concentrations (SSCs) and deposition and effects on sediment transport pathways (as described in Volume 2, Chapter 7: Physical Processes).

21.8.2.9 Where such linked relationships arise, these have been fully assessed within the individual topic chapters. This chapter on inter-related effects therefore 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

21.8.2.10 Individual effects on each of the key receptor groups have been identified across the three phases (i.e. Morven South lifetime effects) as well as the interaction of multiple effects on a receptor (i.e. receptor-led effects), as defined in Table 21.2.

21.8.2.11 The significance of the individual effects is presented in the summary of effects, 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 designed-in 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 21.9). This assessment incorporates qualitative and, where possible, quantitative assessments. Each topic-specific assessment, outlined in Table 21.4 to Table 21.18, presents an assessment of the significance of effect to any such inter-related effect.

21.8.2.12 The inter-related effects assessment presents and utilises the Maximum Design Scenarios (MDSs) for Morven South including implementation of designed-in measures as part of Morven South where appropriate), noting that individual effects may not be significant at the topic specific level but could become significant when their inter-related effect is assessed. Effects of moderate significance or above are therefore considered important in the decision-making process (as they are considered significant in EIA terms (Volume 1, Chapter 6,: EIA Methodology)), whilst effects of minor significance or less warrant little, if any, weight in the decision-making process as they are not considered significant in EIA terms (Volume 1, Chapter 6,: EIA Methodology)). Effects of minor significance or less identified in the individual topic assessments have been included, since there is the potential for interactive effects to increase the level (significance) of effect when considered with other sources.

21.8.3 Part two: Ecosystem based effects assessment methodology

21.8.3.1 The purpose of the ecosystem-based assessment is to qualitatively assess the potential effects of Morven South at the ecosystem level, to better understand and the impact of the infrastructure and activities across the full breadth of the food web, including the effect on specific predator-prey relationships how these could be altered and how this could impact the functioning of the ecosystem.

21.8.3.2 The structure of Part Two: Ecosystem Effects Assessment 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 Morven South on prey species;
- effects of Morven South on predator species.

21.8.3.3 Information and conclusions from the relevant chapters of the EIA Report and their corresponding technical reports have been used to characterise the marine ecosystem in the locality of Morven

South 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 Morven South 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.

21.8.3.4 As new surveys and studies bridge knowledge gaps, the offshore wind industry and academia are developing a greater understanding of how Offshore Wind Farms (OWFs) impact marine ecosystems. Details of two research programmes are provided below, the outcomes of which are, and are expected to be, used to inform policy measures and provide guidance and recommendations on improving stakeholder confidence in the sustainable delivery of OWFs. Furthermore, these projects will be key to informing ecosystem assessment approaches in the future.

PrePARED project

21.8.3.5 Following guidance from the Scottish Ministers, detailed in Table 21.1, the Predators and Prey Around Renewable Energy Developments (PrePARED) project (PrePARED, 2024) has been informing the understanding of predator-prey relationships in and around fixed foundation OWFs.

21.8.3.6 Funded by the Offshore Wind Evidence and Change 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 United Kingdom (UK) government's renewable energy targets and reach net-zero emissions.

21.8.3.7 During the Morven South pre-application phase, the 2024 Annual Report was the latest version available from PrePARED which summarises the first two years of the five-year project (PrePARED, 2024). Part of the project activities included fish, seabird and marine mammal data collection in and around OWFs in the Firth of Forth, Firth of 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;
- collating historical data from various methods to develop marine mammal distribution models.

Ecological Consequences of Offshore Wind

21.8.3.8 The Ecological Consequences of Offshore Wind (ECOWind) ECOWind research programme is seeking to investigate all the possible effects of OWFs on marine biodiversity (ECOWind, 2024). ECOWind is currently undertaking four projects:

- Benthic-Offshore Wind Interactions (BOWIE):
  - The BOWIE project is using a combination of environmental and social research to gain knowledge on the impact of wind expansion on seabed invertebrate and fish species, taking into consideration other pressures on the marine environment including construction noise and vibration, Electromagnetic Fields (EMFs) and elevated temperatures associated with cabling.
- ECOWind ACCELERATE:
  - The ECOWind ACCELERATE project is investigating the ecological implications of accelerated seabed mobility around wind farms. Scientists are studying the combined impacts of climate change and OWFs on seabed habitats and organisms and how baseline changes can cause affect the wider marine ecosystem around the UK.
- Ecosystem Change, Offshore Wind, Net Gain and Seabirds (ECOWINGS):

  - The ECOWINGS project is investigating the cumulative effects of offshore wind on key seabird species, establishing pathways for strategic compensation to ensure net gain for seabird populations and the wider marine ecosystem.
- Physics-to-Ecosystem Level Assessment of Impacts of Offshore Wind Farms (PELAgIO):
  - The PELAgIO project is investigating the impacts that offshore wind development can have on the marine food chain.

Ecological Effects of Floating Offshore Wind (ECOFlow)

21.8.3.9 ECOFlow builds on the ECOWind programme but focuses specifically on delivering impactful, policy-ready science to specifically understand the effects of floating offshore wind on the whole marine ecosystem (ECOFlow, 2025). ECOFlow is currently undertaking two projects:

- Establishing a Framework for Quantifiable Evidence and Impact of Ecosystem Change (EQUIFy):
  - The EQUIFy project is aiming to deliver a framework that quantifies the ecological impacts from potential future floating OWFs. It is assessing the compound and cumulative ecological, social and economic effects of floating OWFs to underpin predictions of likely future pressures including changing marine use and within the context of a changing climate.
- Frontline:
  - Frontline is delivering new ecosystem-scale insight and providing practical guidance to mitigate floating OWFs impacts and promote nature recovery. This includes the establishment of autonomous underwater and satellite-derived monitoring approaches, inform strategic compensation, and evaluate ocean fronts as priority conservation areas.

21.9 Part one: Receptor based inter-related effects assessment

21.9.1 Assessment of inter-related effects

21.9.1.1 The inter-related effects assessment below is presented for each of the receptor groups listed above (as per paragraph 21.8.2.6).

Physical environment

Physical processes

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

- increased SSCs and associated deposition;
- impacts to the wave regime due to the presence of infrastructure;
- impacts to the tidal regime due to the presence of infrastructure;
- impacts to sediment transport and sediment transport pathways due to the presence of infrastructure;
- impacts to seasonal stratification due to the presence of infrastructure.

21.9.1.3 Table 21.4 lists the inter-related effects (Morven South lifetime effects) that are predicted to arise during the construction, O&M and decommissioning of Morven South and the inter-related effects (receptor-led effects) that are predicted to arise for physical processes receptors.

21.9.1.4 As noted in Volume 2, Chapter 7: Physical Processes, effects on physical processes also have the potential to have secondary effects on other receptors and these effects are fully considered in the respective topic-specific chapters. These receptors and effects are:

- Benthic subtidal ecology;

  - increased SSCs and associated deposition;
  - changes in physical processes.
- Fish and shellfish ecology;
  - increased SSCs and associated deposition.
- Marine archaeology;
  - increased SSCs and sediment deposition leading to indirect impacts on marine archaeology receptors;
  - alteration of sediment transport regime leading to indirect impacts on marine archaeology receptors.

Table 21.4: Summary of potential inter-related effects on the environment for physical processes from individual effects occurring across the construction, O&M and decommissioning phases of Morven South and from multiple effects interacting across all phases (receptor-led effects)

C= Construction, O= O&M, D= Decommissioning phases

"✓" is used to denote the phase the potential impact can occur, "✗" outlines there is no impact within this project phase

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Morven South lifetime effects					
Increased SSCs and associated deposition	✓	✓	✓	Increases in SSC during the construction phase would not extend temporally into the O&M phase, as increases in SSC are limited to within a few tidal cycles and to discrete areas. Similarly, those increases which occur in the O&M phase due to maintenance activities would not extend to decommissioning. Therefore, there will be no cumulative impact on SSCs due to these activities over the lifetime of the project. Similarly any associated deposition will be localised and comprised of native material which will be anticipated to be recoverable after some time, and will not span the lifetime of Morven South. The construction and decommissioning phases have the potential to contribute the most to deposition, however these phases are separated in time by limited and isolated instances of repair and reburial events during the longest phase of O&M.	Negligible adverse
Receptor led effects					
During the O&M phase, increased SSCs and associated deposition on physical features may occur due to maintenance activities; which would coincide with changes to tidal currents, wave climate, littoral currents, sediment transport and stratification due to the presence of the Morven South structures. Increased SSCs and associated deposition is the only impact considered in the assessment during the construction and decommissioning phases, and thus these phases are not relevant to receptor-led effects. Maintenance activities are sporadic, with the impacts predicted to be of local spatial extent, short-term duration and intermittent , and will not affect the overall wave, tidal, or sediment transport regime, or impact on stratification, and would therefore not be significant in EIA terms. By definition the impacts to sediment transport are governed by the impacts to the wave and tidal regime and hence is already covered in the assessment within Volume 2, Chapter 7: Physical Processes EIA chapter. Similarly, the impacts to seasonal stratification have been determined by assessing the impact on hydrodynamics, including waves and tides, and therefore have already been considered in Volume 2, Chapter 7: Physical Processes EIA chapter.					

21.9.1.5 These inter-related effects as described above 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 phases. Therefore, these inter-related effects would not be significant in EIA terms.

Biological environment

Benthic subtidal ecology

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

- temporary habitat loss/disturbance;
- increased SSCs and associated deposition;
- long-term habitat loss;
- increased risk of introduction and spread of invasive non-native species (INNS);
- colonisation of hard structures;
- changes in physical processes;
- removal of hard substrate and impacts to benthic invertebrates due to EMF.

21.9.1.7 Table 21.5 lists the inter-related effects (Morven South lifetime effects) that are predicted to arise during the construction, O&M and decommissioning of Morven South and the inter-related effects (receptor-led effects) that are predicted to arise for benthic subtidal ecology receptors.

21.9.1.8 As noted in Volume 2, Chapter 8: Benthic Subtidal Ecology, effects on benthic subtidal ecology also have the potential to have secondary effects on other receptors and these effects are fully considered in the respective topic-specific chapters. These receptors and effects are:

- Fish and shellfish ecology:
  - temporary habitat loss and disturbance;
  - long-term habitat loss;
  - colonisation of hard structures and associated fish aggregation.
- Marine mammals:
  - effects on marine mammals due to changes in prey availability
- Offshore Ornithology:
  - changes in prey availability.

Table 21.5: Summary of potential inter-related effects on the environment for benthic subtidal ecology from individual effects occurring across the construction, O&M and decommissioning phases of Morven South and from multiple effects interacting across all phases (receptor-led effects)

C= Construction, O= O&M, D= Decommissioning phases

"√" is used to denote the phase the potential impact can occur, "X" outlines there is no impact within this project phase

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Morven South lifetime effects					
Temporary habitat loss/disturbance	✓	✓	✓	The total area of habitat potentially affected, when disturbance and loss are considered additively across all phases is greater than for each individual phase (e.g., just the construction phase). However, temporary habitat loss/disturbance arising during each phase of Morven South will be highly localised to the vicinity of the activities being undertaken (i.e., limited to the immediate footprints) during each phase (i.e., construction, operation and maintenance, and decommissioning). Individual activities (e.g., cable installation and repairs, and sandwave clearance) will each cause temporary habitat loss/disturbance intermittently with only a small proportion of the total area of habitat being impacted at any one time. The sandy sediment habitats present within the Morven South Benthic Subtidal Ecology Study Area are typical of, and widespread throughout, the northern North Sea. All sediments and associated benthic communities are predicted to recover. Whilst there is the potential for repeat disturbance to occur during the operation and maintenance phase to habitats previously disturbed during the construction phase (e.g. during cable repair and reburial events), it is predicted that the benthic communities will have fully recovered from construction impacts by this time. Across the project lifetime, the effects on benthic ecology receptors were 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.	Effects are anticipated to interact in such a way as to result in combined effects of minor to moderate adverse significance across all phases (i.e. not of greater significance than the assessments presented for each individual phase), with an overall minor adverse significance, which is not significant in EIA terms. This is due to only a small proportion of the total area for any IEFs or habitats being impacted at any one time.
Increased SSCs and associated deposition	✓	✓	✓	Activities with the potential to result in the greatest level of seabed disturbance and, therefore, highest increases in SSCs/deposition, will occur during the construction and decommissioning phases. Any effects on benthic communities during this time will be intermittent,	Effects are anticipated to interact in such a way as to result in combined effects of minor adverse significance across all phases, (i.e.

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
				temporary and short-term. The benthic subtidal ecology IEFs potentially affected by increased SSCs and deposition are predicted to have recovered in the intervening period between phases (i.e., prior to any localised increases in SSCs during maintenance activities in the operation and maintenance phase). Across the project lifetime, the effects on benthic subtidal ecology receptors were 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.	not of greater significance than the assessments presented for each individual phase), with an overall minor adverse significance, which is not significant in EIA terms.
Long-term habitat loss	✓	✓	✓	This impact will occur throughout the construction, O&M and decommissioning phases of Morven South. The communities that develop on the introduced hard structures will likely differ from the surrounding sedimentary biotopes but may be typical of areas of coarse and stony substrate in the area. Also, the amount of the hard infrastructure is expected to be consistent between the construction and O&M phases, with repair and replacement events not significantly increasing the overall magnitude of the long-term habitat loss, and this will provide long-term stability to any communities which form. There is potential for some infrastructure to remain in situ following decommissioning, but this will only represent a very small proportion of the habitats that the IEFs rely upon and therefore will not represent a significant impact. Across the lifetime of Morven South, the effects on benthic subtidal ecology 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.	Effects are anticipated to interact in such a way as to result in combined effects of minor to moderate adverse significance across all phases (i.e. not of greater significance than the assessments presented for each individual phase), with an overall minor adverse significance, which is not significant in EIA terms. This is due to the low overall area of sedimentary habitat which will be replaced by hard substrates compared to similar habitats present nearby.
Increased risk of introduction and spread of INNS	✓	✓	✓	Although the presence and movement of construction/decommissioning vessels in the area may facilitate the introduction and spread of INNS across all phases of Morven South, this effect will predominantly arise during the O&M phase, if it does occur. This is because, the presence of the hard structures associated with wind turbines and OSP foundations, scour protection, cable protection and cable crossings will be present in the O&M phase which may provide INNS with the necessary structures on which to settle. However, the measures adopted as part of Morven South include a	Effects are anticipated to interact in such a way as to result in combined effects of minor to moderate adverse significance in all phases (i.e. not of greater significance than the assessments presented for each individual phase), with an overall minor adverse significance, which is not significant in EIA terms. This is

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
				commitment to produce an Offshore EMP (MM 5) with provisions for management of INNS. This will ensure that the risk of potential introduction and spread of INNS will be minimised across all phases. As a result, any additional inter related effect is judged to be of minor to moderate adverse significance in all phases of Morven South. Across the lifetime of Morven South, the effects on benthic subtidal ecology receptors were 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.	due to the low number of vessels which will be on site at any one time during any phase.
Receptor led effects					
There is the potential for spatial and temporal interactions between the effects arising from temporary habitat loss/disturbance, increased SSC and associated sediment deposition, long-term habitat loss, colonisation of hard structures and impacts to benthic invertebrates due to EMF during the lifetime of Morven South. Any effects due to changes in the physical processes and removal of hard substrate are likely to be limited, both in extent and also in magnitude, with many benthic subtidal ecology receptors having low sensitivity or high recoverability to the scale of the changes predicted. Based on current understanding, and expert knowledge (as discussed in Volume 2, Chapter 8: Benthic Subtidal Ecology), the greatest potential for inter related impacts is predicted to arise through the interaction of direct (both temporary and long-term) habitat loss/disturbance from sandwave clearance and cable installation, and indirect habitat disturbance due to sediment deposition due mainly to the installation and also the presence of Morven South infrastructure. These individual impacts were assigned a significance of minor to moderate adverse as individual impacts and although potential combined impacts may arise (i.e., spatial and temporal overlap of habitat disturbance), it is not predicted that this will result in effects of more significance than the individual impacts in isolation. This is because the combined extent of habitat potentially affected would be typically restricted to the Morven South Boundary, the habitats affected are widespread across the northern North Sea and, where temporary disturbance occurs, full recovery of the benthic community is predicted. Across the lifetime of Morven South, the additive effects on benthic subtidal ecology receptors were 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 the EIA Report.					

21.9.1.9 These inter-related effects as described above 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 phases. Therefore, these inter-related effects would not be significant in EIA terms.

Fish and shellfish ecology

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

- temporary habitat loss and disturbance;
- underwater sound impacting fish and shellfish receptors;
- increased SSCs and associated deposition;
- long-term habitat loss;
- colonisation of hard structures and associated fish aggregation;
- EMF from subsea electrical cables.

21.9.1.11 Table 21.6 lists the inter-related effects (Morven South lifetime effects) that are predicted to arise during the construction, O&M and decommissioning of Morven South and the inter-related effects (receptor-led effects) that are predicted to arise for fish and shellfish ecology receptors.

21.9.1.12 As noted in Volume 2, Chapter 9: Fish and Shellfish Ecology, effects on fish and shellfish ecology 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:

- marine mammals;
  - changes to prey availability as a result of impacts associated with Morven South upon fish and shellfish ecology;
- offshore ornithology;
  - changes to prey availability as a result of impacts associated with Morven South upon fish and shellfish ecology;
- commercial fisheries;
  - changes to the commercial fisheries industry as a result of impacts associated with Morven South upon fish and shellfish ecology.

Table 21.6: Summary of potential inter-related effects on the environment for fish and shellfish ecology from individual effects occurring across the construction, O&M and decommissioning phases of Morven South and from multiple effects interacting across all phases (receptor-led effects)

C= Construction, O= O&M, D= Decommissioning phases

"✓" is used to denote the phase the potential impact can occur, "✗" outlines there is no impact within this project phase

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Morven South lifetime effects					
Temporary habitat loss and disturbance	✓	✓	✓	If calculated across the construction, O&M, and decommissioning phases, the total footprint area of temporary habitat loss and disturbance would be larger than for each individual stage. However, it should be noted that across these three phases there is potential for the same areas to be repeatedly disturbed, as the footprints of impact are localised to the various infrastructure on the seabed. 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 within the Morven South Boundary that may be temporarily disturbed are widespread across the Regional Fish and Shellfish Ecology Study Area. Therefore, project lifetime effects will be proportionally small in this wider context. This conclusion is supported further 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 Morven South, 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 (minor adverse) inter-related effects are anticipated across the lifetime of Morven South.
Underwater sound impacting fish and shellfish receptors	✓	✗	✓	As this impact is not scoped in for the O&M phase, it is unlikely that elevated underwater sound in the construction and decommissioning phases could interact in a way to result in inter-related effects of greater significance than the assessments presented for these phases individually. This is due to the substantial gap between scoped-in sound producing activities in the construction and decommissioning phase (i.e. the 35-year O&M phase).	Overall, no likely significant (minor adverse) inter-related effects are anticipated across the lifetime of Morven South.
Increased SSCs and associated deposition	✓	✓	✓	Effects from increased SSCs and associated deposition in each phase of Morven South will be short lived and intermittent. Fish and shellfish receptors that may potentially be affected by this impact in each phase are likely to have recovered in the intervening period between the induvial activities resulting in increased SSCs (such as cable installation) and between phases of development.	Therefore, across the lifetime of Morven South, 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

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
				Further, the fish and shellfish IEFs were considered to be of low sensitivity and/or high recoverability to this impact.	each individual phase (e.g. minor adverse throughout). Overall, no likely significant (minor adverse) inter-related effects are anticipated across the lifetime of Morven South.
Long-term habitat loss	✓	✓	✓	The construction and O&M phases were combined as the infrastructure associated with Morven South resulting in long-term habitat loss will be installed throughout the construction phase and will persist into the O&M phase. The footprints of long-term habitat loss in the construction phase will, therefore, be in the same locations as in the O&M phase. The MDS for the decommissioning phase would be for the majority of the infrastructure to be left *in situ*, and the footprints of infrastructure left in situ will also be in the same locations as they were in the combined construction and O&M phases. Therefore, the footprint of long-term habitat loss will not differ if considered additively across the combined construction & O&M phase and the decommissioning phase (i.e. the total area of long-term habitat loss over all three phases will not be larger than within the individual phases). Further, the seabed habitats within the Morven South Boundary are widespread across the Regional Fish and Shellfish Ecology Study Area. Therefore, project lifetime effects will be proportionally small in this wider context.	Across the lifetime of Morven South, 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 (minor adverse) inter-related effects are anticipated across the lifetime of Morven South.
Colonisation of hard structures and associated fish aggregation	✓	✓	✓	As above for 'long-term habitat loss'.	
EMF from subsea electrical cables	×	✓	×	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 Morven South.	
Receptor led effects					
There is potential for temporal and spatial interactions between the impacts discussed in paragraph 21.9.1.10 across all phases of Morven South. However, these were assigned as minor adverse significance as standalone impacts. Although potential receptor-led effects may arise, it should be noted that the					

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
individual activities will not necessarily occur simultaneously or in the same physical areas of the Morven South 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, piling, and seabed preparation). Therefore, across the phases of Morven South, 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 Morven South.					

21.9.1.13 These inter-related effects as described above 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 phases. Therefore, these inter-related effects would not be significant in EIA terms.

Marine mammals

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

- injury and disturbance from underwater sound generated from piling;
- injury and disturbance from underwater sound generation from UXO clearance;
- injury and disturbance to marine mammals from pre-construction site investigation surveys;
- injury and disturbance to marine mammals from vessel use and other non-piling sound-producing activities;
- injury to marine mammals due to collision with vessels;
- effects on marine mammals due to changes in prey availability.

21.9.1.15 Table 21.7 lists the inter-related effects (Morven South lifetime effects) that are predicted to arise during the construction, O&M and decommissioning of Morven South and the inter-related effects (receptor-led effects) that are predicted to arise for marine mammals receptors.

21.9.1.16 As in Volume 2, Chapter 10: Marine Mammals, effects on marine mammals 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:

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

Table 21.7: Summary of potential inter-related effects on the environment for marine mammals from individual effects occurring across the construction, O&M and decommissioning phases of Morven South and from multiple effects interacting across all phases (receptor-led effects)

C= Construction, O= O&M, D= Decommissioning phases

"✓" is used to denote the phase the potential impact can occur, "X" outlines there is no impact within this project phase

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Morven South lifetime effects					
Injury and disturbance from underwater sound generated from piling	✓	×	×	Whilst underwater sound could occur during all phases of Morven South, underwater sound generated during piling is limited to the construction phase only and therefore, no likely significant inter-related effects across multiple phases of Morven South from piling (Morven South lifetime effects) are predicted. Increased underwater sound during piling activities associated with construction of Morven South has the potential to interact with other sources of underwater sound associated with the construction phase of Morven South (such as UXO clearance). However, the underwater sound produced as a result of piling during construction of Morven South is likely to reach over a larger area (e.g. injury range of 4,450m from sound exposure level $(SEL)_{24}$ during the concurrent piling of two foundations, Table 10.45 as per the Volume 2, Chapter 10: Marine Mammals EIA Chapter) compared to other underwater sound producing activities associated with Morven South. Therefore, during this phase, it is considered unlikely that piling would act additively with other sound producing activities occurring at the same time, as the sound produced during piling is likely to mask other sound sources. Although piling itself occurs during the construction phase only, it would contribute to the overall temporal duration of underwater sound impacts (not just piling) across all phases of Morven South and is discussed below in receptor-led effects.	Injury and disturbance from underwater sound generated from piling are anticipated to interact in such a way as to result in combined effects of minor adverse significance in the construction phase (i.e. not of greater significance than the assessments presented for each individual phase).
Injury and disturbance from underwater sound generation from UXO clearance	✓	×	×	Whilst underwater sound could occur during all phases of Morven South, increased underwater sound generated during from UXO clearance is limited to the construction phase only and therefore, no likely significant inter-related effects across	Injury and disturbance from underwater sound generation from UXO clearance are anticipated to interact in such a way as to result in combined effects of minor adverse significance in the

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
				multiple phases of Morven South from UXO clearance (Morven South lifetime effects) are therefore predicted. Increased underwater sound during UXO clearance during pre-construction activities could interact with other sources of underwater sound in the construction phase. This has the potential to contribute to an increase in the underwater sound which in turn could affect marine mammals. Low order clearance methods are the default, which has the potential to result in auditory injury ranges of up to 560m (PK) (Table 10.51) and localised disturbance (temporary threshold shift (TTS) as a proxy) out to 1,330m (SEL) (Table 10.55, both as per the Volume 2, Chapter 10: Marine Mammals EIA Chapter). However, the MDS also includes consideration of a high order detonation, with potential for auditory injury out to 16,300m (PK) for the maximum assumed UXO size (554kg NEQ) and out to 9,310m (PK) for the most realistic maximum UXO size (132 kg net explosive quantity (NEQ)) (Table 10.51 as per the Volume 2, Chapter 10: Marine Mammals EIA Chapter). Disturbance (TTS as a proxy) may occur out to 30,700m (SEL) for the maximum assumed UXO size (554kg NEQ) and out to 20,400m (SEL) for the most realistic maximum UXO size (132kg NEQ). Additional disturbance is possible due to use of acoustic deterrent devices and soft start charges. It should be noted however, that for each UXO clearance, the duration of the impact, including mitigation, 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 underwater sound from other activities (e.g. site investigation surveys), during the construction phase and will contribute to the overall duration of underwater sound impacts across all phases of Morven South and is discussed below in receptor-led effects.	construction phase (i.e. not of greater significance than the assessments presented for each individual phase).

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Disturbance to marine mammals from pre-construction site investigation surveys	✓	✓	×	Elevated underwater sound during pre-construction site investigation surveys could be additive over the construction and operation and maintenance phases of Morven South with sequential sound from site investigation surveys leading to extended effect on marine mammals. However, this impact will occur as short-term events with cessation of sound in between events allowing periods of recovery, and the impact is localised (maximum auditory injury range of 0.9km (Table 10.57)) with disturbance of 3.80km (Table 10.60 both as per the Volume 2, Chapter 10: Marine Mammals EIA Chapter). Additive effects are possible (though unlikely given intermittency of surveys) and the duration of elevated underwater sound from all activities could be extended.	Disturbance to marine mammals from pre-construction site investigation surveys are anticipated to interact in such a way as to result in combined effects of effects of minor adverse significance in the construction phase (i.e. not of greater significance than the assessments presented for each individual phase).
Injury and disturbance to marine mammals from vessel use and other non-piling sound-producing activities	✓	✓	✓	Elevated underwater sound during vessel use and other non-piling sound-producing activities could occur across all three phases of Morven South. Vessels will be used throughout all stages of Morven South and could cause additional disturbance to marine mammals. Auditory injury was not exceeded for all species, and disturbance effects are likely to be localised for non-piling activities and during vessel movements (e.g. out to maximum of 45.3km (Table 10.68 as per the Volume 2, Chapter 10: Marine Mammals EIA Chapter)) with breaks in activity within phases, however, temporally these effects could occur over all phases of Morven South and lead to additive effects.	Injury and disturbance to marine mammals from vessel use and other non-piling sound-producing activities are anticipated to interact in such a way as to result in combined effects of minor adverse significance in all phases (i.e. not of greater significance than the assessments presented for each individual phase).
Injury to marine mammals due to collision with vessels	✓	✓	✓	Over the lifetime of Morven South there will be an ongoing risk of collision associated with vessels throughout the construction and decommissioning 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 (Volume 4, Annex 5: Navigation Safety Plan and Vessel Management Plan (NSPVMP) (Version	Injury to marine mammals due to collision with vessels are anticipated to interact in such a way as to result in combined effects of minor adverse significance in all phases (i.e. not of greater significance than the assessments presented for each individual phase).

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
				1); see Table 10.32 as per the Volume 2, Chapter 10: Marine Mammals) and therefore the risks will be reduced. It is important to consider that, to some extent, the underwater sound 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.	
Effects on marine mammals due to changes in prey availability	✓	✓	✓	Fish and shellfish communities may be affected through all phases of Morven South 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 Morven South 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. 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.	Effects on marine mammals due to changes in prey availability are anticipated to interact in such a way as to result in combined effects of minor adverse significance in all phases (i.e. not of greater significance than the assessments presented for each individual phase).
Receptor led effects					
Stressor 1: injury or disturbance from elevated underwater sound (from piling, UXO clearance, site-investigation surveys, vessels, operational noise from turbines)					
During the pre-construction phase, activities resulting in elevated underwater sound includes UXO clearance, site-investigation surveys, vessel use and other sound 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 pre-construction phase. Prior to piling, for example, UXO clearance could result in no more than 15 single clearance events (Table 10.31 as per the Volume 2, Chapter 10: Marine Mammals EIA Chapter), with disturbance occurring mainly during the implementation of 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, while disturbance during vessel activity will occur intermittently with timings linked to the pre-construction activities (UXO and site-investigation surveys).					

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		

During the construction phase, activities resulting in elevated underwater sound include piling, other construction activities and vessel movements could occur. Since injury to marine mammals will be reduced through the MMMP (Volume 4, Annex 2: Marine Mammal Mitigation Protocol (MMMP) (Version 1)) (Table 10.32 as per the Volume 2, Chapter 10: Marine Mammals EIA Chapter), the key focus is on disturbance effects. Disturbance due to impact piling could occur intermittently on a total of 264 days over the construction phase of five years. Other construction activities (e.g. drilling) and vessel movements would occur intermittently within the 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 underwater sound 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 to 15km at Beatrice and Moray East OWFs; without piling there was still a disturbance response due to vessel activity and other construction, but that the effect ranges (up to 4km) 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 sound producing activities occur in different parts of Morven South (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 operation and maintenance phase, activities resulting in elevated underwater sound include vessel activity and geophysical surveys. 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) 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 within the Morven South Boundary, or temporally due to ongoing disturbance from activities throughout the operation and maintenance phase (e.g. if they occur consecutively).

During decommissioning, vessel movements associated with decommissioning activities will result in elevated underwater sound 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 within the Morven South Boundary, or temporally due to ongoing disturbance throughout the decommissioning phase. Therefore, marine mammal receptors have the potential to experience ongoing disturbance due to elevations in underwater sound from different sources at all phases of Morven South.

The sensitivity of key species will be linked to their ability to tolerate the stressor such that their ability to function normally (e.g. forage, reproduce, communicate, avoid predators) is not impeded. The assessment, which adopts a highly precautionary approach 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 animals returning to baseline levels rapidly.

There are, however, uncertainties as to how all activities interact to contribute to an additive effect from underwater sound as a stressor. It is highlighted that the impact assessment adopted a conservative 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 sound. Graham *et al.* (2019), for example, demonstrated acclimatisation in harbour porpoise (*Phocoena phocoena*), showing that the proportional response of harbour porpoise to piling noise

<table>
<tr><th rowspan="2">Description of impact</th><th colspan="3">Phase</th><th rowspan="2">Likely significant inter-related effect</th><th rowspan="2">Significance</th></tr>
<tr><th>C</th><th>O</th><th>D</th></tr>
<tr><td colspan="6">decreased over the piling phase, with the proportion of animals disturbed at a received level of 160dB 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 within out 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 OWF, possibly in relation to increased prey availability as a result of introduction of hard substrates (e.g. jacket foundations and scour protection) (although there may be an additional energetic cost from the fleeing and distance travelled to compensate for) (Benhemma-Le Gall et al., 2021). Russell et al. (2014) demonstrated pinnipeds trace anthropogenic structures at sea, with three animals concentrating their foraging effort in the windfarms Similarly, Rose et al. (2025) found significantly higher detection rates within OWFs than in their vicinity (surrounding 2.5km), 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.</td></tr>
<tr><td colspan="6">Stressor 2: injury due to collisions with vessels</td></tr>
<tr><td colspan="6">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 Morven South. Over the lifetime of Morven South there will be an increased temporal risk to marine mammal receptors however, with the designed-in measures and mitigation such as the NSPVMP (Volume 4, Annex 5: Navigation Safety Plan and Vessel Management Plan (NSPVMP) (Version 1)) (Table 10.32 as per the 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 sound from the vessels themselves (Stressor 1.) 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 a high level of vessel activity. For example, Buckstaff (2004) demonstrated that bottlenose dolphins 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 an 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.</td></tr>
<tr><td colspan="6">Stressor 3: changes in prey communities</td></tr>
<tr><td colspan="6">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 underwater sound effects on fish and shellfish) whilst 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 (Section 10.11.6 as per the Volume 2, Chapter 10: Marine Mammals EIA Chapter) 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</td></tr>
</table>

<table>
<tr><th rowspan="2">Description of impact</th><th colspan="3">Phase</th><th rowspan="2">Likely significant inter-related effect</th><th rowspan="2">Significance</th></tr>
<tr><th>C</th><th>O</th><th>D</th></tr>
<tr><td colspan="6">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 positive 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 a de-facto MPAs by limiting activities that can negatively 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.</td></tr>
<tr><td colspan="6">Multiple stressors: inter-related effect of all stressors</td></tr>
<tr><td colspan="6">The inter-related effect of all stressors in-combination is discussed in detail in from Paragraphs 21.9.1.17 to 21.9.1.26 below.
The significance is considered to be minor adverse and, therefore, not significant in EIA terms.</td></tr>
</table>

Multiple stressors: inter-related effect of all stressors

21.9.1.17 It is possible that multiple stressors interact across the lifetime of Morven South. Arrigo *et al.* (2020) suggests that large organisms at higher trophic levels, such as marine mammals, may be generally negatively 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.

21.9.1.18 For elevated underwater sound (Stressor 1) 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 to recover 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 sound (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 boundaries of Morven South. Within the Morven South 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 Morven South, 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.

21.9.1.19 Therefore, while 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 between ongoing vessel noise during the operation and maintenance 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 seals and grey seals moved between hard structures at two operational wind farms 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.

21.9.1.20 Similarly, Rose *et al.* (2025) utilised 13 years of data from 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 (2.5km 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 porpoise 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 porpoise. Lindeboom *et al.* (2011) studied the ecological effects of the Egmond aan Zee offshore wind farm 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 operation and maintenance phase, some fish species (e.g. cod) benefited from the ‘shelter’ within the wind farm. 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 wind farm may be correlated with presence of additional increased food sources compared to reference areas.

21.9.1.21 The potential interrelationship between underwater sound and collision risk has been addressed in earlier discussions (Table 21.7) 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 sound) 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 EIA, with the designed-in measures and mitigation in place (Table 10.31 as per the Volume 2, Chapter 10: Marine Mammals) it is likely that any risk of injury from collision with vessels will be negligible.

21.9.1.22 Evidence for the potential long-term effects of offshore wind farm on marine mammals (related to all potential stressors) comes from monitoring programmes which baseline levels of abundance to construction and post-construction phases. Limited monitoring studies regarding impacts on marine mammals from offshore wind farm have been carried out to date.

21.9.1.23 Aerial survey haul-out counts were conducted before, during and after the construction phases at Scroby Sands offshore wind farm, off the coast of Norfolk, to monitor harbour and grey seal counts at haul-out site, located less than two kilometres away from the offshore wind farm 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 seals 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 offshore wind farm, 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 Wind Farm is located 2.5km off the coast of Great Yarmouth whereas Morven South is located further (105.3km from Firth of Tay and Eden Estuary Special Area of Conservation (SAC), designated for harbour seal) offshore and therefore a greater distance from haul-out sites. As a part of marine mammal monitoring at Robin Rigg offshore wind farm, 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.

21.9.1.24 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 porpoise at Horns Rev offshore wind farm and showed a decrease in 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 Reef 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 operation and maintenance phase porpoise activity was higher in both the wind farm and reference area compared to baseline levels. As a result of monitoring at Nysted offshore wind farm, it was demonstrated initially during construction and the first two years of operation that there were lower acoustic detections of harbour porpoise 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 animals were gradually habituating and returning to the wind farm area.

21.9.1.25 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 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.

21.9.1.26 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

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

- direct temporary habitat loss/disturbance;
- changes in prey availability due to temporary habitat loss/disturbance;
- attraction to light.

21.9.1.28 Table 21.8 lists the inter-related effects (Morven South lifetime effects) that are predicted to arise during the construction, O&M and decommissioning of Morven South and the inter-related effects (receptor-led effects) that are predicted to arise for offshore ornithology receptors.

Table 21.8: Summary of potential inter-related effects on the environment for offshore ornithology from individual effects occurring across the construction, O&M and decommissioning phases of Morven South and from multiple effects interacting across all phases (receptor-led effects)

C= Construction, O= O&M, D= Decommissioning phases

"✓" is used to denote the phase the potential impact can occur, "✗" outlines there is no impact within this project phase

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Morven South lifetime effects					
Direct temporary habitat loss/disturbance	✓	✓	✓	The majority of the disturbance/habitat loss during all project phases will be highly localised and the habitats affected are predicted to recover quickly following completion of operation and maintenance activities with prey species for seabirds recovering into the affected areas. Therefore, across the lifetime of Morven South, 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.	Negligible adverse significance which is not significant in EIA terms
Changes in prey availability due to temporary habitat loss/disturbance	✓	✓	✓	The majority of changes in prey availability impacts during all project phases will be highly localised and temporary. Therefore, across the lifetime of Morven South, 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.	Negligible adverse significance which is not significant in EIA terms
Attraction to light.	✓	✓	✓	The nature of lighting in all project phases is not anticipated to be of a level that would attract seabird species that may be vulnerable to attraction to light sources. The effects on seabird receptors are therefore 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.	Negligible adverse significance which is not significant in EIA terms
Receptor led effects					
For species at risk of both displacement and collision, an assessment has been included in the project alone and cumulative assessment sections as per Volume 2, Chapter 11 Offshore Ornithology. It is not expected that there is potential for other impacts to interact to cause additive/synergistic/antagonistic effects that may lead to a significant effects.					

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Direct temporary habitat loss/disturbance and changes in prey availability due to temporary habitat loss/disturbance, take into account the effects on other prey receptors (i.e. shellfish, fish and benthic invertebrates) as part of their assessment. As a result, the receptor-led effects are of negligible adverse significance which is not significant in EIA terms.					

21.9.1.29 These inter-related effects as described above 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 phases. Therefore, these inter-related effects would not be significant in EIA terms.

Human environment

Commercial fisheries

21.9.1.30 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 Morven South;
- 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 Morven South within fishing grounds leading to interference with fishing activity;
- additional steaming to alternative fishing grounds for vessels that would otherwise fish within Morven South;
- increased snagging risk, which could result in loss or damage to fishing gear.

21.9.1.31 As noted in Volume 2, Chapter 12: Commercial Fisheries, effects on commercial fisheries 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:

- Socio-economics:
  - socio-economic effects resulting from changes to commercial fisheries.
- Major accidents and disasters:
  - potential for snagging risk to and from existing commercial fisheries receptors to result in major accidents and disasters.
- Human health:
  - human health effects resulting from changes to employment and income as a result of loss or restricted access to commercial fishing grounds.

Table 21.9: Summary of potential inter-related effects on the environment for commercial fisheries from individual effects occurring across the construction, O&M and decommissioning phases of Morven South and from multiple effects interacting across all phases (receptor-led effects)

C= Construction, O= O&M, D= Decommissioning phases

"✓" is used to denote the phase the potential impact can occur, "X" outlines there is no impact within this project phase

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Morven South lifetime effects					
Reduction in access to, or exclusion from established fishing grounds within Morven South	✓	✓	✓	Loss or restricted access to fishing grounds is considered to be temporary during construction and decommissioning. A buoyed construction area around the entirety of Morven South as it is constructed and decommissioned will lead to loss of access. In the O&M phase it is assumed fishing can resume in Morven South.	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.
Displacement leading to gear conflict and increased fishing pressure on adjacent grounds	✓	✓	✓	Fishing may be disrupted and displaced into other areas due to the loss of access effects described immediately 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.
Disturbance of commercially important fish and shellfish resources leading to displacement or disruption of fishing activity	✓	✓	✓	Morven South lifetime inter-related effects are unlikely, as the nature of potential impacts differs between the construction and O&M phases, with different mechanisms of effect predominating in each phase, as assessed in Volume 2, Chapter 9: Fish and Shellfish Ecology. These include, but are not limited to, underwater sound during construction, and EMF, habitat loss or	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

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
				disturbance, and changes in suspended sediments during the O&M phase. Temporary and long-term habitat loss occurring across all phases is expected to be proportionally small in relation to habitat availability in the Morven South Local and Regional Commercial Fisheries Study Areas.	individual phase and are therefore minor adverse and not significant in EIA terms.
Increased vessel traffic associated with Morven South within fishing grounds leading to interference with fishing activity	✓	✓	✓	With the successful implementation of designed-in mitigation (i.e. issue of Notice to Mariners (NtMs)), preparation of a FMMCP, close liaison with the local vessels), no significant effects are predicted for the construction, O&M, and decommissioning phases of Morven South. Potential effects on commercial fisheries differ by project phase and do not act concurrently in a manner that would give rise to inter-related effects. 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. On this basis, inter-related effects across project phases are not anticipated.	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 Morven South	✓	✓	✓	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 Morven South during the O&M phase, though transit is deemed possible based on wind turbine spacing. As these effects differ by project phase and do not occur concurrently in a manner that would compound effects across phases, inter-related effects on steaming and transit times are not anticipated.	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 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 Morven South seabed infrastructure. At the end of the operational lifetime, it is expected that all structures above the seabed (with the	The effects on commercial fisheries across the phases are not anticipated to interact in such a way as to result in combined effects of

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
				exception of scour protection and cable protection) 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. Any snagging events are not expected to overlap in a manner that would result in compounding interactions; inter-related effects across the construction, O&M and decommissioning phases are not anticipated.	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 a reduction in access to fishing grounds, subsequent displacement of fishing activity, and associated increases in fishing pressure and potential for gear conflict on adjacent grounds. While these two effects may act together, they are individually assessed – taking a precautionary approach to assessment - to be of not more than minor adverse significance, and it is considered that any inter-related effect will not be of any greater significance than this.					

21.9.1.32 These inter-related effects as described above 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 phases. Therefore, these inter-related effects would not be significant in EIA terms.

Shipping and navigation

21.9.1.33 For shipping and navigation, the following potential impacts have been considered within the inter-related effects assessment:

- increased vessel to vessel collision risk resulting from displacement (third-party to third-party);
- increased vessel to vessel collision risk resulting from displacement (third-party to project vessel);
- vessel to structure allision risk;
- reduced access to local ports and harbours.

21.9.1.34 Table 21.10 lists the inter-related effects (Morven South lifetime effects) that are predicted to arise during the construction, O&M and decommissioning of Morven South and the inter-related effects (receptor-led effects) that are predicted to arise for shipping and navigation receptors.

21.9.1.35 As noted in Volume 2, Chapter 13: Shipping and Navigation, 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;
  - displacement from fishing grounds for commercial fishing vessels due to the presence of the buoyed construction and decommissioning areas during the construction and decommissioning phases, respectively;
  - displacement from fishing grounds for commercial fishing vessels due to maintenance activities or the presence of structures during the O&M phase.

Table 21.10: Summary of potential inter-related effects on the environment for commercial fisheries from individual effects occurring across the construction, O&M and decommissioning phases of Morven South and from multiple effects interacting across all phases (receptor-led effects)

C= Construction, O= O&M, D= Decommissioning phases

"√" is used to denote the phase the potential impact can occur, "X" outlines there is no impact within this project phase

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Morven South lifetime effects					
Increased vessel to vessel collision risk resulting from displacement (third-party to third-party)	✓	✓	✓	When displacement and increased collision risk between third-party vessels is considered across all phases, the additive effect is not larger than when considered across an individual phase. Increasing familiarity with Morven South may reduce the potential in later phases for late routeing decisions that can lead to an increased likelihood of an encounter between third-party vessels.	Across the lifetime of Morven South, the effects on shipping and navigation 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.
Increased vessel to vessel collision risk resulting from displacement (third-party to project vessel)	✓	✓	✓	When displacement and increased collision risk between third-party vessels and project vessels is considered across all phases, the additive effect is not larger than when considered across construction or decommissioning phases. Increasing familiarity with Morven South may reduce the potential in later phases for late routeing decisions that can lead to an increased likelihood of an encounter between a third-party and project vessel.	Across the lifetime of Morven South, the effects on shipping and navigation 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.
Vessel to structure allision risk.	✓	✓	✓	When allision risk is considered across all phases, the additive effect is not larger than when considered across an individual phase, given that during the construction and decommissioning phases, the risk will be mitigated by the presence of the buoyed construction or decommissioning area, and during the O&M phase third-party vessels will be well familiar with the structures following on from the construction phase.	Across the lifetime of Morven South, the effects on shipping and navigation 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 effect	Significance
	C	O	D		
Reduced access to local ports and harbours.	✓	✓	✓	When reduced access to local ports and harbours is considered across all phases, the additive effect is not larger than when considered across an individual phase. Increasing familiarity with Morven South may reduce the potential in later phases for late routeing decisions that can lead to less efficient port access.	Across the lifetime of Morven South, the effects on shipping and navigation 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.
Receptor led effects					
Loss of access or exclusion from fishing grounds during construction, O&M and decommissioning phases may lead to displacement of commercial fishing vessels from fishing grounds, which may lead to a reduction in available sea room and increase the risk of vessel-to-vessel collision between third-party vessels. However, it is unlikely that effects will act together and that any interactions between effects will be of any greater significance than those already assessed in isolation.					

21.9.1.36 These inter-related effects as described above 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 phases. Therefore, these inter-related effects would not be significant in EIA terms.

Aviation (military and civil)

21.9.1.37 For aviation (military and civil), the following potential impacts have been considered within the inter-related effects assessment:

- creation of a physical obstacle to aircraft operations;
- wind turbines causing interference to aviation radar systems.

21.9.1.38 Table 21.11 lists the inter-related effects (Morven South lifetime effects) that are predicted to arise during the construction, O&M and decommissioning of Morven South and the inter-related effects (receptor-led effects) that are predicted to arise for aviation (military and civil) receptors.

21.9.1.39 The individual project alone impacts were assigned residual significance of effect of no greater than minor adverse once mitigation is applied. It is therefore anticipated that the significance of combined effects on airspace and radar users will not be of any greater significance than the effects when assessed in isolation.

Table 21.11: Summary of potential inter-related effects on the environment for aviation (military and civil)from individual effects occurring across the construction, O&M and decommissioning phases of Morven South and from multiple effects interacting across all phases (receptor-led effects)

C= Construction, O= O&M, D= Decommissioning phases

"✓" is used to denote the phase the potential impact can occur, "X" outlines there is no impact within this project phase

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Morven South lifetime effects					
Creation of a physical obstacle to aircraft operations	✓	✓	✓	There is potential for the creation of a physical obstruction to aircraft low flying operations as a result of the Morven North construction, O&M and decommissioning activities alongside other offshore wind farms within the cumulative aviation (military and civil) study area. The activities include the use of construction infrastructure including cranes and the erection of wind turbines and OSPs.	Across the lifetime of Morven South, the effects on aviation (military and civil) 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.
Wind turbines causing interference to aviation radar systems	×	✓	×	Wind turbines detectable by a non-cooperative radar system might degrade the system by creating false targets, reduce system sensitivity, create radar shadowing behind the wind turbines and saturate the radar receiver leading to clutter potentially concealing real aircraft targets.	Across the lifetime of Morven South, the effects on aviation, military and communications 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.
Receptor-led effects					
All effects on aviation (military and civil), such as creation of a physical obstruction and wind turbine related interference to aviation radar systems, may interact to produce a different, or greater effect on these receptors than when the effects are considered in isolation. Receptor-led effects may be short-term, temporary or transient effects, or incorporate longer-term effects. The individual project alone impacts were assigned residual significance of effect of no greater than minor					

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
adverse once mitigation is applied. It is therefore anticipated that the significance of combined effects on airspace and radar users will not be of any greater significance than the effects when assessed in isolation.					

Other Sea Users, Marine Infrastructure and Communications

21.9.1.40 For other sea users and communications, the following potential impacts have been considered within the inter-related effects assessment:

- physical restriction on space for recreational fishing vessels;
- physical restriction on space for recreational craft/recreational activities.

21.9.1.41 Table 21.12 lists the inter-related effects (Morven South lifetime effects) that are predicted to arise during the construction, O&M and decommissioning of Morven South and the inter-related effects (receptor-led effects) that are predicted to arise for Other Sea Users and Communications receptors.

21.9.1.42 As noted in Volume 2, Chapter 16: Other Sea Users, Marine Infrastructure and Communications, effects on Other Sea Users and Communications also have the potential to have secondary effects on other receptors and these effects are fully considered in the respective topic-specific chapters. These receptors and effects are:

- physical restriction on space for recreational activities and recreational fishing;
- displacement of recreational sailing, motor cruising and recreational fishing (boat angling).

Table 21.12: Summary of potential inter-related effects on the environment for Other Sea Users and Communications from individual effects occurring across the construction, O&M and decommissioning phases of Morven South and from multiple effects interacting across all phases (receptor-led effects)

C= Construction, O= O&M, D= Decommissioning phases

"✓" is used to denote the phase the potential impact can occur, "✗" outlines there is no impact within this project phase

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Morven South lifetime effects					
Physical restriction on space for recreational fishing vessels	✓	✓	✓	The presence of infrastructure, safety zones and advisory clearance distances during the construction phase may result in the displacement of r recreational fishing vessels from the Morven South Boundary. This likely significant inter-related effect is repeated in the O&M and decommissioning phases of Morven South.	The effects on recreational fishing vessels are anticipated to interact in such a way as to result in combined effects of negligible significance in the construction, O&M and decommissioning phases (i.e. not of greater significance than the assessments presented for each individual phase). As a result, the inter-related effects are of negligible significance which is not significant in EIA terms.
Physical restriction on space for recreational craft/recreational activities	✓	✓	✓	The presence of infrastructure, safety zones and advisory clearance distances during the construction phase may result in the displacement of recreational craft/recreational activities from the Morven South Boundary. This likely significant inter-related effect is repeated in the O&M and decommissioning phases of Morven South.	The effects on recreational craft/recreational activities are anticipated to interact in such a way as to result in combined effects of negligible significance in the construction, O&M and decommissioning phases (i.e. not of greater significance than the assessments presented for each individual phase). As a result, the inter-related effects are of negligible significance which is not significant in EIA terms

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Receptor-led effects					
Potential exists for spatial and temporal interactions between direct and indirect impacts to other sea users, marine infrastructure and communications 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 negligible to minor adverse significance, these impacts are not likely to interact in way that results in a significant inter-related effect.					

21.9.1.43 These inter-related effects as described above 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 phases. Therefore, these inter-related effects would not be significant in EIA terms.

Socio-economics

21.9.1.44 For socio-economics, the inter-related effects are discussed throughout the report where environmental effects from other chapters, such as shipping and navigation, are incorporated into the assessment. Therefore, no potential impacts have been considered within the inter-related and interacting impacts assessment in which there are secondary environmental effects as a result of socio-economic effects.

Marine archaeology

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

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

21.9.1.46 Table 21.13 lists the inter-related effects (Morven South lifetime effects) that are predicted to arise during the construction, O&M and decommissioning of Morven South and the inter-related effects (receptor-led effects) that are predicted to arise for marine archaeology receptors.

Table 21.13: Summary of potential inter-related effects on the environment for marine archaeology from individual effects occurring across the construction, operations and maintenance and decommissioning phases of Morven South and from multiple effects interacting across all phases (receptor-led effects)

C= Construction, O= O&M, D= Decommissioning phases

"✓" is used to denote the phase the potential impact can occur, "✗" outlines there is no impact within this project phase

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Morven South lifetime effects					
Increased SSC and sediment deposition leading to indirect impacts on marine archaeology receptors	✓	✓	✓	When SSC and sediment deposition is considered additively across all phases, the volume of sediment deposited is larger than when considered across an individual phase (i.e. just construction). However, the effects are expected to be short-term, and so the effects on marine archaeology 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.	SSC and sediment deposition are anticipated to interact in such a way as to result in combined effects of minor adverse or beneficial significance in the construction phase and negligible significance in the O&M and decommissioning phases (i.e. not of greater significance than the assessments presented for each individual phase).
Receptor led effects					
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 lifetime of Morven South. The combination of sediment disturbance and deposition and alteration of transport regimes has the potential to further bury marine archaeology receptors. 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) and would be generally beneficial in nature. As a result, the receptor-led effects are of minor adverse significance which is not significant in EIA terms.					

21.9.1.47 These inter-related effects as described above 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 phases. Therefore, these inter-related effects would not be significant in EIA terms.

Major accidents and disasters

21.9.1.48 As it has been concluded that Morven South will not reasonably lead to any major accidents and disasters after consideration of the designed-in measures and mitigation adopted, and as no significant effects are predicted at the project level, there is no pathway for cumulative, inter-related or transboundary effects to arise. Therefore, no further assessment of such effects has been undertaken.

Human health

21.9.1.49 For human health, the following potential impacts have been considered within the inter-related assessment:

- impact of changes to employment and income on human health;
- impact of climate change and adaptation on human health;
- impact of changes to wider societal infrastructure and resources on human health.

21.9.1.50 The areas of potential interaction between effects for a given geographic population are presented in Table 21.14. Vulnerable group effects are expected across all geographic populations, so are not listed separately.

21.9.1.51 Table 21.15 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, O&M and decommissioning of Morven South and the inter-related effects (receptor-led effects) that are predicted to arise for human health receptors.

Table 21.14: Interaction between health determinants and geographic populations

	Regional	National	International
	Aberdeenshire; Angus; City of Aberdeen; City of Edinburgh; Dundee City; East Lothian; Fife; Highland; Moray; Perth and Kinross; and the Scottish Borders;	UK	Global
Impact of changes to employment and income on human health	✓		
Impact of changes to climate change and adaptation on human health		✓	✓
Impact of changes to wider societal infrastructure and resources on human health		✓	

Key		
Positive (green)	Negative (orange)	Positive and negative (blue)

Table 21.15: Summary of likely significant inter-related effects on the environment from individual effects occurring across the construction, O&M and decommissioning phases of Morven South and from multiple effects interacting across all phases (receptor-led effect)

C= Construction, O= O&M, D= Decommissioning phases

"✓" is used to denote the phase the potential impact can occur, "✗" outlines there is no impact within this project phase

Description of impact	Phase			Likely significant inter-related effect	Significance
	C	O	D		
Morven South lifetime effects					
Combined economic effects to employment across project phases	✓	✓	✓	Effects relating to ongoing changes in fishing access and direct employment opportunities for Morven South across construction, operations and maintenance and decommissioning are already taken into account by the health assessment, including where effects are characterised as 'long-term'.	No change
Receptor-led effects					
Combined national population benefits relating to climate change and wider societal resources	✗	✓	✗	Nationally the population would benefit both from a reduction in the severity of health effects associated with climate change and from the benefits to public health of energy security. Effects would be greatest for vulnerable groups, particularly those on low incomes less able to adapt or afford alternatives. As the effects associated with climate change are expected to be driven by the benefit to deprived populations globally, the combined effect in the UK of these health determinants is not expected to be greater than the individual effects.	No change.

21.9.1.52 These inter-related effects as described above 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 phases. Therefore, these inter-related effects would not be significant in EIA terms.

21.10 Part two: Ecosystem based effects assessment

21.10.1 Overview

21.10.1.1 An ecosystem is a community of living (biotic) organisms existing in conjunction with the non-living (abiotic) components of their environment. These biotic and abiotic components are linked together through nutrient cycles and energy flows (LibreTexts, 2022). The biotic components include plankton, seaweed, benthic communities, fish, seabirds and marine mammals and abiotic components include air, salt water, and seabed substrate.

21.10.1.2 Biodiversity is defined as the collection of genomes, species, and ecosystems occurring in a geographically defined region (National Research Council, 1995). The biodiversity can act as a key indicator of health within an ecosystem. A wider variety of generalist species will adapt and cope better with external pressures than a limited number of species in large populations which have specialist environmental requirements. Even if certain species are affected by climate change or human activities, the ecosystem as a whole may adapt and survive (European Commission, 2022).

21.10.1.3 The purpose of this ecosystem-based assessment is to qualitatively assess the potential effects of Morven South at the ecosystem level, to better understand how the ecosystem as a whole, including elements such as predator-prey relationships could be altered and how this could impact the functioning of the ecosystem. This is to address the representations provided by NatureScot which highlighted "the need to understand the potential impacts holistically at a wider ecosystem scale rather than only a set of discrete individual receptor assessments." The Scottish Ministers therefore advised that potential impacts should be considered across key trophic levels, particularly in relation to the availability of prey species (MD-LOT, 2023).

21.10.2 Ecosystem baseline

21.10.2.1 This section provides a summary of the abiotic and biotic components of the marine ecosystem relevant to Morven South, considering the topic specific study areas used for assessment.

21.10.2.2 Morven South will be located off the east coast of Scotland, approximately 86km from the Aberdeenshire coast, and comprising an area of approximately 860km^2. Across the Morven South Boundary, the maximum water depth was recorded at 76m lowest astronomical tide (LAT), and the shallowest area was recorded at 64m LAT. The greatest depths are located near the southeastern edge Morven South Boundary, whilst the shallowest areas are found towards the centre of the site (Volume 2, Chapter 7: Physical Processes).

21.10.2.3 The seabed within the Morven South Boundary was dominated by fine to medium sand with varying amounts of mud and gravel content. The sediment composition was mainly dominated by sand, with small areas of muddy sand throughout, as well as slightly gravelly muddy sand and slightly gravelly sand predominantly in the north of the Morven South Boundary (Volume 2, Chapter 8: Benthic Subtidal Ecology).

21.10.2.4 The geological morphology within the Morven South Boundary is varied and includes sandbanks, shoals, megaripples and boulders (boulder density was highest in the northeast and central regions of the Morven South Boundary).

21.10.2.5 The benthic communities within the Morven South Boundary are characterised by annelids and molluscs. Biomass between grab sampling sites was varied. Echinoderms comprised the majority of the biomass within the grab samples (50%), which was largely due to the prevalence of the purple heart urchin (*Echinocardium cordatum*). The phyletic composition of non-colonial fauna was dominated by annelids, mainly the polychaetes (*Spiophanes bombyx* and *Scoloplos armiger*). The phyletic composition of sessile colonial fauna was dominated by cnidarians and bryozoans, with common colonial or encrusting species including *Electra monostachys*, *Alcyonidium diaphanum*, and *Leptothecata* spp. across many sample stations. The closest designated site (located approximately 17.3km west of the Morven South Boundary) is the Firth of Forth Banks Complex nature conservation Marine Protected Area (ncMPA hereafter MPA) which is designated for ocean quahog (*Arctica islandica*), offshore subtidal sand and gravels, shelf banks and mounds, moraines representative of the Wee Bankie Key Geodiversity Area (Volume 2, Chapter 8: Benthic Subtidal Ecology).

21.10.2.6 Table 21.16 provides a summary of the broad subtidal habitats or species present with the Morven South Boundary. Details of the grab sample locations can be found in Volume 3, Annex 8.1: The Morven North and Morven South Benthic Subtidal Ecology Shared Technical Report.

Table 21.16: Broad Habitat Types and Species

Habitat or Species	Location Identified
Offshore subtidal sands and gravels	Throughout the entire Moven South Boundary and Zone of Influence (ZoI).
Ocean quahog	Identified across the Moven South Boundary and ZoI.

21.10.2.7 The other species groups which are part of the biotic components of the ecosystem include fish, seabirds and marine mammals. These groups are considered further in Sections 21.10.4 and 21.10.5.

21.10.3 The marine food web

21.10.3.1 Trophic levels describe the hierarchical levels which organisms occupy in the food web. Primary producers, such as phytoplankton and seaweed, form the lowest trophic levels in marine food webs. They are consumed by primary consumers (herbivores) such as zooplankton, some crustaceans (e.g. copepods) and molluscs (e.g. clams, snails, mussels). Secondary consumers (carnivores or omnivores) such as fish larvae, Atlantic herring (*Clupea harengus*) (hereafter referred to as "herring") and lesser sandeel (*Ammodytes marinus*), and some crustaceans (e.g. crabs, shrimp) feed on primary consumers and primary producers. These species support tertiary consumers (carnivores), including some fish species, and cephalopods (e.g. octopus and squid species). Marine mammals, along with seabirds, large marine fish and elasmobranchs (sharks, skates and rays), are the top predators of the natural marine food web. An example of a marine food web which illustrates the interactions between the different trophic levels is presented in Figure 21.1.

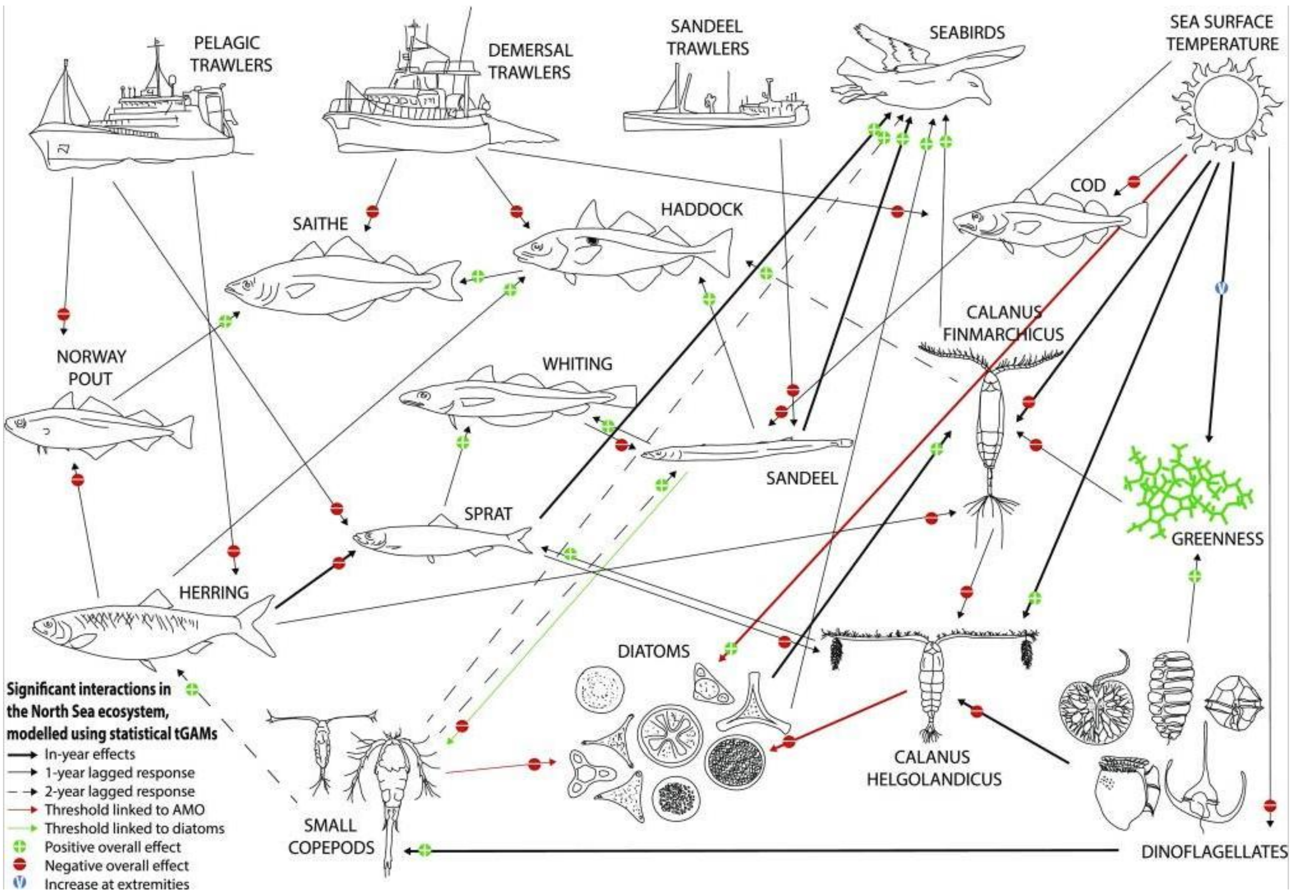

Figure 21.1: Significant interactions between functional groups and drivers (from Lynam *et al.* (2017))

21.10.4 The key predator species

21.10.4.1 Volume 2, Chapter 9: Fish and Shellfish Ecology, Volume 2, Chapters 10: Marine Mammals and Volume 2, Chapter 11: Offshore Ornithology, provide details on the fish, marine mammals and seabirds which are most abundant in the associated topic study areas and are the receptors most likely to be impacted by activities associated with all phases of Morven South. From information on these receptor groups, it is possible to ascertain which fish, marine mammal and seabird species are likely to be key predators in the marine ecosystem in this part of the central North Sea and within the study areas outlined in Section 21.4.

Piscivorous fish

21.10.4.2 The key marine predatory fish likely to utilise the marine environment within the Morven South Boundary are cod (*Gadus morhua)*, European hake (*Merluccius merluccius)* (hereafter referred to as “hake”), haddock (*Melanogrammus aeglefinus)*, ling (*Molva molva)*, saithe (*Pollachius virens)*, whiting (*Merlangius merlangus)* and plaice (*Pleuronectes platessa)*. Piscivorous fish primarily feed on other fish species with this diet of these species including small forage such as sandeel and juvenile whiting. Several elasmobranch species are also likely to be present such as spotted ray (*Raja montagu)*, thornback ray (*Raja clavata)*, tope shark (*Galeorhinus galeus)*, spurdog (*Squalus acanthias)*, small-spotted catshark (*Scyliorhinus canicula)*, thorny skate (*Amblyraja radiata)* and cuckoo ray (*Leucoraja naevus)*.

21.10.4.3 The migration route of diadromous fish species which also feed on small forage fish, and which are likely to pass through the Morven South Boundary during their migration are Atlantic salmon (*Salmo salar)*, sea trout (*Salmo trutta)*, sea lamprey (*Petromyzon marinus)*, European eel (*Anguilla anguilla)*, allis shad (*Alosa alosa*,)] twaite shad (*Allosa fallax)* and.

21.10.4.4 Table 21.17 lists the key predator species and the prey they feed on. This shows that although sandeel, herring, mackerel (*Scomber scombrus)* and European sprat (*Sprattus sprattus)* (hereafter referred to as “sprat”) are components of most of the key predators’ diets, other fish and benthic fauna are also important in the diet of marine predatory fish.

Table 21.17: Key predatory fish species and their prey

Species	Typical Prey Species
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.
Diadromous fish (salmon, trout, sea lamprey, eel, allis shad and twaite shad)	Depending on the species, prey include, invertebrates, molluscs, crustaceans, small fish such as sandeel, herring and sprat. Sea lamprey will prey on larger fish including sturgeon *Acipenseridae* spp., haddock, sea trout and salmon.
Haddock	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.
Hake	Mackerel, herring, pouting *Trisopterus luscus*, sandeel, squid and smaller members of their own species.
Ling	Adult ling feed on herring, mackerel, cod, pouting and flatfish, or crustacea (crabs and lobsters).
Plaice	Cockles, razor shells, worms, crustaceans, brittlestars and sandeel.

Species	Typical Prey Species
Saithe	A young saithe eats crustaceans and small fish, such as sand eel, while the mature saithe eats krill and small fish, such as Norway pout and blue whiting (Faroese Safood, 2022).
Skates and Rays	Crustaceans and crabs mainly, but will also eat small fish, especially flatfish. Larger skates will also hunt in mid-water for pelagic fish.
Small-Spotted Catshark	Decapod crustaceans, molluscs and fishes are their main prey, but echinoderms, polychaetes, sipunculids and tunicates may also be eaten
Spurdog	Small flounder, plaice, codling and sprats, herring, and small crustaceans.
Tope Shark	Dab, flounder and pouting, as well as mackerel and herring. They will also take squid and on occasion crustaceans
Whiting	Worms, crustaceans, shellfish and small fish.

Marine Mammals

21.10.4.5 The key marine mammal species which are most abundant within the Morven South Marine Mammal Study Area and therefore have the potential to be impacted by Morven South are:

- harbour porpoise;
- bottlenose dolphin (*Tursiops truncatus)*;
- white-beaked dolphin (*Lagenorhynchus albirostris)*;
- minke whale (*Balaenoptera acutorostrata)*;
- humpback whale (*Megaptera novaeangliae)*;
- grey seal (*Halichoerus grypus)*;
- harbour seal (*Phoca vitulina)*.

21.10.4.6 These species correspond to the marine mammal IEFs identified in Volume 2, Chapter 10: Marine Mammals. The sensitivity of marine mammals to prey availability within the Morven South Boundary will be affected by how important this area is to each species and how sensitive they are to prey availability. This is discussed further in paragraph 21.10.10.

21.10.4.7 A summary of the dietary preferences of key marine mammal species within the marine mammal study area is presented in Table 21.18. Further details of the most appropriate density values for marine mammals that have then been taken forward in the assessment are detailed in Volume 2, Chapter 10: Marine Mammals.

Table 21.18: Diet and Abundance of Key Marine Mammal Species

Species	Distribution within the Morven South Boundary	Prey	Description
Odontocetes			
Harbour porpoise	Harbour porpoise is widespread throughout the cold and temperate seas of Europe, including the North Sea. Small Cetaceans in European Atlantic waters and the North Sea Survey (SCANS) IV data estimated density in Block NS-D, where Morven South is located, as 0.599 animals/km^2 and presented an abundance of 38,577 individuals Gilles et al. (2023). Density estimates reported by Gilles et al. (2023) are therefore considered the most appropriate to use to reflect densities of harbour porpoise in offshore waters where the Morven South Boundary is located and a density of 0.599 animals/km^2 has been used in Volume 2, Chapter 10: Marine Mammals.	Small fish such as herring, cod, haddock, gobies and sandeel (Scottish Government, 2021). 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 (Hammond et al., 2008; Paxton et al., 2016).	Harbour porpoise has a higher metabolic rate than dolphins and therefore need to feed more frequently and consume more prey per unit body weight, in order to maintain their body temperature and other energy needs ((Rojano-Doñate et al., 2018). For this reason, porpoise may be highly susceptible to changes in the abundance of prey species or disturbance from foraging areas.
Bottlenose dolphin	Bottlenose dolphin is present within the northern North Sea, however, only the coastal population, distributed within the 2m to 20m depth contour and approximately 2km from the shore, is well studied (Geelhoed *et al.*, 2022). No bottlenose dolphins were recorded during digital aerial survey (DAS) of Morven South marine mammal study area. There were no bottlenose dolphin sightings within block NS-D during SCANS IV survey, thus no published density values for this survey (Gilles *et al.*, 2023). Density estimates reported by Lacey *et al.* (2022) are considered the most appropriate to use to reflect densities of bottlenose dolphins in offshore waters where the Morven South Boundary is located and a density of 0.005 animals/km^2 has been used in Volume 2, Chapter 10: Marine Mammals.	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.	Generally, the distribution is influenced by factors such as tidal state, weather conditions, resource availability, life cycle stage or season (Hastie *et al.*, 2004).

Species	Distribution within the Morven South Boundary	Prey	Description
White-beaked dolphin	White-beaked dolphin is considered the second most abundant cetacean in the North Sea, with the highest rates of sightings on the east coast of Scotland during summer months (Weir *et al.*, 2001). Density estimates reported by Waggitt *et al.* (2020) are considered the most appropriate to use to reflect densities of white-beaked dolphin in offshore waters where the Morven South Boundary is located and a density of 0.123 animals/km^2 has been used in Volume 2, Chapter 10: Marine Mammals.	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 (e.g. herring), gadoids (e.g. haddock and cod) and shad (*Alosa* spp.) (Canning *et al.*, 2008; Santos *et al.*, 1994).	Although the distribution and abundance of prey species affects the distribution and abundance of white-beaked dolphin, this species tends to be influenced by temperature with larger numbers and group sizes associated with cooler temperatures (Canning *et al.*, 2008, Evans, 1990; Weir *et al.*, 2007)). Increasing water temperature may therefore lead to reduced areas suitable for foraging, and habitat loss (IJsseldijk *et al.*, 2018). MacLeod *et al.* (2005) reported that there has been a decline in the relative frequency of white-beaked dolphin strandings and sightings in northwest Scotland and attributed climate change as a major cause of this decline.
Mysticetes			
Minke whale	Minke whale is widely distributed in northern North Sea. In Scotland, minke whales display seasonal occurrence patterns with inshore movements during summer, as dictated by increased availability of key prey species (usually sandeel during summer months) (Robinson *et al.*, 2021; Robinson *et al.*, 2009), returning to offshore waters in winter. It is considered that density estimates based on Lacey *et al.* (2022) are the most appropriate to use and a density of 0.027 animals/km^2 has been used in Volume 2, Chapter 10: Marine Mammals.	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).	This species is often known to exploit prey resources through other species that herd prey, enabling a low energy foraging strategy (Robinson and Tetley, 2007). They feed by engulfing prey in their huge open mouths, a feeding strategy known as 'lunge feeding'. Longitudinal furrows on their throat allow their mouths to expand to engulf huge volumes of seawater. When they close their mouths, the seawater is squeezed out through hanging curtains of baleen, the minke's own fishing net, while the fish are swallowed. Some minkes dive deep and chase fish towards the surface; this often attracts large flocks of seabirds which benefit from the feast, and are often a useful signpost that there are whales around (NatureScot, 2024).

Species	Distribution within the Morven South Boundary	Prey	Description
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. One humpback whale was recorded during DAS of the Morven South Marine Mammal Study Area.	Humpback whales are believed to be largely opportunistic foragers. They have been documented feeding on krill, hake and small schooling fish (e.g. herring) (Fleming *et al.*, 2016, Reidy *et al.*, 2022).	Humpback whales can travel long distances during their seasonal migration. During the warmer months, humpback whales build up their fat stores to sustain themselves throughout the winter. Humpback whales filter-feed, using several techniques e.g. herd and corral. They also disorient their prey through sounds, seafloor or using bubble net and lunge feeding (NOAA Fisheries, 2024). Any changes in prey distribution as a result of climate change could lead to changes in foraging behaviour, nutritional stress, and diminished reproduction. Furthermore, changes in water temperature and currents could impact timings of environmental cues important for navigation and migration (NOAA Fisheries, 2024).
Pinnipeds			
Grey seal	The east coasts of Scotland and northern England provide important breeding and haul-out habitats for grey seal. The UK total grey seal population size at the start of the 2022 breeding season was estimated to be 168,400 grey seals of which 129,100 (approximately 80%) were in Scotland (Stevens, 2023). Based on Carter et al. (2022) maps, mean grey seal at-sea usage within the Morven South Marine Mammal Study Area is low, as the hotspots are located closer to the shore and in the vicinity of the Berwickshire and North Northumberland Coast special area of conservation (SAC), Firth of Forth, Tay and Eden Estuaries and north of Aberdeen. Given the uncertainty associated with identification of seals to species level based on DAS, density estimates reported by Carter et al. (2022) are	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.*, 2021a). 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, whilst seals foraging in deeper waters, over sandy substrates, will target pelagic and bentho pelagic species such as blue whiting *Micromesistius poutassou* and sandeel (Gosch, 2017).	Grey seals tend to forage in the open sea, returning to land regularly to haul out. Foraging trips can be wide ranging. However, tracking studies have shown that most foraging is likely to occur within 100km of a haul-out site (SCOS, 2018). Historic Seagreen Firth of Forth Round 3 boat-based surveys (2010 – 2011) recorded highest numbers of grey seals over sandy shallow banks such as Scalp Bank, Marr Bank, Wee Bankie and Berwick Bank, which are thought to be important areas for sandeel, a key prey item of grey seal (Sparling, 2012).

Species	Distribution within the Morven South Boundary	Prey	Description
	considered the most appropriate to use and a density of 0.316 animals/km2 has been used in Volume 2, Chapter 10: Marine Mammals.		
Harbour seal	Harbour seal is widespread around the west coast of Scotland and throughout the Hebrides and Northern Isles. On the east coast of the UK, however, the distribution of this species is more restricted with concentrations in the major estuaries of the Thames, The Wash, the Firths of Forth and Tay, and the Moray Firth (Special Committee on Seals (SCOS, 2023)). Given the uncertainty associated with identification of seals to species level based on DAS, density estimates reported by Carter *et al.* (2022) are considered the most appropriate to use and a density of 3.28 x 10^{-6} animals/km^2 has been used in Volume 2, Chapter 10: Marine Mammals.	Harbour seal is a generalist feeders and diet varies both seasonally and regionally (Hammond *et al.*, 2005). Stable isotopes analysis of mercury and selenium in the blood of North Sea harbour seals revealed that typical diet is comprised of approximately 30% juvenile cod, 29% plaice and sole, and 23% monkfish (*Lophius piscatorius*), hake and haddock (Damseaux *et al.*, 2021b).	Harbour seals are a central place foragers and come ashore in sheltered waters, often on sandbanks, in estuaries and rocky areas (SCOS, 2022). To reduce time and energy searching for prey, animals are likely to travel directly to areas of previously or predictably high foraging success (Bailey *et al.*, 2014) and tend to stay within 50km of the coast, although most foraging trips are over shorter ranges (Carter *et al.*, 2022; Russell and McConnell, 2014).

Seabirds

21.10.4.8 The key seabird species which are most abundant and most likely to be impacted by Morven South (Volume 2, Chapter 11: Offshore Ornithology) are:

- Black-legged kittiwake (*Rissa tridactyla)* (hereafter referred to as "kittiwake");
- Great black-backed gull (*Larus marinus);*
- Herring gull (*Larus argentatus*);
- Common guillemot (*Uria aalge)* (hereafter referred to as "guillemot");
- Razorbill (*Alca torda)*;
- Atlantic puffin (*Fratercula arctica)* (hereafter referred to as "puffin");
- Northern fulmar (*Fulmarus glacialis)* (hereafter referred to as "fulmar");
- Northern gannet (*Morus bassanus)* (hereafter referred to as "gannet").

21.10.4.9 Seabird species diet and foraging behaviour determine the extent to which individual species are impacted and can respond to changes in prey availability. This is discussed further in Section 21.10.10. A summary of their typical feeding strategies and prey species of key seabird species that have the potential to be impacted by Morven South have been outlined in Table 21.19.

Table 21.19: Diet and feeding strategies of key seabird species

Species	Primary Feeding Strategy	Primary Feeding Location	Typical Prey Species
Kittiwake	Surface feeding	Water surface – up to 1m depth	Sandeel, herring and sprat
Great black-backed gull	Surface feeding	Water surface – up to 2m depth	Sandeel, herring and sprat, as well as molluscs and crustaceans.
Herring gull	Surface feeding	Water surface – up to 2m depth	Sandeel, herring and sprat, as well as crustaceans and bivalves.
Guillemot	Pursuit diving	Water column – up to 150m	Sandeel, herring and shad, small marine crustaceans, squid and octopus.
Razorbill	Pursuit diving	Upper water column – up to ~6.5m	Sandeel, sprat and herring
Puffin	Pursuit diving	Water column – up to 120m	Sandeel and sprats, supplemented by crustaceans, molluscs and polychaetes during the breeding season
Fulmar	Surface feeding and pursuit diving	Water surface, up to 1m depth	Sandeel, cod, pollock, herring and small crustaceans
Gannet	Plunge diving	Water column-intermediate depths up to ~30m	Mackerel, sandeel and fisheries discards

21.10.5 The key prey species

21.10.5.1 The key fish and shellfish prey species likely to be present within the Fish and Shellfish Ecology Study Area, are the small shoaling forage fish sandeel, herring, mackerel and sprat. Volume 2, Chapter 9: Fish and Shellfish Ecology identified that these fish species are IEFs for the purposes of the assessment. The abundance of each of these species within the Morven South Fish and Shellfish

Ecology Study Area and their relative importance to predators is discussed in the species summaries below.

21.10.5.2 In addition to the fish and shellfish prey species Section 21.10.4 also identified that benthic invertebrates are a key part of the food web within the Morven South Boundary. Paragraph 21.10.2.5 provides a brief overview of the benthic ecology baseline within the Morven South Benthic Subtidal Ecology Study Area. However, this only represents a small proportion of the species which comprise the wider benthic community which may act as prey for the relevant predators.

Herring

21.10.5.3 Herring is a small shoaling forage fish which is a commercially important pelagic fish. Commonly found throughout European waters, including much of the North Sea, herring filter feeds on plankton and minute sea creatures, supplemented by small sprats and fry of other fish species (British Sea Fishing, 2022a).

21.10.5.4 Nursery grounds for herring are abundant across the east Scottish and Northumberland coastlines (Ellis *et al.*, 2012). These areas serve as feeding grounds for post-larvae juveniles and sub-adults, before individuals reach sexual maturity and migrate further (International Council for the Exploration of the Sea (ICES), 2006).

21.10.5.5 Herring are listed on the Scottish Biodiversity List (SBL) and as a Priority Marine Feature (PMF) and are therefore considered a high priority species for conservation actions in Scotland (Casini *et al.*, 2004; Fauchald *et al.*, 2011). Herring are not only ecologically important, acting as prey species for fish, birds and marine mammals, but are also commercially important (Marine Scotland, 2023).

21.10.5.6 Herring are reliant on particular seabed types for spawning, as they attach adhesive eggs to aquatic vegetation of coarse substrates, which can include coarse sand, shingly, small rocks and gravel, or even broken mollusc shells (Frost and Diele, 2022). Spawning for herring usually takes place in shallow areas between approximately 15m and 40m depth.

21.10.5.7 Herring are considered highly sensitive to underwater noise due to the elaborate specialisations of their auditory apparatus and are therefore vulnerable to injury or disturbance from activities which generate underwater noise, such as pile driving (Volume 2, Chapter 9: Fish and Shellfish Ecology).

21.10.5.8 Three herring stocks exist in the North Sea, based on their spawning seasons: the Southern Bight/Downs stock spawns in the English Channel during winter, the Banks/Dogger stock spawns in the central North Sea between August and October, and the Buchan/Shetlands stock spawns off the Shetlands and Scottish coasts during summer (August and September). The Buchan sub-stock is nearest to Morven South and within the Regional Fish and Shellfish Ecology Study Area (Volume 3, Annex 9.1: Fish and Shellfish Ecology Shared Technical Report).

21.10.5.9 Herring spawning grounds are most accurately mapped using a combination of herring larval data and sediment Particle Size Analysis (PSA), as recommended by (Boyle and New, 2018).

21.10.5.10 The PSA data from all sampling stations across the Morven South Fish and Shellfish Ecology Study Area represented substrates that were classified as 'unsuitable' for herring spawning. Site specific seawater and sediment eDNA metabarcoding detected the presence of herring in a total of three of the 29 eDNA samples from within the Morven South Fish and Shellfish Ecology Study Area (Volume 2, Annex 9.1: Fish and Shellfish Ecology Shared Technical Report).

Sandeels

21.10.5.11 Sandeels, resembling small eels, predominantly feed on plankton of variable sizes, ranging from small plankton eggs up to larger, energy-rich copepods. In Scottish waters, there are five sandeel species, with the lesser sandeel and greater sandeel (*Hyperoplus lanceolatus*) being the most abundant. Lesser sandeel (hereafter referred to as "sandeel") and Raitt's sandeel *Ammodytes* *marinus* are listed as PMF and listed as protected features within the Turbot Bank MPA, which occurs within the Morven South Fish and Shellfish Ecology Study Area.

21.10.5.12 As well as being abundant in Scottish waters, sandeels are highly nutrient dense and therefore serve as the preferred prey item for several fish species, seabirds, seals, dolphins and whales. Sandeel represent an important link between the lower and upper levels of the marine food web, feeding on plankton and preyed upon by marine predators like cod, kittiwake and harbour porpoise (NatureScot, 2022).

21.10.5.13 Sandeel are highly dependent on specific habitat conditions for burial and spawning. The primary variables related to sandeel occurrence are silt, depth, sand, and slope, which are supported by sandeel fisheries data (e.g. data from Jensen *et al*. (2011)) (Volume 3, Annex 9.1: Fish and Shellfish Ecology Shared Technical Report). Greenstreet *et al*. (2010) defined four sandeel sediment preference categories, combining fine sand, three silt grades, and two coarser sand grades into two particle size classes: silt and fine sand, and coarse sand.

21.10.5.14 As described in Volume 2, Chapter 9: Fish and Shellfish Ecology and Volume 3, Annex 9.1: Fish and Shellfish Ecology Shared Technical Report, "marginal" habitat suitability was most commonly recorded using the PSA data. There was one sample station assigned as "preferred" spawning habitat suitability based on the PSA data, with several assigned as "unsuitable", using the methodology defined in Reach *et al*. (2024) and Latto *et al*. (2013). The Morven South Fish and Shellfish Ecology Study Area largely overlaps with low intensity spawning grounds (Ellis *et al*., 2012).

Mackerel

21.10.5.15 Mackerel is a small, fast, predatory fish closely related to tuna *Thunnus* spp. which hunt in vast shoals for smaller fish and sandeel. Mackerel primarily consume zooplankton and small fish and are a batch spawner which produce pelagic eggs (Fishbase, 2023). As a vital prey species for larger fish, birds and marine mammals, mackerel are listed as PMFs in Scottish waters (NatureScot, 2020).

21.10.5.16 Mackerel are migratory fish that are common throughout the UK. In the North Sea they typically arrive in spring before overwintering in the deep water to the east and north of Shetland and on the edge of the Norway Deep (Game and Wildlife Conservation Trust, 2017). Observations have been made that mackerel are arriving in UK waters earlier and leaving later every year, possibly as a result of rising sea temperatures. This has been linked to the complete absence of mackerel in areas around the south of the UK during the winter months (British Sea Fishing, 2022b). The absence of a swim bladder enables mackerel to swiftly adjust their depth, allowing them to maintain constant movement (British Sea Fishing, 2022b).

21.10.5.17 As described in Volume 3, Annex 9.1: Fish and Shellfish Ecology Shared Technical Report, there are nursery grounds for mackerel across the Regional Fish and Shellfish Ecology Study Area, with some areas of spawning ground to the east.

Sprat

21.10.5.18 Sprat is a small foraging fish which is widespread across the UK, inhabiting water depths ranging from a few metres to approximately 150m (Marine Life Information Network (MarLIN), 2008).

21.10.5.19 Sprat predominantly feed on zooplankton, fish eggs and larvae (Kvamme, 2020). Additionally sprat provide a vital food source for more or less all predatory fish species found in UK waters, as well as seabirds and marine mammals (Fish Focus, 2017).

21.10.5.20 As described in Volume 3, Annex 9.1: Fish and Shellfish Ecology Shared Technical Report, there are spawning and nursery grounds for sprat within the centre of the Regional Fish and Shellfish Ecology Study Area (overlapping with the Morven South Boundary).

21.10.6 How the food system works

21.10.6.1 The transfer of energy moves up through the trophic levels of the food chain, starting at the bottom level where primary producers like phytoplankton and seaweeds in the marine environment produce their own food by harnessing energy from the sun through the process of photosynthesis.

21.10.6.2 Phytoplankton are particularly abundant in spring/summer when there is an increase in thermal input to the surface layers, and these surface layers becomes warmer and less dense and less likely to mix with the colder deeper layer below (Venegas *et al.*, 2023). This combination of sunlight and high nutrient levels (upwelled from winter storms and river discharge) leads to a phytoplankton bloom (rapid increases in phytoplankton population abundance) (Silva *et al.*, 2021). In the North Sea, there are two established seasonal blooms, one in spring and another in summer/autumn. However, there are a number of mechanisms which can disrupt this pattern including strong winds (which encourage mixing and prevent stratification) and reduced water transparency (preventing the penetration of sunlight) (Silva *et al.*, 2021). Phytoplankton blooms end as a result of the exhaustion of surface nutrients and other factors including zooplankton grazing (Silva *et al.*, 2021).

21.10.6.3 Primary consumers, such as zooplankton, then feed on the phytoplankton to gain energy which is then transferred up each trophic level of the food chain.

21.10.6.4 The marine environment typically follows a 'wasp-waist' trophic structure, where mid-trophic level species have lower diversity, compared to high diversity in both high and low trophic levels. These mid-trophic level species are crucial in the functioning of ecosystems (Rice, 1995). The main prey species found within the Morven South Boundary are sandeel, herring, mackerel and sprat. These fish link the lowest trophic level (e.g. phytoplankton) to the highest (e.g. marine mammals) (Lynam *et al.*, 2017; Mackinson and Daskalov, 2007).

21.10.6.5 Phenology plays an important role in how the food chain operates because many species have evolved elaborate behaviour and life history strategies that favour certain periods of the year for growth and reproduction and minimise the exposure of sensitive life stages in more stressful periods (Rubao *et al.*, 2010). Any changes to phenology as a result of climate change can affect the lowest trophic levels and cause a cascade effect up through the food chain. For example, changes in sandeel populations will have a resulting effect on higher trophic species such as seabirds (Burthe *et al.*, 2012; Lynam *et al.*, 2017). This is further discussed in Section 21.10.10.

21.10.6.6 Section 21.10.4 describes the key fish, seabird and marine mammal predator species and their typical prey species. It can be noted that whilst the key prey species in Section 21.10.5 are components of most predators' diets, they vary in their importance. For example, kittiwake are more reliant on sandeel than the other key seabird species potentially present within the Morven South Boundary. Kittiwake would therefore be more sensitive to changes in sandeel distribution and availability. This is discussed further in paragraph 21.10.10.

21.10.7 Future ecosystem baseline

21.10.7.1 The EIA Regulations require that a "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 Array as far as natural changes from the baseline scenario can be assessed with reasonable effort, on the basis of the availability of environmental information and scientific knowledge" is included within the EIA Report.

21.10.7.2 If Morven South does not come forward, an assessment of the 'without development' future baseline conditions has also been carried out and is described within this section.

Climate change effects

21.10.7.3 The baseline environment for the physical and biological components of the ecosystem are subject to natural fluctuations over time. These changes will occur with or without the development of

Morven South due to natural variability. Therefore, it is important that when undertaking assessments of effects, any potential impacts must be considered within the context of the envelope of change that might occur over the timescale of Morven South. Rising sea levels, increase sea temperatures and storminess are all likely to alter the future baseline conditions. In terms of physical processes, this is unlikely to have the effect of significantly altering tidal patterns and sediment transport regimes offshore at the Morven South Boundary. The return period of the wave climates would be altered (e.g. what is defined as a 1 in 50 year event may become a 1 in 20 year event) as deeper water would allow larger waves to develop. There is, however, uncertainty in the precise impacts climate change will have on prevailing wave climates within the North Sea and beyond.

21.10.7.4 Sea surface temperatures (SSTs) around Scotland are strongly influenced by the atmosphere (heat flux) and ocean circulation (advection). Temperature variability in Scottish waters is provided regularly as part of the Scottish Ocean Climate Status Report (Hughes *et al.*, 2018). Hughes *et al.* (2018) most recent report showed that Scottish waters (coastal and oceanic) have warmed by 0.05°C to 0.07°C per decade, calculated across the period of 1870 to 2016. Figure 21.2 shows an increasing trend in SST from 1893 to 2018 in all Scottish Marine Regions (SMRs) with trends for each region also ranging between 0.05°C and 0.07°C (Marine Scotland, 2024).

21.10.7.5 Changes in temperature will affect the biological environment baseline (including benthic and intertidal ecology, fish and shellfish ecology, marine mammals and seabirds). Fish will be affected at all biological levels (cellular, individual, population, species, community and ecosystem) both directly and indirectly. For example, as sea temperatures rise, species adapted to cold water (e.g. herring and cod) will begin to disappear while warm water adapted species will become more established, creating a shift in the baseline. Changes in the stratification of water columns and plankton production may occur as a result of increased spring storms which may cause knock on effects through the food chain (Morison *et al.*, 2019). A study looking at 21 years of phytoplankton bloom data in the North Sea found a rapid delay in the onset and increased biomass of the summer blooms (Silva *et al.*, 2021). This shift in the phytoplankton bloom cycle may result in trophic decoupling (a temporal mismatch between trophic levels). Temperate marine environments may be particularly vulnerable to these changes because the recruitment success of higher trophic levels is highly dependent on synchronization with planktonic production (Edwards and Richardson, 2004). The various changes that may occur as a result of climate change are uncertain and therefore it is difficult to predict the future baseline scenario with accuracy.

21.10.7.6 Changes in ocean temperature, ocean acidification, water stratification and nutrient availability, as a result of climate change, are affecting the abundance and diversity of communities at all trophic levels (Walther, 2010). Effects have been identified over a variety of timescales. Short-term variability in environmental conditions impacts interactions between trophic levels and species (Howells *et al.*, 2017). Limitations in prey availability can adversely affect top predators, with population level changes likely to occur over longer timescales, propagating up trophic levels with prolonged exposure (Frederiksen *et al.*, 2006; Howells *et al.*, 2017).

21.10.7.7 The ability of fish species to move in response to temperature varies depending on a range of factors, including their physiological capacity to acclimatise and respond to the change as well as their degree of geographical attachment or how their prey respond. Where a species has a strong geographical attachment, the result can be a localised decline in species (Wright *et al.*, 2020). Effects on prey species are further discussed in Section 21.10.9.

21.10.7.8 There is increased research into the effect of ocean acidification on fish physiology and early survival (Wright *et al.*, 2020). As stated in paragraph 21.10.7.6, ocean acidification is a consequence of climate change due to chemical processes related to increased temperatures and increasing concentrations of carbon dioxide dissolving in seawater. The resulting decrease in pH is affecting phytoplankton which can inhibit shell generation of calcifying marine organisms and skeletal development of larval fish, with potential consequences for forage species (Riebesall *et al.*, 2013). Impacts as a result of ocean acidification are, however, difficult to predict at species and population level due to the complexity of the different trophic levels within the food web (Heath *et al.*, 2012).

21.10.7.9 Understanding climate change impacts on top predators is fundamental to marine biodiversity conservation, due to their increasingly threatened populations and their importance in marine ecosystems (Orgeret *et al.*, 2022). The long lifespans and large-scale mobility of top predators such as seabirds and marine mammals integrates information from the bottom to the top of the food chain and can serve as a sentinel of ecosystem change (Hazen *et al.*, 2019). Burthe *et al.* (2014) conducted a long-term monitoring study (36 years) which found that the majority of a wide range of seabird species (including fulmar, kittiwake and puffin) demonstrated a negative response to increased SST in terms of their population size, breeding success and adult survival. Gannets were found to be less vulnerable which could be due to their higher flexibility in foraging behaviour (particularly in terms of exploiting fisheries discards as an alternative food source) although it is more likely due to a lack of data for this species (Burthe *et al.*, 2014). Additionally, an at-sea distribution modelling study conducted by Searle *et al.* (2022) under future climate scenario UKCP09 found that two species which favoured the coldest waters, puffins and kittiwake, were most likely to respond negatively to climate warming. Furthermore, cliff nesting species, such as kittiwake and razorbill, may be more sensitive to nest failure as a result of high winds and storm surges caused by climate change (Newell *et al.*, 2015).

21.10.7.10 Overall, gannet 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.*, 2021a; Searle *et al.*, 2022). Guillemot, kittiwake, puffin and razorbill abundances have been closely linked to the success of their prey, particularly sandeel (Burthe *et al.*, 2014). Overall, modelling shows climate change will have substantial impacts on demography and abundance of seabirds in the North Sea over the 21st century, and the impacts are likely to vary, in magnitude and form, between species (Searle *et al.*, 2022).

21.10.7.11 Most marine mammal and climate change related studies to date have focused on effects of sea ice change. However, new studies are beginning to be published that consider the broader impacts of climate change on marine mammals. The main impacts are geographic range shifts, reduction/change in suitable habitats, impacts on breeding seasonality and reproductive success, impacts on community success, food web alterations and increased prevalence of disease (Bhagarathi *et al.*, 2024; Evans and Bjorge, 2013). Increased SSTs and resulting marine mammal range shifts are leading to novel interactions, increased predation risk and competition for species (Martin *et al.*, 2023; Waggitt *et al.*, 2020).

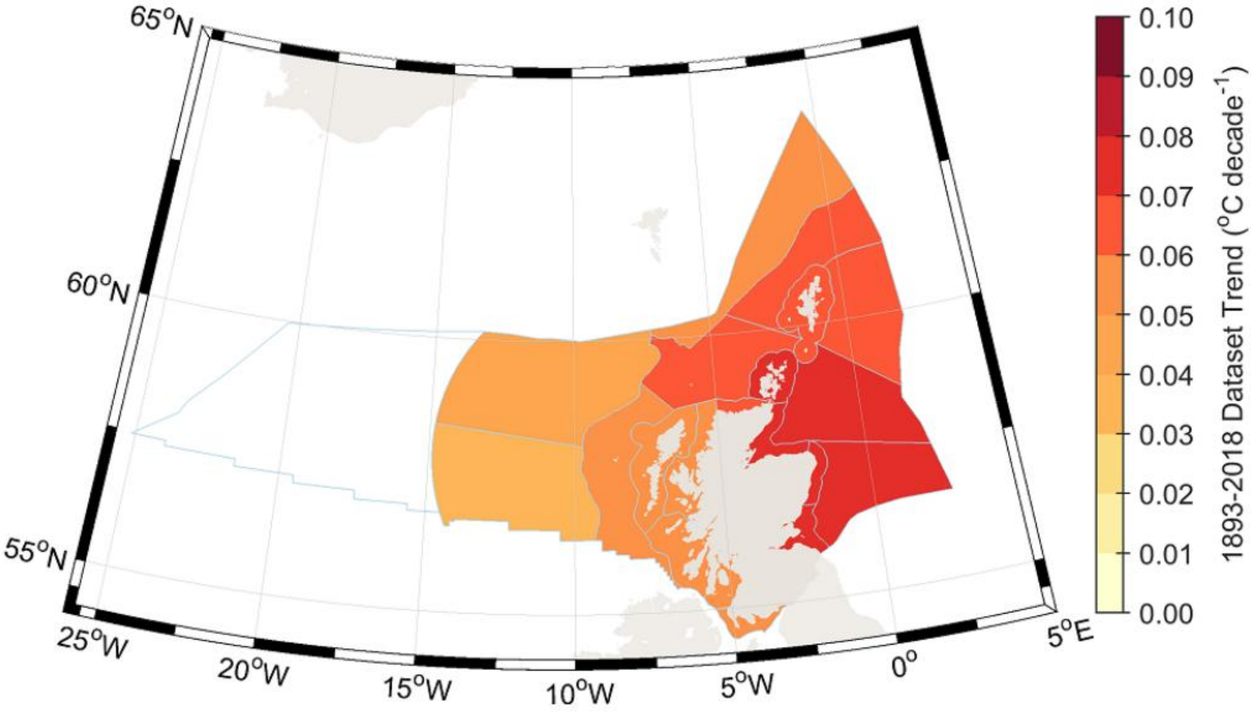

Figure 21.2: Sea surface temperature trend from the Hadley Centre Sea Ice and Sea Surface Temperature data product for the observational period (1893 to 2018) averaged by Scottish Marine Regions and offshore marine regions (Marine Scotland, 2024)

Highly Pathogenic Avian Influenza

21.10.7.12 Seabirds have been severely affected by avian influenza. The most recent Highly Pathogenic Avian Influenza (HPAI) outbreak began in 2021 and has now spread through more than 70 bird species. Between 1 October 2024 and 11 August 2025 there have been 848 cases of HPAI H5 involving 'found-dead' wild birds (Defra, 2025). The wild bird risk level across Great Britain remains at High (Defra, 2025). The virus has moved into species such as guillemot, razorbill, and kittiwake, with dead birds washing up on beaches in Wales, and along the eastern coasts of Scotland and England. At this stage, with little quantitative information, it is difficult to conclude to what extent population levels have been impacted by HPAI. One of the studies which has attempted to quantify the impact of HPAI found nine of the 13 species included in the report decreasing in numbers by over 10% since previous surveys made between 2015 and 2021 (RSPB, 2024). Further information as to how HPAI has been considered in the site specific surveys of the offshore ornithology study area can be found in Volume 3, Annex 11.1: Offshore Ornithology Baseline Characterisation Report.

Sandeel fishery closure

21.10.7.13 As described in Volume 3, Annex 9.1: Fish and Shellfish Ecology Technical Report, the highest density of the sandeel population is considered to be southwest of the Morven South Boundary, in the same area as the Firth of Forth Banks Complex MPA (17.3km from the Morven South Boundary and includes Wee Bankie, Marr Bank and Berwick Bank). However, sandeel do range across much of the North Sea. In the early 1990s, there was a substantial industrial sandeel fishery on the Wee Bankie, Marr Bank and Berwick Bank sandbanks. By 1993, landings from this area had peaked at over 100,000 tonnes (Greenstreet *et al.*, 2010). In 2000, this industrial sandeel fishery was closed, from Rattray Head to St Abbs, in response to concerns that the fishery was having a deleterious effect on sandeel stocks and as a precautionary measure to safeguard marine top predators, particularly seabirds (Scottish Government, 2023).

21.10.7.14 In 2000, the first year of the closure of the Forth and Tay SMR sandeel fishery, high levels of recruitment, combined with a lack of any significant fishing activity resulted in an immediate and substantial increase in the biomass of sandeel on the Wee Bankie sandbank (Greenstreet *et al.*, 2010). However, between 2001 and 2010, sandeel biomass steadily declined to levels that were similar to those observed when the sandeel fishery was active (Greenstreet *et al.*, 2010). This was thought to be due to the absence of sustained recruitment, meaning that predation and other causes of natural mortality still exceeded population growth (Greenstreet *et al.*, 2010).

21.10.7.15 Due to the concerns about stock levels, a sandeel fishery ban was implemented in English waters from 2021 through 2023 for UK vessels (Horton, 2022). Following the initiation of a consultation by the Scottish Government in 2023, in January 2024, the Sandeel (Prohibition of Fishing) (Scotland) Order 2024 was established, closing sandeel fishing in Scottish waters from 2024 onwards. The decision considers the role of sandeel in the marine ecosystem (Scottish Government, 2024).

21.10.7.16 Additionally, the UK government conducted a public consultation on spatial management measures for sandeel fishing in English waters of the North Sea. This consultation followed a 2021 call for evidence, revealing concerns about the impact of industrial fishing on the marine environment. Expert reports indicated that prohibiting sandeel fishing in the North Sea would benefit seabirds, other fish species, and marine mammals. Over 95% of respondents supported some form of prohibition, with a majority favouring the closure of all English waters. Consequently, the UK government decided to prohibit sandeel fishing within English waters of ICES Area 4 (North Sea) starting from 26 March 2024, before the next sandeel fishing season (Defra, 2024). A challenge was brought to this closure by the European Union which claimed the closure was 'discriminatory and disproportionate', however the Permanent Court of Arbitration ruled there was no legal obligation to reverse the closure, therefore it is still in effect (Murphy, 2025).

21.10.8 Existing pressures on prey species

21.10.8.1 Before assessing the potential effects of Morven South on prey species at an ecosystem level, it is important to understand the existing pressures on each prey species.

21.10.8.2 The North Sea is one of the most anthropogenically impacted marine ecosystems in the world (Emeis *et al.*, 2015; Halpern *et al.*, 2015). Small shoal fish in mid-level trophic levels (e.g. sandeel, herring, sprat and mackerel) experience top-down pressure from commercial fisheries. Notably, as more fish are caught, typically the size of individuals in the population falls and fish with a larger biomass form a smaller proportion of the population (Gislason and Sinclair, 2000), resulting in inefficient transfer of energy between prey and predator (Thiebaux and Dickie, 1993).

21.10.8.3 Forage fish landings constitute approximately one-third of global landings of marine fish, not including losses from bycatch discards (Alder *et al.*, 2008). Historically, sandeel have been targeted commercially for their oil and use as an animal feed and fertiliser. Despite being managed, the majority of sandeel stocks have experienced severe declines due to a combination of overfishing and the effects of climate change (NatureScot, 2022). In March 2024, the UK government introduced a prohibited sandeel fishing within English waters of ICES Area 4 (North Sea) (Defra, 2024). Further details of this sandeel fishery closure can be found in Paragraphs 21.10.7.13 to 21.10.7.16.

21.10.8.4 As described in Volume 3, Annex 9.1: Fish and Shellfish Ecology Technical Report, herring are a commercially important pelagic fish in the North Sea which was targeted in the vicinity of the Morven South Boundary. The herring stock collapsed entirely in the 1970s as a consequence of overfishing (Scottish Herring, 2023). Since then, stocks have shown signs of recovery supported by a herring recovery plan implemented for the North Sea in 1996 and a ban on discards for pelagic fisheries, including for herring, from 2015. Active management is however still required to avoid a recurrence of the collapse (Dickey-Collas *et al.*, 2010).

21.10.8.5 Bottom-up processes driven by sea temperature increases, have dominated changes to planktonic groups since the 1960s. Additionally, abiotic changes in temperature can result in bottom up food web disruption, including trophic mismatch (the match-mismatch hypothesis states that a critical factor in predator survival is a match in timing between predator feeding and prey availability (Durant *et al.*, 2013)).

21.10.8.6 These pressures propagate up and down the food chain, with midtrophic fish linking the pressures between the upper and lower trophic levels (Lynam *et al.*, 2017). The fish community in the North Sea has changed over the 20th and 21st Centuries already, shifting towards small bodied pelagic species (Engelhard *et al.*, 2010). As a result of these pressures, catch rates in the North Sea have been highly variable, however, the ICES North Sea Bottom Trawl Survey indicates that fish abundance in the North Sea has increased over the past 30 years (Shetland Fishermen's Association, 2024). Furthermore, annual surveys take place in the North Sea to sample fish species, many do not however use gear which is the most efficient at sampling small fish. A study by Parmentier *et al.* (2025) provides new estimates on the biomass densities for small demersal fish species in the southern North Sea and found that biomass of small bottom fish in the southern North Sea is substantially higher than estimated before. Despite this potentially encouraging trend, factors such as climate change are likely to have a more pronounced effect in the long-term.

21.10.8.7 The prey species present in the marine ecosystem within which Morven South occurs, are also an important food source for larger fish. For example, cod, haddock, hake, ling, plaice, saithe, tope shark, spurdog and whiting all include prey forage species in their diet such as sandeel, herring, sprat and mackerel. Additionally, diadromous fish species are also likely to feed on these species. Volume 2, Chapter 9: Fish and Shellfish Ecology, identified the following diadromous species are likely to migrate through the Fish and Shellfish Ecology Study Area: Atlantic salmon, sea trout, sea lamprey, European eel, allis shad and twaite shad.

21.10.8.8 As described in Section 21.10.7, changes to the baseline environment as a result of climate change (e.g. sea temperature increase and ocean acidification) will have effects on marine fish species across all trophic levels. In terms of prey species, sandeel and herring are particularly vulnerable to the effects of climate change.

21.10.9 Effects of Morven South on prey species

21.10.9.1 This section assesses the potential effects of Morven South on prey species and any impacts on physical processes which may impact prey species indirectly by altering their availability to food sources such as phytoplankton and zooplankton.

21.10.9.2 Information to support this assessment has been extracted from the relevant Morven South EIA Report chapters. Conclusions on likely significant effect 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

21.10.9.3 Volume 2, Chapter 8: Benthic Subtidal Ecology and Volume 2, Chapter 9: Fish and Shellfish Ecology identified that Morven South could result in the following potential impacts on fish and shellfish and benthic ecology:

- temporary habitat loss and disturbance;
- long-term habitat loss;
- colonisation of hard structures and associated fish aggregation;
- increased SSCs and associated deposition;
- underwater noise impacting fish and shellfish receptors;
- changes in physical processes;
- effects to fish and shellfish receptors due to EMFs from subsea electrical cabling.

21.10.9.4 All of the potential impacts were assessed as having minor adverse effects on benthic ecology and marine fish (including prey species) which would not result in a significant change in prey species population (Volume 2, Chapter 8: Benthic Subtidal Ecology and Volume 2, Chapter 9: Fish and

Shellfish Ecology). A summary of the assessment of these impacts is provided in the following sub-sections.

Temporary habitat loss and disturbance

21.10.9.5 As discussed in Volume 2, Chapter 9: Fish and Shellfish Ecology, in general, adult fish are able to avoid areas subject to temporal habitat disturbance as they are highly mobile. Of the key prey species, sandeel and herring are more sensitive to temporary habitat loss as they spawn on or near the seabed, however, recovery is expected to occur quickly as the sediment recovers post-construction and recolonisation occurs. Short and long-term monitoring studies of OWFs have reported that wind farm construction (Jensen *et al.*, 2004; Stenberg *et al.*, 2011) and operation (Van Deurs *et al.*, 2012) did not lead to significant adverse effects on sandeel populations in the long-term, with some localised increases in abundance in the first year following construction. More recently, the results of a post-construction monitoring study at the Beatrice offshore wind farm showed that sandeel abundance either increased or remained at similar levels when comparing abundance from 2014 to 2020, with the offshore construction phase commencing in April 2017 (Beatrice OWF Limited, 2021). One such example of an increase in sandeels was in the southeast of the Beatrice offshore wind farm where monitoring showed sandeel catch increased from 497 individuals in 2014 to 3,556 individuals in 2020 (Beatrice OWF Limited, 2021). This study reported no evidence that construction resulted in adverse impacts on the local sandeel population (Beatrice OWF Limited, 2021). Low intensity spawning grounds for sandeel were identified to be present within the Morven South Boundary (i.e. the ZoI for temporary habitat loss and disturbance; Ellis et al., 2012); however, one sample location within the Morven South Boundary recorded a preferred sandeel habitat sediment classification during site specific surveys. A site specific herring spawning habitat suitability assessment has been undertaken with the habitats present within the Morven South Boundary (and therefore the ZoI for temporary habitat loss) assigned as 'unsuitable' for herring spawning. While there is a small overlap of the Morven South Fish and Shellfish Ecology Study Area with sandeel spawning grounds, the impact is expected to be very limited within the context of available favourable sediments habitat outside the Morven South Fish and Shellfish Ecology Study Area.

Underwater noise impacting fish and shellfish receptors

21.10.9.6 Volume 2, Chapter 9: Fish and Shellfish Ecology assesses the potential impact of underwater noise which may arise due to UXO clearance and piling for the installation of wind turbine and Offshore Substation Platform (OSP) foundations. Underwater noise may result in direct and indirect impacts on fish and shellfish receptors including recoverable injury and mortality. The modelling results suggest that the thresholds for mortality will be exceeded for all fish groups. However, due to the designed-in measures adopted as part of Morven South (including low hammer initiation and ramp up/soft starts which may allow time for mobile fish and shellfish receptors to flee the area prior to full power piling beginning), this is unlikely to result in significant mortality.

21.10.9.7 Behavioural effects are expected over larger ranges. Some fish species (e.g. herring and sandeel) have physiological adaptations for improved hearing (special structures linking the swim bladder to the ear). Herring in particular are vulnerable to the effects of underwater noise as a result of their high sensitivity and specific spawning habitat requirements. As a result of the area of overlap between unmitigated piling contours is limited, compared to the wider availability of herring spawning grounds within the Regional Fish and Shellfish Ecology Study Area, and no overlap with the hotspot for herring spawning as identified from the International Herring Larval Survey (Boyle and New, 2018), the effects are unlikely to result in a measurable impact on prey species.

Increased Suspended Sediment Concentration and associated deposition

21.10.9.8 Sandeels and herring are the prey fish species most likely to be affected by sediment deposition as they spawn on the seabed (Volume 2, Chapter 9: Fish and Shellfish Ecology). The Regional Fish and Shellfish Ecology Study Area is located in an area of both high and low intensity spawning grounds for sandeel and a mix of marginal and unsuitable seabed habitat type. From desktop study, low intensity spawning grounds were identified to be present within the Morven South Boundary (i.e. the ZoI for temporary habitat loss and disturbance; Ellis et al., 2012); however, one sample location within the Morven South Boundary recorded a preferred sandeel habitat sediment classification during site specific surveys. Only a small proportion of the Morven South Fish and Shellfish Ecology Study Area will experience increased SSCs at any one time during the construction phase, as activities will be staggered both spatially and temporally. Sandeel eggs are also likely to be tolerant to some level of sediment deposition due to the nature of the re-suspension and deposition within their natural high energy environment (Ellis *et al.*, 2012). Therefore, effects on sandeel spawning populations are predicted to be limited. Sandeel populations are also sensitive to sediment type, preferring coarse to medium sands and showing reduced selection or avoidance of gravel and fine sediments (Holland *et al.*, 2005). The Feature Activity Sensitivity Tool (FeAST) identifies this pressure as 'siltation changes' (low) and has determined that sandeel have medium sensitivity to this impact (Wright *et al.*, 2000). As a result, any increase in sediment fractions, due to deposition in their habitat, may cause avoidance behaviour until the sediment is returned to baseline conditions over successive tides.

21.10.9.9 Herring utilise gravelly and coarse sand benthic environments for spawning. The habitats present within the Morven South Fish and Shellfish Ecology Study Area were all assigned as 'unsuitable' for herring spawning (Volume 2, Chapter 9: Fish and Shellfish Ecology). It has been shown that herring eggs may be tolerant of very high levels of SSC (Messieh *et al.*, 1981), such as those which may result from Morven South construction activities. However, should the deposited sediment remain *in situ* and not redispersed by current, there may be detrimental effects due to smothering (Birklund and Wijsman, 2005).

Long-term habitat loss

21.10.9.10 As discussed in Volume 2, Chapter 9: Fish and Shellfish Ecology, long-term habitat loss will arise due to the construction and operation of Morven South. As with the potential impact of temporary habitat loss and disturbance, the most sensitive prey species are sandeel and herring. They are expected to recover in the medium term as the sediments recover following installation of Morven South infrastructure, and adults and larvae recolonise the sandy sediments. Sandeel are particularly sensitive to long-term habitat loss because of their specific habitat requirements (e.g. sandy sediments) for spawning and burrowing at night and through the winter. However, while sandeel are assessed to have medium sensitivity to this impact, the impact is expected to be limited in extent, particularly in the context of available habitats in the Morven South Fish and Shellfish Ecology Study Area (0.13%) and the wider northern North Sea. Given the limited availability of highly favourable sediments within the Morven South Boundary, significant effects are not predicted.

21.10.9.11 The habitats present within the Morven South Fish and Shellfish Ecology Study Area were all assigned as 'unsuitable' for herring spawning (Volume 2, Chapter 9: Fish and Shellfish Ecology). Therefore, no herring spawning grounds will be affected by this impact.

Colonisation of hard structures

21.10.9.12 Volume 2, Chapter 8: Benthic Subtidal Ecology, Volume 2, Chapter 9: Fish and Shellfish Ecology and Volume 2, Chapter 10: Marine Mammals discussed how the introduction of infrastructure for Morven South may result in the colonisation of foundations, scour protection and cable protection. Since these hard structures are being installed in areas typically characterised by soft, sedimentary environments, the resulting change of habitat type acts like an artificial reef. Anthropogenic structures on the seabed attract many marine organisms including benthic species normally associated with hard biological structures (e.g. blue mussel) (Karlsson *et al.*, 2022). Introduced hard substrates are known to replace a flat sedimentary environment with a complex three-dimensional structure, which increases the surface area and complexity, and increases the number of available niches in which colonisation may occur (Dannheim *et al*., 2020). Additionally, man-made structures may also have direct effects on fish through their potential to act as fish aggregation devices (Petersen and Maim, 2006). It is uncertain whether artificial reefs facilitate recruitment into the local population, or if these observations are simply a result of concentrating biomass from surrounding areas (Inger *et al.*, 2009). While the reef effect can affect the existing biological soft sediment communities it can also have potentially beneficial effects on the marine ecosystem.

21.10.9.13 The introduction of species such as blue mussels may have wider impacts on the food web due to their ability to filter large amounts of water, removing phytoplankton and zooplankton which an reduce regional annual primary productivity by 8% (Slavik *et al.*, 2019). This may have knock on effects regarding food availability for prey species which utilise these food sources, however this change would only be notable with the Morven South Boundary, if at all, and is unlikely to result in a regional scale impact.

21.10.9.14 The colonisation of new habitats may potentially lead to the introduction of INNS. This may have resulting impacts on benthic and fish and shellfish populations as a result of new competition. A study into the spread of INNS by wind farm hard structure colonisation suggested the risk of this occurring was minor, however more research is required to fully understand, with implementation of precautionary built-in measures recommended to prevent spread where possible (Baulaz *et al.*, 2023). Potential adverse effects of the introduction of INNS are discussed further in Volume 2, Chapter 8: Benthic Subtidal Ecology.

21.10.9.15 Artificial reefs can act as stepping-stones allowing organisms to colonise areas outside their current distribution which can increase the connectivity between natural sub-populations (Coolen, 2017). The impacts of this can extend beyond the local scale of a single operation (e.g. Morven South) with multiple adjacent OWFs creating stepping stones across wider areas and creating a large-scale effect (Degraer *et al.*, 2020). For example, the closest three consented OWFs to Morven South are Seagreen 1 Offshore Wind Farm, Kincardine Offshore Wind Farm and Seagreen 1A Project (Volume 2, Chapter 16: Other Sea Users and Communications). This effect does not extend to benthic communities which are unlikely to be suited to the sedimentary habitats between projects and therefore will only colonise the hard structures of individual projects. Despite this, increased vessel presence could provide vectors and stepping stones for larval species and INNS. As species become established on and around the new hard structures, they can start producing larvae, with one study demonstrating that networks of oil and gas infrastructure in the North Sea could facilitate ecological connectivity by acting as stepping stones for larval connectivity (Henry *et al.*, 2018). There is some evidence (although with uncertainties) that some fish and shellfish populations are likely to benefit from introduction of hard structures. See further details on the effects of the colonisation of hard structures on benthic and fish and shellfish ecology below.

Benthic ecology

21.10.9.16 A review by Degraer *et al.* (2020) explained the process by which rapid colonisation can occur on all submerged parts of wind turbine components. These introduced substrates may only be suitable for colonisation following weathering, the loss of any surface contaminants, the production of biofilms and the subsequent community succession and development after settlement of new species (Chase, 2015; Thompson *et al.*, 1998).

21.10.9.17 Vertical zonation of species is usually observed with different species colonising the splash, intertidal, shallow and deeper subtidal zones (Degraer *et al.*, 2020). Colonising communities on offshore installations are typically dominated by mussels, macroalgae and barnacles near the water surface, which essentially creates a new intertidal zone, while the community is dominated by filter feeding arthropods at intermediate depths, and by anemones at deeper locations (De Mesel *et al.*, 2015; Karlsson *et al.*, 2022). Colonisation of the hard substrates associated with Morven South is therefore likely to result in an increase in biodiversity and a change compared to the baseline, if no hard substrates were present (Lindeboom *et al.*, 2011). In addition, the structural complexity of artificial substrates such as OSP foundations and wind turbine foundations may provide refuge as well as increasing feeding opportunities for larger and more mobile species. For example, Mavraki *et al.* (2020), demonstrated higher food web complexity associated with zones which had high accumulation of organic material (such as soft substrate or scour protection), suggesting potential reef effect benefits from the presence of artificial hard structures.

21.10.9.18 Colonisation of hard structures may have indirect effects on the baseline communities and habitats identified within the Morven South Boundary due to increased predation on and competition for the existing soft sediment species. These effects are difficult to predict, especially as monitoring to date has focused on the colonisation and aggregation of species close to the wind turbine foundations rather than broad scale studies.

21.10.9.19 Some studies have also shown that the installation and operation of OWFs has a negligible impact on the soft sediment environments. De Backer *et al.* (2020) found that the soft sediment benthic community experienced no drastic changes eight to nine years after the installation of C-power and Belwind OWFs in Belgium and that the species originally inhabiting the sandy substrate were still present and remained dominant in the OWFs. Hutchison *et al.* (2020) found that, during post-construction monitoring at the Block Island Wind Farm in the USA, no strong gradients of change in sediment grain size, enrichment or benthic macrofauna within 30m to 90m distance of the wind turbines were observed. APEM (2022) found that at the Beatrice Offshore Wind Farm in the Moray Firth, colonisation of wind turbines resulted in zonation of the foundation itself and had little influence on the sedimentary habitat below. Across all wind turbines, plumose anemones (*Metridium senile)* and tube worms (*Spirobranchus* sp.) were the most abundant species, with the highest biomass at 40m depth. Similarly, at the Hywind Scotland Pilot Park off the coast of Aberdeenshire, plumose anemones and tube worms dominated the bottom and mid-section of wind turbines, and a general increase of epifouling growth between 2018 and 2020 was recorded, indicating a source of food was present (Karlsson *et al.*, 2022). A recent study by Lefaible *et al.* (2025) found a much smaller area of enrichment (within 15m of the scour protection layer, beyond which the communities resembled the control sites) surrounding two Belgian wind farms 10 to 13 years post-installation. These communities exhibited a higher average species richness, abundance and functional richness.

21.10.9.20 The MDS assumes that up to 3,074,239m^2 of artificial hard substrate will be installed on the seabed within the Morven South Boundary. This comprises wind turbines and OSPs, scour protection, cable protection, and cable crossing protection. It is expected that these artificial hard structures will be colonised by epifaunal species local to the Morven South Boundary (Volume 2, Chapter 8: Benthic Subtidal Ecology).

21.10.9.21 The ocean quahog IEF require a sedimentary habitat, and physical change to hard substratum as a result of the installation of Morven South would represent habitat loss for these species, which are highly vulnerable to this impact (Tyler-Walters and Sabatini, 2017).

Fish and shellfish ecology

21.10.9.22 As discussed in Volume 2, Chapter 9: Fish and Shellfish Ecology, the introduction of hard structures can have direct and/or indirect effects on fish species, such as:

- direct effect on fish through the potential to act as fish aggregation devices;
- indirect effects on fish through the potential of the reef effect to bring about changes to food resources.

21.10.9.23 The colonisation of hard structures by epifaunal species may result in the increased availability of prey species, potentially resulting in increased numbers of fish and shellfish species utilising the hard structures.

21.10.9.24 The installation of hard structures, such as wind turbine and OSP foundations, may lead to their colonisation by fish and shellfish species. The initial colonisation may occur within hours or days of the hard substrates installation and will likely be composed of demersal and semi-pelagic species (Andersson, 2011). The colonisation may then proceed for a number of years following installation, until a fully structured community has established (Krone *et al.*, 2013). The colonisation of these structures, with their complex communities, may attract fish from the surrounding areas which will then increase the carrying capacity of the area (Andersson and Öhman, 2010; Bohnsack, 1989). Studies of fish distributions before and after installation of OWFs have demonstrated that some species, such as cod, spend at least part of their life cycles closely associated with these artificial structures (Bergström *et al.*, 2013; Reubens *et al.*, 2014). Increased availability of prey species associated with artificial hard structures may enhance settlement, survival, and/or growth of their predators, such as cod and other gadoids, and allow them to conserve energy (Schwartzbach *et al.*, 2020). The extent and nature of the communities established as a result of colonisation will be determined by the dominant natural seabed substrate of the Morven South Fish and Shellfish Ecology Study Area (primarily deep circalittoral sand as well as deep circalittoral coarse sediment and deep circalittoral mixed sediment). For example:

- Hard structures installed in areas where the seabed is already characterised by rocky substrates, resulted in fewer new species but higher overall abundance (Andersson and Öhman, 2010).
- Hard structures installed on a sedimentary seabed, may result in increased diversity of fish more commonly associated with rocky habitats (Andersson *et al.*, 2009). This will result in a shift in baseline species assemblage as the original soft-bottom population will be displaced (Desprez, 2000).

21.10.9.25 However, monitoring conducted at Lillgrund OWF in the Öresund Strait in southern Sweden (the longest monitoring programme of its kind), showed no overall decrease in fish abundance although distribution had shifted towards the wind turbine foundations for some species (i.e. cod, eel and eelpout) (Andersson, 2011). More species were recorded after construction than before, which supports the hypothesis that the introduction of hard structures may result in a localised increases in biodiversity sedimentary environments. Uncertainty remains regarding whether:

- artificial reefs facilitate recruitment in the local population;
- the effects are simply a result of concentrating biomass from surrounding areas (i.e. additionality vs aggregation) (Inger *et al.*, 2009).

21.10.9.26 Some papers are beginning to assess population level changes in some species and to quantify observations of recolonisation (Bouma and Lengkeek, 2013; Krone *et al.*, 2013), with hard structures consistently increasing species richness in the long-term, but changing community composition with shellfish dominating hard structures communities, thus having an impact of local ecological function (Coolen *et al.*, 2020).

21.10.9.27 Post construction fisheries surveys conducted for the Barrow and North Hoyle OWFs found no evidence of change in fish abundance at either site as a result of the presence of the OWF infrastructure (BOWind, 2008; Cefas, 2009). Therefore any effects are likely to be highly localised and while of uncertain duration, the evidence suggests effects are potential beneficial in some cases, although uncertainty does exist surrounding this issue. Monitoring of fish populations around an offshore wind farm off the coast of the Netherlands indicated that they acted as a refuge for cod (Lindeboom *et al.*, 2011; Winter *et al.*, 2010). Similarly, horse mackerel, mackerel, and sprat, have been reported to utilise artificial hard structures for spawning and/or predation on the newly developed community (Degraer *et al.*, 2020; Glarou *et al.*, 2020).

21.10.9.28 Crustacean species such as crabs and lobsters are likely to experience the greatest potential benefit from the introduction of hard structures. Evidence has been found that foundations can provide new potential sources of food (as a result of the colonising benthic communities), new potential habitat/refuge, and potentially hatchery and nursery grounds for several crab species (BioConsult, 2006; Hooper and Austen, 2014; Linley *et al.*, 2007). Evidence from post-construction monitoring surveys at the Horns Rev offshore wind farm in the North Sea suggest that hard structures are particularly suitable for edible crab hatchery and nursery grounds, as well as several other species (Vattenfall, 2006). These surveys also reported that crustacean larvae and juveniles could rapidly colonise the hard structures associated with the wind farm (Vattenfall, 2006).

21.10.9.29 Other shellfish species may also be able to expand their habitat as a result of the newly available hard structures. Krone *et al.* (2013) found that over a three-year period platform piles were colonised by three key species blue mussel, the amphipod *Jassa* spp. and anthozoans (mainly *Metridium senile*).

21.10.9.30 It is unlikely that diadromous fish will utilise the increase in hard structures within the Morven South Fish and Shellfish Ecology Study Area as they are only likely to interact with the structures during their migration to and from rivers located on the east coast of Scotland. Therefore, the reef effect is not anticipated to effect diadromous fish species numbers or behaviour.

21.10.9.31 There is, however, potential for impacts upon diadromous fish species due to increased predation by marine mammals. Data from Dutch and UK wind farms provides evidence that tagged grey and harbour seal were utilising wind farm sites as foraging habitats (Russell *et al.*, 2014). However, a further study, also using tagging data, concluded that there was no change in seal behaviour within the offshore wind farm (McConnell *et al.*, 2012). It is therefore not certain exactly to what extent seals utilise OWFs, as these results may be site specific. Effects on marine mammals as a result of the colonisation of hard structures is discussed further in Section 21.10.10. Research has shown that Atlantic salmon smolts spend little time in the coastal waters, making their way to feeding grounds swiftly after maturation (Gardiner *et al.*, 2018; Newton *et al.*, 2021; Newton *et al.*, 2019; Newton *et al.*, 2017), therefore they are at low risk of impact from increased predation (see Volume 3, Annex 9.1: Fish and Shellfish Ecology Shared Technical Report for further detail on Atlantic salmon migration).

21.10.9.32 In comparison, sea trout utilise the coastal environment more than Atlantic salmon. Sea trout are generalist, opportunistic feeders with their diet comprising mainly of fish, crustaceans, polychaetes and surface insects depending on the season (Knutsen *et al.*, 2001; Rikardsen *et al.*, 2006). As there is potential for increase in juvenile crustacean species and other shellfish species, which are possible prey items for sea trout, foraging sea trout may be attracted to the hard structures introduced by Morven South, which could in turn lead to increased predation by seal species. There is little evidence at present however documenting an increased abundance of sea trout around offshore wind turbine foundations and sea trout abundance is typically greater inshore. Therefore, it is unlikely that sea trout will be attracted to foundations to forage resulting in a low risk of impact from increased predation from marine predators in the Morven South Fish and Shellfish Ecology Study Area.

Changes in physical processes

21.10.9.33 Beyond the effect of Morven South infrastructure on the seabed, the presence of the turbine and OSP foundations can result in changes to physical processes such as nutrient cycling and vertical mixing of the water column. The enhanced vertical mixing, and decreased stratification, caused by wind turbine infrastructure. Modelling found that at the onset of stratification as a result of Morven South infrastructure, particularly OSP structures due to the size of the obstruction within the water column, mixing was seen to penetrate the thermocline but did not persist through the remainder of the water column to the seabed. Although mixing was evident in the simulations, changes in temperatures due to the infrastructure were less than 0.22% of baseline values following a spring neap cycle, with a stratified water column remaining at the end of this period. However at peak stratification temperature changes reached up to 2.7% of baseline values, with a reduction in surface water temperatures and increase in temperatures through the water column due to vertical mixing, penetrating deeper than during the onset of stratification. The extent of changes of this magnitude remain within the Morven South Physical Processes Study Area (Volume 2, Chapter 7: Physical Processes). Overall it is anticipated that there would be no notable significant impact on the position of the thermocline or breakdown in seasonal stratification due to the infrastructure, although there may be marginally more mixing within the water column. With regard to wind effects on seasonal stratification, a reduction in wind wake which occurs primarily at hub height is anticipated to have very limited effect on stratification though the water column. Any increase in stratification due to a reduction in wind speed would have an opposing effect to any potential reduction in stratification due to the presence of infrastructure within the water column. Any changes to seasonal stratification are considered to be highly localised and will not result in wide scale changes to the tidal front. A full assessment of the impact of Morven South on stratification is provided in Volume 2, Chapter 7: Physical Processes.

21.10.9.34 Although impacts relating to mixing and stratification have been concluded to be at most minor adverse (Volume 2, Chapter 7: Physical Processes), this assessment provides consideration to the potential knock-on consequences to primary productivity and higher trophic levels from impacts to seasonal stratification. Changes in stratification have the potential to attract fish during the O&M phase due to the increase in plankton available. OWFs can reduce local wind stress, which can cause a reduction and/or increase in upwelling intensity depending on the location within the site, and therefore nutrient availability (Raghukumar *et al.*, 2023). Measurements undertaken around a wind turbine foundation in the southern North Sea identified a well-defined band of colder, more saline water at the surface and warmer, less saline water near the seabed (Hendriks *et al.*, 2025). This change in hydrodynamic conditions was confined to within a width of approximately 70m and length 400m downstream of the monopile (Hendriks *et al.*, 2025).

21.10.9.35 These changes in hydrodynamics have the capacity to impact plankton abundance. Modelling undertaken by Zampollo *et al.* (2025) found the presence of OWFs (Inch Cape Offshore Wind Limited, Neart na Gaoithe Offshore Wind Limited, and Seagreen Wind Energy Limited) resulted in a 7% decrease in chlorophyll (indirect measure of phytoplankton concentration) within the wider Firth of Forth study area, with the decrease being more pronounced during the bloom period, with a small increase in chlorophyll in the post-bloom period. Uncertainty still exists in the relationship between stratification and primary productivity changes caused by offshore wind turbine infrastructure and this research was caveated by a suggestion that the effects observed are likely dependent on the spatial and temporal resolution of the data, with large scale analysis masking smaller scale variation. Other research has indicated modelled primary productivity increases of up to 8% within offshore wind farm areas (Slavik *et al*., 2019, van der Molen *et al*., 2014). However this result is however supported by further modelling based on Dutch and German wind farms found a maximum 60% decrease in primary production (the conversion of inorganic compounds to organic matter (e.g. through photosynthesis)) based on a 2031 scenario as a result of increases suspended particle matter. Some scenarios modelled did find an increase in primary production, however, this was attributed to an increase in algae at the modelled site. The interaction between stratification changes and primary productivity has been highlighted as a priority for future research due to the uncertainty arising from existing models (Isaksson *et al*., 2023).

21.10.9.36 Any changes to primary production and the availability of phytoplankton will have immediate impacts throughout the food web, firstly on zooplankton (e.g. krill, jellyfish and fish larvae) who often rely on phytoplankton as their primary food source.

21.10.9.37 The potential disturbance resulting from Morven South is expected to be highly localised and therefore unlikely to result in any changes to plankton availability which would disrupt the further levels of the food web, including prey fish species.

<u>Effects to fish and shellfish receptors due to Electromagnetic Field from subsea electrical cabling</u>

21.10.9.38 The operation of inter-array and interconnector cables within the Morven South Fish and Shellfish Ecology Study Area may result in emissions of localised EMFs which may affect some fish species. It is common practice to block the direct electrical field using conductive sheathing, meaning that the only EMFs that are emitted into the marine environment are the magnetic field and the resultant induced electrical field. Some groups of fish, particularly elasmobranchs (i.e. sharks, rays and skates) and shellfish species are able to detect magnetic fields. In general, the range over which the marine fish IEFs could detect EMFs associated with Morven South is limited to a scale of metres around the subsea cables (Bochert and Zettler, 2006; Hutchison *et al.*, 2021; Snyder *et al.*, 2019). Demersal marine fish IEFs (such as sandeels) are more likely to come into the zone of influence of the cables and thus encounter higher EMF levels when near them. Demersal species are also likely to be exposed for longer periods of time and could be more constrained in terms of lateral location than pelagic species. However, EMF undergoes rapid decay with horizontal and vertical distance (Bochert and Zettler, 2006) (i.e. within metres) creating a highly localised impact.

21.10.9.39 A study investigating the effect of EMFs on sandeel larvae spatial distribution found that there was no effect on the larvae (Cresci *et al.*, 2022), and a prior study concluded the same for herring (Cresci *et al.*, 2020).

Conclusion

21.10.9.40 The impacts resulting from all phases of Morven South (construction, O&M and decommissioning) which are relevant to prey species include temporary habitat loss and disturbance, underwater noise impacting fish and shellfish receptors, long-term habitat loss, colonisation of hard structures, increased SSCs and associated deposition, changes in physical processes and effects to fish and shellfish receptors due to EMFs from subsea electrical cables.

21.10.9.41 Of the identified impacts, colonisation of hard structures is the only one that has the potential to lead to changes in prey species through potential reef effect and fish aggregation. Research regarding the effect of OWFs specifically is limited and, therefore, it is uncertain to what degree this may occur. However, any beneficial effects are predicted to be highly localised and not significant and there is potential for adverse effects as a result of an increase predation on the aggregated prey. The adverse impacts of hard structures in the water column are captured by the impact of long-term habitat loss and changes in physical processes.

21.10.10 Effects of Morven South on predator species

21.10.10.1 This section assesses the sensitivity of predators species within the fish, seabird and marine mammal receptor groups to factors such as prey availability which may be affected by Morven South, and draws on the conclusions of Section 21.10.9 to determine if there are any potentially significant effects on predators as a result. Prey availability is one of the most important controls of species abundance and distribution in the higher trophic levels (Lynam *et al.*, 2017; Mitchell and Harborne, 2020). The likelihood of increased predation of key prey species as a result of Morven South is, however, considered highly unlikely due to the mobile nature of both prey and predator species and therefore has not been assessed further.

Piscivorous fish

21.10.10.2 The key prey species of the piscivorous fish within the Morven South Fish and Shellfish Ecology Study Area are listed in Section 21.10.4, which highlights that these fish species have varied diets comprising of small fish as well as invertebrates, molluscs and crustaceans. Due to their broad diets the fish predator species are less likely to be sensitive to changes in the availability of key prey species such as sandeel, herring, mackerel and sprat.

21.10.10.3 As discussed in Section 21.10.9, the impact associated with Morven South were not assessed to have significant adverse effects on fish and shellfish ecology receptors (including prey species) and, therefore, there would be no significant change to prey species populations. The colonisation of hard structures, such as wind turbine and OSP foundations has the potential to lead to localised increases in fish populations as a result of potential reef effects and fish aggregation. The magnitude of this impact is not currently well understood; however, it is considered to have some a beneficial effect. The assessments of effects concluded any increases would be localised and did not conclude that Morven South would lead to a significant increase in prey species.

Marine mammals

21.10.10.4 Marine mammals are likely to benefit from locally increased food availability and/or shelter and, therefore, have the potential to be attracted to forage within an offshore wind farm. Species such as harbour porpoise, minke whale, white-beaked dolphin, harbour seal and grey seal have been frequently recorded around offshore oil and gas structures (Delefosse *et al.*, 2018; Lindeboom *et al.*, 2011; Todd *et al.*, 2015). However, little is known about the how their distribution is linked to the reef effect or sheltering effect. Fernandez-Betelu *et al.* (2022) deployed an array of Cetacean Porpoise Detectors within the vicinity of four offshore structures. The probability of porpoise occurrence and foraging activity was found to decrease with distance from offshore structures. These findings demonstrated that marine mammals are attracted to man-made structures (Fernandez-Betelu *et al.*, 2022). Acoustic results from a towed passive acoustic monitoring device measurement within a Dutch wind farm found that relatively more harbour porpoise were found in the wind farm area compared to the two reference areas (Lindeboom *et al.*, 2011; Scheidat, 2021). 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. Further evidence suggesting that wind farms are used for foraging includes a study by (Russell and McConnell, 2014) where the movements of tagged harbour seals commonly exhibited grid-like movement patterns within two active wind farms in the North Sea. 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. Whilst there is some evidence of potential benefits of man-made structures in the marine environment (Coolen *et al.*, 2020), 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).

21.10.10.5 Regarding the reef effect, the assessment of effects on prey in Section 21.10.9 concluded any increases would be highly localised and were unlikely to lead to a significant increase in prey species. For example, sandeel, a popular prey species for harbour porpoise and minke whale, have specific sediment requirements in regards to their habitat conditions and are therefore unlikely to be attracted to the hard structures installed as part of Morven South.

21.10.10.6 Marine mammals forage over extensive distances and exploit a wide range of different prey items. As the potential impacts of construction on prey availability will be localised and largely restricted to the Morven South Boundary, in context of the wider available foraging habitat within the northern North Sea, the area of impact is very small. The fish and shellfish communities found within the Morven South Fish and Shellfish Ecology Study Area (see Volume 2, Chapter 9: Fish and Shellfish Ecology) are representative of fish and shellfish assemblages across the northern North Sea. It is therefore reasonable to assume that, due to the highly mobile nature of marine mammals, that a localised change such as that described in Section 21.10.9 would have an insignificant effect on the prey resources available in the wider area surrounding Morven South.

21.10.10.7 Conversely, an increase in foraging distances due to reductions in prey would result in an increased energetic cost. This effect is particularly detrimental for harbour porpoise due to high metabolic rate and limited energy storage capacity, which limits their ability to buffer against diminished food. Despite this, if marine mammals do have to increase their foraging distances, the impacts are expected to be largely short-term and reversible (i.e. elevated underwater noise would occur during certain activities such as site investigation surveys, vessel activity, UXO clearance and piling) and noise levels are likely to return to the baseline following the cessation of these activity.

21.10.10.8 In Volume 2, Chapter 10: Marine Mammals, minke whale were highlighted as being particularly vulnerable to potential changes in sandeel populations, particularly in the event that abundance becomes reduced. Minke whale stomach content analysis found that in the North Sea sandeel is their key food resource, followed by clupeids and to a lesser extent mackerel (Robinson and Tetley, 2005, Tetley *et al.*, 2008); see Volume 3, Annex 10.01: Marine Mammals Shared Baseline Technical Report for more details. However, modelling by Langton *et al.* (2021) shows that the Morven South Marine Mammal Study Area has extremely low probability of sandeel presence, with areas where predicted density is high closer to the coasts or towards the Firth of Forth.

Seabirds

21.10.10.9 It is challenging to separate the effects of different pressures on seabirds (as done for prey species in Section 21.10.9), due to the complexity of their interactions, 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).

21.10.10.10 As discussed in Section 21.10.9, potential reductions in availability or shifts in the distribution of prey species means seabirds are having to increase their foraging distances. 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 in close proximity to the declining colonies is further amplified by increased competition, both intra-specific and inter-specific, which forces birds to forage further from their colonies.

21.10.10.11 There are notable differences in the responses of seabird species to changes in prey availability. Generalist species, such as gulls, have a varied diet and are therefore more resilient to these changes. Whereas specialist species, such as kittiwake, predominantly prey on small fish (such as sandeel and herring) and struggle to adapt to changes in prey availability as easily (Furness and Tasker, 2000).

21.10.10.12 Changes to prey distribution within the water column, resulting from changes to stratification or temperature, will affect surface feeding species (e.g. kittiwake and gulls) differently to water column feeding species (e.g. gannet). Typically, water column feeding species can adapt better to changes in prey availability as they are not restricted to prey available in the upper 1m to 2m 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 Morven South are detailed in Table 21.19.

21.10.10.13 One direct example of the link between prey availability and seabird populations is sandeel and kittiwake. The presence of sandeel has been linked to the reproductive success and survival of kittiwakes (Carroll, 2017; Frederiksen *et al.*, 2006; Frederiksen *et al.*, 2004). During April and May, adult kittiwakes predominantly consume older sandeel (1+ year group), transitioning to juvenile (0 year group) sandeel in June and July while rearing chicks (Lewis *et al.*, 2001). This dietary pattern aligns with the annual cycle of sandeel as 1+ year sandeel group are active in the water column during spring. The 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 lipid reserves they have accumulated during spring and summer (Wright and Bailey, 1996).

21.10.10.14 Sandeel stock levels have seen significant reductions as a result of climate change and commercial fisheries (as detailed in Section 21.10.8) which may contribute to the decline of kittiwake (Carroll, 2017) as well as other seabirds. In the Firth of Forth region, a decline in the average length-at-age of both the 0 year group and 1+ year group sandeels brought to puffin chicks on the Isle of May indicated a considerable decline in prey quality between 1973 and 2015 (Wanless *et al.*, 2018). This trend can also be applied to kittiwake populations. It is estimated that the energy content of sandeel decreased by around 70% and 40% for 0 year and 1+ year sandeel groups, respectively, potentially leading to a significant change in the diet or behaviour of seabirds that rely on sandeel species (Wanless *et al.*, 2018).

21.10.10.15 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 (Wanless *et al.*, 2018). Sprat feed and spawn repeatedly throughout spring and summer in coastal and offshore waters are therefore more abundant, 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).

21.10.10.16 Overall, the construction and operation of Morven South 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 broad diet (Table 21.19), allowing them to adapt to short temporal changes in prey availability due to construction activities. This impact is further discussed in Volume 2, Chapter 11: Offshore Ornithology.

21.10.10.17 The majority of marine fish species are not expected to be affected by habitat loss due to their mobile nature. Species such as sandeels and herring are more sensitive to this impact due to their specific habitat requirements however due to the limited area of the impact and the limited area of suitable habitat within the Morven South Boundary, significant effects are not predicted. As discussed in Section 21.10.9, sandeel are particularly vulnerable to long-term habitat and disturbance. However, the effects are unlikely to result in a measurable impact on fish and shellfish receptors.

21.10.10.18 The assessment conducted in Volume 2, Chapter 9: Fish and Shellfish Ecology of the Morven South EIA Report determined that during the construction phase the impact to all fish and shellfish receptors is considered to be of minor adverse significance. Construction works will be spatially and temporally limited, covering only a small portion of the Morven South Boundary at any one time.

Construction impacts are restricted to the duration of the construction phase (5 years), and once construction has finished, the adverse impacts will cease and any change on prey species will likely be reversed.

21.10.10.19 During the O&M phase the impact to all fish and shellfish species is considered to be of minor adverse significance (Volume 2, Chapter 9: Fish and Shellfish Ecology). Temporary habitat loss will occur as a result of jack-up usage for maintenance at wind turbines and OSPs (777,000m^2 over the 35-year lifecycle), and also due to disturbance caused by repair and reburial of inter-array and interconnector cables (5,152,000m^2 and 2,038,400m^2, respectively). The MDS is for up to 7,967,400m^2 of temporary habitat loss and disturbance during the O&M phase. This equates to a relatively small proportion of the total Morven South Fish and Shellfish Ecology Study Area (4.38%). It should also be noted that only a small proportion of the total temporary habitat loss and disturbance is likely to be occurring at any one time over the 35-year operation phase of Morven South. During the O&M phase, changes to prey availability are expected to be minimal due to the limited extent of this impact within this phase of the project and the wide availability of similar foraging grounds in this region.

21.10.10.20 Overall, generalists such as gannet, herring gull and lesser black-backed gull are thought to be able to adapt to the impacts of climate change, due to their wider variety of prey, but they may be sensitive to controls on fisheries discards (Johnston *et al.*, 2021b). The abundances of more specialised seabirds, such as guillemot, kittiwake, puffin and razorbill, have been closely linked to the success of their prey, making them likely to be more vulnerable to bottom-up climate change impacts (Burthe *et al.*, 2014; Johnston *et al.*, 2021b). 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.*, 2018; Camphuysen *et al.*, 1999; Heubeck *et al.*, 2011; Morley *et al.*, 2014). Cliff nesting species, such as kittiwake and razorbill, may also be sensitive to nest failure in high winds and storm surges as a result of climate change (Newell *et al.*, 2015).

21.10.10.21 Climate change has been identified as the likely primary cause of decline in seabird populations in the future. It is believed that the absence of Morven South 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.

21.11 Conclusion

21.11.1.1 The inter-related effects for all topics have been assessed and are detailed above. It has been concluded that the inter-related effects across the lifetime of Morven South will not result in combined effects of greater significance than the assessments presented for each of the individual phases and therefore the effect is not significant in EIA terms. It has also been concluded that multiple effects will not interact in a way that is likely to result in greater significance than those assessments presented for individual receptors. None of the potential impacts arising from Morven South alone or in combination with other projects, will result in significant adverse effects on prey species and predator species.

21.11.1.2 The ecosystem effects assessment concluded that whilst colonisation of hard structures has the potential to lead to localised changes in fish species through potential reef effects, any increases would be localised and are not expected to lead to a significant increase or decrease in prey species.

21.11.1.3 Predator species most vulnerable to changes in prey availability arising from Morven South impacts include harbour porpoise, minke whale and kittiwake. However, as significant changes to prey species as a result of the Morven South alone and in combination with other projects are not predicted, significant effects on the key predator species are also not predicted.

21.11.1.4 It is concluded that there will be no significant adverse effects on seabirds arising from changes in the behaviour or availability of prey species for seabirds as a result of Morven South. As outlined above, the majority of seabird species have a variety of target prey species and have large foraging ranges, meaning that they can forage for alternative prey species or move to other foraging areas if prey becomes temporarily unavailable due to construction activities.

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