BERWICK BANK WIND FARM
ENVIRONMENTAL IMPACT ASSESSMENT REPORT

Volume 2, Chapter 20: Inter-Related Effects

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20.1. INTRODUCTION

20.1.1. OVERVIEW

1. This chapter of the Offshore Environmental Impact Assessment (EIA) Report presents the assessment of the likely significant effects (as per the "EIA Regulations") on the environment of the Berwick Bank Wind Farm offshore infrastructure which is the subject of this application (hereafter referred to as "the Proposed Development") in relation to inter-related effects. Specifically, this chapter considers the potential impacts of the Proposed Development seaward of Mean High Water Springs (MHWS) during the construction, operation and maintenance, and decommissioning phases.
2. Likely significant effect is a term used in both the "EIA Regulations" and the Habitat Regulations. Reference to likely significant effect in this Offshore EIA Report refers to "likely significant effect" as used by the "EIA Regulations". This Offshore EIA Report is accompanied by a Report to Inform Appropriate Assessment (RIAA) which uses the term as defined by the Habitats Regulations Appraisal (HRA) Regulations.
3. The assessments presented within this chapter have drawn upon individual chapters relevant assessment of effects and conclusions and their associated appendices in this Offshore EIA Report including:
   - volume 2, chapter 7: Physical Processes;
   - volume 2, chapter 8: Benthic Subtidal and Intertidal Ecology;
   - volume 2, chapter 9: Fish and Shellfish Ecology;
   - volume 2, chapter 10: Marine Mammals;
   - volume 2, chapter 11: Offshore and Intertidal Ornithology;
   - volume 2, chapter 12: Commercial Fisheries;
   - volume 2, chapter 13: Shipping and Navigation;
   - volume 2, chapter 14: Aviation, Military and Communications;
   - volume 2, chapter 15: Seascape, Landscape, Visual Resources;
   - volume 2, chapter 16: Cultural Heritage;
   - volume 2, chapter 17: Infrastructure and Other Users;
   - volume 2, chapter 18: Offshore Socio-Economics and Tourism; and
   - volume 2, chapter 19: Water Quality.
4. This chapter is split into two parts. The first part contains a receptor based inter-related effects assessment (section 20.6), and the second part provides an ecosystem effects assessment (20.7). In addition to volume 2, chapters 7 to 19 listed above, the Ecosystem Effects Assessment draws upon volume 3, appendix 20.1.

20.1.2. PURPOSE OF THIS CHAPTER

5. The primary purpose of the Offshore EIA Report is outlined in volume 1, chapter 1. It is intended that the Offshore EIA Report will provide the Scottish Ministers, statutory and non-statutory stakeholders with sufficient information to determine the LSEs of the Proposed Development on the receiving environment.
6. In particular, this Offshore EIA Report chapter presents:
   - the receptor groups considered within the inter-related effects assessment;
   - the potential for effects on receptor groups across the three key project phases (construction, operation and maintenance 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; and
   - the inter-related effects across different trophic levels of the ecosystem, from prey species to predators.
7. 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" (SCBD, 2012). The purpose of the ecosystem based approach is to assess how the LSEs associated with the Proposed Development may interact through the ecosystem, affecting the environment.

20.1.3. STUDY AREA

8. Due to the differing spatial extent of effects experienced by different offshore receptors, the study area for potential inter-related effects varies according to topic and receptor. The potential inter-related effects considered in this chapter are, therefore, also limited to the study areas defined in each of the topic specific chapters outlined in paragraph 3.
9. As the largest study area relates to offshore ornithology, this is the maximum limit of the inter-related effects study area.
10. As part of the consultation process, some topic chapters from those included in paragraph 3 have been excluded from further inter-related effects assessment. The rationale for this exclusion is presented in section 20.3 (see Table 20.1).

20.2. POLICY AND LEGISLATIVE CONTEXT

11. The policy and legislative context for the Proposed Development is set out in volume 1, chapter 2 of the Offshore EIA Report.
12. Of particular relevance, Article 3(1) of the EIA Directive requires that the interaction between the environmental (e.g. human health, biodiversity, land, soil, water, air and climate etc) is identified, described and assessed in an EIA report.
13. Under the EIA Regulations, there is a requirement to consider inter-relationships between topics that may lead to environmental effects. Other than this, there is no policy relevant to inter-related effects in Scotland, thus this chapter has been compiled following advice from stakeholders as detailed in section 20.3 (Table 20.1).

20.3. CONSULTATION

14. A summary of the key issues raised during consultation activities undertaken to date specific to inter-related effects is presented in Table 20.1. Topic chapters which are relevant to the ecosystem based approach include physical processes, benthic ecology, fish and shellfish, marine mammals and offshore ornithology.
15. For each of these topics a Road Map process has been used as a tool to facilitate early and on-going engagement with stakeholders throughout the pre-application phase of the Proposed Development including on reaching points of agreement on scoping impacts out of the assessment, and/or agreeing the level of assessment which will be presented for impacts, so that the focus of the Offshore EIA Report is on likely significant environmental effects as defined by the EIA Regulations. The Road Map for these topics (up to date at the point of Application) are presented in volume 3 as follows:

- volume 3, appendix 8.2: Benthic Ecology, Fish and Shellfish Ecology and Physical Processes Road Map;
- volume 3, appendix 10.3: Marine Mammal Road Map; and
- volume 3, appendix 11.8: Offshore Ornithology Road Map.

16. At the request of Marine Scotland Licensing Operations Team (MS-LOT)[1], an audit document (Audit Document for Post-Scoping Discussions (volume 3, appendix 5.1)) has been produced and submitted alongside the application to document discussions on key issues, post-receipt of the Berwick Bank Wind Farm Scoping Opinion (MS-LOT, 2022).

[1] Meeting on 26 April 2022 between MS-LOT, RPS and the Applicant

Table 20.1: Summary of Key Issues Raised During Consultation Activities Undertaken for the Proposed Development Relevant to Inter-Related Effects

Date	Consultee and Type of Consultation	Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
Relevant Consultation to Date			
October 2020	NatureScot	Increasingly there is a need to understand potential impacts holistically at a wider ecosystem scale rather than via the standard set of discrete individual receptor assessments. This assessment should focus on potential impacts across key trophic levels particularly in relation to the availability of prey species. 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 this may have on population level impacts.	Potential impacts across key trophic levels have been assessed in section 20.7.
October 2020	NatureScot	EIA Report should consider those fish species which provide an important function as a key prey resource, noting many of these are Priority Marine Features (PMFs), further discussion is needed to agree relevant species and assessment process.	Key prey species have been assessed throughout section 20.7. Section 20.7.5 identifies and provides species accounts of the key prey species including their status as PMFs or not.
Consultation on the Proposed Development			
December 2021	NatureScot	More consideration is required in the EIA Report to ensure that impacts to key prey species (such as sandeel, herring, mackerel and sprat) and their habitats are considered across all development phases for Berwick Bank alone and in-combination with other wind farms in the Forth/Tay area, particularly given the importance of this area for a number of prey species.	Potential impacts to key prey species has been assessed in section 20.7.9.
December 2021	NatureScot	NatureScot recognise most EIA Reports concentrate on receptor specific impacts, however, increasingly recognise the need to understand the impacts at the ecosystem scale. Consideration across key trophic levels will enable better understanding of the consequences (positive or negative) of any potential changes in prey distribution and abundance on marine mammal (and other top predator) interests and how this may influence population level impacts. Therefore, consideration of how this loss/disturbance may affect the recruitment of key prey (fish) species through impacts to these important spawning and or nursery ground habitats should also be assessed.	Potential impacts across key trophic levels have been assessed in section 20.7. Potential for changes in prey distribution has been assessed in section 20.7.9. Potential for changes in predators (seabirds and marine mammals) has been assessed in section 20.7.10
December 2021	NatureScot	In addition, the PrePared OWEC project will also assist in the understanding of predator-prey relationships in and around offshore wind farms which will start in January 2022 and will run for 5 years.	Noted, while PrePared OWEC is relevant in considering ecosystem level effects, the project would only be starting in 2022. Therefore, the project will not be relevant at the assessment stage (pre-Application) but may be relevant to consider in terms of potential for post consent monitoring, should the Proposed Development be consented.
December 2021	NatureScot	More consideration is required in the EIA Report to ensure that impacts to key prey species (such as sandeel, herring, mackerel and sprat) and their habitats are considered across all development phases for Berwick Bank alone and in-combination with other wind farms in the Forth/Tay area, particularly given the importance of this area for a number of prey species.	Potential impact to key fish prey species has been assessed in section 20.6.10. For further detail regarding impact on fish and shellfish species, see volume 2, chapter 9.
December 2021	NatureScot	NatureScot recognise most EIA Reports concentrate on receptor specific impacts, however, increasingly need to understand the impacts at the ecosystem scale. Consideration across key trophic levels is suggested to enable better understanding of the consequences (positive or negative) of any potential changes in prey distribution and abundance on marine mammal (and other top predator) interests and how this may influence population level impacts. Advice within the benthic interests and fish/shellfish assessment will be helpful in this regard.	Section 20.7.9 draws on the findings of the benthic subtidal and intertidal ecology and fish and shellfish ecology assessments of effects to assess positive or negative effects on prey species. Section 20.7.10 assesses potential for changes in distribution of marine mammals and other top predators based on literature reviews undertaken in volume 3, appendix 20.1, and the findings of section 20.7.9.
January 2022	NatureScot Ornithology Road Map Meeting 5	NatureScot advised it was interested in the following key points in relation to the Ecosystem assessment: • What are the predators? What are the prey species? How does the whole food chain operate? What other pressures are on these prey species? For example, certain fish prey on other fish species – what are all the impacts on prey species before an Offshore Wind Farm is built? • What effect will an Offshore Wind Farm have on these prey species, in relation to these other impacts? What are the knock-on effects on predators? • If prey species increase following construction of an Offshore Wind Farm, where are they? Does this new distribution draw more predators in? • The assessment should consider potential attraction to the wind turbine bases and how supporting processes are likely to change (e.g. physical processes). • All of these dynamics should be considered through a climate change filter. • An Ecosystem Approach assessment.	Section 20.7 has been structured to answer each of these questions raised by NatureScot. The Ecosystem Approach assessment is presented in this chapter and aims to provide a holistic overview of ecosystem level impacts drawing from a range of topics. It was agreed with stakeholders that established approaches to ecosystem assessment are currently lacking.

Date	Consultee and Type of Consultation	Issue(s) Raised	Response to Issue Raised and/or Where Considered in this Chapter
January 2022	RSPB Ornithology Road Map Meeting 5	Key to the assessment is drawing upon physical processes, benthic subtidal and intertidal ecology, fish & shellfish ecology, marine mammal and ornithology assessments to provide a holistic overview of ecosystem level impacts" – for example if there are changes in water flow effects – how do these affect plankton distribution? How do changes in plankton distribution affect sandeel distribution and hence kittiwake distribution?	It was agreed during ornithology Road Map meeting 5 that quantitative modelling was not appropriate to address these questions. Rather a literature review, focussing on seabirds, their prey and climate change effects would be provided. This review is shown in volume 3, appendix 20.1.
January 2022	RSPB Ornithology Road Map Meeting 5	Positive/negative effects from prey changes on kittiwakes in relation to CRM and climate change need to be considered.	As above
December 2021	NatureScot	More consideration is required in the EIA Report to ensure that impacts to key prey species (such as sandeel, herring, mackerel and sprat) and their habitats are considered across all development phases for Berwick Bank alone and in-combination with other wind farms in the Forth/Tay area, particularly given the importance of this area for a number of prey species.	Part One of this chapter considers effects produced by the Proposed Development and not those effects arising from other projects, which are considered within the Cumulative Effects Assessment (CEA) sections of each topic chapter. However, cumulative effects between projects have been considered in Part Two: Ecosystem Effects Assessment. This information has also been used to inform the assessments within these sections to ultimately conclude whether the Proposed Development, and cumulatively with other projects, has the potential to result in changes to prey species which in turn will result in changes to predator species

20.4. DATA SOURCES

17. The baseline environments for the receptor groups considered in section 20.6 of this chapter are specific to each receptor group and are, therefore, set out in detail in the relevant topic specific chapters. For the purposes of the ecosystem effects assessment in section 20.7, a summary of the baseline informed by volume 2, chapters 7 to 11 and their respective technical reports is described to provide an overview of the ecosystem baseline conditions.

18. This chapter draws on the conclusions made within the technical chapters for the assessment of impacts acting in isolation on the receptor groups. The relevant sections drawn upon in this inter-related effects assessment are presented in the Offshore EIA Report in volume 2 chapters 7 to 19.

20.5. ASSESSMENT METHODOLOGY

19. The assessment presented in this chapter has been split into two parts, Part One: Receptor Based Inter-Related Effects Assessment and Part Two: Ecosystem Effects Assessment.

20.5.1. PART ONE: INTER-RELATED EFFECTS ASSESSMENT METHOD

20. The following sections present the approach for the inter-related effects assessment for the Proposed Development. For the purpose of this assessment, the following definition of inter-related effects has been applied throughout this chapter:

21. Multiple effects upon the same receptor arising from the Proposed Development occur 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, for example marine mammals.

22. Two types of inter-related effects have therefore been identified:

- **project lifetime effects** - individual effects on each of the key receptor groups across the three Proposed Development phases (construction, operation and maintenance, and decommissioning); and
- **receptor-led effects** - multiple effects on the same receptor.

23. Table 20.2 presents a full definition of the above terms.

Table 20.2: Definitions of Proposed Development Lifetime Inter-Related Effects and Receptor-led Inter-Related Effects

Inter-Related Effect Type	Definition
Proposed Development lifetime inter-related effects	Assessment of the scope for effects that occur throughout more than one phase of the Proposed Development (construction, operation and maintenance, and decommissioning) to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three key project stages (e.g. underwater noise effects from construction piling, operational wind turbines, vessels and decommissioning).
Receptor-led inter-related effects	Assessment of the scope for multiple effects to interact to create interactive effects on a receptor. As an example, multiple effects 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 effects are considered in isolation. Receptor-led effects might be short term, temporary or transient effects, or incorporate longer term effects.

Guidance

24. There is limited guidance available relating to assessment of inter-related effects however the following guidance documents have been followed:

- The Guidelines for the Assessment of Indirect and Cumulative Impacts as well as Impact Interactions (EC, 1999); and
- Institute of Environmental Management and Assessment (IEMA) Environmental Impact Assessment Guide to Shaping Quality Development (IEMA, 2016).

Approach to assessment

25. The approach to assessing inter-related effects within Part One of this chapter has followed a four stage process, as summarised in Table 20.3 and outlined below. More details of the approach summarised above and used to develop this chapter are presented in volume 1, chapter 6.

Table 20.3: Staged Approach to Assessing Inter-Related Effects

Stage	Description
1	Assessment of effects undertaken for individual Offshore EIA topic areas within chapters 7 to 21.
2	Review of assessments undertaken within chapters 7 to 21 to identify ‘receptor groups’ requiring assessment.
3	Identification of potential inter-related (offshore) effects on receptor groups through review of the topic specific assessments in the Offshore EIA Report chapters.
4	Assessment undertaken on how individual effects may combine to create inter-related effects on each receptor group for: • ‘Proposed Development lifetime effects’ (i.e. during construction, operation and maintenance, and decommissioning phases); and • ‘Receptor-led effects’ (i.e. multiple effects on a single receptor).

Stage 1: Topic specific assessments

26. The first stage of the assessment of inter-related effects is presented in each of the individual Offshore EIA topic chapters and comprises the individual assessments of effects on receptors across the construction, operation and maintenance and decommissioning of the Proposed Development.

Stage 2: Identification of receptor group

27. Stage 2 involved a review of the assessments undertaken in the topic specific chapters to identify 'receptor groups' requiring assessment within the inter-related effects assessment. The term 'receptor group' is used to highlight that the approach taken for the inter-related effects assessment will not assess every individual receptor assessed at the EIA stage, but rather potentially sensitive groups of receptors. The receptor groups assessed can be broadly categorised as those relating to the physical environment, the biological environment and the human environment, as follows:

- physical environment:
  - physical processes; and
  - water quality.
- biological environment:
  - benthic subtidal and intertidal ecology;
  - fish and shellfish ecology;
  - marine mammals; and
  - offshore and intertidal ornithology.
- human environment:
  - commercial fisheries;
  - shipping and navigation;
  - aviation, military and communication;
  - seascape and visual resources;
  - cultural heritage;
  - infrastructure and other users; and
  - offshore socio-economics and tourism.

Stage 3: Identification of potential interactions on receptor groups

28. Following the identification of receptor groups, the potential inter-related effects on these receptor groups have been identified via review of the assessment of effects sections for each topic chapter. The judgement as to which impacts may result in inter-related effects upon receptors associated with the Proposed Development was exercised using a precautionary approach and was based on the professional judgement and experience of the technical author.

Linked receptor groups

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

- volume 2, chapter 8 addresses effects on benthic habitats and species arising from changes to the physical environment (as described in volume 2, chapter 7);
- volume 2, chapters 10 and 11 assess the effects on marine mammal and seabird receptors arising from potential changes in the distribution of fish, which form their principal prey (as described in volume 2, chapter 9);
- volume 2, chapter 12 assesses the effects on commercial fisheries receptors arising from potential impacts on commercial species of fish and shellfish as a result of a combination of effects caused by Electromagnetic Fields (EMFs), suspended sediments, habitat alteration/loss and underwater noise impacts; and
- volume 2, chapter 17 assesses the effects on aggregate extraction areas arising from potential impacts on aggregate resource as a result of potential increase in suspended sediment concentrations (SSC) and deposition and effects on sediment transport pathways (as described in volume 2, chapter 7).

30. 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.

31. It should be noted that it is not considered that there are likely to be any cumulative receptor led effects from onshore and offshore activities associated with the Project. This is primarily due to offshore export cable installation using trenchless techniques (such as Horizontal Directional Drilling (HDD)) through the intertidal area between Mean Low Water Springs (MLWS) and MHWS. As a result this has not been considered further in this Inter-Related Effects Offshore EIA Report chapter or the inter-related effects chapter of the Onshore EIA Report (volume 4, chapter 15.2) (SSER, 2022a).

Stage 4: Assessment of interactions on each receptor group

32. Individual effects on each of the key receptor groups have been identified across the three Proposed Development phases (i.e. Proposed Development lifetime effects) as well as the interaction of multiple effects on a receptor (i.e. receptor-led effects), as defined in Table 20.2. The assessment of these interactions has been presented in this chapter using a matrix approach, (see Table 20.4 to Table 20.15).

33. It is important to note that the interactions assessment in Part One considers only those effects produced by the Proposed Development and not those effects arising from other projects, which are considered within the Cumulative Effects Assessment (CEA) sections of each topic chapter. However, cumulative effects between projects have been considered in Part Two: Ecosystem Effects Assessment.

34. Within the interactions matrix for each topic, the significance of the individual effects, as concluded within the topic specific chapters, have been presented for each receptor group. A descriptive assessment of the scope for these individual effects to interact to create a different or greater effect has then been undertaken and presented (see Table 20.4 to Table 20.15). This assessment incorporates qualitative and, where reasonably possible, quantitative assessments. The assignment of significance of effect to any such interactive effect is not undertaken, rather, any interactive effects that may be of greater significance than the individual effects acting in isolation on a given receptor are identified and discussed within this chapter.

35. The interactions assessment presents and utilises the maximum significant adverse effects for the Proposed Development (i.e. the maximum design scenarios including implementation of any further mitigation where appropriate), noting that individual effects may not be significant at the topic-specific level but could become significant when their interactive effect is assessed. Effects of negligible significance or greater (slight, moderate, major or profound) may occur in only one phase of the project lifecycle (e.g. during the construction phase, but not during the operation and maintenance or decommissioning phases). Where this is the case, it has been made clear that, as a result, there will be no interactive effects across the project phases. Effects of imperceptible significance 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.

20.5.2. PART TWO: ECOSYSTEM BASED EFFECTS ASSESSMENT METHOD

36. The purpose of the ecosystem-based assessment is to qualitatively assess the potential impacts of the Proposed Development at the ecosystem level, to better understand how predator – prey relationships could be altered and how this could impact the functioning of the ecosystem.

37. The method applied to undertake this assessment has been led by the questions NatureScot raised in the ornithology Road Map Meeting 5, January 2022 (Table 20.1). It should be noted, however, that it was agreed during the Ornithology Road Map Meeting 5, that an ecosystem modelling approach or ecosystem services approach were not deemed appropriate for this assessment. Part Two has therefore been broadly structured around these questions: "*What are the predators? What are the prey species? How does the whole food chain operate? What other pressures are on these prey species? For example, certain fish prey on other fish species - what are all the impacts on prey species before an Offshore Wind Farm is built? What effect will an Offshore Wind Farm have on these prey species, in relation to these other impacts? What are the knock-on effects on predators? If prey species increase following construction of an Offshore Wind Farm, where are they? Does this new distribution draw more predators in?* (volume 3, appendix 11.8, annex A)."

38. The structure of Part Two is as follows:

- section 20.7: Part Two: Ecosystem Effects Assessment;
- section 20.7.1: Overview;
- section 20.7.2: Ecosystem baseline;
- section 20.7.3: The Marine Food Web;
- section 20.7.4: The Key Predator Species;
- section 20.7.5: The Key Prey Species;
- section 20.7.6: How the Whole Ecosystem Works;
- section 20.7.7: Future Ecosystem Baseline;
- section 20.7.8: Existing Pressures on Prey Species;
- section 20.7.9: Effects of the Proposed Development on Prey Species; and
- section 20.7.10: Effects of the Proposed Development on Predators.

39. Information and conclusions from the relevant chapters of the Offshore EIA Report and their corresponding technical reports, along with volume 3, appendix 20.1 and the Firth of Forth Banks Complex (FFBC) MPA Report, have been used to build up a picture of the marine ecosystem in the locality of the Proposed Development. This information has also been used to inform the assessments within these sections to ultimately conclude whether the Proposed Development, and cumulatively with other plans and projects, has the potential to result in changes to prey species which in turn will result in changes to predator species.

40. Currently our understanding of how offshore wind farms impact marine food webs is limited.

41. The Ecological Consequences of Offshore Wind research programme (ECOWind) will investigate all possible effects of offshore wind farms on the marine environment. The outcomes of this research will be used to inform policy measures to minimise negative impacts on marine life while tackling climate change and will be key to informing ecosystem assessment approach.

42. The Aberdeen and Grampian Chamber of Commerce (2022) commented that "*Preliminary studies indicate that windfarms may influence the food production at the base of the marine food chain and our range of real data collection and modelling approaches will take this new understanding from physics to fish, to ecosystems to help ensure we make the most efficient use of our marine spaces*." (Aberdeen & Grampian Chamber of Commerce, 2022)).

20.6. PART ONE: RECEPTOR BASED INTER-RELATED EFFECTS ASSESSMENT

43. For each of the receptor groups listed above, the scope for impacts to these receptors to create Proposed Development lifetime effects over all phases and/or receptor-led effects through interacting together on a particular receptor group has been explored and discussed in the following sections.

20.6.1. COMMERCIAL FISHERIES

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

- loss or restricted access to fishing grounds; and
- displacement of fishing activity into other areas.

45. Table 20.4 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, operation and maintenance phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for commercial fisheries receptors.

46. No inter-related effects (project lifetime effects) are predicted to arise during the construction, operation and maintenance phase, and decommissioning of the Proposed Development, since the potential impacts listed above will not be further exacerbated over the lifetime of the Proposed Development.

47. As noted above, effects on commercial fishing 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:

- fish and shellfish receptors; and
- socio-economic receptors.

Table 20.4: Summary of Likely Significant Inter-Related Effects on the Environment from Individual Effects Occurring across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
Loss of or restricted access to fishing grounds and associated displacement	✓	✓	✓	During construction and decommissioning, fishing may be excluded from buoyed construction and decommissioning areas. The need to implement safety zones and advisory measures may result in a localised loss or restricted access to established fishing grounds. During operation and maintenance, the presence of the Proposed Development's infrastructure and cable protection will be long term, but effects highly localised and intermittent (i.e. due to safety zones around discrete areas for maintenance works). A reduction in available fishing areas could cause increased fishing pressure in other areas (which could affect fish and benthic receptors). In view of a range of fisheries liaison and management measures to minimise loss of access and that fishing will continue around exclusion areas, effects did not exceed "minor adverse significance" for any fisheries assessed in isolation. Measures implemented to minimise loss of access during operation such as cable burial status assessments aim to reduce interactions with mobile fisheries. In view of the limited effects on vessels that

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
				are typically nomadic, combined effects of a greater significance are not predicted to result on commercially important fisheries and/or their prey species.
Impacts on commercially exploited species	✓	✓	✓	Activities that result in changes to seabed habitats (loss of benthic habitats and prey resource), water quality (increased suspended sediment concentrations) and underwater noise levels (e.g., during piling) could interact within a phase, or over the lifetime of the Proposed Development to influence disturbance displacement effects on, or the depletion of commercial fisheries resources. The potential for inter-related impacts would be greatest during construction and decommissioning (diminishing as the Proposed Development becomes operational). With regards to interactions, the effects are not considered mutually exclusive; heightened underwater noise levels would likely displace receptors from areas subject to increased sediment concentrations for example, and during construction, safety zones would already account for a temporary, localised displacement of fisheries. As impacts from these effects in isolation are highly localised and temporary (no impact above “minor adverse significance” on fish and shellfish species has been identified), combined effects of greater significance on commercially important fish and or their prey species are not predicted.
Displacement of fishing activity into other areas	✓	✓	✓	The individual effects of vessels associated with the Proposed Development could interfere with commercial fishing activities across all phases. Vessel traffic (that could result in interference with fishing) would however, peak during construction and decommissioning. Due to a range of fisheries liaison and management measures that will be implemented to manage vessel traffic, impacts are predicted to be of local spatial extent, medium term duration and intermittent. Effects of negligible adverse significance were predicted for fisheries assessed in isolation. In this context, the interactions of transiting construction vessels with the other interactions (as they predicted to arise) would not result in an effect of greater significance in any individual phase.
Increased steaming times	✓	×	✓	During construction and decommissioning, the implementation of safety zones and advisory measures could result in increased steaming distances, with a very small spatial extent expected to result. This effect will only arise during construction and decommissioning as it is assumed vessels will steam through the site once operational. The consequent impacts are limited in both extent (highly localised) and duration (temporary) assessed for all fisheries to be of minor adverse significance. The interaction of other individual effects during the construction phase is not predicted to result in a significant inter-related effect.
Snagging risk and associated loss or damage to fishing gear and safety issues	×	✓	×	During operation and maintenance, damage or loss of fishing gear and/or vessel safety issues could result if fishing gear interacted with seabed obstacles, including cables temporarily awaiting burial or protection. The implementation of safety zones and advisory measures are specifically designed to reduce interactions thereby limiting the potential for interaction with other effects. As fishing vessels operating in and around the Proposed Development would be made aware of applicable safety zones and advisory measures and as the risk is only present in the immediate footprint of the obstacles, the probability of occurrence is deemed to be remote. In view of the fisheries liaison and management measures that will be implemented and the minor adverse significance predicted for all fisheries in isolation, significant inter-related effects are not predicted to arise.
Receptor-led Effects				
Potential exists for spatial and temporal interactions between the majority of the impacts outlined above. However, it should be noted that many of the effects will be minimised through all phases via the use of liaison and management measures such as ongoing communication via appointment of a Fisheries Liaison Officer (FLO), issue of Notice to Mariners (NtMs) and the development of a FMMS. Therefore, based on current understanding and expert knowledge, the greatest scope for potential interactions between impacts is predicted to arise through the reduction in access to fishing grounds and the displacement of fishing activity into other areas. During the construction and decommissioning phases, effects will be temporary and short lived, with potential loss of ground or restricted access to fishing grounds being limited to the discrete areas where construction and decommissioning activity is being undertaken and associated advisory safety zones. During the operation and maintenance phase, some fishing activity may be displaced from areas where infrastructure has been built and move to other fishing areas and this may lead to conflict with different fishing fleets (e.g. mobile gear). Fishing will be permitted across the area of the Proposed Development during the operation and maintenance phase, and the potential for significant displacement of activity and conflict with other fisheries is limited. Furthermore, activity in areas of relevance to the Proposed Development is primarily undertaken by local fishing vessels operating in nearshore areas. As a result, it is unlikely that effects will act together and that any interactions between effects will be of any greater significance than those already assessed for the Proposed Development alone				

48. 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.

20.6.2. SHIPPING AND NAVIGATION

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

- vessel displacement;
- increased vessel to vessel collision risk between a third-party vessel and a project vessel;
- increased vessel to vessel collision risk between third-party vessels;
- vessel to structure allision risk; and
- reduced access to local ports.

50. Table 20.5 lists the inter-related effects (receptor-led effects) that are predicted to arise for shipping and navigation receptors. No inter-related effects (Proposed Development lifetime effects) are predicted to arise during the construction, operation and maintenance phase, and decommissioning of the Proposed Development, since the potential impacts listed above will not be further exacerbated over the lifetime of the Proposed Development.

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

- commercial fisheries;
  - 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.

Table 20.5: Summary of Potential Inter-Related Effects for Shipping and Navigation from Individual Effects Occurring across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact from Project Effects
Receptor-led Effects
The presence of the buoyed construction and decommissioning areas during the construction and decommissioning phases, respectively, may result in the displacement from fishing grounds of commercial fishing vessels. This displacement and the associated reduction in available sea room will increase the vessel to vessel collision risk 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 for the Proposed Development alone.

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.

20.6.3. AVIATION, MILITARY AND COMMUNICATIONS

53. For aviation, military and communications, the following potential impacts have been considered within the inter-related assessment:

- creation of physical obstacles affecting air traffic; and
- interference with civil and military Air Traffic Control (ATC) radar systems.

54. Table 20.6 lists the inter-related effects (Proposed Development lifetime effects) that are predicted to arise during the construction, operation and maintenance, and decommissioning phases of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for aviation, military and communications receptors.

55. Effects on aviation, military and communications receptors also have the potential to have secondary effects on other receptors and these effects are fully considered in the topic specific chapters.

Table 20.6: Summary of Potential Inter-Related Effects for Aviation, Military and Communications from Individual Effects Occurring across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
Potential impact on low flying (including Search and Rescue (SAR) helicopter operations) due to presence of obstacles (cranes, stationary wind turbines)	✓	✓	✓	The scale of effects on civil and military aviation receptors progressively increases during construction as the wind turbines and ancillary structures are installed. Once installed, the infrastructure causing physical obstacles to air traffic will remain constant until the decommissioning phase. The effects on aviation, military and communications 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. No potential for likely significant effects therefore predicted for this impact.
Potential impact on National Air Traffic Services En-Route PLC (NERL) ATC radars due to presence of wind turbines	×	✓	×	This effect will only arise during the operation and maintenance phase and as such there will be no interactions between effects across the Proposed Development phases. No potential for likely significant effects therefore predicted for this impact.
Potential impact on Military ATC radars due to presence of wind turbines	×	✓	×	This effect will only arise during the operation and maintenance phase and as such there will be no interactions between effects across the Proposed Development phases. No potential for likely significant effects therefore predicted for this impact.
Potential impact on Military Air Defence (AD) radars due to presence of wind turbines	×	✓	×	This effect will only arise during the operation and maintenance phase and as such there will be no interactions between effects across the Proposed Development phases. No potential for likely significant effects therefore predicted for this impact.
Receptor-led Effects				
Potential exists for spatial and temporal interactions between direct impacts to civil and military aviation and radar. Based on current understanding and expert knowledge there is scope for potential interactions between impacts to arise from creation of physical obstacles affecting air traffic and interference with civil and military ATC radar systems during the operation and maintenance phase. 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 (i.e. imperceptible to slight adverse significance).				

56. 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.

20.6.4. SEASCAPE, LANDSCAPE, VISUAL RESOURCES AND CULTURAL HERITAGE

57. A description of the likely inter-related effects arising from the Proposed Development on seascape, landscape and visual receptors is provided in volume 3, appendix 18.1 of the Offshore EIA Report.

58. For seascape, landscape and visual receptors, the following likely significant effects have been considered within the inter-related assessment:

- Changes to views experienced by people from specific and representative viewpoints and from visual receptors;
- Changes to the perceived seascape (coastal) character of coastal character areas;
- Changes to the perceived landscape character and qualities of designated landscapes; and
- Changes to night-time views and perceived character of coastal character as a result proposed development lighting.

59. Table 20.7 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, operation and maintenance phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for seascape, landscape and visual receptors.

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

- cultural heritage
  - temporary (during construction, operation and maintenance and decommissioning phases), long-term (during operation and maintenance phase only) and reversible (post-decommissioning)

addition of Proposed Development resulting in direct effect to views from and indirect effect to perceived character of Gardens and Designed Landscapes (GDLs) and Registered Parks and Gardens (RPGs), including Lindisfarne Castle, and the North Northumberland Heritage Coast; and

- socio-economics and tourism
  - temporary (during construction, operation and maintenance and decommissioning phases), long-term (during operation and maintenance phase only) and reversible (post-decommissioning) addition of Proposed Development resulting in indirect effect to visitor and tourist use of the coast including receptors such as beaches, recreational routes, golf courses and visitor attractions.

Table 20.7: Summary of Potential Inter-Related Effects for Seascape, Landscape and Visual Receptors from Individual Effects Occurring across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase			Project Effects
	C	O	D	
Proposed Development Lifetime Effects				
Changes to views experienced by people from specific and representative viewpoints and from visual receptors	✓	✓	✓	No greater than individually assessed impacts. Although impacts are broken down into different receptors (viewpoints and visual receptors) the actual receptor is the same in each case (i.e., the people perceiving the effect). Therefore, these people will only perceive the effect one way (visually) at one point in time, and will not experience the construction, operation and decommissioning phases simultaneously, or across multiple pathways.
Changes to the perceived seascape (coastal) character of coastal character areas	✓	✓	✓	No greater than individually assessed impacts. Although impacts are broken down into different receptors based upon physical and perceived characteristics (coastal character areas) the actual receptor is the same in each case (i.e., the people perceiving the effect on coastal character). Therefore, these people will only perceive the effect one way (visually) at one point in time, and will not experience the construction, operation and decommissioning phases simultaneously, or across multiple pathways.
Changes to the perceived landscape character and qualities of designated landscapes	✓	✓	✓	No greater than individually assessed impacts. Although impacts are broken down into different receptors based upon physical and perceived characteristics (landscape character types) and planning policies (landscape designations) the actual receptor is the same in each case (i.e. the people perceiving the effect on coastal character). Therefore, these people will only perceive the effect one way (visually) at one point in time, and will not experience the construction, operation and decommissioning phases simultaneously, or across multiple pathways.
Changes to night-time views and perceived character of coastal character as a result proposed development lighting	×	✓	×	No greater than individually assessed impacts. Although impacts are broken down into different receptors (viewpoints and visual receptors) the actual receptor is the same in each case (i.e., the people perceiving the effect). Therefore, these people will only perceive the effect one way (visually) at one point in time, and will not experience the construction, operation and decommissioning phases simultaneously, or across multiple pathways.
Receptor led effects				
Receptor led effects (i.e. those that interact, spatially and temporally, to create inter-related effects on a receptor) will not occur on seascape, landscape and visual receptors, since changes are experienced by the same receptor in each case (people) and in one way (visually) at one point in time, therefore effects on views and on perceived character are inter-linked, and do not interact to produce a different, or greater effect, on a receptor than when effects are considered in isolation.				

61. 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.

20.6.5. INFRASTRUCTURE AND OTHER USERS

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

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

63. Table 20.8 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, operation and maintenance and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for infrastructure and other users receptors.

64. As noted above, effects on infrastructure and other users also have the potential to lead to secondary effects on other receptors and these effects are fully considered in the topic-specific chapters. These receptors and effects are:

- shipping and navigation:
  - physical restriction on space for recreational craft and recreational fishing vessels;
  - displacement of recreational sailing and motor cruising, recreational fishing (boat angling) and other recreational activities (diving vessels);
  - physical restriction on space for recreational activities/recreational fishing;
  - displacement of recreational fishing (shore angling) and other recreational activities (kayaking, kite surfing, surfing and windsurfing, scuba diving and beach users); and
  - physical impact or loss of access to existing cables and pipelines.

Table 20.8: Summary of Likely Significant Potential Inter-Related Effects for Infrastructure and Other Users from Individual Effects Occurring across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
Physical restriction on space for recreational craft/recreational fishing vessels.	✓	✓	✓	The presence of infrastructure, safety zones and advisory safety distances during the construction phase may result in the displacement of recreational craft and recreational fishing vessels from the Proposed Development array area and along the Proposed Development export cable corridor. During the operation and maintenance phase, the presence of infrastructure, operational safety zones and temporary safety zones and advisory safety distances around maintenance activities may result in the displacement of recreational craft and recreational fishing vessels from the Proposed Development array area and along the Proposed Development export cable corridor. During the decommissioning phase, the presence of infrastructure, safety zones and advisory safety distances may result in the displacement of recreational craft and recreational fishing vessels from the Proposed Development array area and along the Proposed Development export cable corridor. The level of recreational activity within the Proposed Development array area is low. There is low to medium recreational vessel activity in nearshore areas of the Proposed Development export cable corridor, with boating and angling also taking place closer to shore, however any displacement along the Proposed Development export cable corridor will be temporary. Therefore, across the project lifetime, the effects on recreational craft users and recreational fishing vessels are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase.
Physical restriction on space for recreational activities/recreational fishing.	✓	✓	✓	The presence of infrastructure, safety zones and advisory safety distances during the construction phase may result in the displacement of recreational activities and recreational fishing from the Proposed Development array area and along the Proposed Development export cable corridor. During the operation and maintenance phase, the presence of infrastructure, operational safety zones and temporary safety zones and advisory safety distances around maintenance activities may result in the displacement of recreational activities and recreational fishing from the Proposed Development array area and along the Proposed Development export cable corridor. During the decommissioning phase, the presence of infrastructure, safety zones and advisory safety distances may result in the displacement of recreational activities and recreational fishing from the Proposed Development array area and along the Proposed Development export cable corridor. The level of recreational activity within the Proposed Development array area is low. There is low to medium recreational activity in nearshore areas of the Proposed Development export cable corridor. Any displacement along the Proposed Development export cable corridor will be temporary. Therefore, across the project lifetime, the effects on recreational users and recreational fishing 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.
Physical impact or loss of access to existing cables and pipelines.	✓	✓	✓	Existing cables and pipelines may be affected where they are crossed by Proposed Development infrastructure. In addition, the presence of Proposed Development infrastructure, safety zones and advisory safety distances may restrict access to existing cables and pipelines during construction, maintenance and decommissioning activities. Cable and pipeline crossing and proximity agreements will be developed and implemented with each relevant cable and pipeline operator to minimise the potential for any impact. Crossing agreements will include the ability of a cable/pipeline operator to access their infrastructure as far as practical during the Proposed Development construction and decommissioning phases and the crossing agreements will ensure close communication and planning between the affected parties to ensure disruption of activities is minimised. Therefore, across the project lifetime, the effects on infrastructure and other users are not anticipated to interact in such a way as to result in combined effects of greater significance than the assessments presented for each individual phase.
Receptor-led Effects				
Potential exists for spatial and temporal interactions between direct and indirect impacts to infrastructure and other users receptors. Based on current understanding and expert knowledge, there is scope for potential inter-related impacts to arise from the physical restriction on space for recreational craft and recreational fishing vessels interacting with the displacement of recreational sailing and motor cruising, recreational fishing (boat angling) and other recreational activities (diving vessels). Where both impacts overlap spatially and temporally, there is potential for inter-related effects as the restriction/displacement on movements of recreational activity may cover a larger area. However, as a vast extent of alternative resource for recreational activities will remain available and the impacts initially identified were of minor adverse significance. These impacts are not likely to interact in way that results in a significant inter-related effect.				

65. 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.

20.6.6. OFFSHORE SOCIO-ECONOMICS AND TOURISM

66. For offshore socio-economics and tourism receptors, all potential impacts have been considered within the inter-related assessment.

67. Table 20.9 lists the inter-related effects (Proposed Development lifetime effects) that are predicted to arise during the construction, operation and maintenance phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for offshore socio-economics and tourism receptors.

Table 20.9: Summary of Likely Significant Potential Inter-Related Effects for Offshore Socio-Economics and Tourism from Individual Effects Occurring across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
Impact on employment in activities (including supply chain) associated with: manufacturing, construction, and installation; operation and maintenance; and decommissioning.	✓	✓	✓	There will be beneficial effects on employment throughout the construction and installation; operation and maintenance; and decommissioning phases. Employment effects will occur within different locations and sectors of the economy, and at different times and intensities. In combination the Proposed Development will provide a long term employment stimulus

Description of Impact	C	O	D	Likely Significant Inter-Related Effects
				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.
Impact on GVA (£) supported in activities (including supply chain) associated with: manufacturing, construction, and installation; operation and maintenance; and decommissioning.	✓	✓	✓	There will be beneficial effects on GVA throughout the construction and installation; operation and maintenance; and decommissioning phases. GVA effects will occur within different locations and sectors of the economy, and at different times and intensities. In combination the Proposed Development will provide a long term GVA stimulus. 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.
Impact on access to employment amongst local residents in activities (including supply chain) associated with: manufacturing, construction, and installation; operation and maintenance; and decommissioning.	✓	✓	✓	There will be beneficial effects on the potential for local workers to access employment throughout the construction and installation; operation and maintenance; and decommissioning phases. Access to employment effects will occur within different locations, sectors of the economy, and labour market – and at different times and intensities. In combination the Proposed Development will provide a long-term employment stimulus. 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.
Impact on the demand for housing, accommodation and local services.	✓	✓	✓	Direct and indirect employment generated during the construction phase could increase demand for housing, accommodation and local services during the construction phase. Direct and indirect employment generated during the operation and maintenance phase could increase demand for housing, accommodation and local services. It is anticipated that due to the long term nature of the operation and maintenance requirements the workforce will live locally. Some of those may relocate to the area requiring long term/permanent housing within the vicinity of the operation and maintenance port. Direct and indirect employment generated during the decommissioning phase could increase demand for housing, accommodation and local services during the decommissioning phase. The housing and accommodation needs of employment during each phase differs. 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.
Impact on tourism and recreation activity and associated economic value.	✓	✓	✓	Potential impacts of the construction, operation and maintenance, and decommissioning of the Proposed Development on tourism and recreation are indirect in nature. 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.

Description of Impact	C	O	D	Likely Significant Inter-Related Effects
Receptor-led Effects				
By definition, most of the impacts outlined above will interact. The exception is the tourism and recreation receptor, which is primarily determined on the basis of visual impact. Expenditure associated with the Proposed Development will result in employment and GVA impacts – these impacts are the basis for assessing potential socio-economic effects. Therefore the interactions between socio-economic receptors are inherent in the assessments of these impacts. It is not possible for socio-economic impacts to act together in a manner that multiplies effects. Employment-related receptors are likely to interact with the demand for housing, accommodation and local services receptor. In the event that employment impacts were to increase or decrease, effects related to the demand for housing, accommodation and local services would similarly increase or decrease. The same applies to GVA impacts. However, these impacts would not act together in a manner that multiplies effects. With regards to tourism and recreation, it is possible that interactions with the impact on demand for housing, accommodation, and local services will occur. This interaction is considered appropriately within the assessment of impacts on tourism and recreation and is assessed to be not significant in EIA terms. Any impacts assessed as being significant in EIA terms are beneficial in nature.				

68. 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.

20.6.7. PHYSICAL PROCESSES

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

- increased SSCs and associated deposition on physical features; and
- changes to tidal currents, wave climate, littoral currents and sediment transport.

70. Table 20.10 lists the inter-related effects (Proposed Development lifetime effects) that are predicted to arise during the construction, operation and maintenance, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for physical processes receptors.

71. As previously noted, effects on physical processes 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:

- benthic subtidal and intertidal ecology:
  - increased SSC; and
  - sediment deposition.
- fish and shellfish ecology:
  - increased SSC; and
  - sediment deposition.
- marine mammals:
  - changes to tidal current and wave climate;
  - increased SSC; and
  - sediment deposition.
- infrastructure and other users:

- increased SSC; and
- changes to tidal current and wave climate.

Table 20.10: Summary of Likely Significant Potential Inter-Related Effects on the environment for Physical Processes from Individual Effects Occurring across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
Increased SSCs and associated deposition on physical features	✓	✓	✓	Increases in SSC during construction phase would not extend into the operation and maintenance phase. Similarly, those increases which occur in the operation and maintenance phase due to maintenance activities would not extend to decommissioning.
Changes to tidal currents, wave climate, littoral currents and sediment transport	✓	✓	✓	Changes to tidal currents and wave climate due to structures relate to the same structures within the construction, operation and decommissioning phases. The decommissioning phase structures are only those remaining bed structures, such as scour and cable protection, not possible or practical to be removed, thus resulting in a lesser magnitude of the same impact.
Receptor-led Effects				
Firth of Forth Banks Complex ncMPA: During principally the operation and maintenance phase increased SSCs and associated deposition on physical features may occur due to maintenance activities; this would coincide with changes to tidal currents, wave climate, littoral currents and sediment transport due to the presence of the structures. Maintenance activities are sporadic, with the impacts predicted to be of local spatial extent, short term duration and intermittent. These would not be significant in EIA terms.				

72. 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.

20.6.8. WATER QUALITY

73. For water quality, the following potential impacts have been considered within the inter-related effects assessment:

- increased risk of introduction and spread of INNS;
- accidental release of lubricants, chemicals or similar;
- operational painting and cleaning of marine growth; and
- deterioration of bathing water quality from offshore export cables landfall works.

74. Table 20.11 lists the inter-related effects (project lifetime effects) that are predicted to arise during the construction, operation and maintenance phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for water quality receptors.

75. As noted above, effects on water quality 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:

- benthic, subtidal and intertidal ecology:
  - the potential temporary (construction phase), long term (operation and maintenance phase) and permanent (decommissioning (and post-decommissioning) phase) change in community composition from the introduction and spread of INNS resulting in direct effects on benthic, subtidal and intertidal ecology of minor adverse significance (volume 2, chapter 8);
  - the accidental release of lubricants, chemicals or similar (construction, operation and maintenance and decommissioning phases), resulting in direct effects on benthic, subtidal and intertidal ecology of minor adverse significance;
  - operational painting and cleaning of marine growth (operation and maintenance phase) may have similar impact as accidental release of lubricants, chemicals or similar, resulting in direct effects on benthic, subtidal and intertidal ecology of minor adverse significance; and
  - effects of the offshore export cables crossing the intertidal area have been scoped out as this will be achieved via trenchless techniques, and has therefore not been taken forward for assessment.
- fish and shellfish ecology:
  - the accidental release of lubricants, chemicals or similar (construction, operation and maintenance and decommissioning phases), resulting in direct effects on fish and shellfish ecology of minor adverse significance (volume 2, chapter 9); and
  - operational painting and cleaning of marine growth (operation and maintenance phase) may have similar impact as accidental release of lubricants, chemicals or similar, resulting in direct effects on fish and shellfish ecology of minor adverse significance.
- socio-economics and tourism:
  - water sports including diving, windsurfing, sailing and paddleboarding are popular in the area. Within the water quality study area, North Berwick and Tantallon are popular for kayaking, and Belhaven for surfing. Recreational fishing takes place at Dunbar and North Berwick, which lie within the water quality study area, and from which recreational fishing trips are commonplace; and
  - assessment of the potential effects of the Proposed Development upon socio-economics and tourism (volume 2, chapter 18) concluded a negligible to low adverse significance upon recreational water users.

Table 20.11: Summary of Likely Significant Inter-Related Effects on the Environment from Individual Effects Occurring Across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across All Phases (Receptor-led Effects)

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
Increased risk of introduction and spread of invasive and non-native species	✓	✓	✓	Although the operation of construction and decommissioning vessels in the area (potentially from countries of origin other than the UK) may facilitate the spread of INNS across all phases, this effect will predominantly arise during the operation and maintenance phase as INNS will require the hard substrate to be in place to provide substrate on which to settle. However, the designed-in measures include the implementation of an INNS Management Plan, which will be included in the Environmental Management Plan (EMP) (volume 4, appendix 22) 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 no greater significance than those assessed for each individual phase, which in this case is a minor adverse effect which is not significant in EIA terms.
Accidental release of lubricants, chemicals or similar	✓	✓	✓	The operation of construction and decommissioning vessels in the area may facilitate the accidental release of lubricants, chemicals or similar, the risk will predominantly arise during the operation and maintenance phase as this is the period when these substances are present, or delivered to replenish

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
				consumed stocks. However, the designed in measures include the implementation of an MPCP and EMP, which will ensure that the risk of potential release of synthetic compounds to the environment will be minimised across all phases. As a result, any additional inter-related effect is judged to be of no greater significance than those assessed for each individual phase, which in this case is a minor adverse effect which is not significant in EIA terms.
Operational painting and cleaning of marine growth	×	✓	×	This effect will only arise during the operation and maintenance phase and as such there will be no interaction effects across the Proposed Development phases. A minor adverse significance was concluded for this impact which is not significant in EIA terms.
Deterioration of water quality from cable and landfall works	✓	×	✓	The construction and decommissioning phases are anticipated to be 35 years apart. As a result, any additional inter-related effect is judged to be of no greater significance than those assessed for each individual phase, which in this case is a minor adverse effect which is not significant in EIA terms.
Receptor-led Effects				
There is potential for interactions to exist between the effects arising from the introduction of synthetic compounds into the marine environment (“accidental release of lubricants, chemicals or similar” and “operational painting and cleaning of marine growth”) and the increased risk of introduction and spread of INNS. Aquatic pollution may increase the success of INNS in the event that preceding pollution events have weakened the ability of native species to resist colonisation by non-native species. These individual impacts were assigned a significance of negligible to minor as standalone impacts and although potential combined impacts may arise (i.e. invasion of INNS following accidental release of synthetic compounds), it is predicted that this will not be any more significant than the individual impacts in isolation.				

76. 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.

20.6.9. BENTHIC SUBTIDAL AND INTERTIDAL ECOLOGY

77. For benthic subtidal and intertidal ecology, the following likely significant effects have been considered within the inter-related assessment:

- temporary and long-term habitat loss/disturbance;
- increased suspended sediment concentrations and associated sediment deposition;
- impacts to benthic invertebrates due to EMF;
- increased risk of introduction and spread of INNS; and
- alteration of seabed habitats arising from effects of physical processes.

78. Table 20.12 lists the inter-related effects (Proposed Development lifetime effects) that are predicted to arise during the construction, operation, and maintenance phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for benthic subtidal and intertidal ecology receptors.

79. As noted above, effects on benthic subtidal and intertidal 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:

- fish and shellfish ecology
  - temporary (during construction, operation and maintenance and decommissioning phases), long-term (during operation and maintenance phase only) and permanent habitat alteration (post-decommissioning) habitat loss resulting in indirect effects on fish ecology of negligible to moderate adverse significance (volume 2, chapter 9);
- marine mammals
  - changes in fish and shellfish communities affecting prey availability (during construction, operation and maintenance and decommissioning phases); and
- ornithology
  - changes in habitat or abundance and distribution of prey across all project phases resulting in indirect effects on ornithological receptors of negligible to minor significance (volume 2, chapter 11).

Table 20.12: Summary of Likely Significant Inter-Related Effects on the Environment for Benthic Subtidal and Intertidal Ecology from Individual Effects Occurring across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
Temporary and long term habitat loss/disturbance	✓	✓	✓	When habitat loss or disturbance is considered additively across all phases, the total area of habitat affected is larger than when considered across an individual phase (i.e. just construction). However, the temporary loss/disturbance will be highly localised to the vicinity of the construction activity (i.e. limited to the immediate footprints) during each phase (i.e. construction, operation and maintenance and decommissioning). Individual activities resulting in temporary habitat loss/disturbance will occur intermittently throughout this time with only a small proportion of the total area of habitat being impacted at any one time. The predominantly sand and coarse sediment habitats that are most likely to be affected are typical of, and widespread throughout, the UK and in the northern North Sea. All benthic habitats are predicted to recover. There is the potential for repeat disturbance to occur during the operation and maintenance phase, although it is predicted that the communities will have fully recovered from construction impacts by this time. Therefore, across the project lifetime, the effects on benthic ecology Important Ecological Features (IEFs) are anticipated to interact in such a way as to result in combined effects of minor to moderate (reducing to minor) significance in the construction and decommissioning phases and minor to negligible significance in the operation and maintenance phase (i.e. not of greater significance than the assessments presented for each individual phase).

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
Increased suspended sediment concentrations and associated sediment deposition	✓	✓	✓	The majority of the seabed disturbance (resulting in highest SSC/deposition) will occur during the construction and decommissioning phases, with any effects being short lived (i.e. during the construction and decommissioning phases). Benthic IEFs potentially affected by increased SSC and deposition are likely to have recovered in the intervening period between phases. Due to this and the low sensitivity (and/or high recoverability) of the species and habitats in question, the interaction of these impacts across the stages of the project life cycle is predicted to result in an effect negligible to minor significance in the construction and decommissioning phases and negligible significance in the operation and maintenance phase (i.e. not of any greater significance than those assessed for each individual phase).
Impacts to benthic invertebrates due to EMF	×	✓	×	This effect will only arise during the operation and maintenance phase and as such there will be no interaction effects across the project phases.
Increased risk of introduction and spread of invasive and non-native species	✓	✓	✓	Although the operation of construction/decommissioning vessels in the area (potentially from countries of origin other than the UK) may facilitate the spread of INNS across all phases, this effect will predominantly arise during the operation and maintenance phase as INNS will require the hard substrate to be in place to provide substrate on which to settle. However, the designed-in measures include the implementation of an INNS Management Plan, which will be included in the EMP (volume 4, appendix 22). 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 significance in all phases of the Proposed Development (i.e. of no greater significance than those assessed for each individual phase).
Alteration of seabed habitats arising from effects of physical processes	×	✓	×	This effect will only arise during the operation and maintenance phase and as such there will be no interaction effects across the project phases.
Receptor-led Effects				
Potential exists for spatial and temporal interactions between the effects arising from habitat loss/disturbance/alteration and increased SSC and associated sediment deposition effects on benthic habitats during the lifetime of the Proposed Development. Based on current understanding, and expert knowledge, the greatest potential for inter-related impacts is predicted to arise through the interaction of direct (both temporary and permanent) habitat loss/disturbance from seabed preparation, foundation installation/jack-up/anchor placement/scour, indirect habitat disturbance due to sediment deposition and indirect effects of changes in physical processes due to the operational wind farm. These individual impacts were assigned a significance of negligible to moderate (in the short term) as standalone impacts and although potential combined impacts may arise (i.e. spatial and temporal overlap of direct habitat disturbance), it is predicted that this will not be any more significant than the individual impacts in isolation. This is because the combined amount of habitat potentially affected would be typically restricted to the Proposed Development, the habitats affected are widespread across the UK and northern North Sea and, where temporary disturbance occurs, full recovery of the benthos is predicted. In addition, any effects due to changes in the physical processes are likely to be limited, both in extent (i.e. largely within the Proposed Development array area) and also in magnitude, with benthic ecology receptors having low sensitivity to the scale of the changes predicted. As such, these interactions are predicted to be no greater than the individual effects assessed in isolation.				

80. 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.

20.6.10. FISH AND SHELLFISH ECOLOGY

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

- temporary and long term subtidal habitat loss/disturbance;
- increased suspended sediment concentrations and associated sediment deposition;
- EMF from underwater electrical cabling;
- injury and/or disturbance to fish and shellfish from underwater noise and vibration; and
- colonisation of foundations, scour protection and cable protection.

82. Table 20.13 lists the inter-related effects (Proposed Development lifetime effects) that are predicted to arise during the construction, operation and maintenance phase, and decommissioning of the Proposed Development and also the inter-related effects (receptor-led effects) that are predicted to arise for marine mammal and offshore ornithology receptors.

83. As noted above, 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 in the fish and shellfish community resulting from impacts during construction, operation and maintenance, and decommissioning may lead to loss of prey resources for marine mammals resulting in effects of imperceptible significance volume 2, chapter 10.
- offshore ornithology:
  - one key stressor has been identified for offshore and intertidal ornithology. The assessment considers the overall effects on foraging seabirds from potential changes in prey communities that could be caused by disturbance, habitat loss, SSC, and therefore, in this respect, has taken an ecosystem-based approach. The assessment of effects, however, demonstrated that due to the high mobility of foraging seabirds and their ability to exploit different prey species, and the small scale of potential changes in context of wider available habitat, the changes to fish prey communities are unlikely to have a significant effect on foraging seabirds; and
- commercial fisheries;
  - changes in the fish and shellfish community resulting from impacts during construction, operation and maintenance, and decommissioning may affect commercial fisheries receptors by effects on target species, however as noted in this chapter, there are negligible or minor effects on fish and shellfish receptors therefore negligible or minor effects are predicted for commercial fisheries, which are not significant in EIA terms.

Table 20.13: Summary of Potential Inter-Related Effects for Fish and Shellfish Ecology from Individual Effects Occurring across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase C	Phase O	Phase D	Likely Significant Inter-Related Effects
Temporary and long term subtidal habitat loss/disturbance	✓	✓	✓	When subtidal habitat loss (temporary and long term) is considered additively across all phases of the project, although the total area of habitat affected is larger than for the individual project stages, similar habitats are widespread across the UK and in the northern North sea. During the operation and maintenance phase, the majority of the disturbance will be highly localised and the habitats affected are predicted to recover quickly following completion of maintenance activities with fish and shellfish IEFs recovering into the affected areas. In addition, many operation and maintenance activities will be affecting the same areas affected during construction (e.g. jack up operations adjacent to wind turbines, reburial of exposed cables). Therefore, across the project lifetime, the effects on fish and shellfish IEFs 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.
Increased suspended sediment concentrations and associated sediment deposition	✓	✓	✓	The majority of the seabed disturbance (resulting in highest SSC/deposition) will occur during the construction and decommissioning phases. IEFs and associated spawning/nursery habitats potentially affected by increased SSC and deposition are likely to have recovered in the intervening period between the construction and decommissioning phases. Therefore, across the project lifetime, the effects on fish and shellfish IEFs 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.
Injury and/or disturbance to fish and shellfish from underwater noise and vibration	✓	×	×	The majority of disturbance from underwater noise (resulting in greatest potential for injury or behavioural effects) is predicted to result from piling during the construction phase. Noise associated with the operation and maintenance and decommissioning phases was scoped out of the assessment, therefore, across the project lifetime, the effects on fish and shellfish 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 assessment.
Electromagnetic Fields (EMF) from underwater electrical cabling	×	✓	×	This effect will only arise during the operation and maintenance phase and as such there will be no interaction effects across the phases of the Proposed Development.
Colonisation of foundations, scour protection and cable protection	×	✓	×	This effect will only arise during the operation and maintenance phase and as such there will be no interaction effects across the phases of the Proposed Development.
Receptor-led Effects				
Potential exists for spatial and temporal interactions between habitat loss/disturbance, increased SSC/deposition, underwater noise, colonisation of foundations, scour protection and cable protection, and EMF effects and during the lifetime of the Project. Based on current understanding, and expert knowledge, there is scope for potential interaction impacts to arise through the interaction of habitat loss (temporary and long term), increased SSC, underwater noise from piling during the construction phase and EMF effects during the operation and maintenance phase. These individual impacts were assigned a significance of negligible to minor as standalone impacts and although potential combined impacts may arise, it is important to recognise that the individual activities will not necessarily occur simultaneously or in the same area of the Proposed Development. Further, some construction related impacts are likely to result in effects on fish and shellfish over a much wider scale than others. For example, the majority of effects associated with an increase in SSC/deposition will arise from seabed preparation works installation of Proposed Development offshore export and inter-array cables with relatively limited effects on fish behaviour (e.g. avoidance over a relatively small range in the immediate proximity of cable installation operations), whereas for underwater noise impacts associated with foundation piling, these will affect fish behaviour over a much larger area, with avoidance predicted over the range of several km from the construction operations. In any case, all construction related impacts will be temporary and reversable following cessation of construction or decommissioning with fish and shellfish communities recovering into wind farm areas following cessation of construction. Furthermore, underwater noise will result in the displacement of mobile fish from areas around foundations which in turn will mean that these species will not be exposed to the greatest predicted increases in SSC. Any potential behavioural effects as a result of EMF would be likely to occur over the same area as habitat loss/change effects (i.e. within metres of the cable) and therefore habitat loss effects would not be additive to EMF effects. There may be localised changes in fish and shellfish communities in the areas affected by long term habitat loss, due to potential changes in substrate type, increased foraging opportunities, and behavioural effects associated with EMF. Any shifts in baseline assemblage will be limited to these areas, therefore, effects of greater significance than the individual impacts in isolation (i.e. negligible to moderate) are not predicted.				

84. 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.

20.6.11. MARINE MAMMALS

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

- injury and disturbance from elevated underwater noise during piling (fixed foundations);
- injury and disturbance to marine mammals from elevated underwater noise during site investigation surveys;
- injury and disturbance to marine mammals from elevated underwater noise during Unexploded Ordnance (UXO) clearance;
- injury and disturbance to marine mammals from elevated underwater noise due to vessel use and other activities;
- increased potential to experience injury by marine mammals due to collision with vessels; and
- changes in fish and shellfish communities affecting prey availability.

86. Table 20.14 lists the inter-related effects that are predicted to arise during the construction, operation and maintenance, and decommissioning phases of the Proposed Development. Table 20.14 also lists the inter-related effects where stressors may combine to lead to greater effects on marine mammal receptors (receptor-led effects).

87. There are no identified effects on marine mammal receptors that have the potential to have secondary effects on other receptors.

Table 20.14: Summary of Likely Significant Inter-Related Effects for Marine Mammals from Individual Effects Occurring across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase C	Phase O	Phase D	Likely Significant Inter-Related Effects
Injury and disturbance from elevated underwater noise during piling (fixed foundations).	✓	×	×	Elevated underwater noise during piling (construction phase only) could interact with other sources of underwater noise associated with the Proposed Development. This could contribute to an increase in the soundscape which in turn could affect marine mammals. However, the underwater noise from piling is likely to reach over a greater extent compared to other noise-producing activities and therefore during this time it is unlikely that it would act additively with other noise-producing activities occurring at the same time as piling noise is likely mask other noise sources. Piling noise, although occurring during construction phase only, would contribute to the overall duration of noise impacts throughout all phases of the Proposed Development.
Injury and disturbance to marine mammals from elevated underwater noise during site investigation surveys.	✓	✓	×	Elevated underwater noise during site investigation surveys could interact with other sources of underwater noise over the construction and operation and maintenance phases of the Proposed Development and contribute to an increase in the soundscape which in turn would affect marine mammals. This impact will occur during short term events. Additive effects are possible as more animals may be affected at any one time and/or the duration of elevated underwater noise from all activities could be extended.
Injury and disturbance to marine mammals from elevated underwater noise during UXO clearance.	✓	×	×	Elevated underwater noise during UXO clearance (pre-construction phase) could interact with other sources of underwater noise. This could contribute to an increase in the soundscape which in turn could affect marine mammals. The proposed approach to UXO clearance is clearance using low order techniques which would result in localised disturbance (Temporary Threshold Shift (TTS) fleeing) out to ~3 km. Additional disturbance is possible due to use of ADDs and soft start charges as part of the mitigation approach to reduce the risk of injury. Additive effects are possible as more animals may be affected at any one time, although noting that for each UXO clearance the duration – including mitigation - will be very short (approximately 1.5 hour). However, temporally UXO clearance could add to the overall duration of elevated underwater noise from all other activities during pre-construction and will contribution to the overall duration of noise impacts throughout all phases of the Proposed Development.
Injury and disturbance to marine mammals from elevated underwater noise due to vessel use and other activities.	✓	✓	✓	Elevated underwater noise during vessel use and other non-piling construction activities could interact with other impacts that produce underwater noise and contribute to an increase in the soundscape which in turn would affect marine mammals. Vessels will be used throughout all stages of the Proposed Development and could cause additional disturbance to marine mammals. Other construction activities include drilling (foundation installation) and cable trenching/laying and could also lead to disturbance effects. Effects are likely to be localised for non-piling construction activities and during vessel movements (e.g. out to maximum of 4.3 km), however, temporally these effects could occur over all phases of the Proposed Development.
Increased risk of injury of marine mammals due to collision with vessels.	✓	✓	✓	Over the lifetime of the Proposed Development there will be an ongoing risk of collision associated with vessel activity throughout all phases. If injury to marine mammals from collisions did occur this could lead to losses of individuals and potentially have an effect at the population-level, particularly for species with smaller populations (i.e. MUs), such as bottlenose dolphin *Tursiops truncatus* and harbour seal *Phoca vitulina*. However, with designed-in measures the risk of collisions will be reduced through adopting good practice code of conduct for vessel operators and therefore the risks will be reduced. In addition, to some extent the noise from the vessels themselves would act antagonistically with this impact by deterring animals away from vessels and thereby further reducing the risk of injury due to collision.
Changes in fish and shellfish communities affecting prey availability.	✓	✓	✓	Fish and shellfish communities may be affected variously through all phases of the Proposed Development and therefore could present a long-term effect on marine mammals through changes/reductions to prey availability. Inter-related effects on fish and shellfish receptors are described in more detail in volume 2, chapter 9. For all potential impacts and at all phases of the Proposed Development the effects were, however, predicted to be very localised and 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.
Receptor-led effects				
A number of the impacts identified could potentially interact to cause an additive/synergistic/antagonistic effects on marine mammal receptors. There are three key stressors identified for marine mammals: • stressor 1: injury or disturbance from elevated underwater noise; • stressor 2: injury due to collisions with vessels; and • stressor 3: changes in prey communities. Various activities described from the impacts considered above could interact to contribute to each of these stressors (i.e. there are a number of activities that lead to elevations in underwater noise) and in additional each stressor could interact to contribute to a different, or greater effect on marine mammal receptors than when the effects are considered in isolation.				

88. 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.

Stressor 1. Injury or disturbance from elevated underwater noise:

89. During the pre-construction phase activities resulting in elevated underwater noise include UXO clearance, site investigation surveys and vessel movements. These activities are likely 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 each activity. For example, UXO clearance would result in no more than 14 single events with disturbance occurring mainly during 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 (due to an accidental a high order detonation). Site investigation surveys are likely to occur over a total duration of up to three months whilst disturbance during vessel activity will occur intermittently throughout this phase with timings linked to the pre-construction activities.

90. During the construction phase, activities resulting in elevated underwater noise include pile-driving, other construction activities and vessel movements. Since injury to marine mammals will be mitigated through

an MMMP, the key focus is on disturbance effects. Disturbance could occur intermittently on a total of 372 days (within a 52-month piling period) during the construction phase of 96 months. Other construction activities (e.g. drilling and cable laying) and vessel movements would occur intermittently within the 96 months construction phase. When piling occurs the disturbance effects are likely to be greater than for any of the other activities contributing to elevated underwater noise so there is less likely to be an additive or synergistic effect during piling. There may, however, be an additive effect spatially where two or more noise-producing activities occur in different parts of the Proposed Development area, or temporally due to ongoing disturbance from activities throughout the construction phase (e.g. if they occur consecutively).

91. Activities resulting in elevated underwater noise during the operation and maintenance phase include vessel activity and geophysical surveys. These activities are likely 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 each activity and there may be an additive effect spatially where two or more noise-producing activities occur in different parts of the Proposed Development area, or temporally due to ongoing disturbance from activities throughout the operation and maintenance phase (e.g. if they occur consecutively).

92. Vessel movements associated with decommissioning activities will result in elevated underwater noise which could lead to disturbance to marine mammals. Disturbance is likely to occur as short term, localised events and there may be an additive effect spatially where vessels are operating in different parts of the Proposed Development area, or temporally due to ongoing disturbance throughout the decommissioning phase.

93. Marine mammal receptors will experience ongoing disturbance due to elevations in underwater noise from different sources at all phases of the Proposed Development. The sensitivity of key species will be linked to their ability to tolerate the stressor such that their ability to function normally (forage, reproduce, communicate, avoid predators, etc) is not impeded. The assessment - which adopted a highly precautionary approach - has demonstrated that for all impacts, considered in isolation, the residual effects will not be significant (after implementation of mitigation) as either the spatial scale is very localised or where larger scale effects do occur (i.e. during piling) these will be highly reversible with animals returning to baseline levels rapidly. After implementation of appropriate mitigation there is, however, potentially a small residual number of harbour porpoise *Phocoena phocoena* that could experience auditory injury during UXO clearance activities and would represent only a very small proportion of the North Sea MU population. There are, however, uncertainties as to how all activities interact to contribute to an additive effect from underwater noise as a stressor. In a Before-After-Control-Impact design (BACI) study looking at foraging activity of harbour porpoise between baseline periods and different construction phases of the Beatrice and Moray East Offshore Wind Farms, Benhemma-Le-Gall *et al*., (2021) found an eight to 17% decline in porpoise occurrence in the impacted area during pile-driving and other construction activities with probability of detection negatively related to levels of vessel intensity and background noise.

94. To some extent it is anticipated that animals will acclimatise to or compensate for such increases in underwater noise. For example, Graham *et al*. (2019) demonstrated acclimatisation by showing that the proportional response of harbour porpoise to piling noise decreased over the piling phase; from the first pile to the last pile the proportion of animals disturbed at a received level of 160 dB re 1 µPa decreased from 91.5% to 49.2%. 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, harbour porpoises displaced during wind farm construction of Beatrice and Moray East Offshore Wind Farms increased their buzzing activity, potentially compensating for lost foraging opportunities (although there may be an additional energetic cost from the fleeing and distance travelled to compensate for) (Benhemma-Le Gall *et al*., 2021).

<u>Stressor 2. Injury due to collisions with vessels:</u>

95. This stressor is associated with vessel movement, the impact of which was assessed from different types of vessels and at different phases of the Proposed Development. Over the lifetime of the Proposed Development there will be a longer term risk to marine mammal receptors however, with designed-in measures in place the potential of experiencing injury is likely to be reduced and therefore it is not anticipated that an additive effect will occur. In addition, as mentioned in volume 2, chapter 10, Table 10.65, to some extent the noise from the vessels themselves would act antagonistically with this impact by deterring animals away from vessels and thereby further reducing the risk of injury due to collision. Furthermore, marine mammals in this area are already accustomed to high level of vessel activity. 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. Increased whistle production may be a tactic to reduce signal degradation to ensure that information is being communicated in noisy environment, but it also demonstrates that animals are aware of approaching vessel from a distance. Findings of this study also corroborated previous research of Nowacek *et al.* (2001) who found that bottlenose dolphins swim in tighter groups during vessel approaches and that if the vessel is loud enough to be detected by an animal, the likelihood of collision decreases.

<u>Stressor 3: Changes in prey communities:</u>

96. The assessment considers overall effect on fish and shellfish communities from multiple stressors (i.e. habitat loss, SSC, underwater noise, EMF etc) and therefore, in this respect, has taken an ecosystem-based approach. For some, stressors (e.g. underwater noise the effects on fish and shellfish) will be over the same timescales as marine mammals whilst for others, such as temporary habitat loss, timescales may be different (e.g. low mobility or sessile species may recover slowly). The assessment of effects, however, demonstrated that due to high mobility of marine mammals and ability to exploit different prey species, and small scale of potential changes in context of wider available habitat, the changes to fish and shellfish communities are unlikely to have an effect even from multiple stressors.

<u>Multiple stressors: inter-related effect of all stressors</u>

97. Arrigo *et al.* (2020) studied synergistic interactions among growing stressors to an Arctic ecosystem and found that synergistic interactions amplify adverse stressor effects and the impact of synergy is predicted to increase with the magnitude of stressors. Findings of this study suggest that although large organisms at higher trophic levels, such as marine mammals, tend to be generally negatively impacted by increasing stressor interaction strength, the variability in the response to stressor is small and therefore reduces the probability of population collapse.

98. For stressor 1 (increase in underwater noise), the potential for marine mammals to forage in different habitats and to compensate for reduced foraging time was discussed. The ability of displaced animals will therefore 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). Namely, due to the importance of the areas for survival, (i.e. high resource availability), animals may be highly motivated to remain in an area despite adverse impacts (Rolland *et al.,* 2012). Thus, the inter-related effects of underwater noise and changes in fish and shellfish prey resources needs to be considered. Impacts on fish and shellfish prey resources (stressor 2) 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 the Proposed Development area. Within the boundaries of the Proposed Development there may, however, be short term inter-related effects of noise disturbance and reduced fish and shellfish prey resources. For example, for animals

remaining in proximity to the Proposed Development a disruption in foraging may not be 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 that it might be possible that damaged or disoriented prey could attract marine mammals to an area of impact, providing short term feeding opportunities but increasing levels of exposure, however, there have as yet been no attempts to investigate such indirect effects on marine mammals.

99. The assessment has described only potential adverse effects but there is also potential for some beneficial effects on marine mammal receptors. The introduction of hard substrates in offshore wind farms can lead to the establishment of new species and new fauna communities which may in turn attract marine mammals (Lindeboom *et al*., 2011; Raoux *et al.,* 2017; Fowler *et al.,* 2018). 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) demonstrated that harbour seals and grey seals *Halichoerus grypus* 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. Lindeboom *et al.* (2011) studied the ecological effects of the Offshore Wind Farm Egmond aan Zee and reported that even though the fish community was highly dynamic in time and space and only minor effects upon fish assemblages were observed during the operation and maintenance phase, some fish species, such as cod, positively benefited from the 'shelter' within the wind farm due to reduced fishing activity and the new hard substratum with associated fauna. Increased echolocation activity of harbour porpoise within the wind farm may be correlated with presence of additional food sources, suggesting that more harbour porpoises were found within the wind farm area compared to the reference areas due to increased food availability (Lindeboom *et al.,* 2011).

100. Inter-related effects between underwater noise and collision risk have been discussed previously and it is considered likely that marine mammals will move away from moving vessels in response to engine noise therefore reducing the risk of collision (classed as an antagonistic interaction). Alternatively, marine mammals may tolerate and persist in a highly stressed state (as a result of injury caused by underwater noise) while the vessels are approaching (Muto *et al.* 2018) and/or become habituated to vessel noise, not moving away from the vessel (McWhinnie *et al.,* 2018), which would result in a synergistic interaction (Weilgart, 2011). Subsequently, the outcome will depend on the degree of habituation and a number of acoustical properties that allow an approaching vessel to be detected by a marine mammal species (Gerstein *et al.,* 2005). However, with designed-in measures in place it is likely that any risk of injury from collision with vessels will be negligible.

101. Evidence for the potential long-term effects of wind farms on marine mammals, related to all potential stressors, comes from monitoring programmes comparing baseline levels of abundance to construction and post-construction (operation and maintenance) phases. It is not common to prescribe impact monitoring studies with regard to marine mammals as a part of licence conditions in the UK and therefore data is sparse.

102. At Scroby Sands Offshore Wind Farm, off the coast of Norfolk, aerial survey haul-out counts were conducted before, during and after the construction phases in order to monitor harbour and grey seal counts at haul-out site, located less than two kilometres away from the offshore wind farm array (Skeate and Perrow 2008; Skeate *et al.,* 2012). Studies reported a decline in harbour seal numbers 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 operation and maintenance phase. 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). Regional changes in patterns of haul-out use by harbour seals in the Wash coincided with the construction of the Scroby Sands Offshore Wind Farm, however, such changes in harbour seal number could have been part of wider regional dynamics (Verfuss *et al.,* 2016).

103. 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 (Walls *et al.,* 2013). Data suggested that harbour porpoise were displaced from the wind farm site during the construction phase and operation and maintenance phase 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 (Verfuss *et al.,* 2016).

104. With the expansion of offshore wind farms, post-construction monitoring programmes are being executed at various developments in Europe. A study on short-term effects of the construction of wind turbines on harbour porpoises at Horns Rev Offshore Wind Farm showed a decrease in porpoise acoustic activity within the wind farm at the onset of piling operations and subsequent recovery to higher levels a few hours after each piling operation was completed (Tougaard*, et al.,* 2003). Another study at Horns Rev has shown that over the entire construction phase there was a negligible change in the abundance of harbour porpoise in the wind farm area compared to reference areas (Teilmann *et al.,* 2008). 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. At Nysted Offshore Wind Farm, initially during construction and the first two years of operation there were lower acoustic detections of harbour porpoises in the wind farm area with recovery starting to occur within two years after the end of construction suggesting that animals were gradually habituating and returning to the wind farm area (Teilman *et al.,* 2008).

105. Simulations of the response of harbour porpoise to wind farm construction undertaken by Nabe-Nielsen *et al.* (2011) suggested that wind farms already existing off Danish coast do not have impact on porpoise population dynamics and that the that construction of new wind farms is not expected to cause any changes in the long-term dynamics of the population. Similarly, various studies investigated possible interactions between seals and Danish offshore wind farms (Nysted Wind Farm, 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 (Edren *et al*., 2010; McConnell *et al.,* 2012).

106. These examples of monitoring studies suggest that, despite the potential effects from multiple stressors associated with offshore wind farms, marine mammals can quickly recover and return to the impacted area. Therefore, these inter-related effects would not be significant in EIA terms.

20.6.12. OFFSHORE AND INTERTIDAL ORNITHOLOGY

107. For offshore and intertidal ornithology, the following potential impacts have been considered within the inter-related assessment:

- disturbance and displacement from increased vessel activity and other construction/decommissioning activity
- temporary and long-term subtidal habitat loss/disturbance;
- increased suspended sediment concentrations; and
- disturbance and loss of seabed habitat arising from cable installation/removal within the Outer Firth of Forth and St Andrews Bay Complex SPA

108. In addition volume 3, appendix 20.1, outlines potential interactions on ornithological receptors which could contribute to an ecosystem assessment.

109. Table 20.15 lists the inter-related effects (Proposed Development lifetime effects) that are predicted to arise during the construction, operation and maintenance phase, and decommissioning of the Proposed Development.

110. Table 20.15 also lists the inter-related effects where stressors may combine to lead to greater effects on offshore and intertidal ornithology receptors (receptor-led effects).

111. One key stressor has been identified for offshore and intertidal ornithology. The assessment considers the overall effects on foraging seabirds from potential changes in prey communities that could be caused by disturbance, habitat loss, SSC, and therefore, in this respect, has taken an ecosystem-based approach. The assessment of effects, however, demonstrated that due to the high mobility of foraging seabirds and their ability to exploit different prey species, and the small scale of potential changes in context of wider available habitat, the changes to fish prey communities are unlikely to have a significant effect on foraging seabirds. Further discussion is presented in volume 3, appendix 20.1.

Table 20.15: Summary of Potential Inter-Related Effects for Offshore and Intertidal Ornithology from Individual Effects Occurring across the Construction, Operation and Maintenance and Decommissioning Phases of the Proposed Development and from Multiple Effects Interacting Across all Phases (Receptor-led Effects)

Description of Impact	Phase			Likely Significant Inter-Related Effects
	C	O	D	
Disturbance and displacement from increased vessel activity and other construction/decommissioning activity	✓	✓	✓	Disturbance arising from these operations has the potential to affect identified key species directly (e.g. disturbance of individuals) and indirectly (e.g. disturbance to prey distribution or availability). Such disturbance is predicted to occur intermittently throughout the construction and decommissioning periods, with less disturbance from vessel activity predicted in the operation and maintenance phase. Overall, the significance of any such effects on seabirds were considered to be no more than minor adverse (see volume 2, chapter 11). As this disturbance will be temporary and intermittent in nature, effects on seabirds 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 period.
Temporary and long term subtidal habitat loss/disturbance	✓	✓	✓	When subtidal habitat loss (temporary and long term) is considered additively across all phases of the project, although the total area of habitat affected is larger than for the individual project stages, similar habitats are widespread across the UK and in the northern North Sea. During the operation and maintenance phase, the majority of the disturbance will be highly localised and the habitats affected are predicted to recover quickly following completion of maintenance activities with prey species for seabirds recovering into the affected areas. In addition, many operation and maintenance activities will be affecting the same areas affected during construction (e.g. jack up operations adjacent to wind turbines, reburial of exposed cables). Overall, the significance of any such effects on seabirds were considered to be no more than minor adverse (see volume 2, chapter 11). Therefore, across the project lifetime, the effects on seabirds 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.
Increased suspended sediment concentrations	✓	×	✓	The majority of the seabed disturbance (resulting in highest SSC will occur during the construction and decommissioning phases. Fish prey species and associated spawning/nursery habitats potentially affected by increased SSC and deposition will recover quickly following impact exposure such that there will be no inter-related effects across the construction and decommissioning phases. Overall, the significance of any such effects on seabirds were considered to be no more than minor adverse (see volume 2, chapter 11). Therefore, across the project lifetime, the effects on seabirds 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.
Disturbance and loss of seabed habitat arising from cable installation/removal within the Outer Firth of Forth and St Andrews Bay Complex SPA	✓	✓	✓	Disturbance arising from these activities has the potential to affect identified species directly (e.g. disturbance of individuals) and indirectly (e.g. disturbance to prey distribution or availability). Such disturbance is predicted to occur intermittently throughout the construction and decommissioning periods, with occasional disturbance predicted in the operation and maintenance phase. Overall, the significance of any such effects on seabirds were considered to be no more than minor adverse (see volume 2, chapter 11). As this disturbance will be temporary and intermittent in nature, effects on seabirds 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 period.
Displacement and barrier effects from offshore infrastructure	×	✓	×	This effect will only arise during the operation and maintenance phase and as such there will be no interaction effects across the project phases.
Collision effects from wind turbines during operation and maintenance phase	×	✓	×	This effect will only arise during the operation and maintenance phase and as such there will be no interaction effects across the project phases.
Receptor-led Effects				
Potential exists for spatial and temporal interactions between habitat loss/disturbance, increased SSC/deposition and colonisation of foundations, scour protection and cable protection, during the lifetime of the Project. Based on current understanding, and expert knowledge, there is scope for potential interaction impacts to arise through the interaction of habitat loss (temporary and long term) and increased SSC. There is the potential for these identified impacts to interact to cause an additive/synergistic/antagonistic effect on offshore and intertidal ornithology receptors. One key stressor has been identified for offshore and intertidal ornithology: • changes in prey communities. Various activities described from the impacts considered above could interact to contribute to a different, or greater effect on changes in prey communities than when the effects are considered in isolation, which in turn could affect foraging seabirds.				

112. The assessment of potential inter-related effects on seabirds from the impacts outlined above considered that due to the high mobility of foraging seabirds and their ability to exploit different prey species, and the small scale of potential changes in the context of wider available habitat, these effects are not anticipated to interact in such a way as to result in a significant effect on foraging seabirds. For further information on foraging seabirds see paragraph 256 onwards. Overall, it is concluded that these inter-related effects would not be significant in EIA terms.

20.7. PART TWO: ECOSYSTEM EFFECTS ASSESSMENT

20.7.1. OVERVIEW

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

114. Biodiversity, the variety of life on Earth, is the key indicator of the health of an ecosystem. A wide variety of species will cope better with external pressures than a limited number of species in large populations. Even if certain species are affected by climate change or human activities, the ecosystem as a whole may adapt and survive (European Commission, 2022).

115. The purpose of this ecosystem-based assessment is to qualitatively assess the potential impacts of the Proposed Development at the ecosystem level, to better understand how predator – prey relationships could be altered and how this could impact the functioning of the ecosystem. Whilst not included in the 2020 Berwick Bank Wind Farm Scoping Opinion (MS-LOT, 2021), the 2020 Berwick Bank Wind Farm Offshore Scoping Report (SSER, 2020) included a description of the need to address effects at an ecosystem level: "*Increasingly there is a need to understand potential impacts holistically at a wider ecosystem scale rather than via the standard set of discrete individual receptor assessments. This assessment should focus on potential impacts across key trophic levels particularly in relation to the availability of prey species. 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 this may have on population level impacts*."

20.7.2. ECOSYSTEM BASELINE

116. This section provides a summary of the abiotic and biotic components of the marine ecosystem within the Proposed Development array area and Proposed Development export cable corridor.

117. The Proposed Development will be located in the central North Sea, a shallow continental shelf sea, approximately 47.6 km offshore of the East Lothian coastline and 37.8 km from the Scottish Borders coastline at St. Abbs. The bathymetry of the Proposed Development array area is influenced by the presence of Marr Bank and the northern extent of the Berwick Bank. These two bank features are defined as Shelf Banks and Mounds. A maximum seabed depth is recorded at two locations where deep channels cut into the seabed east and west of the central point of the Proposed Development array area (68.5 m Lowest Astronomical Tide (LAT)). The shallowest area is observed in the west of the Proposed Development array area (33.4 m LAT). The average seabed depth across the array area is 51.7 m below LAT.

118. The seafloor morphology within the Proposed Development array area and export cable corridor is very varied. Table 20.16 summaries the types of morphological features present within the Proposed Development.

Table 20.16: Seafloor Morphology Within the Proposed Development Array Area and Export Cable Corridor

Seafloor Morphology		
Primary Morphological Features		**Secondary Morphological features**
Proposed Development Array Area	**Proposed Development Export Cable Corridor**	
• large scale banks (the Marr Bank and the Berwick Bank); • arcuate ridges; • incised valleys, relic glacial lakes and channels; and • bedforms.	• outcrops and erosional surfaces and platforms; • ridges; and • high topographic mounds and incised valleys and channels.	• subaqueous dunes; • irregularity of the seafloor; • features related to anthropogenic activity; and • boulder fields.

119. Most of the seabed within the Proposed Development array area is 'featureless', with the exception of the southern and north-western extents which are dominated by megaripples, sand waves, ribbons and bars. Boulders are also prevalent across the array area and are either represented as isolated boulders or as clusters.

120. Seabed sediments present within the Proposed Development are summarised in Table 20.17.

Table 20.17: Seabed Sediments within the Proposed Development

Seabed Sediments	
Proposed Development Array Area	**Proposed Development Export Cable Corridor**
• coarse gravel, shelly gravelly sand with boulders; • mixed sediment; • mixed sediments with patchy coarse material or boulders; and • muddy sand.	• hard substrate: coarse sediment with cobbles, boulders and rock outcropping or sub outcropping characterised by high reflectivity signature in the side-scan data; • gravelly sand and coarse sediments with medium reflectivity; and • sandy sediments including fine sand and muddy sand with low reflectivity.

121. The benthic communities within the Proposed Development array area and Proposed Development export cable corridor are characterised by echinoderms (sea urchins and brittle stars), bivalves and polychaetes in both the Proposed Development array area and Proposed Development export cable corridor, both exhibiting similar diverse communities. The predominantly sand and coarse sediment habitats within the Proposed Development are typical of, and widespread throughout, the UK and in the northern North Sea. The muddy sediments in the central section of the Proposed Development export cable corridor are characterised by communities of sea pens and burrowing megafauna. Additionally, both the Proposed Development Array area and Proposed Development export cable corridor overlap with the Firth of Forth Banks Complex marine protected area which is designated for ocean quahog, offshore subtidal sand and gravels, shelf banks and mounds, moraines representative of the Wee Bankie Key Geodiversity Area (volume 2, chapter 8).

122. Table 20.18 provides a summary of the seven main broad subtidal habitats present within the Proposed Development area.

Table 20.18: Broad Subtidal Habitat Types

Broad Habitat	Description	Conservation Interest
Subtidal Habitats		
Subtidal sand and muddy sand sediments	Subtidal sand and muddy sand, characterised by amphipods, bivalves and Amphiura.	Scottish PMF, UK Biodiversity Action Plan (BAP) priority habitat
Subtidal coarse and mixed sediments	Subtidal coarse and mixed sediments characterised by amphipods, bivalves, polychaetes and barnacles.	UK BAP priority habitat, Scottish PMF
Moderate energy subtidal rock	Subtidal rock with sparce communities within the Proposed Development Array Area and inshore Proposed Development export cable corridor.	Scottish PMF, potential OSPAR habitat
Seapens and burrowing megafauna	Muddy sediments with large burrow and seapens within the Proposed Development export cable corridor.	OSPAR habitat, Scottish PMF, UK BAP priority habitat
Cobble/stony reef outside of an SAC	Cobble/stony reef outside an SAC with high epifaunal diversity.	Annex I habitat outside of an SAC, Scottish PMF
Rocky reef outside an SAC	Medium potential rocky reef outside an SAC	Annex I habitat outside of an SAC
Sabellaria reef outside of an SAC	Low potential Sabellaria reef outside of an SAC	Annex I habitat outside of an SAC, UK BAP priority habitat, OSPAR habitat
MPA Qualifying Features		
Subtidal sands and gravels	Subtidal sand and gravels within the FFBC MPA.	UK BAP habitat Qualifying feature of an MPA, Scottish PMF.
Shelf banks and mounds	Banks and mounds on the continental shelf composed of coarse sands and gravels.	
Ocean Quahog *A. islandica*	Ocean Quahog *A. islandica*	Qualifying feature of an MPA, Scottish PMF

123. 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 the following sections 20.7.4, 0, 20.7.8, 20.7.9 and 20.7.10.

20.7.3. THE MARINE FOOD WEB

124. Trophic levels describe the hierarchal 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 herring) and lesser sandeel *Ammodytes marinus* (hereafter 'sandeel'), 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). Seabirds, along with marine mammals, 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 20.1.

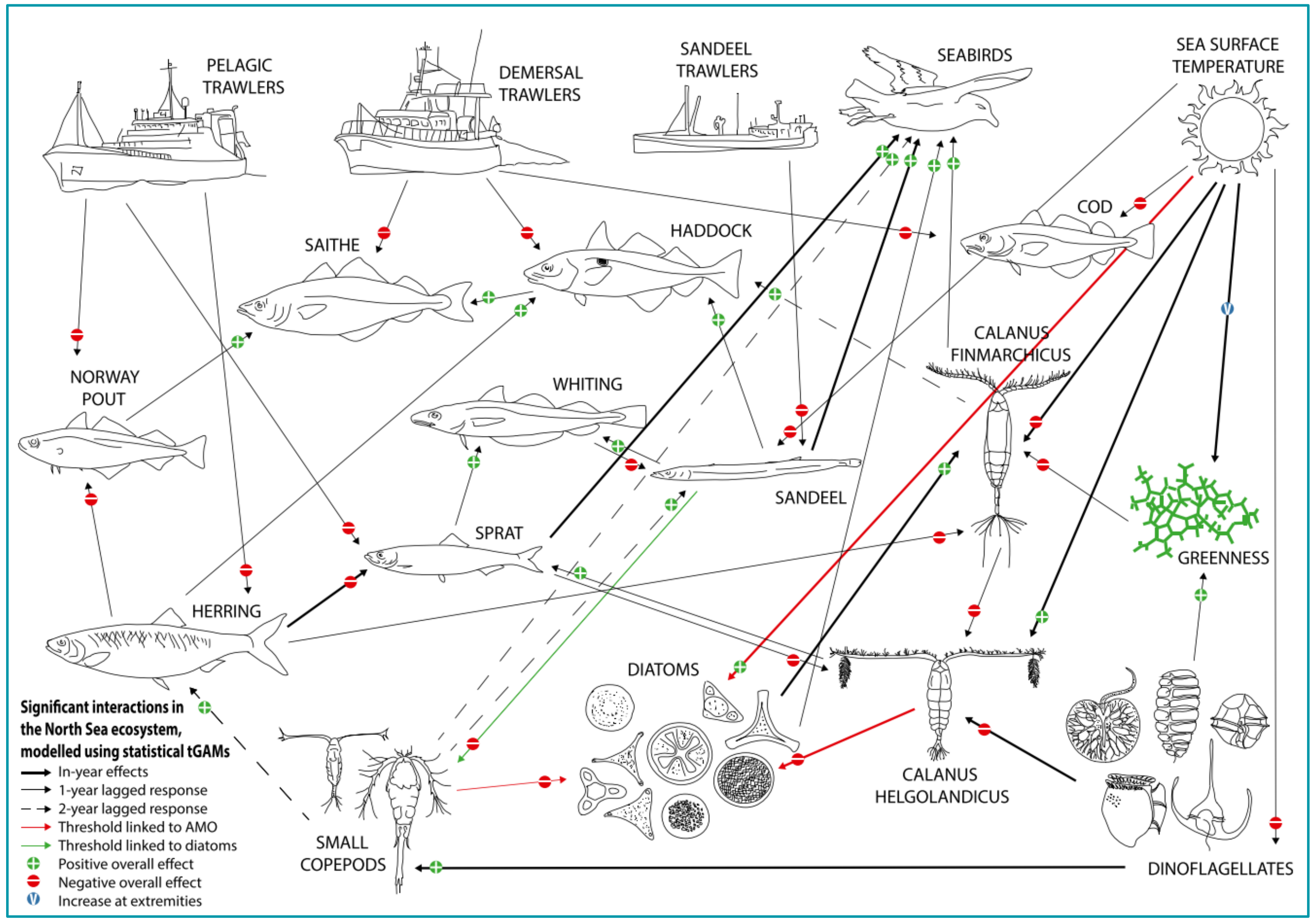

Figure 20.1: Significant Interactions Modelled Between Functional Groups and Drivers (From Lynam *et al.*, 2017)

20.7.4. THE KEY PREDATOR SPECIES

125. Volume 2, chapters 9, 10 and 11, provide details on the fish, marine mammals and seabirds which are most abundant in the associated topic Proposed Development study area and are the receptors most likely to be impacted by activities associated with all phases of the Proposed Development. From information on these receptors groups it is possible to ascertain which fish, seabird and marine mammals species are likely to be the key predators in the marine ecosystem in this part of the central North Sea and within the study areas outlined in section 20.1.3.

Piscivorous fish

126. The key marine predatory fish likely to utilise the marine environment within the Proposed Development array area and Proposed Development export cable corridor are plaice, cod, haddock, whiting, saithe, pollark and European hake. The diet of these species includes small forage such as sandeel, juvenile

whiting, juvenile haddock and small flounder. Elasmobranchs which are likely to be present and whose diet will also include small forage fish include tope, spurdog, common skate and rays.

127. The migration routes of diadromous fish species which also feed on small forage fish, and which are likely to pass through the Proposed Development area during migration (volume 3, appendix 9.1) are sea trout, European eel, sea lamprey, twaite shad, allis shad and Atlantic salmon.

128. Table 20.19 lists the key predatory fish species and the prey they feed on. This shows that although sandeel, herring, mackerel and sprat are components of most of the key predators' diets, other fish as well as other benthic fauna are also important in their diet.

Table 20.19: Key Predatory Fish Species and their Prey

Species	Typical Prey Species
Plaice	Cockles, razor shells, worms, crustaceans, brittle stars and sandeel
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.
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.
Whiting	Worms, crustaceans and shellfish and small fish
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 Seafood, 2022).
Pollark	Pollack small fish and sandeel, but will also scour the seabed for anything it can find such as worms and crustaceans
Hake	Mackerel, herring, pouting, sandeel, squid and smaller members of their own species
Tope	Dab, flounder and pouting, as well as mackerel and herring. They will also take squid and on occasion crustaceans.
Spurdog	Small flounder, plaice, codling and sprats, herring, and small crustaceans.
common skate	Crustaceans and shellfish, as well as other fish such as flatfish. Larger skate will also hunt in mid-water for pelagic fish.
Rays	Crustaceans and crabs mainly, but will also eat small fish, especially flatfish.
Diadromous fish (Sea trout, eel, sea lamprey, twaite shad, alis shad, salmon)	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, haddock, sea trout and salmon.

Marine mammals

129. The key marine mammal species which are most abundant within and therefore have the potential to be impacted by the Proposed Development are:

- harbour porpoise;
- bottlenose dolphin;
- white-beaked dolphin *Lagenorhynchus albirostris*;
- minke whale *Balaenoptera acutorostrata*;
- harbour seal; and
- grey seal.

130. These species also correspond to the marine mammal IEFs identified in volume 2, chapter 10. The sensitivity of marine mammals to prey availability within the Proposed Development array area and Proposed Development export cable corridor will be affected by how important this area is to the species and how sensitive they are to prey availability. This is discussed further in section 20.7.10.

131. A summary of the dietary preferences of key marine mammal species within the Proposed Development marine mammal study area is presented in Table 20.20.

Table 20.20: Diet and Abundances of the Key Marine Mammal Species

Species	Distribution	Prey	Description
Toothed Porpoise and Dolphins			
Harbour porpoise	Present throughout Proposed Development marine mammal study area. Densities highest in spring and summer months.	Small fish such as herring, cod, haddock, gobies and sandeel (Scottish Government 2021). Dominant prey in North Sea in summer sandeel *Ammodytidae* and whiting *Merlangius merlangus*; During the winter season European sprat and Atlantic herring	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	Coastal species, low numbers recorded during the DAS (0.0005 and 0.0024 animal per km in 2019 and 2021 respectively) in Proposed Development marine mammal study area.	Benthic and pelagic fish (both solitary and schooling species), squid and octopus (Scottish Government 2021) Typical prey items in Scottish waters include cod *Gadus morhua*, saithe *Pollachius virens*, whiting, salmon *Salmo salar* and haddock *Melanogrammus aeglefinus*.	Generally, the distribution is influenced by factors such as tidal state, weather conditions, resource availability, life cycle stage or season (Hastie *et al.,* 2004)
White-beaked dolphin	Low numbers (0.009 animals per km^2) recorded during the DAS in Proposed Development marine mammal study area.	Small schooling pelagic fish (e.g. mackerel, herring, and sprat), haddock, as well as crustaceans, octopus and squid (Scottish Government 2021). Main prey species in Scottish waters is whiting, but also clupeids *Clupeidae* (e.g. herring), gadoids (e.g. haddock and cod) and shad (Alosa spp.) (Canning *et al.,* 2008; Santos et *al.,* 1994).	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 (Evans, 1990; Weir *et al.,* 2007; Canning *et al.,* 2008). 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 north-west Scotland and attributed climate change as a major cause of this decline.
Baleen Whales			
Minke whale	During the DAS, minke whales were recorded throughout the Proposed Development marine mammal study area. However, the mean	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 website Minke	This species is often known to exploit prey resources through other species that herd prey, enabling a low energy foraging strategy (Robinson *et al.,* 2007).

Species	Distribution	Prey	Description
	encounter rate for minke whale was comparatively low (0.001 animals per km).	whale | NatureScot). Sandeel are the key food resource throughout the North Sea, with sprat, shad and herring also preferred prey items (Robinson and Tetley, 2005).	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 website Minke whale | NatureScot)
Pinnipeds			
Harbour seal	Mean harbour seal at sea usage in the vicinity of the Proposed Development is low, with the main area of usage within the Firth of Forth estuary (Carter *et al.,* 2020). Within the Proposed Development array area the average value (of the mean at sea usage) is estimated at 0.003 animals per 5 x 5 km grid cell, equating to a density of 0.0001 animals per km^2.	Harbour seal are generalist feeders and their diet varies both seasonally and from region to region (Hammond *et al.,* 2001). The analysis of stable isotopic composition and concentration of Hg and Se ions in blood of harbour seals from the North Sea demonstrated that harbour seals diet is comprised of 30% juvenile cod, 29% of plaice Pleuronectes platessa and 23% of monkfish Lophius piscatorius as well as European hake *Merluccius merluccius* and haddock (Damseaux *et al.,* 2021).	Harbour seals, are central place foragers, requiring haul-out sites on land for resting, moulting and breeding, and dispersing from these sites to forage at sea. In order 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). Harbour seals persist in discrete metapopulations and tend to stay within 50 km of the coast, although most foraging trips are over shorter ranges (Russell and McConnell, 2014). This finding is supported by tagging studies of seals in the UK (SCOS, 2018).
Grey seal	Within the Proposed Development array area the average value (of the mean at sea usage) within grid cells was estimated at 30.3 animals per 5 x 5 km grid cell, equating to a density of 1.2 animals per km2.	Grey seal have a selective diet, mostly comprised of flatfish and sandeel. A study on the diet of grey seals in Scottish waters found that 50% of prey items were plaice and sole *Solea solea* and 46% of prey items were sandeel (Damseaux *et al.,* 2021). Gosch (2017) reported that there are significant regional and temporal differences in the diet of grey seal. Seals in shallow waters show a preference for demersal and groundfish species such as cephalopods and flatfish, 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 100 km 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).

Seabirds

132. The key seabird species which are most abundant (listed in abundance order) and most likely to be impacted by the Proposed Development (volume 2, chapter 11) are:

- common guillemot;
- black-legged kittiwake;
- razorbill;
- northern gannet;
- Atlantic puffin;
- European herring gull; and
- lesser black-backed gull.

133. Seabird species diet and foraging behaviour determine the extent to which individual species can respond to changing prey availability. This is discussed further in section 20.7.10. A summary of the typical feeding strategies and prey species of key seabird species that have the potential to be impacted by the Proposed Development has been outlined in Table 20.21.

Table 20.21: Diet and Feeding Strategies of the Key Seabird Species

Species	Primary Feeding Strategy	Primary Feeding Location	Typical Prey Species
Guillemot	Pursuit diving[2]	Water column- up to 150 m	sandeel, herring and shad small marine crustaceans, squid and octopus.
Kittiwake	Surface feeding	Water surface- up to 1 m depth	sandeel, herring and sprat
Razorbill	Pursuit diving	Upper water column – to ~6.5 m depth	sandeel, sprat and herring
Gannet	Plunge diving	Water column- intermediate depths ~30 m	mackerel and sandeel fisheries discards
Puffin	Pursuit diving	Water column – up to 120 m	sandeel and sprats, supplemented by crustaceans, molluscs and polychaetes during the breeding season
Herring gull	Opportunistic scavenging	Water surface, intertidal and terrestrial	marine invertebrates, fish, small seabirds, eggs, molluscs, crustaceans as well as fisheries discards, human trash and carrion and other food sources from terrestrial environments
Lesser black-backed gull	Opportunistic foraging	Water surface, intertidal and terrestrial	fish, crustaceans, molluscs, eggs and human discards

20.7.5. THE KEY PREY SPECIES

134. The key fish and shellfish prey species likely to be present within the Proposed Development fish and shellfish study area, within the central North Sea marine ecosystem, are the small shoaling forage fish sandeel, herring, European sprat *Sprattus sprattus* (hereafter 'sprat') and Atlantic mackerel *Scomber scombrus* (hereafter 'mackerel'). Volume 2, chapter 9, identified that these four fish species are IEFs, which are species that are considered to be important and could be potentially impacted by the Proposed Development. The abundance of each of these species within the Proposed Development fish and shellfish study area and their relative importance to predators is discussed in the species summaries below.

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

Sandeel

135. Sandeel are small eel like fish which feed primarily on plankton of variable size, ranging from small plankton eggs up to larger energy rich copepods found in great abundance in Scotland's seas (NatureScot, 2022).

136. There are five species of sandeel found in Scottish waters with lesser sandeel *Ammodytes tobianus* and Raitt's sandeel *Ammodytes marinus* being the most commonly recorded species, particularly in the vicinity of the Proposed Development fish and shellfish ecology study area.

137. As well as being abundant in Scottish waters, sandeel are highly nutritious and are therefore the preferred prey item for many other species of fish, seabirds, seals, whales and dolphins. As they feed on plankton and are eaten by larger marine predators such as cod, harbour porpoise and kittiwake, sandeel represent an important link between the lower and upper levels of the marine food web (NatureScot, 2022).

138. Lesser sandeel and Raitt's sandeel are listed as PMFs in Scottish waters and are listed as protected features within the Turbot Bank Nature Conservation MPA, which overlaps within the Proposed Development northern North Sea fish and shellfish ecology study area.

139. Sandeel have a close association with sandy substrates into which they burrow. They are largely stationary after settlement and show a strong preference to specific substrate types (volume 3, appendix 9.1).

140. As described in volume 2, chapter 9 and volume 3, appendix 9.1, sandeel have been identified as likely to be present in the Proposed Development array area and Proposed Development export cable corridor, based on historic data and habitat preference. The wider Forth and Tay Scottish Marine Region (SMR) has been known historically to support important sandeel populations. The highest density of this population is focused on the Wee Bankie, however sandeel do range across much of the wider North Sea.

141. Modelled predicted density and probability of occurrence of sandeel around the British Isles (Langton *et al.,* 2021) and site specific survey of the Proposed Development indicate that much of the Proposed Development Array area is predominantly sandeel preferred habitat. The Proposed Development export cable corridor has a significant patch of unsuitable sandeel habitat which corresponds to an area of largely muddy sediment (see volume 3, appendix 9.1).

Herring

142. Herring is a small shoaling forage fish which is a commercially important pelagic fish, common across much of the North Sea. Herring filter feeds on plankton and minute sea creatures, but will also take very small sprats and fry of other fish (British Sea Fishing, 2022).

143. Herring nursery grounds are also widespread along the east Scottish and Northumberland coastlines (Ellis *et al*., 2012), with post larvae juveniles up to sub adults that are yet to reach sexual maturity feeding in these areas until migrating to feeding grounds further offshore where they remain until reaching sexual maturity (International Council for the Exploration of the Seas (ICES), 2006).

144. Herring is an important prey species for larger fish, birds and marine mammals and is listed as a PMF in Scottish waters.

145. Herring utilise specific benthic habitats during spawning, which increases their vulnerability to activities impacting the seabed. Further, as a hearing specialist, herring may be vulnerable to impacts arising from underwater noise.

146. Herring deposit eggs on a variety of substrates from coarse sand and gravel to shell fragments and macrophytes, although gravel substrates have been suggested as their preferred spawning habitat. Once spawning has taken place (the peak spawning months being August and September for the Buchan stock), the eggs take approximately three weeks to hatch after which the larvae drift in the plankton (Dickey-Colas *et al*., 2010).

147. North Sea herring fall into a number of different 'races' or stocks, each with different spawning grounds, migration routes and nursery areas (Coull *et al.,* 1998). North Sea autumn-spawning herring have been divided into three, mainly self-contained stocks — the Buchan, Dogger, and Downs herring groups, which show differences in spawning areas and spawning periods. The Buchan stock which spawn between August and September off the Scottish east coast are most relevant to the Proposed Development.

148. 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).

149. Habitat suitability classifications for herring spawning, based on site-specific data (grab sampling undertaken as part of benthic subtidal surveys – volume 3, appendix 9.1), shows that the majority of the Proposed Development fish and shellfish ecology study area has unsuitable sediment for herring spawning, with a small patch of suitable habitat in the north-west section of the Proposed Development array area (volume 3, appendix 9.1, Figure 4.8).

150. Herring have high intensity nursery areas throughout the Proposed Development fish and shellfish ecology study area, with spawning grounds to the south which overlaps very slightly with the Proposed Development export cable corridor (see volume 3, appendix 9.1, Figure 4.6) and more extensive spawning grounds to the north along the Aberdeenshire coast. The presence of high intensity nursery grounds for herring within the Proposed Development fish and shellfish study area is not supported by outputs from Aries *et al*. (2014), with predicted aggregations of zero group herring found further inshore (see volume 3, appendix 9.1).

Sprat

151. Sprat is a small shoaling forage fish which occurs all around the UK and can be found in water depths from a few metres to approximately 100 metres.

152. Sprat feed predominantly on fish eggs, larvae and plankton (volume 2, chapter 9).

153. Sprat are a major part of the marine food chain in the North Sea, as they provide a source of food for more or less all predatory fish found in UK waters. They are also an important source of food for marine mammals and seabirds such as gannets and herring gulls.

154. As described in volume 3, appendix 9.1, sprat have relatively high abundance within the fish and shellfish study area, where thousands of individuals were frequently recorded per hour trawled (volume 3, appendix 12.1). However, the abundances recorded were found to be quite sporadic, with low numbers being recorded frequently. There are no obvious differences in seasonal or age distribution of individuals recorded.

155. Sprat spawning and nursery grounds (unspecified intensity) coincide with the Proposed Development fish and shellfish ecology study area, with only nursery grounds coinciding with the offshore export cable route (see volume 3, appendix 9.1, Figure 4.5). The presence of sprat nursery grounds within the fish and shellfish study area is not supported by outputs from Aries *et al*. (2014), with aggregations of 0 group fish seemingly limited to areas further inshore from the Proposed Development array area within the inner regions of the Firth of Forth (see volume 3, appendix 9.1).

Mackerel

156. Mackerel are small, fast, predatory fish closely related to tuna (*Thunnini sp.*) which hunt in vast shoals for small fish and sandeel

157. Mackerel are important prey species for larger fish, birds and marine mammals and are listed as a PMF in Scottish waters (NatureScot, 2020).

158. Mackerel are migratory and are common throughout the UK, arriving in spring and early summer, when they will feed actively before they migrate to warmer seas in the autumn months to spawn, during which time they will feed little.

159. Mackerel appear to be arriving in UK waters earlier and leaving later every year, possibly as a result of rising sea temperatures. In some locations around the south of the UK, mackerel are now only absent during the winter months.

160. They have no swim bladder which means they can change depth rapidly and must keep moving all of the time (British Sea Fishing, 2022).

161. As described in volume 3, appendix 9.1, recorded abundance of mackerel within the fish and shellfish study area was low during 2020 Q1, however higher abundances were recorded during Q3, and also in Q1 of 2021. This suggests that presence of mackerel in the northern North Sea can vary annually and can be sporadic, as shown by a particular haul capturing over 246,000 mackerel per hour trawled, with other hauls recording very few or no mackerel per hour trawled (volume 3, appendix 12.1).

162. Mackerel have low intensity nursery grounds which coincide with the majority of the Proposed Development fish and shellfish ecology study area (Ellis *et al.*, 2012), with no spawning grounds identified in the Proposed Development fish and shellfish ecology study area (see volume 3, appendix 9.1, Figure 4.5). Mackerel spawn over summer months from May to August. The presence of mackerel nursery grounds within the fish and shellfish study area is not supported by outputs from Aries *et al*. (2014), with no modelled observations of 0 group fish on the east coast of Scotland (see volume 3, appendix 9.1).

20.7.6. HOW THE WHOLE FOOD CHAIN OPERATES

163. The flow of energy moves up the trophic levels of a food chain starting at the bottom level where producers such as phytoplankton and algae in the marine environment make their own food by harnessing the energy of the sun through the process of photosynthesis. The next level in the food chain, the primary consumers such as zooplankton, feed on the phytoplankton to gain energy and energy continues to be transferred up the food chain through each trophic level to the top predators.

164. Typically, the marine environment 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 play an important role in ecosystem functioning (Rice, 1995). As discussed in section 20.7.5. the main prey species are sandeel, herring, mackerel and sprat. These fish link the lowest trophic levels to the highest (Mackinson and Daskalov, 2007; Fauchald *et al*., 2011; Lynam *et al*., 2017).

165. Phenology plays an important role in how the food chain operates because many species have evolved elaborate behavioural and life history strategies that exploit favourable periods of the year for growth and reproduction and minimise exposure of sensitive life stages to stressful periods (Rubao *et al*., 2010). Changes in phenology brought about by climate change, can affect the lowest trophic levels, which comprise plankton, and these effects can cascade up the food web and effect mid-trophic level species such as sandeel which can in turn effect top trophic level species such as seabirds (Burthe *et al*., 2012; Lynam *et al*., 2017). This is discussed further in section 20.7.8.

166. Section 20.7.4. described the key fish, seabird and marine mammal predator species and their typical prey species. From this it is possible to see that whilst sandeel, herring, mackerel and sprat are components of most these 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 Proposed Development study areas, and therefore will be more sensitive to changes in prey availability and the distribution of sandeel. This is discussed further in section 20.7.10.

20.7.7. FUTURE ECOSYSTEM BASELINE

167. The EIA Regulations (as defined in volume 1, chapters 1 and 2) 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 development as far as natural changes from the baseline scenario can be assessed with reasonable effort, on the basis of the availability of environmental information and scientific knowledge" is included within the Offshore EIA Report.

168. In the event that the Proposed Development does not come forward, an assessment of the future baseline conditions has been carried out and has been described within the topic chapters (volume 2, chapters 7 to 11) and are summarised in paragraphs 169 to 173.

Climate change effects

169. The baseline environment for the physical and biological components of the ecosystem are not static and will exhibit a degree of natural change over time. Such changes will occur with or without the Proposed Development in place due to natural variability. Future baseline conditions would be altered by climate change resulting in sea level rise and increased storminess. In terms of physical processes, this is unlikely to have the effect of significantly altering tidal patterns and sediment transport regimes offshore at the Proposed Development array area. 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, a notable degree of uncertainty regarding how future climate change will impact prevailing wave climates within the North Sea and beyond.

170. UK waters are facing an increase in sea surface temperature. The rate of increases is varied geographically, but between 1985 and 2009, the average rate of increase in Scottish waters has been greater than 0.2 °C per decade, with the south-east of Scotland having a higher rate of 0.5°C per decade (Marine Scotland, 2011). A study completed over a longer period of time showed Scottish waters (coastal and oceanic) have warmed by between 0.05 °C and 0.07 °C per decade, calculated across the period 1870 – 2016 (Hughes *et al.*, 2018).

171. Changes in temperature will affect fish at all biological levels (cellular, individual, population, species, community and ecosystem) both directly and indirectly. As sea temperatures rise, species adapted to cold water (e.g. cod and herring) will begin to disappear while warm water adapted species will become more established. It is also predicted that due to changes in weather patterns, for example increased numbers of spring storms, changes in stratification of water columns and plankton production may occur (Morison *et al*., 2019). This may cause knock on effect to fish and shellfish species due to changes in food availability for prey species. Climate change presents many uncertainties as to how the marine environment will change in the future; therefore, the future baseline scenario is difficult to predict with accuracy.

172. The biological environment baseline (including benthic and intertidal ecology, fish and shellfish, marine mammals and seabirds) is not static and will exhibit some degree of natural change over time, even if the Proposed Development does not come forward, due to naturally occurring cycles and processes and additionally any potential changes resulting from climate change and anthropogenic activity. Therefore, when undertaking assessments of effects, it will be necessary to place any potential impacts within the context of the envelope of change that might occur over the timescale of the Proposed Development.

173. The impact of climate change on harbour porpoise remains poorly understood. Macleod *et al*. (2005) reported that there has been a decline in the relative frequency of white-beaked dolphin strandings and sightings in north-west Scotland and attributed climate change as a major cause of this decline.

20.7.8. EXISITNG PRESSURES ON PREY SPECIES

174. Before assessing the potential effects of the Proposed Development on prey species at an ecosystem level, it is important to understand the existing pressures on prey species.

175. As described in volume 3, appendix 20.1, the North Sea is one of the most anthropogenically impacted marine ecosystems (Halpern *et al*., 2015; Emeis *et al*., 2015). Small, shoaling forage fish in mid-trophic levels experience top-down pressure from commercial fisheries (volume 3, appendix 20.1, Figure 4.1), whilst bottom-up processes driven by temperature, have dominated changes to planktonic groups since the 1960s. These pressures propagate up and down the food chain, with mid-trophic fish linking the pressures between the upper and lower trophic levels (Lynam *et al*., 2017).

176. Forage fish landings account for approximately one third of global landings of marine fish, not considering additional loss from bycatch discards (Alder *et al*., 2008). In the past, sandeel have been commercially important, targeted by industrial fisheries in the North Sea for their oil and use as an animal feed and fertiliser. Despite being highly managed, the majority of sandeel stocks have experienced severe declines, thought to have been brought about by a combination of overfishing and the effects of climate change (Nature Scot, 2022).

177. As described in volume 3, appendix 9.1, in the early 1990s there was a substantial industrial sandeel fishery on the Wee Bankie, Marr Bank and Berwick Bank sandbanks. In 2000, this industrial sandeel fishery was closed in response to concerns that the fishery was having a deleterious effect on sandeel stocks within the Forth and Tay (SMR).

178. After the Forth and Tay SMR sandeel fishery closed, 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. However, since 2001, sandeel biomass has steadily declined to levels that were similar to those observed when the sandeel fishery was active (Greenstreet *et al*., 2010). More recently sandeel stocks have recovered leading to an increase in sandeel fishing adjacent to the closed area. However, ICES recently stated "The escapement strategy [by which sandeel stocks are managed] is not sustainable for short-lived species unless the strategy is combined with a ceiling (Fcap) on fishing mortality" (ICES, 2022).

179. As described in volume 3, appendix 9.1, herring is a commercially important pelagic fish and has a relatively large fishery; the most recently published figures (2020) for herring in the North Sea (ICES Area IVa to IVc) landed by Scottish vessels was 46,742 tonnes with a value of £26,078,000 (Scottish Government, 2020a).

180. Herring stocks in the North Sea crashed as a result of overfishing in the latter part of the 20th century. Although there has since been a recovery, active management is required to prevent a recurrence (Dickey-Collas *et al.,* 2010). A herring recovery plan to reduce fishing mortality was implemented in 1996 for the North Sea and was revised in 2004. Although this was considered generally successful, it was not as successful for those herring stocks found in the northern North Sea. A ban on discards for pelagic fisheries such as herring commenced on 1 January 2015.

181. The prey species present in the marine ecosystem within which the Proposed Development occurs, are also an important food source for larger fish. For example, plaice, cod, haddock, whiting, saithe, tope and spurdog all include prey forage fish species in their diet such as sandeel, herring, sprat and mackerel.

Additionally, diadromous fish species which migrate between the sea and freshwater are also likely to feed on these species. Volume 2, chapter 9, identified the following diadromous species are likely to migrate through the Proposed Development fish and shellfish ecology study area: Atlantic salmon *Salmo salar*, sea trout *salmo trutta*, European eel *Anguilla anguilla*, sea lamprey *Petromyzon marinus*, twait shad *Alosa fallax* and allis shad *Alosa alosa*.

182. As described in volume 3, appendix 20.1, climate change is leading to dramatic changes in ecosystem structure, through effects on ocean temperature, water stratification and nutrient availability, leading to changes in the abundance and diversity of communities at all trophic levels, from primary producers to top predators (Walther, 2010). Effects of climate change 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).

183. Declines in abundance and quality of mid-trophic level-species, such as forage prey species, have been linked to multiple factors, including rising sea surface temperature (SST), changes in stratification and alterations in the North Atlantic Oscillation (Johnston *et al.*, 2021).

184. 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).

185. As described in volume 3, appendix 20.1, sandeel are one of the most important trophic links between plankton and predators in North Sea ecosystems; however, climate driven changes to phytoplankton and zooplankton have led to declines in the abundance and nutritional quality of these species and other small planktivorous fish since 2000 (Macdonald *et al*., 2015; Clausen *et al*., 2017; Wanless *et al*., 2018; MacDonald *et al*., 2019). Factors such as rising SST may have altered the phenology, abundance and distribution of many species, with a switch in the dominant zooplankton species in the North Sea and northwards shift in distribution for multiple fish species such as sandeel and sprat (Burthe *et al*., 2012).

186. Climate change impacts on sandeel will be influenced both directly through their metabolic rate and indirectly via their planktonic prey (MCCIP, 2018).

187. Changes in temperature can have a large impact on the metabolic rate of sandeel, which can in turn affect the success of their reproduction and increase their mortality rate (NatureScot, 2022). Increased temperatures have been observed to cause inhibited gonad development in sandeel, which means warmer seas can delay the spawning time and lead to reduced reproductive success (Wright, Orpwood and Scott, 2017). Adult sandeel feed on zooplankton in the spring and summer months; building up lipids to survive the winter period buried in sand when plankton production is lower. Increased temperatures lead to increased energy usage whilst overwintering, meaning less energy can be allocated to gonad development. (Boulcott and Wright, 2008; Wright, Orpwood, and Scott, 2017).

188. A key factor in sandeel larval success is synchrony between the larval hatching times and the spring zooplankton bloom. Through impacts on gonad development, warming is expected to lead to later larval hatch times and earlier zooplankton blooms, resulting in a decrease in zooplankton available for sandeel to feed upon and a reduction in sandeel growth and survivorship, leading to low recruitment (Réginer, Gibb and Wright, 2017).

189. The life cycle of sandeel ties them to sandy sediments of a particular grain size which they burrow into at night and during the winter months. This means that their ability to move and redistribute to new suitable habitats in response to rising sea temperature relies on larval distribution (Macdonald *et al*., 2015).

190. Herring are also constrained as demersal spawners, by their requirement to spawn at specific locations, depositing their sticky eggs on coarse sand, gravel, small stones and rocks (Wright *et al*., 2020).

191. Additionally, there is an increasing body of research into the effect of ocean acidification on fish physiology and early survival (Wright *et al*., 2020). As described in volume 3, appendix 20.1, climate change is leading to ocean acidification, by chemical processes related to increased temperatures increasing dissolved levels of carbon dioxide in seawater. Decreasing pH is affecting phytoplankton, which can inhibit shell generation of calcifying marine organisms and may impact skeletal development in larval fish, with potential consequences to forage species (Riebesall *et al*., 2013). However, these impacts are difficult to predict at species and population levels due to the complexity of these food web interactions (Heath *et al*., 2012).

20.7.9. EFFECTS OF THE PROPOSED DEVELOPMENT ON PREY SPECIES

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

193. Information to support this assessment has been taken from the relevant receptor topic Offshore EIA Report chapters. Each assessment of an impact focuses on the prey species most vulnerable to the impact to explain the maximum adverse scenario without repeating all the detail from the original receptor topic chapter. For example, where sandeel and/or herring are the most sensitive prey species to a given impact, details are provided for these species only.

Potential impacts on prey species

194. Volume 2, chapter 9, identified that the following potential impacts as a result of the Proposed Development could result in positive/negative effects on fish and shellfish ecology:

- temporary habitat loss/disturbance;
- increased suspended sediment concentrations (SSC) and associated sediment deposition;
- injury and/or disturbance to fish and shellfish from underwater noise and vibration;
- long-term subtidal habitat loss;
- EMFs from underwater electrical cabling; and
- colonisation of foundations, scour protection and cable protection.

195. Of these potential impacts, the first five were assessed as having minor adverse effects on marine fish (including prey species), which would not result in a significant change to prey species populations. A summary of the assessment of these impacts is provided in the following sub-sections.

196. The final impact, colonisation of foundations, scour protection and cable protection, has the potential to affect numbers of prey species and predators and so is described in more detail, drawing on the findings of volume 2, chapters 8, 9 and 10.

Temporary habitat loss/disturbance

197. As discussed in volume 2, chapter 9, in general, mobile fish species are able to avoid areas subject to temporary habitat disturbance. Of the key prey species, sandeel and herring are most sensitive to temporary habitat loss because they spawn on or near the seabed sediment. However, the assessment concluded that sandeel populations would recover quickly from any adverse effects following construction and due to the limited overlap of seabed disturbance with suitable herring spawning habitat in the Proposed Development fish and shellfish study area, there would be minor effects on herring and sandeel, which are not significant in EIA terms.

Increased SSC and associated sediment deposition

198. As stated in volume 2, chapter 9, the prey fish species most likely to be affected by sediment deposition are sandeel and herring because they spawn on the seabed. However, sandeel eggs are likely to be tolerant to some level of sediment deposition, due to the nature of re-suspension and deposition within their natural high energy environment. Therefore, effects on sandeel spawning populations are predicted to be limited. Sandeel populations are also sensitive to sediment type within their habitat, preferring coarse to medium sands and showing reduced selection or avoidance of gravel and fine sediments (Holland *et al*., 2005). However, modelled sediment deposition levels are expected to be highly localised (within metres) and at very low levels (less than 10 mm).

199. It has been shown that herring eggs may be tolerant of very high levels of SSC (Messieh *et al*., 1981). Any deposited sediment which could result in smothering would be expected to be removed quickly by currents (i.e. within a couple of tidal cycles) with a very small amount of sediment deposition being forecast. Furthermore, there is a relatively limited amount of suitable sediments for herring spawning and the mapping of the core herring spawning habitats are well outside the Proposed Development fish and shellfish ecology study area, which would also limit the potential for effects on herring spawning.

Injury and/or disturbance to fish and shellfish from underwater noise and vibration

200. As discussed in volume 2, chapter 9, injury and/or mortality for all prey fish species is to be expected for individuals within very close proximity to piling operations. However, this is unlikely to result in significant mortality due to soft start procedures allowing individuals in close proximity to flee the area prior to maximum hammer energy levels.

201. Behavioural effects are expected over larger ranges. Herring are known to be particularly sensitive to underwater noise and have specific habitat requirements for spawning which makes them particularly vulnerable to impacts associated with construction related increases in underwater noise. However, noise modelling indicated minimal overlap of mapped underwater noise contours with core herring spawning grounds, and where there is an overlap, the noise levels are considerably lower than levels expected to result in behavioural effects.

Long-term subtidal habitat loss

202. As discussed in volume 2, chapter 9, long-term habitat loss will occur within the direct footprint of wind turbine and OSP/Offshore converter substation platform foundations, associated scour protection and cable protection (including at cable crossings) where this is required. However, the area of habitat loss equates to a small proportion (0.7%) of the Proposed Development fish and shellfish study area. Of the prey fish species, sandeel are particularly sensitive to this impact because they have specific habitat requirements (i.e. sandy sediments) for spawning and for burrowing in at night and through the winter. Whilst sandeel were assessed to have medium sensitivity to this impact, given the relative small area potentially impacted (0.7%), significant effects are not predicted.

203. Herring are also sensitive to this impact due to their demersal spawning requirement; however herring were assessed as having low sensitivity due to the limited suitable spawning habitat overlapping with the Proposed Development fish and shellfish ecology study area.

EMFs from electrical underwater cabling

204. As discussed in volume 2, chapter 9, and the Berwick Bank Wind Farm Marine Protected Area Assessment (SSER, 2022b), the presence and operation of inter-array, interconnector and offshore export cables within the Proposed Development fish and shellfish ecology study area may result in emission of localised EMFs which may affect some fish species. It is common practice to block the direct electrical field (E) using conductive sheathing, meaning that the EMFs that are emitted into the marine environment are the magnetic field (B) and the resultant induced electrical field (iE). Fish species (particularly elasmobranchs) are able to detect applied or modified magnetic fields. However, the rapid decay of the EMF with horizontal distance (i.e. within metres) minimises the extent of potential impacts. A study investigating the effect of EMF on lesser sandeel larvae spatial distribution found that there was negligible effect on the larvae (Cresci *et al*., 2022), and a further study concluded the same for herring (Cresci *et al*.,2020). Overall, the assessment concluded the effect on all fish species (including prey species) would not be significant.

Colonisation of foundations, scour protection and cable protection

205. Volume 2, chapters 8 and 9 discussed how the introduction of infrastructure within the Proposed Development array area and Proposed Development export cable corridor may result in the colonisation of foundations, scour protection and cable protection. Since these hard structures are added to areas typically characterised by soft, sedimentary environments, the resulting change of habitat type acts like an artificial reef and the impact is known as the 'reef effect'.

206. The reef effect has the potential to adversely affect existing biological soft sediment communities but also have some potentially beneficial effects on the marine ecosystem.

207. A review by Degraer *et al* (2020) explained the process by which wind turbine foundations are colonised, and the vertical zonation of species that can occur. Installation of an offshore wind farm is typically followed by rapid colonisation of all submerged parts by biofouling organisms. Vertical zonation can be observed on wind turbine foundations with different species colonising the splash, inter-tidal, shallow and deeper subtidal zones. In general, biofouling communities on offshore installations are dominated by mussels, macroalgae, and barnacles near the water surface, essentially creating a new intertidal zone; filter feeding arthropods at intermediate depths; and anemones in deeper locations (De Mesel *et al*., 2015). Colonisation by these species will likely represent an increase in biodiversity and a change compared to if no hard substrates were present (Lindeboom *et al.,* 2011).

208. As stated in volume 2, chapter 8, this may produce some potentially beneficial effects such as:

- an increase in biodiversity and individual abundance of reef species and total number of species over time, as has been observed at the monopile foundations installed at Lysekil research site (a test site for offshore wind-based research, north of Gothenburg, Sweden) (Bender *et al.,* 2020);
- structural complexity of the substrate may provide refuge as well as increasing feeding opportunities for larger and more mobile species; and
- a higher food web complexity associated with zones where high accumulation of organic material is present such as soft substrate or scour protection, suggesting potential reef effect benefits from the presence of the hard structures, as was observed in a study of gravity based foundations in the Belgian part of the North Sea (Mavraki *et al*. 2020).

209. Colonisation of the wind turbine foundations, associated scour protection and cable protection may have indirect adverse effects on baseline communities and habitats due to increased predation on, and competition with, 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 foundations rather than broad scale studies.

210. Some studies (De backer *et al*. 2020; Hutchison *et al* 2020; Apem, 2021) have also shown that the installation and operation of offshore wind farms has a negligible impact on the soft sediment environments. For example:

- De Backer *et al.* (2020) found that eight to nine years after the installation of C-power and Belwind offshore wind farms (offshore Belgium) the soft sediment epibenthos underwent no drastic changes; and the species originally inhabiting the sandy bottom were still present and remained dominant in both wind farms;
- a review of monitoring from Block Island wind farm in the United States showed no strong gradients of change in sediment grain size, enrichment, or benthic macrofauna within 30 m to 90 m distance bands of the wind turbines (Hutchison *et al.,* 2020); and
- the most recent benthic post-construction monitoring data of wind turbine foundations from Beatrice offshore wind farm (APEM, 2021) found foundation colonisation of wind turbines has resulted in zonation on the foundation itself but had little influence on the sedimentary habitat below.

211. As described in volume 2, chapter 8, the maximum design scenario of habitat creation due to the installation of jacket foundations, associated scour protection and cable protection associated with inter-array cables, OSPs/Offshore convertor substation platforms, interconnector cables and offshore export cables equates to 0.70% of the Proposed Development benthic subtidal and intertidal ecology study area. This value is likely an over estimation of habitat creation as it has been calculated assuming the foundations were a solid structure. In reality the jacket foundations will have a lattice design rather than a solid surface, which would result in a smaller surface area. It is expected that the foundations and scour and cable protection will be colonised by epifaunal species already occurring in the benthic subtidal and intertidal ecology study area (e.g. tunicates, bryozoans, mussels and barnacles which are typical of temperate seas).

212. The Firth of Forth Banks Complex (FFBC) MPA overlaps with the Proposed Development array area and Proposed Development export cable corridor and therefore some habitat creation and colonisation of hard structures will occur within the FFBC MPA (SSER, 2022b). Based on the maximum design scenario for the Proposed Development, new habitat for colonisation equates to 0.13% of the FFBC MPA.

213. As discussed in volume 2, chapter 8, where scour and cable protection are deployed, use of smaller rock sizes, where reasonably practicable at the time of operation and maintenance, may facilitate the colonisation of rock protection by epifaunal species typical of coarse sediment which are found within the Proposed Development export cable corridor. Previous studies have shown that for artificial hard substrate to be colonised by a benthic community similar to that of the baseline, its structure should resemble that of the baseline habitat as far as reasonably practicable (Coolen, 2017). The addition of smaller grained material to scour/cable protection may therefore be of some benefit to the native epifaunal communities (Van Duren *et al.*, 2017; Lengkeek *et al*., 2017).

214. Additionally, the designed in measures regarding the suitable implementation and monitoring of cable protection will ensure that no more than the declared amount of new hard substrate habitat is created and that any buried infrastructure remains so and does not impede upon the surface sedimentary habitat (volume 2, chapter 8, Table 8.16).

215. Volume 2, chapter 8, concluded that although the sensitivity of benthic ecology IEFs to this impact was high, the magnitude of the effect would be low and therefore overall, the effect on benthic ecology was not predicted to be significant in EIA terms.

216. The Berwick Bank Wind Farm MPA Assessment Report (SSER, 2022b), concluded that whilst the installation of hard structures will result in the loss of some sedimentary habitat directly below it and with a small radius around it, the remaining sedimentary habitat will not be continually degraded and will largely remain unchanged as a result of the introduction and colonisation of hard substrate. There may be some benefits for species which prefer hard substrates as a result of the reef effect, but this is unlikely to affect species which inhabit the offshore subtidal sands and gravels. The Applicant is committed to engaging in discussions with Marine Scotland and the Statutory Nature Conservation Bodies (SNCBs) to identify, and input to, strategic benthic monitoring of the colonisation of hard structures and impacts to surrounding soft sediments across wind farms off the east coast of Scotland, if available and proposed by Marine Scotland.

217. As discussed in volume 2, chapter 9, the introduction of hard substrates can have indirect and direct effects on fish as follows:

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

218. The colonisation by epifauna of the foundations, scour, and cable protection, may result in an increased availability of prey species, which in turn may lead to increased numbers of fish and shellfish species utilising the hard substrate habitats.

219. As discussed in volume 2, chapter 9, hard substrate habitat created by the introduction of wind turbine foundations and scour/cable protection are likely to be primarily colonised within hours or days after construction by demersal and semi-pelagic fish species (Andersson, 2011). Continued colonisation has been seen for a number of years after the initial construction, until a stratified recolonised population is formed (Krone *et al*., 2013). Feeding opportunities or the prospect of encountering other individuals may attract fish aggregates from the surrounding areas, which may increase the carrying capacity of the area (Andersson and Öhman, 2010; Bohnsack, 1989). The dominant natural substrate character of the Proposed Development fish and shellfish ecology study area (e.g. soft sediment or hard rocky seabed) will determine the number of new species found on the introduced vertical hard surface and associated scour protection as follows:

- hard structures on an area of seabed already characterised by rocky substrates, results in few new species but may sustain a higher abundance (Andersson and Öhman, 2010); and
- hard structures on a soft seabed, may result in increased diversity of fish normally associated with rocky (or other hard bottom) habitats, (Andersson *et al.,* 2009). A new baseline species assemblage will be formed via recolonisation, and the original soft-bottom population will be displaced (Desprez, 2000).

220. However, it was noted volume 2, chapter 9, that the longest monitoring programme conducted to date at the Lillgrund offshore wind farm in the Öresund Strait in southern Sweden, showed no overall increase in fish numbers although redistribution towards the foundations within the offshore wind farm area was noticed for some species (i.e. cod, eel and eelpout; Andersson, 2011). More species were recorded after construction than before, which is consistent with the hypothesis that localised increases in biodiversity may occur following the introduction of hard substrates in a soft sediment environment. However, there is uncertainty as to whether:

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

221. Linley *et al*. (2007) concluded that finfish species were likely to have a neutral to beneficial likelihood of benefitting, which is supported by evidence demonstrating that abundance of fish can be greater within the vicinity of wind turbine foundations than in the surrounding areas, although species richness and diversity show little difference (Wilhelmsson *et al*., 2006; Inger *et al*., 2009).

222. Volume 2, chapter 9 also noted that, in contrast, post construction fisheries surveys conducted in line with the Food and Environmental Protection Act (FEPA) licence requirements for the Barrow and North Hoyle offshore wind farms, found no evidence of fish abundance across these sites being affected, either beneficially or adversely, by the presence of the offshore wind farms (Cefas, 2009; BOWind, 2008) therefore suggesting that any effects, if seen, are likely to be highly localised and while of uncertain duration, the evidence suggests effects are not adverse.

223. As described in volume 2, chapter 9, diadromous species that are likely to interact with the Proposed Development fish and shellfish ecology study area are only likely to do so during migration when passing through the area to and from rivers located on the east coast of Scotland. In most cases, it is expected that diadromous fish are unlikely to utilise the increase in hard substrate within the Proposed Development

fish and shellfish ecology study area for feeding or shelter opportunities, due to the limited time they are likely to be in the area. Therefore, the reef effect is not anticipated to effect diadromous fish species numbers or behaviour. There is potential for impacts upon diadromous fish species resulting from increased predation by marine mammal species within offshore wind farms. Tagging of harbour seal and grey seal around Dutch and UK wind farms provided significant evidence that the seal species were utilising wind farm sites as foraging habitats (Russel *et al*., 2014), specifically targeting introduced structures such as wind turbine foundations. However, a further study using similar methods concluded that there was no change in behaviour within the wind farm (McConnell *et al*., 2012), so it is not certain to what extent seals utilise offshore wind developments and therefore effects may be site-specific.

224. Research has shown that Atlantic salmon smolts spend little time in coastal waters, and instead are very active swimmers in coastal waters, making their way to feeding grounds in the north quickly (Gardiner *et al*., 2018a; Gardiner *et al*., 2018b; Newton *et al*., 2017; Newton *et al*., 2019; Newton *et al*., 2021). Due to the evidence that Atlantic salmon tend not to forage in the coastal waters of Scotland, it is unlikely that they will spend time foraging around wind turbine foundations and therefore are at low risk of impact from increased predation from seals and other predators (volume 2, chapter 9).

225. Sea trout may be at higher risk of increased predation from seals than Atlantic salmon due to their higher usage of coastal environments. Sea trout are generalist, opportunistic feeders, with their diet including crustaceans as well as smaller fish species. Due to the potential for increases in juvenile crustaceans and other shellfish species from colonisation of the hard structures introduced by installation of the Proposed Development, it is possible that foraging sea trout may be attracted to the hard substrates. This attraction could in turn lead to their increased predation by seal species. However, there is little evidence at present documenting an increased abundance of sea trout around wind turbine foundations. Further, the Proposed Development fish and shellfish ecology study area is situated in an area of high sandeel abundance, and it is likely that sandeel will make up a considerable proportion of sea trout diet when in the marine environment (Svenning *et al*., 2005; Thorstad *et al*., 2016). Sandeel species are unlikely to be associated with wind turbine structures due to habitat preferences (discussed in volume 3, appendix 9.1) and therefore sea trout may be less likely to be attracted to increased prey availability colonised on hard substrates, when there is an abundance of prey species which is not associated with the installation of hard substrate (volume 2, chapter 9).

226. Sea lamprey are parasitic in their marine phase, feeding off larger fish and marine mammals (Hume, 2017). As such it is not expected that they will be particularly attracted to structures associated with offshore wind developments. However, this is not certain, as there is limited information available on the utilisation of the marine environment by sea lamprey (volume 2, chapter 9).

227. In volume 2, chapter 9 overall, the impact “colonisation of foundations, scour protection and cable protection from the Proposed Development” on diadromous fish was assessed as negligible to minor adverse significance.

228. As discussed in volume 3, appendix 20.1, artificial reefs can also act as stepping-stones, which allow organisms to colonise areas not typical of their species or they may increase the connectivity between natural sub-populations (Coolen *et al*., 2017). The impacts of this can extend beyond the scale of a single operation (e.g. at the scale of individual wind turbines or Project scale) with multiple adjacent offshore wind farms creating stepping stones over wider areas and creating a large-scale effect (Degraer *et al*., 2020). For example, the Proposed Development is close to four offshore wind farms in the Forth and Tay area: Seagreen 1 and Seagreen 1A Project to the north, Inch Cape to the north-west and Neart na Gaoithe to the west.

229. As stated in volume 2, chapter 8, colonisation is likely to only occur on new infrastructure and not extend far beyond the infrastructure because the benthic communities colonising the hard structures are unlikely to be suited to the sedimentary habitats which the Proposed Development is largely composed of. Impacts from the colonisation of hard structures are predicted to be localised to the individual projects and therefore neither stepping stone effects or significant cumulative effects are anticipated.

230. As discussed in volume 2, chapter 10, higher trophic levels, such as marine mammals, are likely to profit from locally increased food availability and/or shelter and therefore have the potential to be attracted to forage within an offshore wind farm array area. However, still relatively little is known about the distribution and diversity of marine mammals around offshore anthropogenic structures. 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 (Todd *et al*., 2016; Delefosse *et al*., 2018; Lindeboom *et al*., 2011). Acoustic results from a T-POD measurement within a Dutch wind farm found that relatively more harbour porpoises are found in the wind farm area compared to the two reference areas (Scheidat *et al*., 2011; Lindeboom *et al*., 2011). Authors of this study concluded that this effect is directly linked to the presence of the wind farm due to increased food availability as well as the exclusion of fisheries and reduced vessel traffic in the wind farm (shelter effect). However, as discussed above in volume 2, chapter 10, different studies on marine mammals’ use of offshore wind farm structures return different results. Whilst there is some mounting evidence of potential benefits of man-made structures in the marine environment (Birchenough and Degraer, 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 (Petersen and Malm, 2007; Inger *et al*., 2009; Rouse *et al*., 2020, McLean *et al*., 2022; Elliott and Birchenough, 2022).

231. In summary, the direct and indirect impacts of the Proposed Development on prey species will largely result in temporary and highly localised effects which are reversible, with a return to baseline conditions anticipated to occur shortly after the cessation of construction activities. As discussed in section 20.6.9, Table 20.12 , the individual impacts on fish and shellfish were assigned a significance of negligible to minor as standalone impacts. As described in volume 2, chapter 9, cumulative impacts arising from the Proposed Development together with other projects and plans were predicted to result in effects of negligible to minor adverse significance (not significant in EIA terms) upon fish and shellfish IEFs within a 25 km buffer of the Proposed Development fish and shellfish ecology study area.

232. The impact 'colonisation of foundations, scour protection and cable protection' has the potential to lead to localised increases in fish species through potential reef effect. However, the assessment of effects concluded any increases would be localised and did not conclude that the Proposed Development would lead to a significant increase in prey species. Sandeel, for example require specific sediment habitat conditions and are therefore unlikely to be attracted to the hard structures of offshore wind farm infrastructure.

Potential impacts on supporting processes

<u>Changes to water flow</u>

233. The RSPB raised the question during the ornithology Road Map Meeting 5, January 2022, “*If there are changes in water flow effects, how do these changes affect plankton distribution? How do changes in plankton distribution affect sandeel distribution and hence kittiwake distribution?*”

234. As discussed in volume 2, chapter 7, the presence of infrastructure may lead to changes to tidal currents, wave climate, littoral currents, and sediment transport, principally during the operation and maintenance phase of the Proposed Development, and following decommissioning associated with residual infrastructure. Additionally, volume 2, chapter 8 assessed whether alteration of seabed habitats may arise from the effects of changes to physical processes, including scour effects and changes in the sediment transport and wave regimes resulting in potential effects on benthic receptors. It was noted that this in turn could have knock on effects up trophic levels.

235. Volume 3, appendix 7.1 stated that the construction of the Proposed Development was seen to marginally reduce wave heights in the lee of the structures whilst a marginal increase was noted at the periphery, however, during larger storm events these effects were less marked. Any changes in tidal currents and wave climate would not extend to the coastline and there would be no change in physical processes in this area.

236. Residual currents are effectively the driver of sediment transport and therefore any changes to residual currents would have a direct impact on sediment transport which would persist for the lifecycle of the Proposed Development. However, if the presence of the foundation structures does not have a significant influence on either tide or wave conditions as concluded in volume 3, appendix 7.1, they cannot therefore have a significant effect on the sediment transport regime. As discussed in volume 2, chapter 8, the limited nature of changes to tidal flows would not influence the hydrodynamic regime which underpins offshore bank morphology and is the supporting process for aspects of the Firth of Forth Banks Complex MPA, in particular Berwick and Marr Banks geomorphological features. It was concluded that for the subtidal sands and gravels and shelf banks and mounds IEF, the effect will be negligible adverse significance, which is not significant in EIA terms, because of the small scale of change as a result of the Proposed Development and the dynamic nature of these IEFs.

237. Volume 2, chapter 7 concluded that the magnitude of increased infrastructure leading to changes in the hydrodynamic environment and sediment transport during the operation and maintenance phase would be negligible to minor for the Proposed Development alone. Modelling and assessment for Neart na Gaoithe (Mainstream Renewable Power, 2018) included Neart na Gaoithe, Inch Cape, and Seagreen in addition to the Proposed Development (which is referred to in documentation as Seagreen Phase 2 and Phase 3). The impact of multiple developments on tidal currents was predicted by the study to be low and localised to the near field of each development.

238. The Neart na Gaoithe study also showed that with all offshore wind farms *in situ*, the cumulative effect on the wave climate is low (< 3% average significant wave height) but the effect on wave climate has a larger extent than a single offshore wind farm. The cumulative effect from the combined wind farm developments on sediment transport processes is low, resulting in a 1% to 3% exceedance in the typical critical bed shear stress. Changes are within the immediate vicinity of each of the developments and it is not expected that there would be changes to the far field sediment regimes.

239. Given that any changes to the hydrodynamic regime as a result of the Proposed development alone or in-combination with other projects, are predicted to be negligible to minor and restricted to the near field, significant changes to the distribution of plankton from this impact are not anticipated.

Conclusions

240. This section assessed the impacts of the Proposed Development on prey species, to determine whether there will be any increases or decreases in prey distribution and availability.

241. The impacts resulting from the Proposed Development over all phases of the Proposed Development lifecycle (construction, operation and maintenance and decommissioning) which are relevant to prey species include temporary habitat loss/disturbance; increased suspended sediment concentrations (SSC) and associated sediment deposition; injury and/or disturbance to fish and shellfish from underwater noise and vibration; long-term subtidal habitat loss; EMFs from underwater electrical cabling; and colonisation of foundations, scour protection and cable protection.

242. For the Proposed Development alone, these individual impacts were assigned a significance of negligible to minor (volume 2, chapter 9). Cumulative impacts arising from the Proposed Development together with other projects and plans were also predicted to result in effects of negligible to minor adverse significance (volume 2, chapter 9). As such negligible or minor changes to prey species are predicted, which are not significant in EIA terms.

243. The impact 'colonisation of foundations, scour protection and cable protection' has the potential to lead to increases in fish species through potential reef effect. It is uncertain to what degree this may occur, however; any beneficial effects are predicted to be highly localised and not significant.

244. Impacts on the supporting process, 'changes to waterflow' which could affect seabed habitats and plankton communities was assessed. Any changes to the hydrodynamic regime as a result of the Proposed Development alone or in-combination with other projects, are predicted to be negligible to minor and restricted to the near field (volume 2, chapter 7). Significant changes to the distribution of plankton from this impact are not anticipated. As such, any further knock-on effects on higher trophic levels such as sandeel distribution and kittiwake distribution are also not anticipated.

20.7.10. EFFECTS OF THE PROPOSED DEVELOPMENT ON PREDATORS

245. Section 20.7.9 examined the impacts as a result of the Proposed Development which could have either positive or negative effects on the distribution of key prey species. This section assesses the sensitivity of fish, seabird and marine mammal predator species to prey availability and draws on the conclusions of section 20.7.9 to determine if there are any potentially significant effects on predators as a consequence of changes in prey availability.

Piscivorous fish

246. The typical prey species of the key fish predators (piscivorous fish) are listed in section 20.7.4, Table 20.19, which shows these fish species have broad diets comprising not only small fish but also benthic species including invertebrates, molluscs and crustaceans. This suggests, the fish predator species are likely to be less sensitive to the availability of the key prey species sandeel, herring, sprat and mackerel, which are important to the key marine mammal and seabird species discussed in this chapter.

247. As discussed in section 20.7.9, adverse effects on prey species as a result of the Proposed Development were assessed as having minor adverse effects on marine fish (including prey species), which would not result in a significant change to prey species populations. The impact 'colonisation of foundations, scour protection and cable protection' has the potential to lead to localised increases in fish species through potential reef effect. However, the assessments of effects concluded any increases would be localised and did not conclude that the Proposed Development would lead to a significant increase in prey species.

248. As such, it is concluded that there would be negligible consequences either negative or beneficial from the effects of the Proposed Development on prey species, on key fish predators.

Marine mammals

249. As discussed in volume 2, chapter 10, marine mammals exploit a range of different prey items and can forage widely, sometimes covering extensive distances. Given the potential impacts of construction on prey resources will be highly localised and largely restricted to the boundaries of the Proposed Development, only a small area will be affected when compared to available foraging habitat in the North Sea. The fish and shellfish communities found within the Proposed Development fish and shellfish ecology study area (see volume 2, chapter 9) are characteristic of the fish and shellfish assemblages in the northern North Sea. It is therefore reasonable to assume that, due to the highly mobile nature of marine mammals, there will be similar prey resources available in the wider area.

250. However, volume 2, chapter 10 noted there may be an energetic cost associated with increased travelling, and two species, harbour porpoise and harbour seal, may be particularly vulnerable to this effect. Harbour porpoise has a high metabolic rate and only a limited energy storage capacity, which limits their ability to buffer against diminished food while harbour seal typically, forage close to haul out sites (i.e. within nearest

50 km). Despite this, if animals do have to travel further to alternative foraging grounds, the impacts are expected to be short term in nature and reversible. It is expected that all marine mammal receptors would be able to tolerate the effect without any impact on reproduction and survival rates and would be able to return to previous activities once the impact had ceased.

251. Minke whale was identified as being sensitive to effects on sandeel abundance in volume 2, chapter 10. Studies analysing the stomach contents of minke whale found that sandeel is their key food source in the North Sea (Robinson and Tetley, 2005; Tetley *et al.*, 2008; see volume 3, appendix 10.2 for more details); the results of Firth of Forth Round 3 boat-based survey results from May 2009 to November 2011 which identified a spatial overlap between positions of minke whale and areas of high probability of sandeel presence (Langton *et al*., 2021); and various studies reported seasonal movement of minke whales to favoured feeding grounds, optimal for sandeel (from May to August; Robinson *et al*., 2009; Risch *et al*., 2019).

252. However, as discussed in volume 2, chapter 10, Anderwald *et al*. (2012) studied flexibility of minke whales in their habitat use and found that although significantly higher sighting rates often occur in habitats associated with sandeel presence, an area of high occupancy by minke whale, coincided with high densities of sprat during spring. Hence, the low energetic cost of swimming in minke whales and their ability to switch between different prey according to their seasonal availability indicates that these species are able to readily respond to temporal changes in pelagic prey concentrations.

253. Volume 2, chapter 10, concluded that all marine mammal IEFs, and therefore all key marine mammal predator species, have low sensitivity to the impact 'changes in fish and shellfish communities affecting prey availability'. The magnitude was assessed as low on the basis that the impact on marine mammals is predicted to be of local spatial extent, medium-term duration, intermittent and highly reversible. Therefore overall, the effect was assessed to be of minor adverse significance.

254. In summary, as discussed in section 20.7.9, it is possible that higher trophic levels, such as fish and marine mammals, will profit from locally increased food availability and/or shelter and therefore have the potential to be attracted to forage within offshore wind farm array area. However, still relatively little is known about the distribution and diversity of marine mammals around offshore anthropogenic structures. Whilst there is some mounting evidence of potential benefits of man-made structures in the marine environment (Birchenough and Degrae, 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 (Petersen and Malm, 2007; Inger *et al.,* 2009; Rouse *et al*., 2020, McLean *et al*., 2022; Elliott and Birchenough, 2022).

255. Section 20.7.9 concluded that the impact 'colonisation of foundations, scour protection and cable protection' has the potential to lead to localised increases in fish species through the reef effect. However, the assessments of effects concluded any increases would be localised and did not conclude that the Proposed Development would lead to a significant increase in prey species. Therefore, adverse or beneficial effects on marine mammals is not predicted to be significant.

Seabirds

256. Prey availability is one of the most important controls of species abundance and distribution in the higher trophic levels, including seabirds (Lynam *et al*., 2017; Mitchell *et al*., 2020). Reduced prey availability and changing prey distribution means that seabirds may have to forage further for food. For example, Fayet *et al*. (2021) compared the foraging costs in puffin populations in the north-east Atlantic. Puffins from declining populations in southern Iceland and north-west Norway had the greatest foraging ranges and least energy-dense diet. Low prey availability close to the colonies, potentially resulting from climate or commercial fisheries effects, is also amplified by increased intra-specific and inter-specific competition which forces birds to forage further from their colonies (volume 3, appendix 20.1).

257. Diet and foraging behaviour determine the extent to which seabird species can respond to changing prey availability. Generalist species, such as gulls, which feed on a wide range of prey types will be more resilient to changing prey availability than more specialist species such as kittiwake which predominantly prey on small fish (Furness and Tasker, 2000). Water column feeders, such as auks, forage from the surface to the seabed (depending on water depth) and can feed on both pelagic and demersal fish species, as well as invertebrates such as squid and zooplankton. Surface feeders, including kittiwake and terns, are restricted to prey available within the upper 1 m to 2 m of the sea surface, such as small fish, zooplankton and other invertebrates. Therefore, changes to prey distribution within the water column resulting from changes to stratification or temperature, for example, will affect surface feeding species differently to water column feeding species (volume 3, appendix 20.1).

258. This has been demonstrated in the North Sea, where almost 50% of surface feeding seabird species exhibited widespread breeding failures between 2010 and 2015; compared with only two of the eight-water column feeding species assessed (volume 3, appendix 20.1, Figure 4.2; OSPAR, 2017; Mitchell *et al.,* 2018). Typically, seabirds that feed within the water column are better able to cope with changes in prey availability rather than surface feeding species, as explained above (Mitchell *et al.,* 2020). This is likely linked to changes in the availability of small fish species (such as sandeel and sprat species) which are the predominant prey of surface feeding species such as kittiwake. A summary of the typical feeding strategy and prey of key seabird species for the Project have been outlined in Table 20.21. Plunge divers dive into the sea from a height to catch prey, whereas pursuit divers dive and can then swim underwater in pursuit of prey (volume 3, appendix 20.1).

259. The availability of sandeel has been correlated with the breeding success and adult survival of kittiwakes (Frederiksen *et al.,* 2004, 2008; Carroll *et al.,* 2017). Adult kittiwakes eat mostly older (1+ year group) sandeel during April and May; switching to juvenile (0 year group) sandeel in June and July during chick rearing (Lewis *et al.,* 2001). This correlates with the annual cycle of sandeel. The 1+ year group (sandeel hatched prior to the current year) are active in the water column during spring. Once they have accumulated enough lipid they bury themselves in the sand, usually in June-July, and live off their stored lipid during the winter. The 0-year group (young of the year) sandeel are available from June onwards following metamorphosis from larvae into juveniles, and prior to burying themselves to overwinter (Wright and Bailey, 1996). However, density dependence also influences sandeel recruitment, and the biomass of the sandeel stock tends to be driven by occasional especially good years (ICES, 2017). In sandeel stocks with low fishing mortality, years with high stock biomass tend to show low recruitment, whereas high recruitment is more likely when adult stock biomass is lower (ICES, 2017, Lindegren *et al*. 2018). Both climate change and commercial fisheries are implicated with a reduction in sandeel abundance, which may contribute to kittiwake declines (Carroll *et al.,* 2017) (volume 3, appendix 20.1).

260. In the Firth of Forth region, a decrease in mean length-at-age of both for 0-year group and 1+ year group sandeel brought in for puffin chicks on the Isle of May suggested a dramatic deterioration in prey quality from 1973 to 2015. This is correlated with decreases in kittiwake populations. It is estimated that the energy content of sandeel decreased by approximately 70% and 40% for 0 and 1+ year groups respectively, which can result in significant dietary or behavioural shifts in seabirds which feed on them (Wanless *et al.,* 2018).

261. In the western North Sea between 1973 and 2015, the diet of chick-rearing kittiwakes, puffins, razorbills and shags was predominantly comprised of sandeel (Wanless, *et al.,* 2018). Clupeids (sprat and herring) were the second-most important prey species, however these rarely exceeded 10% of the food biomass per year. Juvenile gadids were another important prey species (1 - 10% biomass) for these seabird species in some years (Wanless, *et al*., 2018) (volume 3, appendix 20.1).

262. For guillemots, sandeel were the predominant prey until the late 1990s, when a shift to sprat (93%) and herring (7%) was observed (Wanless*, et al.,* 2018). Between 1982 and 2019, sandeel were largely confined to the early part of the chick period as they have declined (Harris *et al.,* 2022). A trend towards more sprat and herring have also been observed since the mid-2000s in razorbills and kittiwakes during chick-rearing,

though sandeel are still the dominant prey (Wanless *et al.,* 2018). Sprat feed and spawn repeatedly through spring and summer in coastal and offshore waters, and so are available for a wider period. Gannet predominantly feed on pelagic fish such as mackerel and sandeel or fisheries discards (Le Bot *et al.,* 2019) (volume 3, appendix 20.1).

263. Gull species, such as herring gull and lesser black-backed gull are able to feed on a diverse range of prey and food from both natural and anthropogenic sources. In the south-eastern North Sea, faecal samples revealed that both lesser black-backed gulls and herring gull diets were predominantly composed of bivalves and crustaceans (Kubetzki and Garthe, 2003). A decline in herring gull abundance has been observed in Scotland since the 1969-70 National Census, and lesser black-backed gull populations have strongly fluctuated, which has been associated with changes in waste management such as covering refuse tips, and a reduction in fisheries discards (Burthe *et al*., 2014; Foster, Swann and Furness, 2017; JNCC, 2021a; JNCC, 2021b; Tyson et al., 2015); this may be evidence of the over-reliance of these species on these food sources. Foraging at landfills can also increase the risk of disease and mortality from Clostridium botulinum infection (Coulston 2015) (volume 3, appendix 20.1).

264. Overall, construction activities and the presence of wind turbines may change the behaviour or availability of prey species for seabirds, resulting in the availability of such prey species being temporarily reduced. However, 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.

265. For long-term subtidal habitat loss due to the presence of the wind turbines and associated infrastructure, the majority of fish species would be able to avoid habitat loss effects due to their greater mobility and would recover into the areas affected following cessation of construction. Sandeels (and other less mobile prey species) would be affected by long term subtidal habitat loss, although recovery of these species is expected to occur quickly as the sediments recover following installation of infrastructure and adults recolonise and also via larval recolonisation of the sandy sediments which dominate the Proposed Development fish and shellfish ecology study area.

266. Following a minor adverse impact on fish that are prey species for seabirds, the impact on seabirds is predicted to be of local spatial extent, indirect and of medium-term duration, as prey species distribution is considered likely to recover over time. The magnitude is therefore considered to be negligible, and any effects on seabirds will not be significant. It is considered that any effects on seabirds such as kittiwake from a temporary reduction on prey species as a result of the wind farm will not significantly add to other predicted effects such as collision.

267. As discussed in volume 3, appendix 20.1, it is challenging to separate the effects of different pressures, due to the complexity of how they interact and the combined impact they have on seabird populations, their environment and their prey at all scales. Although offshore wind farms can impact local seabird populations directly through displacement and collision, there may also be beneficial indirect impacts from offshore wind farms, for example through the creation of artificial reefs on wind turbine foundations to increased prey availability for some seabird species (Coolen, 2017).

268. Overall, gannet, herring gull and lesser black-backed gull are thought to be buffered from the impacts of climate change, mostly relating to their ability to access a wider variety of prey, but they may be sensitive to controls on fisheries discards (Johnston *et al.,* 2021). Guillemot, kittiwake, puffin and razorbill abundances have been more closely linked to the success of their prey, which may make them more vulnerable to bottom-up climate change impacts (Burthe *et al*., 2014; Johnston *et al*., 2021). A reduction in prey quality and availability may also reduce the resilience of these species against storm events, which could lead to an increase in large-scale wrecks as climate change leads to an increase in extreme weather (Anker-Nilssen *et al*., 2017; Camphuysen *et al*., 1999; Heubeck *et al*., 2011; Morley *et al.,* 2016). Cliff nesting species, such as kittiwake and razorbill, may also be sensitive to nest failure in high winds and storm surges (Newell *et al*., 2015). Whilst auks and gannet may be sensitive to fisheries bycatch, high-risk fishing gear such as static net, longline and midwater trawls, are not common in the Forth and Tay region (Bradbury *et al*., 2017; Larsen *et al*., 2021). In the Forth and Tay region, and elsewhere, gannet, herring gull, kittiwake and lesser black-backed gull may also be vulnerable to effects from offshore wind farms, including collision and displacement (Burthe *et al*., 2014; Furness *et al*., 2013).

269. Whilst there is uncertainty around the in-combination effects from a growing number of windfarms, without action to lower carbon emission, climate change related impacts are likely to continue having an adverse effect on seabird populations, which must be considered when weighing up ecological trade-offs (Scott, 2022).

Proposed monitoring

270. As described in the Berwick Bank Wind Farm Compensatory Measures EIA Report (SSER, 2022f), sandeel monitoring has been put-forward as part of the proposed fisheries based compensatory measure.

271. The effects on sandeel will be monitored, likely through an acoustic survey during April/May in the relevant sandeel locations. This will be complimented by a dredge survey in December when the sandeel are hibernating in the sand/gravel on the seabed. The acoustic survey is non-lethal but the dredge survey will result in some sandeel mortality and limited disturbance of the seabed (Berwick Bank Wind Farm Compensatory Measures EIA Report (SSER, 2022f).

Conclusions

272. This section assesses whether there will be any changes to the key predator species as a result of the Proposed Development. This was achieved by assessing the sensitivity of the predator species to changes in prey availability and drawing on the conclusions of section 20.7.9 along with the findings of the relevant Offshore EIA Report chapters to determine if any changes to predator species are predicted. The following conclusions were made:

- piscivorous fish generally have a broad range of prey species they feed on which include small fish, molluscs and crustaceans which makes them less sensitive to the availability of the key forage prey species sandeel, herring, sprat and mackerel;
- of the marine mammal key species, harbour porpoise, harbour seal and minke whale were identified as being potentially sensitive to changes in prey availability;
- harbour porpoise and harbour seal may be sensitive to disturbance from their favoured habitat due to an energetic cost associated with increased travelling, however, the impacts are expected to be short term in nature and reversible. It is expected that all marine mammal receptors would be able to tolerate the effect without any impact on reproduction and survival rates and would be able to return to previous activities once the impact had ceased;
- minke whale was identified as being sensitive to effects to sandeel abundance, however, Anderwald *et al.* (2012) found they could switch between different prey according to their seasonal availability which indicates that these species are able to readily respond to temporal changes in pelagic prey concentrations; and
- of the seabird key species, kittiwake was identified as being particularly sensitive to changes in prey availability of its favoured prey species, sandeel. However, section 20.7.9 concluded significant changes to prey species as a result of the Proposed Development alone and in-combination with other projects are not predicted. Therefore, significant consequences on the key predator species are also not predicted.

20.7.11. SUMMARY AND CONCLUSIONS

273. The inter-related effects for all topics have been considered and are detailed above. It has been possible to conclude that inter-related effects across phases of the Proposed Development will not result in combined effects of greater significance than the assessments presented for each of the individual phases. It has also been concluded that multiple effects will not interact in a way that are likely to result in greater significance than those assessments presented for individual receptors.

274. The assessments within volume 2, chapter 9 of the Offshore EIA Report concluded that none of the potential impacts arising from the Proposed Development alone or in combination with other projects, would result in significant adverse effects on prey species.

275. This ecosystem effects assessment concluded that whilst colonisation of foundations, scour protection and cable protection has the potential to lead to localised increases in fish species through potential reef effects, any increases would be localised and are not expected to lead to a significant increase in prey species.

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

277. It is concluded that there will be no adverse effects on seabirds arising from changes in the behaviour or availability of prey species for seabirds as a result of the Proposed Development. 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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