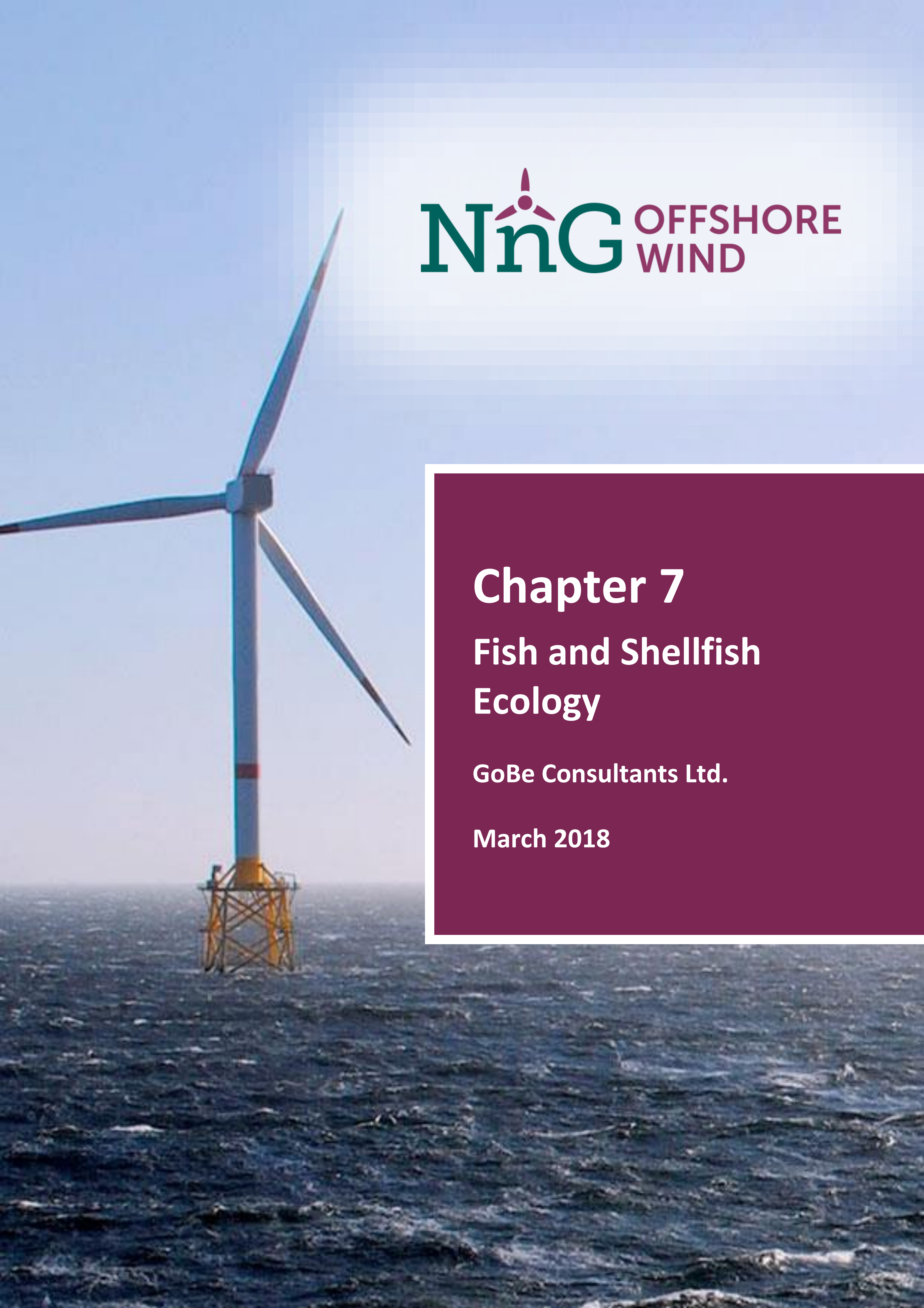

NnG OFFSHORE WIND

Chapter 7

Fish and Shellfish Ecology

GoBe Consultants Ltd.

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7 Fish and Shellfish Ecology

7.1 Introduction

1. This chapter of the EIA Report presents an assessment of the potential impacts upon Fish and Shellfish Ecology arising from the construction, operation and decommissioning of the Project, as detailed in Chapter 4: Project Description.

2. This chapter is comprised of the following elements:

- A summary of relevant policy and guidance;
- Details of the data sources used to characterise the study area;
- A summary of the relevant consultations with stakeholders;
- A description of the methodology for assessing the impacts of the Project, including details of the study area and approach to the assessment of potential effects;
- A review of the baseline conditions;
- A description of the most likely worst-case design scenario relevant to fish and shellfish ecology;
- An assessment of the likely effects arising from the construction, operation and decommissioning phases of the Project, including cumulative effects;
- Identification of any further mitigation measures or monitoring requirements in respect of any significant effects; and
- A summary of the residual impact assessment determinations taking account of any additional mitigation measures identified.

3. This chapter is supported by two technical appendices which are contained within Volume 4 of this EIA Report:

- Appendix 7.1: Benthic Ecology Characterisation Report; and
- Appendix 7.2: Atlantic Salmon – Appraisal of Original EIA

7.2 Legislation, Policy and Guidance

4. There is no policy or guidance directly relevant to the assessment of potential impacts on fish and shellfish ecology arising from offshore wind farm development. However, a number of the general guidance documents set out in Chapter 6: EIA Methodology include guidance on the matters to be considered in relation to the potential impacts of offshore wind farm development on fish and shellfish ecology, or otherwise provide guidance on data acquisition and data sources to be applied in describing the baseline conditions.

5. In legislative terms, a number of fish species relevant to the Project are protected under various Acts of legislation; for example, Atlantic salmon (*Salmo salar*) and sea lamprey (*Petromyzon marinus*) are listed as Annex II species under the Habitats Directive (and within the Habitats Regulations) as animal species of community interest whose conservation requires the designation of special areas of conservation. Salmon and sea trout (*Salmo trutta*) are also protected under the Salmon and Freshwater Fisheries (Consolidation) (Scotland) Act 2003 (as amended) which, amongst other things, gives protection to spawning gravels and eggs. European eel (*Anguilla anguilla*) is protected under a European Commission eel recovery plan (Council Regulation No. 1100/2007), with an Eel Management Plan being in place for Scotland. Other species including Atlantic herring (*Clupea harengus*), Atlantic cod (*Gadus morhua*), whiting (*Merlangius merlangus*) and plaice (*Pleuronectes platessa)* are listed as Scottish Biodiversity List (SBL) species. Relevant species are described further under Section 7.6.

6. The UK Marine Policy Statement (HM Government, 2011) and Scotland's National Marine Plan (Marine Scotland, 2015) contain relevant policy provision related generally to biodiversity and, in some cases identify issues specific to fish, such as outlining policies to protect commercially sensitive fish spawning grounds and spawning adults such as herring and cod. The policy statement also identifies the potential for adverse effects on marine fish (and other species) primarily through construction noise. Scotland's National Marine Plan identifies a list of priority marine features (PMFs) that must be considered when planning decisions are being made, taking account of the advice of Statutory Advisors. Several fish species are listed as PMFs and these are discussed further in Section 7.6. Further information on the Marine Policy Statement and Scotland's National Marine Plan is provided in Chapter 2: Policy and Legislation.

7. Both these national policy documents make reference to the EU Marine Strategy Framework Directive (MSFD) and the role of that Directive in protecting and enhancing the marine environment. The UK government has published its Marine Strategy Part Three in response to the requirements of the Habitats Directive (Defra, 2015) which sets out the UKs programme of measures, which are designed to achieve or maintain Good Environmental Status (GES) for the UK marine waters.

8. Measures are set out specifically for fish (Descriptors 1 and 4) identifying the requirement to maintain or enhance (or to avoid any human actions leading to an impact on) fish populations; measures are predominantly aimed at the management of commercial fisheries and the maintenance or development of protected areas.

9. Descriptor 11 relates to underwater noise and identifies the requirement to establish a noise registry to record, assess and manage the distribution and timing of anthropogenic sound sources exceeding 186 decibels (dB) re 1 10^{-6} Pascal squared, per metre, per second ($\mu Pa^2 m^2 \cdot s$) (a measure of sound exposure level) and for noise (and the requirement for any mitigation) to be a consideration in the marine licensing process for sensitive species including some fish.

7.3 Data Sources

10. The assessment considers the potential interaction between the Project, as described in Chapter 4: Project Description, and Fish and Shellfish receptors within the study area and in regard to those issues scoped into this EIA Report (See Section 7.4).

11. The study area includes the Wind Farm Area. In addition, a wider area has been used to provide the appropriate ecological context for mobile fish and shellfish species. It is dependent upon the species in question and the nature of the impact being assessed, but generally extends across the Forth and Tay area in a manner sufficient to characterise the baseline, and to provide a basis for the assessment process.

12. Baseline characterisation data has been collated combining a thorough desk-based study of extant data supplemented by site-specific surveys. Site-specific geophysical and geotechnical surveys have been completed for the Development Area, including sediment particle size analysis (PSA) and contaminant analysis using grab samples. In addition, benthic faunal analysis was undertaken based on samples collected during benthic grab and beam trawl surveys. These data have been reviewed to consider the presence of source-receptor pathways when assessing the potential for fish and shellfish receptors to be affected by the impacts arising from the Project.

13. Table 7.1 details the key data sources used to inform the baseline characterisation within the study area (other data sources are referenced within the baseline description – Section 7.6).

Table 7.1 Data sources used to inform the baseline description.

Data Source	Study/Data Name	Overview
NnGOWL	Neart na Gaoithe Proposed Offshore Wind Farm Benthic Ecology Characterisation (EMU, 2010a)	EMU Ltd was commissioned to undertake a series of benthic ecology sampling surveys of the Wind Farm Area, the Offshore Export Cable route options and associated intertidal area options where the Offshore Export Cable was proposed to make landfall. Fish and shellfish resources were sampled using a scientific beam trawl to provide a primary description of the site-specific communities, within, and peripheral to, the Wind Farm Area. A total of 19 stations were trawled. Grab samples were also taken. Ten species of fish were caught within the Development Area. Four species are of commercial importance. No rare or protected species were found. The report of the characterisation is included as Appendix 7.1.
NnGOWL	Neart Na Gaoithe Proposed Offshore Wind Farm and Cable Routes Geophysical Survey (EMU 2010b)	Geophysical survey of the Wind Farm Area and the Offshore Export Cable Corridor, including side scan sonar, AGDS and swath bathymetry.
Fisheries Research Services and Cefas	Fisheries Sensitivity Maps in British Waters, Coull et al. (1998)	Distribution of Spawning and Nursery Grounds in the vicinity of the Wind Farm Area
Cefas	Spawning and Nursery Grounds of Selected Fish Species in UK waters, Ellis et al. (2012)	Distribution of Spawning and Nursery Grounds in the vicinity of the Wind Farm Area
IHLS	International Herring Larvae Survey	Data derived from herring larval surveys conducted by the IHLS in the North Sea; early stage herring larvae are used as an indicator of herring spawning grounds.

7.4 Relevant Consultations

14. As part of the EIA process, NnGOWL has consulted with various statutory and non-statutory stakeholders. A formal scoping opinion was requested from MS-LOT following submission of the Scoping Report on 15 May 2017.

15. Following submission of the Scoping Report MS-LOT hosted a consultation meeting to discuss any issues relating to fish and shellfish with NnGOWL and key stakeholders on 13 June 2017. Key items raised are summarised in Table 7.2.

16. In response to NnGOWL's request, MS-LOT issued a Scoping Opinion on 8 September 2017 which included a number of issues that could not be scoped out of the assessment of potential impacts on fish and shellfish ecology. The key items raised for further consideration in respect of fish and shellfish are summarised in Table 7.2.

Table 7.2: Summary of consultation relating to Fish and Shellfish

Date and consultation phase / type	Consultation and key issues raised	Section where comment addressed
13/06/2017, MS-LOT Pre-application scoping meeting	Marine Scotland Science (MSS) requested that the EIA Report should include consideration of recent publications on the distribution and migratory patterns of Atlantic salmon based on recent Atlantic salmon tagging studies. MSS also advised that recent publications on the role of electromagnetic fields on Atlantic salmon navigation should be considered.	For a review of recent publications regarding Atlantic salmon see Appendix 7.2
	MSS advised that it may be necessary to scope in impacts related to particle motion (whilst acknowledging that there is no satisfactory quantitative assessment method available); a qualitative assessment to address the potential effects of particle motion on fish and shellfish species was requested. MSS confirmed that effects on herring from pile driving noise was not a concern for the Project alone (whilst noting the increase in hammer energy proposed at the Inch Cape site).	For impacts related to particle motion see Section 7.8. Effects on herring are scoped out.
	SNH advised that it would be acceptable to SNH to scope the assessment of potential impacts on diadromous fish out of the EIA and HRA from their perspective.	On the advice of MSS, diadromous fish have been considered further in respect of updating the baseline information. See Appendix 7.2.
08/09/2017, Scoping Opinion – Scottish Ministers	The Scottish Ministers note the point raised by SFF in relation to the possible negative impacts of suspended sediment and smothering, but as gravity base structures are not going to be used for NnGOWL they consider this does not need further assessment. The Scottish Ministers agree with SFF that the information regarding the presence of scallop populations and associated catching grounds should be clarified.	Potential effects from suspended sediment and smothering are scoped out. Information on scallops and their catching grounds is presented in Chapter 10: Commercial Fisheries.
	The 2017 EIA Regulations require that the Scottish Ministers come to a reasoned conclusion, based on up to date information, on the significant effects of the Project. As the information noted above [references relating to diadromous fish ecology provided by MSS] has been published since the previous assessment, the Scottish Ministers advised NnGOWL to consider whether it changes the outcome of the Original ES and, if so, carry out a further assessment. If NnGOWL consider no further assessment is required, they must provide justification of their reasons.	For a justification for scoping out diadromous fish from the EIA, see Appendix 7.2
	The Scottish Ministers have considered the concerns raised by the River Tweed Commission (RTC) and taken into account the advice provided by MSS in relation to the behaviour of seals, and advise that this issue can be scoped out. This is based on the advice from MSS that, if salmon are present, they will be actively migrating through the site and less at risk of being predated.	Effects upon the behaviour of seals have been scoped out.

Date and consultation phase / type	Consultation and key issues raised	Section where comment addressed
	The Scottish Ministers agree, with the exception of diadromous fish and clarification of information regarding scallop populations and catching grounds, that the existing fish and shellfish baseline and proposed updates are appropriate to the potential level of impact from the Project.	Diadromous fish are addressed within Appendix 7.2. Scallop population and catching ground information is provided in Chapter 10: Commercial Fisheries.
	The Scottish Ministers are satisfied with the embedded mitigation but note that further mitigation may be required if any concerns are raised following the outcome of the assessment on diadromous fish and particle motion.	See Chapter 17 for details of embedded mitigation. See Appendix 7.2 regarding diadromous fish.
	The Scottish Ministers agree that the potential impact of particle motion should be assessed and suggests that NnGOWL follows the approach outlined by MSS.	See Section 7.8 for the assessment of particle motion.
	The Scottish Ministers note the comments of RTC and the Forth District Salmon Fishery Board (FDSFB) and advise NnGOWL to take account of the new information available and include it in the EIA as noted above.	The new information available is detailed in Appendix 7.2.
	The Scottish Ministers agree that, with the exception of diadromous fish and particle motion, the assessment of fish and shellfish ecology receptors should be scoped out of the EIA.	For diadromous fish, see Appendix 7.2. For particle motion assessment, see Section 7.8.
	The Scottish Ministers advise NnGOWL to review the cumulative impact assessment for the Original Application to take account of the points raised in relation to particle motion and diadromous fish. If, after this review, NnGOWL considers that there is no need to update the cumulative impact assessment, they should provide justification for this decision. The Scottish Ministers note the comments of RTC and FDSFB and advise NnGOWL to take account of the new information available and include it in the EIA as noted above.	Cumulative effects are discussed in Section 7.8.4. The new information available is detailed in Appendix 7.2.
08/09/2017, Scoping – Scottish Natural Heritage	SNH confirmed that the Scoping Report provides full consideration and justification for scoping out diadromous fish species (and other qualifying interests of SAC rivers) from further assessment.	On advice of MSS, diadromous fish have been considered further in respect of updating the baseline information - See Appendix 7.2.

Date and consultation phase / type	Consultation and key issues raised	Section where comment addressed
08/09/2017, Scoping – Marine Scotland Science	MSS is content with regards to scoping out marine fish on the basis of the project design envelope being reduced and with the application of embedded mitigation.	The consideration of the impact of the project on marine fish species has been scoped out (with the exception of particle motion effects).
	Consideration should be given to potential changes to the Inch Cape or Seagreen design envelopes in regards to need for and scope of the CIA.	See Section 7.8.4 for the cumulative impact assessment.
	MSS provided a list of references in relation to diadromous fish and effects of particle motion on fish species to inform the assessment for the Project.	See Section 7.8 for the assessment of particle motion See Appendix 7.2 for information of diadromous fish.
08/09/2017, Scoping – East Lothian Council	ELC requested that fisheries baseline information include the species and location of fish being caught within the study area.	The commercial fisheries baseline is presented in Chapter 10: Commercial Fisheries.
	East Lothian Council have highlighted the need to consider any areas where the onshore works might contribute towards cumulative impacts.	The scope of this part of the EIA focuses on potential impacts from particle motion associated with construction and operation of the Project as agreed through Scoping, see Section 7.4. Given the distance of the onshore works to the Wind Farm Area there is no likelihood of cumulative effects from the Project affecting fish and shellfish species.
08/09/2017, Scoping – Forth District Salmon Fishery Board	FDSFB consider the information presented in the Scoping Report to be insufficient to scope out diadromous fish species. FDSFB suggested use of the Harding *et al*. (2016); Knudsen *et al*. (1996) and Malcolm *et al*. (2010).	See Appendix 7.2 for further information in relation to diadromous fish.
	FDSFB also proposed that a piling strategy informed by further assessment be considered to mitigate the risk to effects on salmonids.	See Section 0; embedded mitigation

Date and consultation phase / type	Consultation and key issues raised	Section where comment addressed
	Expressed concern over use of wind farms by seals and effects on salmon of increased seal predation.	The Scottish Ministers concluded in the Scoping Opinion, based on advice from MSS, that Atlantic salmon present within the Wind Farm area are likely to be actively migrating through the site and less at risk of being predated. This is scoped out of the Project EIA.
08/09/2017, Scoping – River Tweed Commission	Highlighted information relating to salmon tagging studies in Norway and records of fish returning to the east coast of Scotland indicating migrating salmon may pass through the project area.	See Appendix 7.2 for discussion of Atlantic salmon.
	The RTC concludes that diadromous fish should be scoped in to the EIA.	See Appendix 7.2 for further information regarding diadromous fish.
08/09/2017, Scoping – Scottish Fishermen's Federation	SFF believes that in areas identified as scallop and Nephrops grounds, more attention needs to be given to any possible negative impacts on these species by operations that produce suspended sediment and the potential to smother the animals or interfere with their feeding or breeding.	The Scottish Ministers agree with SFF that the information regarding the presence of scallop populations and associated catching grounds should be clarified. See Chapter 10: Commercial Fisheries. The Scottish Ministers confirmed that as the Project design envelope does not include gravity base foundations they were content with the conclusions of the Scoping Report that impacts resulting from increased suspended sediment be scoped out of the Project EIA.

Date and consultation phase / type	Consultation and key issues raised	Section where comment addressed
	The SFF contend that habitat disturbance, suspended sediment concentration (SSC) and sediment settlement in the wind farm area must be properly defined as there is little scientific evidence to back up the claim of minor significance. Similarly, these effects also need to be assessed for the export cable, and both the windfarm and cable route need to be included in a proper assessment of the cumulative impacts with other projects.	The Scottish Ministers confirmed they were content with the conclusions of the Scoping Report that impacts resulting from increased suspended sediment should be scoped out of the Project EIA. The worst case in the Original EIA comprised gravity base foundations and impacts were assessed informed by a sediment dispersal model, with impacts found to be not significant. Gravity bases are not part of the Project and therefore impacts are considered to be lower and therefore not significant and are scoped out.

17. In summary and as set out in Table 7.2, the Scoping Opinion and justification set out in Appendix 7.2 has confirmed that (based on the scheme design as set out in the Scoping Report, and on the assumption that the embedded mitigation will be applied) that only the following matters should be scoped in to the EIA of impacts on fish and shellfish ecology:

- Particle motion resulting from increased sound pressure (noise) from pile driving activity and the construction and operation of turbines, foundations and Offshore Substation Platforms (OSPs) and sheet piling of interlocking sheets around the HDD exit point. Potential effects to be assessed for all fish and shellfish species.

18. In addition, the Scottish Ministers advised that the location of scallop populations and catching grounds should be clarified; this information is presented in Chapter 10: Commercial Fisheries.

19. The Scottish Ministers (along with SNH) have advised NnGOWL to review the updated published information relating to the behaviour of diadromous fish to ensure that the conclusions of the previous Original ES provide a robust basis for the scoping out of impacts on those species from this EIA (for the Project alone and cumulatively). This review is provided as Appendix 7.2 where justification is provided to confirm that the assessment provided in the Original ES remains valid and this aspect can be scoped out.

20. All other potential impacts on marine and diadromous fish have been scoped out of this assessment, for the Project alone and for the cumulative impact assessment, and are not considered further in this chapter.

7.5 Impact Assessment Methodology

21. This assessment considers the potential impacts associated with the construction, operation and maintenance and decommissioning of the Project and those effects on Fish and Shellfish that have been scoped into the EIA. The impact assessment process and methodology follows the principles and approach outlined in Chapter 6: EIA Methodology. For decommissioning, it is anticipated that the potential effects will be less than those for the construction due to potential for no pile driving activity

and for subsea structures / cables to be left in situ, but for the purposes of this assessment the precautionary principle is applied and the potential effects are considered to be the same as for the construction stages.

7.5.1 Assessment and Assignment of Significance

22. The sensitivities of Fish and Shellfish receptors are defined by both their potential vulnerability to an impact from the Project, their recoverability, and the value or importance of the receptor. The definitions of terms relating to Fish and Shellfish are detailed in Table 7.3.

Table 7.3: Sensitivity / importance of the environment

Receptor sensitivity / importance	Description / justification
High	Nationally and internationally important receptors with high vulnerability and no ability for recovery.
Medium	Regionally important receptors with high vulnerability and no ability for recovery. Nationally and internationally important receptors with medium to high vulnerability and low to medium recoverability.
Low	Locally important receptors with medium to high vulnerability and low recoverability. Regionally important receptors with low vulnerability and medium recoverability. Nationally and internationally important receptors with low vulnerability and medium to high recoverability.
Negligible	Receptor is not vulnerable to impacts regardless of value/ importance. Locally important receptors with low vulnerability and medium to high recoverability.

23. The magnitude of impact is defined by a series of factors including the spatial extent of any interaction, the likelihood, duration, frequency and reversibility of a potential impact. The definitions of the levels of magnitude used in this assessment in respect of Fish and Shellfish are described in Table 7.4.

Table 7.4: Magnitude of the impact

Magnitude of impact	Description (adverse effects)
High	The impact would affect the conservation status of the site or feature, with loss of ecological functionality. Major negative shift away from baseline conditions.
Medium	The feature’s conservation status would not be affected, but the impact is likely to be significant in terms of ecological objectives or populations. Fundamental negative shift away from baseline conditions.
Low	Minor shift away from baseline but the impact is of limited temporal or physical extent.
Negligible	Very slight change from the baseline condition.
No change	No loss or alteration or characteristics, features or elements; no observable impact in either direction.

24. The magnitude of the impact is correlated against the sensitivity of the receptor to provide a level of significance. For the purposes of this assessment, any effect that is moderate or major is considered significant in EIA terms, and would potentially require additional mitigation.

Table 7.5: Significance of potential effects

		Magnitude			
		High	Medium	Low	Negligible
Sensitivity	High	Major	Major	Moderate	Minor
	Medium	Major	Moderate	Minor	Negligible
	Low	Moderate	Minor	Minor	Negligible
	Negligible	Minor	Negligible	Negligible	Negligible

7.5.2 Uncertainty and Technical Difficulties Encountered

25. The description of spawning and nursery grounds is primarily based on the information presented in Ellis et al. (2012) and Coull et al. (1998). The limitations of these sources of information should, however, be recognised. These publications provide an indication of the general location of spawning and nursery grounds, particularly in the context of the relatively small footprint of the Wind Farm Area, based on historical data, and do not necessarily represent the location of current spawning activity.

26. Similarly, the spawning times given in these publications represent the maximum duration of spawning on a species / stock basis. In some cases, the duration of spawning may be much more contracted, on a site-specific basis, than reported in Ellis et al. (2012) and Coull et al. (1998). Therefore, where available, additional research publications have also been reviewed to provide site specific information.

27. It is also the case that mobile species, such as fish (and to some extent shellfish), exhibit varying spatial and temporal patterns.

28. In relation to the assessment process, the use of particle motion in fish and shellfish species and, particularly, the response of individual species to a given level of acoustic particle motion, as may arise from, for example, pile driving operations, is an area of incomplete knowledge. Measurement of acoustic particle motion at sea is an area of emerging science and there is yet to be a means of modelling the acoustic particle motion arising from offshore wind farm construction or operation in the way that can be done for the sound pressure component of underwater noise. This is acknowledged in the Scoping Opinion by Marine Scotland *"… understanding of the effects from particle motion, and extent of these effects, is currently an area for further development, and there are various initiatives being progressed."*

29. As a result, MSS advised that the following approach be taken to the assessment of acoustic particle motion:

- Provide an overview of currently available information on particle motion within the vicinity of noise producing construction and operational activities – both within the water column and the seabed. This should include consideration of the likely distances at which elevated levels of particle motion may be detected;
- Provide an overview of the published information on sensitive species and potential physiological and behavioural effects of particle motion;
- Consider the potential effects of particle motion on species known to occur around the Wind Farm Area, making use of information on species distribution from the Original ES and information which has become available since then. Particular attention should be given to potential effects on species of commercial or conservation concern; and

- Provide information on opportunities that the Project may present to investigate effects of particle motion on fish and invertebrates.

7.6 Baseline Description

7.6.1 Uncertainty and Technical Difficulties Encountered

30. The following sections present a description of the baseline characteristics that are relevant to those issues scoped into the EIA, which comprise an assessment of particle motion in relation to construction and operation within the Wind Farm Area for all fish and shellfish species (see Section 7.4). The baseline information presented here identifies these key species, their sensitivities.

31. A review of recently published information regarding the ecology of diadromous fish species and the most up to date position on migration routes, behaviour at sea and responses to noise and EMF is provided separately in Appendix 7.2 in response to the requirements set out in the Scoping Opinion (see Section 7.4).

7.6.2 Overview

32. The following section presents an overview of the main fish and shellfish species that are characteristic of the central North Sea, with particular regard to the southeast Scotland region, as described by Barne et al. (1997). This region encompasses the Wind Farm Area and the Firth of Forth, the seaward boundary of which falls between Fife Ness and Dunbar (Eleftheriou et al., 2004).

33. The North Sea comprises two main fish assemblages located above and below the 50 metre (m) depth contour, respectively. A third, minor assemblage occurs in the far north around the 200 m depth line (Calloway et al., 2002). The sea around the southeast Scotland region is considered part of the Central North Sea (ICES Division IVb) (Cefas, 2001). This region comprises fish assemblages that are strongly depth and temperature related, made up of shallower pelagic (50 - 100 m water depth) and deeper demersal (100 - 200 m water depth) species groups.

34. The southeast Scotland region hosts important inshore populations of shellfish, the distribution of which is highly influenced by the substratum type, as these highly sedentary organisms have habitat specific requirements. Shellfish (as with fish species) are of considerable ecological value as prey species for a number of marine mammals and birds. In addition, they represent a source of revenue for the commercial fishing industry (see Chapter 10: Commercial Fisheries).

35. The water depth across the Wind Farm Area ranges between 40 m and 58 m relative to Lowest Astronomical Tide (LAT), with the deeper water in the north and west of the site. Geophysical and geotechnical surveys at the Wind Farm Area indicate that seabed conditions are similar to much of the surrounding North Sea region and are generally characterised by slightly gravelly sand sediments with small amounts of silt, characterised by typical mud and sand fauna with prominent mounds and burrows produced by megafauna. The seabed within the Wind Farm Area includes a series of interspersed mounds, each approximately 1 km across and up to 6 m higher than the surrounding sea bed, comprised of areas of mixed coarse sediment cobbles and boulders representing exposed Wee Bankie formation.

36. Similar fish and shellfish communities exist within the Wind Farm Area and surrounding Firth of Forth (EMU, 2010). The shrimp species *Crangon allmani* and *Pandalus montagui* dominate the catch composition across this area with American plaice, gobies and dab accounting for the most common fish species. No particular distributional trends have been observed. The mobile epibenthic assemblages recorded during the beam trawl sampling (EMU, 2010) were found to be more characteristic of the Southern North Sea but concur with the findings of historic surveys in the area (Calloway et al., 2002 & Jennings et al., 1999).

37. A number of species (Table 7.6) are potentially present within the Wind Farm Area and surrounding areas as informed through review of the Original ES, a literature review (including data from Ellis et al. (2012), Greenwood and Hill (2003), Greenwood et al. (2002) and Coull et al. (1998)), site-specific surveys and through consultation with local fishery stakeholders (refer to Chapter 10: Commercial Fisheries).

Table 7.6: Species potentially present within the Wind Farm Area

Group / Species	
Pelagic	
Mackerel (*Scomber scombrus*) [2]	Atlantic salmon (*Salmo salar*)[1 2 3]
Sprat (*Sprattus sprattus*)	Sea trout (*Salmo trutta*) [2 3]
Blue whiting (*Micromesistius poutassou*) [2 3]	Shad (*Alosa spp.*)[1 3]
Herring (*Clupea harengus*) [2 3]	Basking shark (*Cetorhinus maximus*) [2 3]
Inshore / Coastal Species	
Catfish (Anarhichas lupus)	Scaldfish (*Arnoglossus laterna*)
Gobies (Gobidae) [2 (only sand goby)]	Four-bearded rockling (*Rhinonemus cimbrus*)
Greater pipefish (Syngnathus acus)	Wrasses (*Labrus spp.*)
Demersal	
Whiting (*Merlnagius merlangus*) [2 3]	**Sandeels (*Ammodytes spp.*)** [2 3]
Lemon Sole (*Microstomus kitt*)	Gurnards – Red (*Aspitrigla cuculus*)
Plaice (*Pleuronectes platessa*) [3]	Gurnards – Grey (*Eutrigla gurnardus*)
Turbot (*Scophthalmus maximus*)	Red Mullet (*Mullus barbatus*)
Halibut (*Hippoglossus hippoglossus*) [2 3]	Monks or Anglers (*Lophius spp.*) [2 3]
Dab (*Limanda limanda*)	Dogfish (*Scyliorhinus canicular*)
American plaice (*Hippoglossoides platessoides*)	Tope (*Galeorhinus galeus)* [3]
Megrim (*Lepidorhombus whiffiagonis*)	Thornback Ray (*Raja clavata*) [3]
Witch (*Glyptocephalus cynoglossus*)	Blonde Ray (*Raja brachyura*)
Sole (*Solea solea*) [3]	Cuckoo Ray (*Raja naevus*)
Brill (*Scophthalmus rhombus*)	Pollack (*Pollachius pollachius*)
Haddock (*Melangrammus aeglefinus*)	Cod (*Gadhus morhua*) [2 3]
Hake (*Merluccius merluccius*) [3]	Bass (*Dicentrarchus labrax*)
Saithe (*Pollachius virens*) [2]	Conger Eels (*Conger spp*)
Ling (*Molva molva*) [2 3]	Long rough dab (*Hippoglossoides platessoides*)
Shellfish	
Norwegian Lobster (*Nephrops norvegicus*)	Queen Scallops (*Aequipecten opercularis*)

Lobster (*Homarus gammarus*)	Razor Clam (*Ensis spp.*)
Brown crab (*Cancer pagurus*)	Clams (*Mya arenaria*)
Green Crab (*Carcinus maenus*)	Whelks (*Buccinum undatum)*
Squat Lobster (*Munida rugosa*)	Shrimp species (*Crangon spp., Pandalus montagui*)
Velvet swimming crab (*Necora puber*)	Squid (*Loligo spp.*)
King scallops (*Pecten Maximus*)	
Key to Conservation Status	
1. Habitats Regulations and Offshore Habitats Regulations Schedule 3 Species. 2. Scottish PMF's. 3. SBL species.	

7.6.3 Pelagic Species

38. Pelagic fish inhabit the water column including the near surface. Their distribution and abundance is strongly affected by hydrographic conditions and can vary significantly from year to year. The principal pelagic species found in the region are typical of the wider North Sea and include herring, sprat, mackerel and whiting.

39. These species are commercially exploited in the wider region (see Chapter 10: Commercial Fisheries) and sprat and herring can also play an important ecological role as principal prey items for several larger fish species, marine birds and mammals.

7.6.3.1 Spawning Areas

40. Data from Ellis et al. (2012) and Coull et al. (1998) indicate that sprat and herring spawn in the southeast Scotland region (Figure 7.1 (Volume 2). The Wind Farm Area does not coincide directly with the sprat or herring spawning areas but they are located to the east (for sprat) and to the north and south (for herring). Adult spawning herring are highly sensitive due to their specialist hearing capabilities, but are also susceptible to particle motion due to the presence of their swim bladder and its connection to the hearing system. Consideration of the more contemporary and detailed information provided by the ICES International Herring Larvae Survey (IHLS) data, conducted over the last ten years (Figure 7.2 (Volume 2)) confirms that herring spawning activity has been centred to the north of the Wind Farm Site off the Aberdeenshire coast and shows no evidence of spawning activity in the vicinity of the Wind Farm Area. MS-LOT has advised during scoping that there will be no potential effects upon these spawning areas or on the Buchan or Orkney / Shetland herring stocks. Some data (Ellis et al, 2012) suggests that whiting spawning grounds may occur near to the Wind Farm Area and although not affected directly by the Project, it is possible that larval draft may result in the presence of eggs / larvae within the Wind Farm Site (whiting eggs in the pelagic stage are of conservation interest (Table 7.7) are protected).

7.6.3.2 Nursery Areas

41. Data from Ellis et al. (2012) and Coull et al. (1998) further indicate that herring, sprat and mackerel nursery areas overlap with the Wind Farm Area as shown (Figure 7.1 (Volume 2) and Figure 7.3 (Volume 2)). Whiting nursery areas are present to the east of the Wind Farm Area (Figure 7.3 (Volume 2)).

42. Coull et al. (1998) found sprat to be ubiquitous across the region and around the UK during nursery periods. It also noted that data for specific nursery periods are not readily available as *"nursery grounds for most fish species are dynamic features of life history"* (Cefas, 2001).

7.6.3.3 Vulnerabilities and Seasonal Sensitivities

43. Sensitivity data for the specific pelagic species considered here are relatively sparse as is an understanding of how individual fish actually respond to underwater noise in terms of reaction and behavioural responses. However, research shows that the main issues for pelagic fish species are noise and SSC levels (in turn affecting water quality). The relative mobility of pelagic fish may allow localised avoidance of some impacts such as suspended sediments (Birklund and Wijsman, 2005), however suspended sediments can settle and smother habitats or spawn / eggs and affect recruitment to a fish population (e.g. herring have very specific spawning bed requirements). For other pelagic species, such as mackerel or herring, raised sediment levels may also cause avoidance behaviour or communication issues (e.g. affect shoaling behaviour). Man-made noise introduced to the marine environment causes sound pressure waves which can affect the hearing capabilities of fish species with swim bladders, but sound waves can also cause particle waves (or particle motion) which can be detected by a wider range of fish and invertebrates.

44. Effects such as sound pressure changes can be detected at relatively long distances. Herring, unlike most other fish, have specialised adaptations connecting the swim bladder and oesophagus to the inner ear, which classifies them as 'hearing specialists'. These morphological adaptations make them one of the most sensitive fish species to sound pressure (ICES, 2006a). They are also however, susceptible to particle motion.

45. Table 7.7 details the key pelagic species, their conservation status and seasonality of spawning activity. A brief summary of herring biology with regard to the North Sea population is presented below, with a view to identifying species key life stages likely to be particularly sensitive to sound pressure and particle motion.

Table 7.7 Seasonal sensitivities and conservation importance for key pelagic species

	Seasonal Spawning Activity												
Name	J	F	M	A	M	J	J	A	S	O	N	D	Notes on conservation importance
Mackerel *S.scombrus*													Scottish Priority Marine Feature (PMF) and UK BAP species
Herring *C.harengus*													PMF (juveniles and spawning adults); and Scottish Biodiversity list; and UK BAP species
Sprat *S.sprattus*													PMF; and UK BAP species
Whiting *M.merlangus* (NB. pelagic at egg stage only)													Scottish Nature Conservation Marine Protected Area (MPA) search feature (juvenile); and Scottish Biodiversity List; and PMF (juveniles); and UK BAP species

	peak spawning
	spawning

46. Herring is a pelagic species, which is abundant in the summer and autumn throughout the southeast Scotland region (Robson, 1997). Breeding takes place on the seabed within specific habitat types, where there is a low proportion of fine sediment and in well oxygenated water (Ellis et al., 2012). Their eggs, which have adhesive qualities, sink through the water column and onto the seabed. Herring have historically been reported to exhibit natal spawning site fidelity that results in predictable patterns of migration to and from spawning grounds (McPherson et al., 2001). This spawning fidelity, together with the predictable nature of spawning, has been shown to take place in discrete groups (McPherson et al., 2001).

47. Most authors distinguish four major spawning groups within the North Sea defined by distinct spawning times and sites (Payne, 2010). Those that spawn off the east of Scotland are known as the Orkney/Shetland and Buchan components. The Orkney-Shetland component spawns in August/September between the Islands that give it its name; the Buchan component to the east of Scotland in September/October. Some authors consider Buchan/Shetland as one component (Ellis et al., 2012; Cefas, 2001), spawning between August and September (Cefas, 2001).

48. In the context of the current study, the spawning period has been considered to extend from August to October with peak activity in September (Table 7.7). Natural variability in the timing of spawning is to be expected (Payne, 2010), owing to year to year changes of environmental conditions at the time of egg development and larval hatch, as well as changes in the timing of emergence of eggs and larvae or a combination of both (Wieland et al., 2000).

7.6.4 Demersal Species

49. Demersal fish are bottom feeders that live on or near the seabed. In coastal waters, they are found on or near the continental shelf whereas in deep waters they are more associated with the continental slope or continental rise. Their distribution is related to abiotic factors such as sediment type (which is usually important as a refuge in predation avoidance or for cryptic behaviour), hydrography, biotic processes (e.g. predator-prey interactions) and competition for space. Demersal species found in the region include gadoids (soft finned fish species of the family Gadidae), flatfish, sandeel and elasmobranchs.

7.6.4.1 Spawning Areas

50. Data from Ellis et al. (2012) and Coull et al. (1998) indicate that several demersal round and flatfish species spawn in the region surrounding the Wind Farm Area. Figure 7.3 (Volume 2) shows spawning grounds for whiting, Figure 7.4 (Volume 2) for cod and Figure 7.5 (Volume 2) for lemon sole and plaice, all of which spawn in the region.

51. Many demersal species, such as plaice, have buoyant eggs that are released into the water column where they remain for several weeks until the pelagic larvae emerges (van Damme et al., 2011).

52. There are five species of sandeel in the North Sea, though the majority of commercial landings are of *Ammodytes marinus* (Cefas, 2001). Sandeel occur in the southeast Scotland region and are abundant on the series of sandbanks that lie at about 30 - 50 kilometres (km) offshore of the coast, including the Berwick Bank, Scalp Bank, Montrose Bank and Wee Bankie (Robson, 1997). Ellis et al 2012 fish sensitivity maps show that there are high intensity sandeel spawning areas present within the Wind Farm Area.

53. Sandeel generally inhabit shallow turbulent sandy areas with a high percentage of medium to coarse grained sand (particle size 0.25 - 2 millimetres (mm)) (Greenstreet et al., 2010). Sandeel are considered to have highly specific habitat requirements, requiring well flushed tidally active areas (Wright et al., 2000) with current flows greater than 0.6 m s^{-1} (Jensen et al., 2011).

54. Results of site-specific surveying and analysis using recommendations outlined in Greenstreet et al. (2010) indicated that due to the relatively high mud content, the habitats within the Wind Farm Area are unlikely to support a substantial sandeel spawning population. Results of the faunal analyses showed that the total number of sandeel recorded was very low (five individuals were captured across the entire survey area) (See Appendix 7.1).

55. Elasmobranch species produce relatively small numbers of live young (10 - 100 per year) or lay eggs on the seabed close to their nursery areas (Robson, 1997). Several species of elasmobranchs have been reported in the region, namely spurdog, lesser spotted dogfish, thornback ray, cuckoo ray and tope (Ellis et al., 2010; Robson, 1997). Basking sharks have also been reported. Several elasmobranchs are recognised as of conservation importance (particularly basking shark) and some are targeted by commercial or recreational fishermen.

56. The distribution of elasmobranch breeding grounds, in relation to the Wind Farm Area is presented in Figure 7.7 (Volume 2). The breeding grounds of both spotted ray and skate occur outside the Wind Farm Area. With respect to the spurdog and the tope, both species' breeding grounds coincide with the Wind Farm Area.

57. The seasonality of elasmobranch breeding is summarised in Table 7.9.

7.6.4.2 Nursery Areas

58. Data indicate that high intensity nursery areas for cod (Figure 7.4 (Volume 2)) and low intensity nursery areas for lemon sole and plaice (Figure 7.5 (Volume 2)) and blue whiting and ling (Figure 7.6 (Volume 2)) overlap with the Wind Farm Area. There are also low intensity nursery areas for sandeel recorded within the fish sensitivity maps (Ellis et al, 2012).

59. Table 7.8 summarises the spawning seasonality of some of the key demersal species.

7.6.4.3 Vulnerabilities and Seasonal Sensitivities

60. Adult spawning demersal fish and shellfish are susceptible to particle waves that are created from sound pressure waves (noise), as even fish and shellfish that do not possess swim bladders can detect these potential effects. Such sound and particle waves can result in adults avoiding or being driven away from their regular spawning areas, resulting in failed spawning or reduced survival of eggs that are laid within unsuitable habitat conditions due to displacement and disturbance of usual spawning activity. This type of sensitivity is restricted to certain times of the year however, during key spawning periods.

61. Juvenile fish are also susceptible to particle motion and their behaviour may also be affected within their key nursery grounds and as a result, their survival rates may potentially be affected. The level of these types of effect are not however currently fully understood.

Table 7.8: Seasonal sensitivities and conservation importance for key demersal species

	Seasonal Spawning Activity												
Name	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Notes on conservation importance**
Cod *G.morhua*													Scottish Nature Conservation Marine Protected Area (MPA) search feature; Scottish Biodiversity list; Scottish Priority Marine Feature (PMF) and UK BAP species; listed as vulnerable on the IUCN red list; and OSPAR species.
Whiting *M.merlangus*													Scottish Nature Conservation Marine Protected Area (MPA) search feature (juvenile); Scottish Biodiversity List; PMF (juveniles); and UK BAP species.
Ling *M.molva*													Scottish Biodiversity List; PMF; and UK BAP species.
Plaice *P.platessa*													UK BAP species
Lemon sole *M.kitt*													
Blue whiting *M.potassou*													UK BAP species
Sandeels *Ammodytes spp.*													Scottish Nature Conservation Marine Protected Area (MPA) search feature; and PMF.
	peak spawning												

	Seasonal Spawning Activity												
Name	J	F	M	A	M	J	J	A	S	O	N	D	Notes on conservation importance
	spawning												

Table 7.9: Seasonal sensitivities and conservation importance for key elasmobranch species

	Seasonal Spawning Activity												
Name	J	F	M	A	M	J	J	A	S	O	N	D	Notes on conservation importance
Spurdog (or spiny dogfish) *S.acanthius*													Scottish Nature Conservation Marine Protected Area (MPA) search feature; OSPAR species; listed as critically endangered on the IUCN red list.
Basking shark *C.maximus*													Listed under several international conventions as of conservation importance including: EC Habitats Directive Annex V species; listed as vulnerable on the IUCN red list; Barcelona convention listed species (Annex II); Bern convention listed species (Appendix IIb); and Convention on migratory species/Bonn convention list species (Appendix I and IId)
Tope *G.galeus*													Listed as vulnerable on the IUCN red list; and UK BAP species.
	spawning												

7.6.5 Diadromous Fish

62. Diadromous species are migratory fish moving between the sea and freshwater (or vice versa) for breeding/spawning purposes. They spend a significant period of their life cycle in both freshwater and seawater habitats. There are two types of diadromous fish: anadromous and catadromous. Anadromous fish are those that spend the majority of their lives at sea, but specifically move upstream to freshwater to breed and spawn e.g. Atlantic salmon. Conversely catadromous fish are those that move from freshwater to the sea to spawn e.g. the European eel.

7.6.5.1 Spawning Areas

63. There are no spawning areas within, or immediately surrounding the Wind Farm Area. The nearest Atlantic salmon and sea trout spawning areas are within the network of rivers that feed into the Firth of Forth.

7.6.5.2 Nursery Areas

64. Similar to spawning areas, there are no nursery areas within, or immediately surrounding the Wind Farm Area.

65. Although no diadromous species have nursery or breeding areas directly in the vicinity of the Wind Farm Area, they are known to travel through the Forth and Tay area en route to and from their natal rivers. Anadromous species may spawn or have nursery areas in the lower estuary (e.g. shad) or in fully freshwater rivers (e.g. salmon and sea trout), whereas catadromous species (e.g. eel) will pass through the Firth of Forth on their way to their oceanic spawning grounds.

66. The following diadromous species are known to be present in the Firth of Forth region, although in small numbers (Greenwood et al., 2002) and may therefore be present in and around the Wind Farm Area:

- Atlantic salmon;
- Sea trout;

- European eel;
- Smelt / sparling;
- River lamprey;
- Sea lamprey;
- Allis shad; and
- Twaite shad.

67. A review of the migratory habits of Atlantic salmon is provided in Appendix 7.2. In summary, Atlantic salmon may be present within the Development Area at certain times of the year. Atlantic salmon spawn in Scottish east coast rivers before migrating to remote feeding grounds. Adult Atlantic salmon return to natal rivers to spawn after one or more winters at sea. Atlantic salmon's use of the Development Area is thought to be transitory in nature with individuals migrating predominately in surface waters although studies have observed individuals using the full water column (Godfrey et al., 2015). Returning adults have been observed migrating along coastal waters in a northerly direction when migrating to Scottish east coast rivers although evidence is limited (Malcolm et al., 2010). Smolts have been observed to undergo rapid and active migration towards open marine areas within the uppermost surface waters (Finstad, et al., 2005; Lothian, et al., 2017; Thorstad et al., 2007). A full review of the current understanding of Scottish salmon migratory behaviour is presented in Appendix 7.2.

7.6.5.3 Vulnerabilities and Seasonal Sensitivities

68. The migratory behaviour of diadromous species means that they have the potential to be sensitive to certain impacts arising from the construction of the Project, specifically pile driving noise. During operation they may be sensitive to EMF generated by subsea cables where the migration occurs in close proximity to the Project, or in such a way that the migratory behaviour might be disturbed. This might have secondary impacts in relation to the success of individuals migrating to or from their spawning sites (for example, by interfering with the migration of returning adult salmon to their natal rivers such that their spawning success is somehow reduced).

69. Table 7.10 summarises the key seasonal sensitivities (related to migratory periods) and the conservation status of the named diadromous species.

Table 7.10: Seasonal sensitivities and conservation importance of diadromous species

	Timing of migration to and from natal rivers												
Name	J	F	M	A	M	J	J	A	S	O	N	D	Notes on conservation importance
Atlantic salmon *Salmo salar*[1]													EC Habitat Directive Annex II and V (and transposed regulations) species; Qualifying feature of the River South Esk, River Tay and River Teith Special Areas of conservation (SACs) with varying conservation objectives and statuses as part of these sites (see SNH, 2012); Scottish Nature Conservation MPA search feature (marine life stages); Priority Marine Feature Scottish Waters (Marine part of life cycle).UK BAP species; Bern Convention Appendix 3; OSPAR species; Scottish Biodiversity List;
Sea trout *Salmo trutta*													Scottish Nature Conservation MPA search feature (marine life stages); and UK BAP species.
European eel *Anguilla anguilla*													IUCN Red List critically endangered; OSPAR species; and PMF (marine part of life cycle).
Smelt/sparling *O.eperlanus*													UK BAP species; Scottish Biodiversity List species; and PMF (marine part of life cycle).
River lamprey *Lampetra fluviatilis*													EC Habitat Directive Annex II and V (and transposed regulations) species; Qualifying feature for River Tay SAC; Bern Convention, Appendix 3; Habitat Regulations, Schedule 3; Scottish Biodiversity List species; and PMF (marine part of life cycle).
Sea lamprey *Petramyzon marinus*													EC Habitat Directive Annex II and V (and transposed regulations) species; Qualifying feature of River Tay SAC; UK BAP species; OSPAR species; Scottish Biodiversity List species; and PMF (marine part of life cycle).
Allis shad *Alosa alosa*													EC Habitat Directive Annex II and V (and transposed regulations) species; Qualifying feature of a number of Special Areas of Conservation (SACs) in the region; UK BAP species; Bern Convention, Appendix 3; Habitat Regulations, Schedule 3; and Scottish Biodiversity List species.
Twaite shad *Alosa fallax*													Conservation information as per Allis shad.

	Main migratory period

[1] The peak timing of migrations reflects periods of peak post-smolt emigration and periods of peak returning MSW salmon, however, the Scottish salmon stock is known to enter natal rivers over a broader period and may therefore be present within the Development Area throughout the year, the impact assessment has been undertaken on this basis.

7.6.6 Shellfish

70. A number of commercially important shellfish species have been recorded within the Wind Farm Area. The commercial species most commonly targeted within the Wind Farm Area are Nephrops, lobster and brown crab, which accounts for over 90% of commercial landings by value. All of these shellfish species are potentially affected by particle motion resulting from increased noise (sound pressure waves).

71. The southeast Scotland region hosts important inshore populations of European lobster *Homarus gammarus*, edible crab *Cancer pagurus*, common mussel *Mytilus edulis*, and large offshore populations of Norway lobster *Nephrops norvegicus* (commonly referred to as Nephrops) and king scallops *Pecten maximus*. Queen scallops *Aequipecten opercularis* are present in a large area off the coast of the region and around the Isle of May, but not in exploitable quantities (Robson, 1997).

7.6.6.1 Spawning and Nursery Areas

72. Female lobsters reach sexual maturity when they are 75-85 mm (5-7 years old), whereas males mature at a slightly smaller size (Beard and McGregor, 2004). Mating occurs in the summer and berried females (those carrying the eggs) begin to appear from September to December in all areas where lobsters are present (Pawson, 1995). The eggs can be carried up to 12 months depending on the water temperature (Beard and McGregor, 2004), before hatching in spring and early summer (Pawson, 1995). Hatching occurs at night and larvae swim to the surface where they drift with the currents. This stage lasts for 15 to 35 days and involves three moults. After the third moult, the juveniles take on a form close to that of the adults and adopt a benthic lifestyle (Beard and McGregor, 2004). The main lobster nurseries are found on rocky grounds in coastal waters (Beard and McGregor, 2004).

73. Female crabs move inshore in late spring to moult and shortly afterwards they mate. After mating, the females move offshore in late summer or autumn, against the prevailing current to ensure that after spawning the larvae can drift back to the coastal nursery area. The berried females rarely feed or move; instead, they lay in pits dug in the sediments or under rocks. In late spring/early summer, the larvae are released into the water column where they remain in pelagic form for two months before settling as juveniles in the intertidal zone in late summer/early autumn (Pawson, 1995).

74. Nephrops do not travel far from their burrows and as a result, the distribution of spawning and nursery grounds coincide with the adult population. Females mature at about three years old and from then on carry eggs each year from September to April or May. After hatching, the larval stage lasts 6 to 8 weeks, before settlement to the seabed (Cefas, 2001). The distribution of Nephrops spawning and nursery grounds in relation to the Wind Farm Area and the North Sea is shown in Figure 7.8 (Volume 2). Marine Scotland (2017) has reported an increase in Nephrops stock abundance within the Firth of Forth functional unit between 2013 and 2015 with the stock being harvested above the maximum sustainable yield.

75. Scallops are sedentary for most of their life cycle; hence, their spawning areas correspond with the areas of adult distribution (Pawson, 1995). There is considerable regional variation in the time of spawning; in Scottish waters, spawning occurs in the spring and in the autumn (Cefas, 2001). It is speculated that a minimum density of spawning adults may be necessary to ensure good recruitment of juvenile scallops; consequently, productive spawning areas may be more restricted than the overall distribution of the species (Pawson, 1995). Scallop landings in the vicinity of the Wind Farm Area are limited with the scallop fleet focusing effort to the north and east of the Wind Farm Area (See Chapter 10: Commercial Fisheries).

76. Concentrations of squid *Loligo forbesi* occur seasonally along the southeast coast of Scotland, particularly within the kelp aggregations around the Isle of May, which also offer shelter to fish and crabs. Squid reach sexual maturity at about one year of age. They mainly reproduce only once during their limited lifespan of one to two years although they occasionally live up to three years. Breeding

occurs yearly from autumn through to spring. At night, females lay up to 100,000 eggs in colourless capsules attached to the seafloor (Taylor, 2002). Winter breeding cohorts spawn in inshore waters and some evidence suggests that spawning grounds of the summer breeders may also be inshore (Viana et al., 2009). The embryonic development stage lasts approximately 30 days after which the young squid hatch. The young maintain a vertical body structure for a period of time, floating and drifting passively. Growth occurs rapidly during the summer and the species reaches sexual maturity between June and October (Taylor, 2002).

77. Razor shells (*Ensis spp*.) occur in the inshore areas of the Firth of Forth where the seabed is clean sand (Robson, 1997). The presence of potentially exploitable burrowing bivalve molluscs such as razor shells has been reported to occur at various sites around the southeast coast of Scotland (Robson, 1997).

78. Two resident shrimp species, brown shrimp *Crangon crangon* and pink shrimp *P. montagui*, and a migrant species, *C. allmani*, have been identified as the main three species of shrimp in the Firth of Forth (Jayamanne, 1995), whereas crawfish *Palinurus elehas* are reported as being uncommon (Robson, 1997). *C. crangon* has been recorded throughout the estuary, while the pink shrimp occurred in the lower reaches of the estuary (Jayamanne, 1995). This is reflected in the site-specific surveys with brown and pink shrimp dominating the beam trawl catch data within the study area.

79. Inshore bedrock and rocky habitats also support velvet swimming crab *Necora puber*. In northwest Scotland, the main spawning period is reported to start in March with all berried females recorded in June carrying eggs at the hatching stage. No berried females are reported to occur between July and January (Bakir and Healy, 1995).

80. Mussels are found around most of the east coast of Scotland, from the mid shore to the subtidal zone (Robson, 1997). Important areas for mussels around this region include the Montrose Basin, the south shores of the Firth of Tay at Tayport, the Eden Estuary and the south shore of the Firth of Forth (Robson, 1997). Intertidal rocky habitats support the winkle *Littorina littorea*.

81. Ocean quahog *Arctica islandica*, the bivalve mollusc *Devonia perrieri* and the gastropod *Simnia patula* are also known to occur in the North Sea within Scottish waters (SNH, 2011).

7.6.6.2 Vulnerabilities and Seasonal Sensitivities

82. Although shellfish do not possess swim bladders, a literature review suggests that marine shellfish are potentially affected by particle motion, particularly as they are not as mobile as fish species and cannot alter their behaviour to avoid particle motion (e.g. by fleeing behaviour). The effects of particle motion on shellfish is not yet fully understood and therefore shellfish are considered vulnerable at all life stages.

7.6.7 Summary of Sensitive Fish Species

83. As outlined above, many species of fish and shellfish are known to value the seabed habitats in relatively close proximity to, or potentially overlapping with the Wind Farm Area for the purposes of spawning or for use as nursery areas for juvenile life stages (Coull et al., 1998; Ellis et al., 2012). Adult spawning fish could potentially be affected by particle motion, which could influence behaviour and affect spawning activity and success.

84. Spawning activity is summarised as follows:

- Three species have spawning areas that directly overlap the Wind Farm Area; these are plaice, lemon sole and Nephrops (Coull et al., 1998);
- Ellis et al., (2012) report low intensity spawning areas overlapping the Wind Farm Area for plaice, lemon sole, mackerel, blue whiting and ling;
- Coull et al. (1998) reports spawning areas overlapping the Wind Farm Area for Nephrops, spurdog and tope (undetermined intensity); and

- High intensity nursery areas are reported to overlap the Wind Farm Area for whiting, cod and herring (Ellis et al., 2012).

7.6.8 Development of Baseline Conditions without the Project

85. Mobile species, such as fish and some shellfish species, exhibit varying spatial and temporal patterns. Short term trends often exhibit fluctuations in fish and shellfish stock abundance often in response to abiotic factors and / or fishing pressure. It is anticipated that in the absence of the Project, fish and shellfish abundance in the region would be anticipated to fluctuate within its natural range unless affected by changes in fishing behaviour. There are unlikely to be any major changes in seabed habitats and therefore the species present within the study area are unlikely to experience any fundamental shift in species composition.

86. Recent research has suggested that there have been substantial changes in the fish communities in the northeast Atlantic over several decades as a result of a number of factors including climate change and fishing activities (DECC, 2016).

87. Climate change may influence fish distribution and abundance, affecting growth rates, recruitment, behaviour, survival and response to changes of other trophic levels. Within the North Sea, increased sea surface temperatures may lead to an increase in the relative abundance of species associated with more southerly areas, whilst other fish species will extend their distribution into deeper, colder waters where habitat exists to allow them to do so. Climate change may also affect key life history stages of fish and shellfish species, including the timing of spawning and migrations. However, climate change effects on marine fish populations are difficult to predict, and the evidence is not easy to interpret and therefore it is difficult to make accurate estimations of the future baseline scenario for the entire lifetime of Project.

88. Overfishing subjects many fish species to considerable pressure, reducing the biomass of commercially valuable species, and non-target species. Overfishing can reduce the resilience of fish and shellfish populations to other pressures, including climate change and other anthropogenic impacts. There are indications that overfishing in UK waters is reducing to some degree, with declines in fishing mortality estimates in recent years and ICES advice suggesting that some of the stocks are recovering, with increased quotas for several species in 2016. However, OSPAR's Quality Status Report (OSPAR, 2010) concluded that many fish stocks are still outside safe biological limits, although there have been some improvements in some stocks. Should these improvements continue, this may not result in significant changes in the species assemblage in the vicinity of the Project, although may result in increased abundances of the characterising species present in the area.

89. The fish and shellfish baseline characterisation described in the preceding sections represents a 'snapshot' of the fish and shellfish assemblages in the area, within a gradual and continuously changing environment. Any changes that may occur during the lifetime of the Project (i.e. construction, operation and decommissioning) should be considered in the context of the natural variability and anthropogenic effects, including climate change, overfishing and other environmental impacts.

7.7 Design Envelope – Worst Case Design Scenario

90. The Project application is for the construction, operation and decommissioning of an offshore wind farm with an output of up to 450 MW, comprising of up to 54 turbines.

91. The assessment scenarios identified in respect of Fish and Shellfish Ecology have been selected as those having the potential to represent the greatest effect on an identified receptor based on the design envelope described in Chapter 4: Project Description. The worst-case design scenarios are set out in Table 7.11 and in relation to those issues scoped into this EIA.

Table 7.11: Design envelope scenario assessed

Potential Impact	Worst Case Design Scenario	Justification
Construction (and Decommissioning)		
Disturbance or injury as a result of particle motion arising from pile driving	Installation of 54 turbine jackets comprising of up to 6 piles per jacket and 2 OSP jackets comprising of up to 8 piles per jacket and one met mast comprising of up to 4 piles per jacket. Total number of piles: up to 344 Driven only piles: 0 – 10% Drill-drive-drill / drill only pile: 90 – 100% Absolute maximum hammer energy of 1,635 kJ Pile Driving time for 6 piles: 6 – 21 hours. Pile driving to occur over a 15 month (maximum). If concurrent piling takes place, piling will be completed within a maximum of 9 months.	The maximum worst case design scenario equates to the greatest likely effect from particle motion with respect to both spatial and temporal coverage, i.e. maximum hammer energy for the greatest period of time.
Disturbance from noise and particle motion arising from the HDD pipe site works	Installation of interlocking steel sheets being lifted in to place by an excavator and being sheet piled – with the potential for noise generated by this installation operation.	The worst-case scenario considers the piling element of installation taking place over a number of days at the HDD exit point relatively close to shore.
Operation		
Disturbance resulting from particle motion arising from turbine operation	Operation of up to 54 turbines	It is assumed that the greatest operational noise will result from the maximum number of turbines.

7.7.1 Embedded Mitigation

92. A number of mitigation options, both embedded and for implementation, were identified within the design envelope for the Originally Consented Project, during the consultation phase of the Original Application and during the on-going liaison with stakeholders and MS-LOT. As set out in the Scoping Report (and as summarised in Chapter 5: Scoping and Consultation) these have been adopted into the Project design as the design envelope has evolved.

93. Those embedded mitigation measures that are relevant to the potential impacts on Fish and Shellfish that have been captured within the design envelope for the Project are:

- Inter-array, interconnector and Offshore Export Cables will be suitably buried or will be protected by other means when burial is not practicable. This will reduce the potential for effect and exposure of electromagnetically sensitive species to the strongest electromagnetic fields (EMF);
- To minimise the extent of any unnecessary habitat disturbance, material displaced as a result of cable burial activities will be back filled, where necessary, in order to promote recovery; and
- Cable specifications will be used that reduce EMF emissions as per industry standards and best practice such as the relevant IEC (International Electrotechnical Commission) specifications.

7.7.2 Anticipated Consent Conditions Commitments

94. A number of consent conditions were attached to the Consents to manage the environmental risk associated with the Originally Consented Project. NnGOWL anticipates that any future consents issued to the Project may incorporate similar conditions to manage the risk to fish and shellfish receptors commensurate with the Project design envelope, where it remains necessary to do so. Table 7.12 sets out the conditions attached to the Consents which have some relevance to the management of effects on Fish and Shellfish Ecology.

Table 7.12: Original Consent Requirements relating to Fish and Shellfish

Mitigation Measure	Deliverable
Piling Strategy	Setting out, for approval, the pile driving methods, in accordance with the Application and detailing associated mitigation incorporating data collected as part of pre-construction survey work to demonstrate how the risk to species will be managed.
Cable Plan	Setting out, for approval, in accordance with the application and detailing routing considerations, including environmental sensitivities based on pre-construction survey data, and any relevant mitigation to ensure all relevant environmental risks associated with cable installation and operation are managed in respect of fish receptors.
Environmental Management Plan	Setting out, for approval, the over-arching environmental management procedures that will be implemented across the Project to minimise the risk to environmental receptors from, for example, potential pollution, introduction of non-native species, and dropped objects.
Project Environmental Monitoring Programme	Setting out, for approval, the proposed environmental monitoring programme, to include as relevant and necessary the monitoring of sandeels, marine fish and diadromous fish.
Participation in the Forth and Tay Regional Advisory Group (FTRAG)	Participate in the monitoring requirements as laid out in the 'National Research and Monitoring Strategy for Diadromous Fish' so far as they apply at a local level (the Forth and Tay).
Participation in the Scottish Marine Environment Group (SSMEG)	Participation in the SSMEG with respect to monitoring and mitigation of diadromous and commercial fish.

Mitigation Measure	Deliverable
Participation in the 'National Research and Monitoring Strategy' for Diadromous Fish	Engage with and participate in the delivery of the strategic salmon and trout monitoring strategy at a local level (the Forth and Tay).

7.8 Impact Assessment

95. As identified in Section 7.4, the Scoping Opinion only required potential impacts arising from acoustic particle motion as a result of construction activities and operation of the turbines, foundations and OSPs to be assessed for fish and shellfish receptors (all other potential impacts being scoped out of this EIA). An assessment of decommissioning activity is not required at this time due to no requirement for pile driving to take place.

96. As noted in Section 7.5.2, the understanding of acoustic particle motion and its effects on fish and shellfish is acknowledged as an area of uncertainty and subject to ongoing research. MSS identified an approach for the following assessments, set out under Section 7.5.2; that approach has been followed in so far as the knowledge base allows. The following assessment sections therefore present the following:

- An overview of currently available information on particle motion (including within the vicinity of noise producing construction and operational activities and both within the water column and the sea bed), combined with an overview of the published information on sensitive species and potential physiological and behavioural effects of particle motion;
- Impact assessment of the potential effects arising as a result of particle motion arising from construction activities (pile driving) on key fish species known to occur in the vicinity of the Wind Farm Area; and
- Impact assessment of the potential effects arising as a result of particle motion arising from the operation of the Project (operational turbines) on key fish species known to occur in the vicinity of the Wind Farm Area.

97. Cumulative impacts are subsequently considered and any requirements for mitigation or monitoring are set out under Sections 7.7.1 and 7.7.2 above and 7.9 respectively.

7.8.1 Overview of available information on particle motion and the sensitivity of fish and shellfish to particle motion

98. Published literature acknowledges the relative paucity of information surrounding the effects of the particle motion element of noise on fish and shellfish species (Hawkins et al., 2014b). Nonetheless, it is widely reported that the majority of species are likely to detect the particle motion component of noise rather than the sound pressure level component, which is more commonly considered within EIA.

99. Particle motion is the displacement or movement of fluid particles within a sound field. Most fish respond to particle motion as it is detected by the lateral line of fishes (a visible line along the side of a fish consisting of a series of sense organs which detect pressure and vibration), which contain hundreds of flow sensors and neuromasts (hair cell sensors) and also by the otolithic organs (small oval calcareous structures in the inner ear of vertebrates, involved in sensing gravity and movement) which contain sensory epithelium and sensory hair cells which cause otoliths to vibrate, which the fish then detect. It is the otolithic organs of fish that respond to particle motion of the surrounding fluid. The receptors of the lateral line system in fish also respond to the particle motion but over a very

short range (one or two body lengths away from the source) (Popper et al, 2014). Directional hearing in fishes is based on the detection of particle motion.

100. Different species of fish respond differently to the particle motion and pressure components of noise. Fish species lacking a gas-filled cavity primarily detect particle motion and do not detect sound pressure. Fish that have a functional connection between the swim bladder and the inner ear are likely to predominately detect sound pressure. However, they are still likely to have a capacity of the detection of particle motion similar to non-hearing specialists. Herring are considered more sensitive to sound pressure; cod and eel sensitive to both components of sound and the species such as dab, plaice and Atlantic salmon are predominately sensitive to particle motion (Popper et al, 2014).

101. Particle motion attenuation is known to deviate significantly from the attenuation of sound pressure (except under very specific conditions) and will also be highly site specific, especially in shallow coastal areas (Nedelec et al., 2016) (so that it cannot be assumed that the measurement or modelling of sound pressure levels provides a proxy for particle motion). Popper et al. (2014) note that the three-dimensional particle motion field is quite complex near boundaries that include the air/water interface and the seabed, as well as in shallow water. In these instances, the particle motion may be unpredictable. For example, there can also be instances where transient sound waves in the sediment are transmitted from the sediment into the water column resulting in localised areas of high and low particle motion. In this way it is has been postulated that it would be possible for higher measurements of particle motion to be detected at distance from the sound source (Caltrans, 2001; Hawkins, 2009).

102. The development of modelling techniques for particle motion has been inhibited by the limited availability of any field measurements of particle motion at varying distance from a noise source (Farcas et al., 2016; Hawkins and Popper, 2016). This absence of field measurements during, for example, pile driving means that few studies have been able to model predicted impact ranges in respect of particle motion that could be applied in the EIA process to predict a range of effects on any given species and at any given level of noise.

103. However, Miller et al. (2016) used a novel modelling technique to estimate impact ranges on two species and compared the model outputs with measured data for the driving of a 1.2 m pile in up to 30 m of water. Extant information on species sensitivity was then used to estimate impact ranges for flounder and American lobster. Miller et al. (2016) concluded that flounder and American Lobster may be able to detect particle motion at a distance of 250 m and 500 m from the sound source, respectively.

104. Bass and Clark (2003) report that the particle motion component of sound is likely to decrease more rapidly than the sound pressure component.

105. Studies of very low frequency sound have indicated that consistent deterrence from the source is only likely to occur at particle accelerations equivalent to a free-field SPL of 160 dB re 1 μPa^2 (RMS) (Sand et al., 2001). Particle acceleration resulting from an operational wind turbine has also been measured by Sigray et al. (2011) with the resultant levels being considered too low to be of concern for behavioural reactions from fish. Furthermore, the particle acceleration levels measured at 10 m from an operational wind turbine were comparable with hearing thresholds. Whilst limited, the available data provides an indicator that operational wind turbines are unlikely to result in disturbance of fish except within very close proximity of the turbine structure, as postulated by Wahlberg and Westerberg (2005).

106. Similarly, although there is general acknowledgment that fish and shellfish species will detect the particle motion component of anthropogenic noise, there has been little progress in identifying hearing or response thresholds that could be used to determine the response of any given species to a given level of impact (i.e. a pile driving event). Studies that have observed responses to sound have generally failed to distinguish whether observed responses are as a result of sound pressure or particle motion (Mueller-Blenke et al., 2010; Harding et al., 2016). Radford et al. (2012) isolated the

particle motion component of sound and exposed three species of teleost fish with different sound pressure hearing capabilities. It was observed that the three species exhibited a similar capacity to detect particle motion despite large difference in their ability to detect sound pressure, although the author notes that further investigations into other species are required to draw any firm conclusions.

107. However, more general classifications of 'particle motion sensitivity' have been attempted. Popper et al. (2014) report that, where species of fish have a mechanical connection between the swim bladder and the inner ear, such as those present in clupeids, they are more likely to respond to the sound pressure component of a stimuli (although these species are likely to also detect particle motion). Species without specialised connections between the inner ear and swim bladder, or with no swim bladder at all, are more likely to respond to the particle motion component of sound. Demersal fish that live on or in the Wind Farm Area are also likely to be more sensitive to sediment-borne vibrations resulting from pile driving. A range of behavioural responses have been reported in response to pile driving noise exposure. Cod and sole were observed to change swimming behaviour, although again the study did not distinguish between sound pressure and particle motion (Mueller-Blenkle et al., 2010).

108. Invertebrates are considered unlikely to detect sound pressure levels but are known to detect particle motion via other anatomical adaptions such as superficial surface receptors, internal statocyst receptors and the chordotonal organs (Thomsen et al., 2015; Roberts and Elliot, 2017). Particle motion detection has been demonstrated in bivalves with responses including closing their siphon, burrowing deeper and increased clearance rate (Roberts et al., 2015; Solan et al., 2016; Spiga et al, 2016 Roberts et al., 2017). A number of crustacean species have been reported to respond to anthropogenic noise including hermit crab (*Pagurus bernhardus;) Roberts* et al., 2016), Nephrops (Goodall et al., 1990), American lobster (*Homarus americanus*) (Payne et al., 2007) the shore crab *Carcinus maenus* (Wale et al., 2013a; 2013b) and the two shrimp species *Crangon crangon* and *Pandulus borealis* (Roberts *et al.,* 2017). Roberts et al. (2015) and Roberts et al. (2016) concluded that both the mussel (*Mytilus edulis)* and *hermit crab* responded to noise from blasting within 300 m of the source.

109. The sensitivity of the receptor systems in crustaceans appears to be much less compared to fish - up to 105 times lower in terms of particle velocity (Fay and Simmons, 1998). This suggests that any impacts resulting from particle motion would only be detectable at relatively close range to the sound source.

110. It is important to note that, to date, there has been no indication that high levels of particle motion can cause tissue damage, although research into this area is limited (Popper et al., 2014). There is, currently, therefore an assumption that sensitivity to particle motion in fish (and invertebrates) is most likely to result in behavioural responses rather than injury (Hawkins, 2009; Mueller-Blenkle et al., 2010; Hawkins et al., 2014a).

111. As noted above, Popper et al. (2014) categorised fish species into four distinct groups with regard to their likely sensitivity to noise (sound pressure and particle motion components):

- **Group 1**: Fishes lacking swim bladders that are sensitive only to sound particle motion and show sensitivity to a narrow band of frequencies (includes flatfishes and elasmobranchs);
- **Group 2**: Fishes with a swim bladder where the organ does not appear to play a role in hearing. These fish are considered sensitive only to particle motion and show sensitivity to a narrow band of frequencies (including salmonids and some tuna);
- **Group 3**: Fishes with swim bladders that are close, but not intimately connected to the ear. These fishes are considered sensitive to both particle motion and sound pressure and show a more extended frequency range than groups 1 and 2, extending to about 500 Hz (includes gadoids and eels); and

- **Group 4**: Fishes that have special structures mechanically linking the swim bladder to the ear. These fishes are considered sensitive primarily to sound pressure, although they also detect particle motion. These species have a wider frequency range extending to several kHz and generally show higher sensitivity to sound pressure than fishes in Groups 1, 2 and 3 (includes clupeids such as herring, sprat and shads).

112. For the purposes of assessing the potential impacts of particle motion arising from construction and operation, these four groupings have been considered in relation to the potential for adverse effects to fish.

7.8.2 Construction Phase Impacts

7.8.2.1 Disturbance or injury as a result of particle motion arising from pile driving

113. The greatest levels of noise, and specifically particle motion, will result from the pile driving of foundation piles for the wind turbine and OSP jackets. The following describes the likely effects on each of the four fish groups, and for shellfish, in relation to the worst case design envelope scenario. Note that the assessment focuses on the behavioural effects resulting from particle motion since the current knowledge base indicates that physical trauma from particle motion is not currently thought likely to occur.

114. Popper et al (2014) set out qualitative behavioural criteria for fish from a range of noise sources. These categorise the risks of effects in relative terms as “high”, “moderate” or “low” at three distances from the source: “near” (i.e. tens of metres), “intermediate” (i.e. hundreds of metres) or “far” (i.e. thousands of metres). These behavioural criteria (for pile driving operations) are summarised in Table 7.13.

Table 7.13: Criteria for onset of behavioural effects in fish from pile driving operations considered within this assessment (Popper et al., 2014)

Type of fish	Masking	Behaviour
Group 1 Fish: no swim bladder (particle motion detection)	N: Moderate risk I: Low risk F: Low risk	N: High risk I: Moderate risk F: Low risk
Group 2 Fish: swim bladder is not involved in hearing (particle motion detection)	N: Moderate risk I: Low risk F: Low risk	N: High risk I: Moderate risk F: Low risk
Group 3 and 4 Fish: swim bladder involved in hearing (pressure and particle motion detection	N: High risk I: High risk F: Moderate risk	N: High risk I: High risk F: Moderate risk

Group 1 and 2 Species

115. Group 1 and 2 fish species are reported to be insensitive to sound pressure and most likely to detect the particle motion component of sound.

116. Group 1 species found within the Wind Farm Area will include flat fish such as dab and plaice and elasmobranch species such as tope and ray species. These are species that predominantly live in close proximity to the sea bed (or within sediments i.e. sandeels) and are therefore more likely to be susceptible to particle motion and vibration effects than pelagic species. Although spawning and nursery habitats are present within the Wind Farm Area and surroundings, these nursery and spawning habitats also extend over a wider area.

117. Group 2 species would include salmonids such Atlantic salmon and sea trout. Atlantic salmon and sea trout are likely to pass through the Wind Farm Area and surroundings both as smolts, leaving their

natal rivers and entering the marine environment heading, and as adults returning to natal rivers to spawn (and in the case of some sea trout as residents of coastal waters).

118. The Popper et al. (2014) criteria suggest that particle motion effects on these species will be limited to within hundreds of metres of the source, with a low risk of disturbance at greater distances (kilometres). This being the case, and given the small area of effect that would arise against the broader distribution of key spawning and nursery habitats, the sensitivity of these species to particle motion effects arising from pile driving is considered to be low for all Group 1 species. Group 2 species include salmonids which have a higher conservation status, however, their use of the site is considered to be transitory in nature with individuals passing through the Development Area on migrations to remote feeding grounds or on return migrations to natal rivers (See Appendix 7.2). Therefore, the sensitivity of these species to particle motion effects arising from pile driving is also considered to be low.

119. The magnitude of the effect will be limited so that the proportion of key habitat will be small, and the effect will be short term, intermittent and reversible. The magnitude of effect for all Group 1 and 2 species is therefore considered to be low.

120. The impact of construction related particle motion on Group 1 and 2 species is therefore considered to be of minor significance and not significant in EIA terms for all Group 1 and 2 species.

Group 3 and 4 Species

121. Group 3 and 4 fish species are considered to be 'hearing specialists', being more likely to respond to the sound pressure component of noise rather than the particle motion component. Therefore, whilst the Popper et al 2014 criteria suggest these species are at higher risk of disturbance over a considerably greater range, this response will be predominantly in relation to the sound pressure component of the pile driving noise rather than the particle motion component. As a result, the sensitivity of these species to particle motion is considered to be low.

122. The exposure will be short term, intermittent and reversible. The magnitude of the impact is therefore considered to be low for Group 3 and 4 species.

123. The significance of effect on Group 3 and 4 species arising from the particle motion component of noise generated by pile driving is therefore considered to be minor and not significant in EIA terms.

Shellfish

124. Shellfish species present in the survey area include the commercially important crustacean species Norwegian lobster, European lobster and brown crab and velvet swimming grab. There are both spawning and nursery grounds for Nephrops overlapping the Wind Farm Area, and commercial fishing data and site specific survey data indicates that this species is common in the area. The reported Nephrops nursery and spawning grounds extend over a wide area, and the relative proportion of these habitats affected by pile driving operations at any one time will therefore be small in the context of the wider habitat available.

125. Mollusc species potentially found within the study area include kind scallops, queen scallops, blue mussels, razor clams and squid. Site specific survey work and commercial fisheries data suggests that these species are not found in large numbers within the study area.

126. As noted under Section 7.8.1 above, although any invertebrates are likely to be able to detect particle motion they are likely to be much less sensitive than fish species so that noticeable behavioural effects are only likely to occur within relatively close proximity to the source. Therefore, sensitivity is considered to be low for all shellfish species.

127. Construction related particle motion will represent a temporary, short term and intermittent source of disturbance and will be reversible. The magnitude of the impact on all invertebrate species is therefore considered to be low.

128. The significance of particle motion effects on invertebrates is therefore, considered to be minor and not significant in EIA terms for all species.

7.8.2.2 Disturbance from noise and particle motion arising from the HDD pipe site works

129. In addition to the main wind turbine and substation foundation pile driving works, installation of a temporary circular or rectangular steel casing is proposed in the shallow subtidal area to facilitate the excavation of a dry area within which a second receiving pit would be constructed for the emergence of the Horizontal Directional Drill (HDD) (as described in Chapter 4: Project Description). This would involve interlocking steel sheets being lifted in to place by an excavator – with the potential for noise generated by this installation operation. Here, the cable will emerge and, if required, be joined with the Offshore Export Cable. The cable will then be buried, the disturbed area reinstated and the casing removed.

130. The installation of the steel casing, which may require sheet piling, has the potential to give rise to underwater noise – both particle motion and sound pressure, which may lead to the disturbance of marine and diadromous fish species. The installation of the sheet piling will take place in relatively shallow water close to shore with installation taking a relatively short period (e.g. a number of days at most). Given this, the noise generated will attenuate over a relatively short distance (given the shallow water depths) so that effects on fish will be limited spatially and temporally – given the short period for installation and the effects are considered temporary and reversible. The magnitude is therefore considered to be low.

131. Sensitivity is judged to be greatest in diadromous fish species such as salmon which may be present in nearshore waters during their migratory periods (as smolt on outward migration or as adults returning to their natal rivers). Salmon are considered to be relatively low sensitivity to noise (Group 2 species as defined by Popper et al, 2014); the sensitivity of these species therefore is considered to be low. The significance of the effect on fish species arising from the impact of sheet piling works at the landfall is therefore considered to be minor, which is not considered significant in EIA terms.

7.8.3 Operational Phase Impacts

7.8.3.1 Disturbance resulting from vibration / particle motion arising from turbine operation

132. The available studies on particle motion effects arising from operational wind turbines (see Section 7.8.1) suggest that any behavioural response in fish or shellfish would be limited to within very close proximity of the source.

133. The sensitivity of fish and shellfish species to the low level of particle motion arising from operational turbines is considered to be low for all species.

134. The magnitude of the effect will be continual (during turbine operation), and over a long period, but will affect a very small area, and is therefore considered to be low for all species.

135. The significance of particle motion effects arising from the operational wind turbines is therefore considered to be minor and not significant in EIA terms for all species.

7.8.4 Cumulative Impacts

136. Cumulative effects refer to effects upon receptors arising from the Project when considered alongside other proposed developments and activities and any other reasonably foreseeable project(s) proposals. In this context, the term ‘projects’ is considered to refer to any project with comparable effects and is not limited to offshore wind projects.

137. Project and activities considered within the cumulative impact assessment are set out in Table 7.14. There may be an element of uncertainty associated with the design envelope of proposed projects;

therefore, a judgement is made on the confidence associated with the latest available design envelope.

138. As the impacts of particle motion are localised, not impacting receptors beyond a regional scale, only the Inch Cape and Seagreen projects are considered in this cumulative assessment.

139. In assessing the cumulative impacts for the Project, two scenarios are considered to take into account the consented design envelopes of the Inch Cape Offshore Wind Farm and the Seagreen Phase 1 Wind Farm Project. Scenario one incorporates the design envelopes for the proposed Inch Cape and Seagreen projects as detailed in the Scoping Reports submitted to MS-LOT (ICOL, 2017; Seagreen, 2017). Scenario two incorporates the consented design envelopes as detailed in the respective project consents.

Table 7.14: Projects for cumulative assessment – fish and shellfish

Development Type	Project	Status	Data Confidence Assessment / Phase
Offshore Wind Farm	Inch Cape Offshore Wind Farm	Consented	High – Consented project details available.
Offshore Wind Farm	Inch Cape Offshore Wind Farm	Proposed	High – Scoping report publicly available.
Offshore Wind Farm	Seagreen Alpha	Consented	High – Consented project details available.
Offshore Wind Farm	Seagreen Bravo	Consented	High – Consented project details available.
Offshore Wind Farm	Seagreen Phase 1	Proposed	High – Scoping report publicly available.

140. Table 7.15 sets out the potential cumulative impacts and the worst case cumulative design envelope scenario considered within the cumulative impact assessment.

Table 7.15: Cumulative worst-case design envelope scenarios – fish and shellfish

Impact	Worst Case Design Scenario	Justification
Construction		
Disturbance or injury as a result of particle motion arising from pile driving	Scenario 1: ▪ Seagreen Phase 1: Installation of up to 120 turbines on monopiled foundations. 2400 kJ hammer (maximum hammer energy limited to 2300kJ) is assumed for the proposed Seagreen project. ▪ Inch Cape Offshore Wind Farm: Installation of up to 72	The maximum cumulative impact is considered to be the project scenarios that generate the greatest noise. Therefore, the scenarios consider the greatest number of turbines and installation of the largest piled foundations. This will generate the greatest spatial footprint in terms of propagation of the particle motion component of noise.

Impact	Worst Case Design Scenario	Justification
	turbines on piled 4 leg jacket foundations using a 2400 kJ hammer. Scenario 2: ▪ Seagreen Alpha and Bravo Offshore Wind Farms: Installation of up to 150 turbines on piled 4 leg jacket foundations using 3 m piles with a 1800 kJ hammer (maximum hammer energy limited to 1500kJ). Driving duration will be 0.5 hrs per pile; ▪ Inch Cape Offshore Wind Farm: Installation of up to 110 turbines on piled 4 leg jacket foundations using 2.43 m piles with a maximum hammer energy of 1200 kJ. Driving duration will be 4.2 hrs per pile.	
Operation		
Disturbance as a result of particle motion arising from turbine operation	Scenario 1: ▪ Seagreen Phase 1: Operation of up to 120 turbines. ▪ Inch Cape Offshore Wind Farm: Operation of up to 72. Scenario 2: ▪ Seagreen Alpha and Bravo Offshore Wind Farms: Operation of up to 150 turbines; ▪ Inch Cape Offshore Wind Farm: Operation of up to 110 turbines.	The maximum cumulative impact is considered to be the project scenarios that generate the greatest noise. Therefore, the scenarios consider the greatest number of turbines in operation at the largest capacity. This will generate the greatest footprint in terms of the propagation of the particle motion component of noise.

7.8.4.1 Cumulative Construction Phase Impacts

141. There is the potential for cumulative effects of particle motion arising from construction noise (pile driving) to occur. The only projects within the wider Forth and Tay region that could theoretically be under construction at the same time as the Project are the Inch Cape Offshore Wind Farm (either consented or proposed) and Seagreen Alpha and Bravo projects (or the proposed Phase 1 project) (Table 7.14). It is however considered to be highly unlikely that there would be overlap between the construction of any of those projects with NnG's construction programme. As is the case for the Project alone assessment (Section 7.8.2), since there are currently no reported injurious effects on fish and shellfish resulting from particle motion, only the potential behavioural effects are assessed.

142. As noted for the Project alone assessment (Section 7.8.2), the criteria for disturbance developed by Popper et al. (2014) suggests that for all hearing sensitive groups, the particle motion component of pile driving noise is likely to give rise to a disturbance response that would be limited to within hundreds of metres of the source, with a low risk of disturbance at greater distances (kilometres) (noting that the sound pressure component may give rise to disturbance at greater ranges for species sensitive to sound pressure). This being the case for all of the Forth and Tay projects there would be no spatial overlap in the particle motion impact even under the Scenario that all three projects were pile driving simultaneously. Even considered additively, the spatial area of key fish and shellfish habitats (i.e. spawning or nursery grounds) affected would be minimal when considered as a proportion of the whole.

143. Sequential and / or spatially-separated concurrent pile driving could give rise to individual fish encountering particle motion from the different projects as they move around the Forth and Tay region (i.e. an individual could successively over time encounter particle motion generated by pile driving events at the various Projects) leading to a potential dative effect. This could, theoretically, increase the magnitude of effect for a given individual, although the sensitivity would be unchanged. Similarly, sequential pile driving would mean that a proportion of a sensitive habitat (spawning or nursery habitat for example) could be affected over a longer period of time even if the spatial footprint remained the same at any given time; again, this could lead to a somewhat greater magnitude of effect although again the sensitivity would remain unchanged.

144. The Scenario 1 cumulative impact considers the installation of 246 foundations within the Forth and Tay region. The assessment considers that the 192 foundations associated with the Inch Cape and Seagreen projects will all be pile driven. As detailed in Table 7.11 it is assumed 10% of foundations will be piled for the Project; therefore, the cumulative assessment considers 198 pile driven foundations with the remaining 48 installed using a drill-drive-drill, or drive-only method. The construction period for the Inch Cape and Seagreen project is not currently known. Construction periods could vary and taking a worst case of sequential pile driving over a 5 year period, this would represent a medium term impact, that will have a localised spatial extent but in a regional context. The magnitude of the impact for Scenario 1 is therefore considered to be medium.

145. As detailed above in the Project alone assessment all Group 1, 2, 3 and 4 fish species and all shellfish species are considered to have a low sensitivity to the impact of particle motion from pile-driving.

146. In the case of Scenario 2, the worst-case scenario would be in the installation of 314 foundations within the Forth and Tay region. It is assumed that the 260 foundations associated with the Inch Cape and Seagreen projects and 6 foundations associated with the Project will all be pile driven with the remaining 48 installed using a drill-drive-drill, or drive-only method. Construction might, therefore, be expected to occur more frequently but it is assumed would still be completed over the same duration as Scenario 1, i.e. 5 years of sequential, but intermittent, pile driving. Again, this would be localised in a regional context, temporary and reversible and would remain as a medium magnitude impact.

147. The cumulative effect arising from particle motion for all species will therefore be minor and not significant in EIA terms.

7.8.4.2 Cumulative Operational Phase Impacts

148. As noted in the project alone assessment (Section 7.8.3), particle motion arising from offshore wind turbine operation will be detectable only in close proximity to the turbines and will therefore give rise, for each project, to a highly localised effect. As such, there will be no additive effect arising from the Forth and Tay projects in the operational phase (i.e. the noise footprints will not overlap); although fish or shellfish species that move between the projects may be exposed to several sources of low level particle motion as they pass in close proximity to the operational turbines of each project. This conclusion would be the same for both Scenario 1 and Scenario 2 as defined in Table 7.15.

149. The sensitivity of fish and shellfish species to the low level of particle motion arising from operational turbines is considered to be low for all species.

150. The magnitude of the effect will be continual (during turbine operation at each project) and over a long period but will be affect a very small area in each case and with no overlap between the separate wind farms and is therefore considered to be low for all species.

151. The significance of cumulative particle motion effects arising from the operational phase is therefore considered to be Minor and not significant in EIA terms for all species.

7.8.5 Inter-relationships

152. Inter-relationships considers the impacts and associated effects of different aspects of the proposal on the same receptor. These are considered to be:

- **Project lifetime effects:** Assessment of the scope for effects that occur throughout more than one phase of the project (construction, operation, decommissioning) to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three key project phases (e.g. subsea noise effects from pile driving, operational turbines, vessels and decommissioning);
- **Receptor led effects:** Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor. As an example, all effects on a given receptor such as fish and shellfish – direct habitat loss or disturbance, sediment plumes, underwater noise and EMF 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.

153. The greatest disturbance from particle motion is predicted to result from pile driving during the construction phase with minor effects predicted. Noise produced during the operation of the turbines was assessed to result in effects of minor significance being highly localised. 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 (in relation to particle motion) of greater significance than the assessments presented for each individual phase.

154. The potential exists for spatial and temporal interactions between habitat loss / disturbance / alteration, increased SSC, sediment deposition, underwater noise (both sound pressure and particle motion), EMF and contamination effects during the lifetime of the Project. All of these individual impacts, with the exception particle motion, were scoped out of the EIA, as the effects were deemed to be not significant as standalone impacts. As a result, and given the minor level of significance attributed to the potential effects arising from particle motion, significant inter-related effects are not predicted.

7.9 Mitigation and Monitoring

155. The assessment of impacts, both in isolation and cumulatively, on Fish and Shellfish receptors as a result of the construction, operation and decommissioning of the Project are predicted to be of minor significance and therefore not significant in EIA terms. Based on the predicted effects it is concluded that no additional mitigation is required beyond the embedded mitigation set out in Chapter 17.

156. As noted in Section 7.5.2, there are a number of acknowledged uncertainties in the general knowledge base relating to the particle motion component of underwater noise and the effects of particle motion arising from activities such as pile driving on fish and shellfish species. Whilst the assessments presented within this EIA Report are considered to represent a reasonable consideration of the issue using the best available information, the lack of e.g. modelling techniques or clear thresholds of effects for key species inevitably means that uncertainties remain.

157. Many of these uncertainties relate to the fundamental understanding of particle motion and the effects on fish and shellfish, which require ongoing academic research initiatives and which would lie beyond the normal scope of project-specific monitoring. No monitoring related to particle motion is proposed at this stage, but this will be discussed further during the post-consent phase. Final monitoring proposals will be discussed with the FTRAG as part of the approval process for the Project Environmental Monitoring Plan (PEMP).

7.10 Summary of the Residual Effects

158. This chapter has assessed the potential effects on Fish and Shellfish of the construction, operation and decommissioning of the Project, both in isolation and cumulatively. Where significant effects were identified, additional mitigation has been considered and incorporated into the assessment. Table 7.16 summarises the impact determinations discussed in this chapter and presents the post-mitigation residual significance.

Table 7.16: Summary of predicted impacts of the Project

Potential Impact	Significance of Effect	Mitigation Measures	Residual Significance of Effect
Construction			
Disturbance or injury as a result of particle motion arising from pile driving	Minor adverse for all Group 1, 2, 3 and 4 species. Minor adverse for all shellfish species,	n/a	Minor adverse for all Group 1, 2, 3 and 4 species. Minor adverse for all shellfish species
Operation			
Disturbance resulting from particle motion arising from turbine operation	Minor adverse for all species	n/a	Minor adverse for all species
Cumulative Effects			
Disturbance or injury as a result of particle motion arising from pile driving	Minor adverse for all fish and shellfish species	n/a	Minor adverse for all fish and shellfish species
Disturbance resulting from particle motion arising from turbine operation	Minor adverse	n/a	Minor adverse

7.11 References

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