CHAPTER 9: NATURAL FISH AND SHELLFISH RESOURCE

Chapter Summary

This chapter of the EIA Report considers the effects of the proposed optimised Seagreen Project on natural fish and shellfish resource. Scoping in 2017 identified that the proposed use of wind turbine generator (WTG) monopile foundations may result in significant adverse impacts to fish or shellfish, with effects potentially arising from the greater magnitude of underwater noise associated with hammer piling of monopiles, compared to the lower hammer energies required to install pin piles for jacket foundations assessed in the 2012 Offshore ES. Underwater noise from monopile installation was therefore modelled and potential impacts assessed, in line with current best practice which was also applied to update information on likely noise levels from piling of jacket pin piles.

This EIA Report also provides updated information on acoustic particle displacement, as distinct from the sound pressure component of underwater noise. Consideration is also given to the potential for gravity base installation to have adverse impacts upon shellfish receptors, notably scallops and nephrops. This matter was assessed in the 2012 Offshore ES and a review of the potential for effects mediated by suspended sediment mobilisation in this EIA Report supports the original conclusions of no significant impact.

In line with the 2017 Scoping Opinion and further discussions with Marine Scotland during consultation the assessment is focused on herring, a hearing specialist which spawns a short distance to the north of the Project Area (approximately 6km at the closest point). The potential for impacts to other fish and shellfish species is also considered.

Consultation has taken place throughout the EIA with Marine Scotland and Scottish Natural Heritage. This chapter of the EIA Report also draws upon the results of consultation with commercial fishing organisations and other stakeholders engaged by the wider project team.

The assessment is based on worst case build scenarios in terms of foundation design which would maximise either the potential spatial extent (monopiles) or duration of underwater noise impacts (jacket pin piles).

The baseline is predominantly based on the 2012 Offshore ES, but is updated where appropriate, particularly in relation to Atlantic salmon, in line with the Scoping Opinion.

No significant impacts to any fish or shellfish species are predicted. Physical injury and mortality impacts of piling are expected to be Negligible while behavioural impacts, including to herring engaged in spawning behaviour, are expected to be not more than Minor adverse significance which is not significant in EIA terms. This applies to Project Alpha and Project Bravo in isolation, combined and cumulatively with other regional wind farm developments.

INTRODUCTION

9.1. As set out in Chapter 1 (Introduction), the original Seagreen Project (herein referred to as the originally consented Project) received development consents from Scottish Ministers in 2014. This was confirmed in November 2017, following legal challenge to the consent award decision. Seagreen is now applying for additional consents for an optimised design (herein referred to as the optimised Seagreen Project), based on fewer, larger, higher capacity wind turbines that have become available since the 2014 consent decision, and inclusion of monopiles as a foundation option.

9.2. This Environmental Impact Assessment (EIA) Report provides an assessment of the potential environmental impacts of the optimised Seagreen Project, to support a new application for development consent. This chapter of the EIA Report assesses the potential impacts upon natural fish and shellfish resource throughout the construction, operation and decommissioning phases of the Project.

9.3. The originally consented Project comprises the Seagreen Alpha Offshore Wind Farm (OWF) (herein referred to as 'Project Alpha'), Seagreen Bravo OWF (herein referred to as 'Project Bravo') and the Offshore Transmission Asset. It is noted that the Offshore Transmission Asset has been separately licensed, no changes are proposed and therefore this is not considered further within this assessment. A full description of the optimised Seagreen Project is provided in Chapter 5 (Project Description) of this EIA Report.

9.4. The Structure of this chapter is as follows:

- Legislation, policy and guidance: sets out key legislation, policy context and guidance with reference to latest updates in guidance and approaches for natural fish and shellfish resource;
- Consultation: provides details of consultation undertaken to date and how this has informed the assessment;
- Scope of assessment: sets out the scope of the impact assessment for natural fish and shellfish resource in line with the 2017 Scoping Opinion and further consultation;
- Methodology: sets out the study area, data collection undertaken and approach to the assessment of impacts for natural fish and shellfish resource;
- Baseline Conditions: describes and characterises the baseline environment for natural fish and shellfish resource and information used to inform the baseline;
- Assessment of impacts: confirms the project design parameters to be assessed (the Worst Case Scenario [WCS]) and presents the impact assessment for natural fish and shellfish resource throughout the construction, operation and decommissioning phases and concludes on the likely significance of impacts. The assessment includes the consideration of any mitigation measures (both embedded and additional) and sets out any monitoring proposals for potentially significant effects, if required;
- Cumulative impact assessment: presents the cumulative impact assessment for natural fish and shellfish resource throughout the construction, operation and decommissioning phases and concludes on the likely significance of impacts with consideration of mitigation measures;
- Interrelationships: Assesses the potential interrelated impacts on any given receptor scoped into the assessment;
- Transboundary impacts: Considers the potential for any transboundary impacts in relation to natural fish and shellfish resource; and
- Assessment summary: provides a summary of the impact assessment undertaken.

9.5. All figures supporting this chapter can be found in Volume II: Figures.

9.6. The following documents support this chapter and are provided in Volume III: Appendices:

- Appendix 9A – Seagreen Phase 1 and ECR Benthic Survey (IECS, 2012);
- Appendix 9B – Acoustic Particle Motion Technical Note;

- Appendix 9C – Gravity Base Installation (Coastal Processes Technical Note);
- Appendix 10B – Cefas Noise Modelling Report;
- Appendix 10C – Noise Modelling Plan;
- Appendix 11A – Commercial Fisheries Technical Report.

9.7. This chapter was produced by NIRAS Consulting Limited.

LEGISLATION, POLICY AND GUIDANCE

9.8. This section summarises legislation, policy and guidance informing the natural fish and shellfish resource assessment. Overarching information on marine planning and renewable energy policy and legislation is summarised in Chapter 4 (Policy and Legislation).

Policy Context

9.9. Policy measures are important when defining the scope of the assessment in order to ensure that the EIA Report reflects the relevant policy issues. The following policy measures have been identified as summarised in Table 9.1.

Table 9.1 Policy context

Policy	Description	Relevance to assessment
Scotland's National Marine Plan (Marine Scotland, 2015)	This is a framework for marine spatial planning that aims to promote the sustainable development of marine areas and sustainable use of marine resources.	The Plan includes specific entries for fisheries and diadromous fish. The Plan includes a commitment to not having significant impact on Priority Marine Features which includes certain fish species (see below).
Scottish Priority Marine Features (SNH, 2014)	These are habitats and species which are considered to be conservation priorities in Scottish waters.	The list includes thirty species of fish, seven of which are elasmobranchs and one large decapod crustacean. Atlantic herring *Clupea harengus* are included; in territorial waters the focus is on juveniles and spawning adults.
The Scottish Biodiversity Strategy (Biodiversity Scotland, 2016)	This document sets out how the government will conserve biodiversity for the people of Scotland now and in the future.	Policy includes the objective to halt the loss of biodiversity.

9.10. Other plans exist which are of relevance to fish species potentially present in the vicinity of the optimised Seagreen Project but these are not of direct relevance to issues scoped into the assessment. For example, there is a management plan for European eel (*Anguilla anguilla*) which is afforded protection under a European Commission recovery plan (Council Regulation No. 1100/2007) but impacts on eels are not scoped into the assessment beyond a requirement to consider the potential for impacts to arise from underwater noise associated with wind turbine generator foundation piling to all fish and shellfish species.

Legislative Requirements

9.11. The following legislation is identified that is relevant to the assessment for natural fish and shellfish resource.

9.12. The Habitats Directive and Habitats Regulations afford protection to certain migratory species (e.g. Atlantic salmon) within their freshwater habitats.

9.13. The Salmon Conservation Regulations came into force in 2016 and include measures to prohibit the killing of fish in coastal waters and in estuaries and rivers where the stocks were determined to be in poor conservation status.

9.14. European Council Directive 2008/56/EC, the Marine Strategy Framework Directive (MSFD) Requires Member States to prepare national strategies to manage their seas to achieve Good Environmental Status (GES) by 2020. The Directive came into force on 15 July 2008 and was transposed into UK law by the Marine Strategy Regulations 2010. The following descriptors in Annex I of the MSFD are relevant to natural fish and shellfish ecology:

- 'Descriptor 1' relating to the maintenance of biodiversity;
- 'Descriptor 3' relating to the maintenance of a healthy population of commercial fish species; and
- 'Descriptor 4' relating to key elements of the food web, including fish groups which are targeted commercially.

9.15. It is noted that The Scottish Marine Regions Order 2015 has been introduced subsequent to the 2012 Offshore ES which will lead to the development of Regional Marine Plans; however, this relates to the preparation of plans for the Scottish marine area to 12nm which Projects Alpha and Bravo lie outside of.

Guidance

9.16. Key guidance/best practice referred to in undertaking the assessment of impacts for natural fish and shellfish resource is as follows:

- Chartered Institute of Ecology and Environmental Management (CIEEM) guidelines for marine and coastal ecological impact assessment in Britain and Ireland (CIEEM, 2010; CIEEM, in prep);
- Oslo Paris Convention (OSPAR) Guidance on Environmental Considerations for Offshore Wind Farm Development (OSPAR 2008).

CONSULTATION

9.17. As part of the EIA process, Seagreen has consulted with a number of statutory and non-statutory organisations to inform the approach to assessment on natural fish and shellfish resource.

9.18. A Scoping Report was submitted by Seagreen in May 2017. This considered the proposed changes to the optimised Seagreen Project and identified potential requirements for assessment. A Scoping Opinion was issued by the Marine Scotland Licensing Operations Team (MS-LOT) on behalf of Scottish Ministers in September 2017. This considered the information presented within the Scoping Report and set out key issues to be addressed within the impact assessment.

9.19. Table 9.2 sets out the consultation undertaken to date, including the date and type of consultation, the issues raised and how these have been addressed within this EIA Report. With the exception of the issues detailed in this table, statutory consultees agreed that the assessment for Natural Fish and Shellfish Resource should focus upon the potential impact of pile driving for installation of monopile foundations for herring. This has been confirmed during subsequent progress meetings during the assessment process.

Table 9.2 Summary of consultee responses

Consultee and Date	Summary of issues raised	How issues have been addressed
Scoping Opinion 2017		
MS-LOT	The existing baseline remains appropriate with the exception of diadromous fish, in relation to which MSS has provided new references and requests that the baseline be updated accordingly.	The Baseline Description has been updated in light of this new information on salmonids. See paragraph 9.187.
Marine Scotland Science (MSS)	MSS considered that the 2012 Offshore ES understated the likelihood that salmon will be present and that this new evidence (as noted above) provides more detail regarding where the salmon are likely to be.	The potential for Atlantic salmon *Salmo salar* to be present has been considered in the Baseline Description. It is also noted here that the 2012 offshore ES concluded that salmon could be present (Chapter 12, paragraph 12.179: "*it can be assumed that a proportion of this species will cross the ISA at some point*"). This EIA Report also assumes that salmon could be present (paragraph 9.209).
MS-LOT	During consultation on commercial fisheries in June 2017 the Scottish Fishermen's Federation (SFF) raised the issue of the impact of suspended sediment in smothering species such as scallops and nephrops. The Scottish Ministers advised that the following two pieces of work be undertaken: • A review of literature on effects of suspended sediments to scallops and nephrops (including different life stages); and • Physical process modelling of likely spatial extent of suspended sediments from activities of concern. If Seagreen consider that there are no significant effects and scope this potential impact out of further assessment they must provide justification for this decision.	Gravity bases were included within the 2012 Offshore ES and no significant adverse impacts to scallops or nephrops were predicted. No changes to the design of gravity bases are included in the revised application for the optimised Seagreen Project and no greater impact would therefore be anticipated. Notwithstanding this, the following additional activities have been completed: • Collation of information on the distribution of scallops and nephrops in relation to fishing activity (see Appendix 11A – Commercial Fisheries Technical Report); • Review of the sensitivity of scallops and nephrops to suspended sediments (paragraphs 9.169 and 9.183 respectively); • Study of the potential for suspended sediment mobilisation and deposition from gravity base works to assess whether additional modelling is appropriate (Appendix 9C).
MSS	MSS highlighted considerable increase in the relevant literature which suggests that there is potential for impacts from acoustic particle motion on fish and invertebrates and suggested that Seagreen provide a Briefing Note on this topic.	A Technical Note has been prepared which is provided as Appendix 9B and acoustic particle displacement effects are considered within the impact assessment (from paragraph 9.244).
Meetings		
Kick off meeting, MS-LOT & MSS, 16 November 2017	MSS offered to provide additional unpublished information on salmonid migratory behaviour. This was not expected to change the scoping opinion or assessment but could be used to update the baseline.	Information was requested but has not been received to allow salmonid baseline to be further updated.
	Assessment should be focused on potentially significant effects, i.e. underwater noise and herring spawning.	Addressed within Impact Assessment from paragraph 9.244

Consultee and Date	Summary of issues raised	How issues have been addressed
	Previous (2012 offshore ES) data sets on distribution of herring spawning stocks to be used.	Included within Baseline (From paragraph 9.74 and Figure 9.2)
	Popper *et al*. (2014) criteria to be used for impact assessment.	Included within Impact Assessment
	Assessment should consider the potential effect of acoustic particle motion.	Addressed within Impact Assessment
	As different assessment methods (i.e. Popper criteria) are being used compared to the 2012 Offshore ES the assessment will need to look at implications for other species (than herring).	Other species are considered within the Impact Assessment
	Salmon to be considered under EIA, not HRA	Considered within this chapter of the EIA Report.
	Fisheries information is a good proxy for older scallops, but not necessarily juveniles	Information on the distribution of juvenile scallops is recognised as an information gap, but because of the expected limited effects of suspended sediments and sediment deposition, the gap is not believed to be significant.
	Seagreen need to investigate potential for sediment mobilisation due to gravity base installation, making use of the best available information.	This has been considered in Appendix 9C.
	ORJIP report on herring and piling should be reviewed and made use of if available in time for the assessment.	The ORJIP herring report was received shortly before the draft fish and shellfish natural resource chapter was completed. The report was reviewed and some information utilised in the assessment.
Baseline update meeting, MS-LOT and MSS, 26 January 2018	The underwater noise modelling approach is understood to reflect the requirements of both fish/shellfish and marine mammal assessments. The locations selected to represent pile driving and piling parameters selected are accepted.	Noted. The underwater Noise modelling Plan is provided as Appendix 10C.
	Soft start should not be considered as mitigation for fish if fleeing is not assumed in the noise modelling	Fleeing is not assumed for fish and the assessment is made on this precautionary basis.
	As no fleeing from pile driving by fish was assumed for initial noise modelling, this approach should be maintained for all modelled scenarios	Adopted in underwater noise modelling (Appendix 10B and 10C).
	Spawning period for herring stated in 2012 Offshore ES and Scoping Report (July to September) is probably slightly too long. July likely represents start of spawning aggregation, peak spawning more likely towards end of this period.	Noted (adopted in assessment, from paragraph 9.77).
Updated consenting strategy meeting, MS-LOT & MSS, 30 April 2018	Scoping Report and Opinion agreed to remain valid in light of move to a 'New Application'. Assessment to focus on underwater noise, other impacts (e.g. EMF, water quality) remain scoped out	Noted

SCOPE OF ASSESSMENT

9.20. With reference to the 2017 Scoping Opinion and confirmed through further consultation, the scope of the assessment for natural fish and shellfish resource considers only the potential effects of underwater noise from pile driving due to the inclusion of an additional piled foundation option (monopiles) and developments in the approach to the assessment of underwater noise impacts for fish (Popper *et al*., 2014) since the 2012 Offshore ES.

9.21. The focus of the assessment is on herring and the potential effects of piling noise to impact their spawning behaviour. The potential for significant impacts to occur on other fish species, and shellfish, is also considered.

9.22. This is based on the optimised Seagreen Project design set out in Chapter 5 (Project Description) and with the assumption that mitigation measures and consent conditions as set out in Chapter 7 (Scope of EIA Report) will be applied.

9.23. All other potential impacts on natural fish and shellfish ecology have been scoped out of the assessment for the optimised Seagreen Project and are not assessed further within this impact assessment.

9.24. In addition to the above, this EIA Report also provides the following additional information as agreed during Scoping:

- Updated baseline information on Atlantic salmon;
- Review of the potential for suspended sediment mobilisation and smothering from gravity base installation in relation to scallops and nephrops; and
- Review of underwater noise in terms of particle motion effects.

METHODOLOGY

9.25. This section presents the impact assessment methodology applied to assess the potential environmental impacts associated with the construction, operation and decommissioning phases of the optimised Seagreen Project.

Study Area

9.26. In order to maximise consistency, the assessment for natural fish and shellfish resource maintains the approach of the 2012 Offshore ES and considers receptors in terms of the same three spatial scales, which is considered to provide appropriate context for the assessment. These are the Immediate Study Area (ISA), the Regional Study Area (RSA) and the Wider Study Area (WSA) as detailed in Figure 9.1 and described below:

- The Immediate Study Area (ISA) encompasses Project Alpha and Project Bravo. An area to the west encompassing part of the Offshore Transmission Asset Project is also included within the ISA but is not directly relevant to this assessment ;
- The Regional Study Area (RSA) encompassing the ISA and a surrounding area defined by ICES rectangles 42E7, 41E7 and 41E8 and 42E8; and
- The Wider Study Area (WSA) - Encompassing the RSA and defined by 12 ICES rectangles as shown in Figure 9.1. This area is also used as the Cumulative Study Area.

Data Collection

9.27. The optimised Seagreen Project has the same area and is within the same application boundaries as the originally consented Project and, therefore, data collected to inform the 2012 Offshore ES remain an appropriate source of information to inform the assessment of impacts for this EIA Report. This includes a range of detailed project specific surveys and site characterisation studies to define baseline conditions. Where data from the 2012 Offshore ES are used, this is set out below and data are provided as supporting information to this chapter (Appendix 9A – Seagreen Phase 1 and ECR Benthic Survey).

9.28. Baseline characterisation for natural fish and shellfish resource has been undertaken using a combination of desk based research and site specific surveys completed for the previous application. Table 9.3 details the key data sources used to inform this assessment.

Table 9.3 Summary of key data and surveys

Title	Source	Year(s)	Reference
Spawning data 2010	Centre for Environment, Fisheries and Aquaculture Science (Cefas)	2010	Cefas (2010)
Nursery data 2010	Cefas	2010	Cefas (2010)
Fisheries Sensitivity Maps in British Waters (Data layers)	Cefas	1998	Coull *et al.* (1998)
Seagreen Benthic Survey-Benthic Trawl samples Phase 1 and Export Cable Route	IECS	2011	IECS (2012) Appendix 9A
Seagreen Benthic Survey-Video trawl data- Phase 1 and Export Cable Route	IECS	2011	IECS (2012) Appendix 9A
Seagreen Benthic Survey-Fish length data- Phase 1 and Export Cable Route	IECS	2011	IECS (2012) Appendix 9A
Noise Modelling Report	Cefas	2018	Cefas (2018) Appendix 10B

Survey Work

9.29. No additional survey work is required in relation to the assessment for Natural Fish and Shellfish Resource, as confirmed through consultation (Table 9.2). The assessment therefore relies on previous survey work undertaken in 2011 in support of the 2012 Offshore ES. A total of 53 epibenthic trawl sample stations were surveyed within the ISA between February and April 2011. Fifty trawl stations were within the original Seagreen Phase 1 area (encompassing Project Alpha and Project Bravo). Detailed methods and results can be found in Appendix 9A.

Impact Assessment

9.30. The impact assessment follows the same approach set out within the 2012 Offshore ES and summarised within Chapter 6 (EIA Process) of this EIA Report. This includes consideration of Project Alpha alone; Project Bravo alone; Project Alpha and Project Bravo combined (the optimised Seagreen Project) and Project Alpha and Project Bravo in a cumulative scenario.

9.31. The significance of potential impacts has been evaluated using a structured process, based upon identification of the importance of receptors and their sensitivity to the project activity (e.g. disturbance by underwater noise), together with the predicted magnitude of the impact.

Approach to Underwater Noise Assessment

9.32. Underwater noise propagation modelling completed to inform the impact assessment for the Seagreen Project is detailed in Appendix 10B (Cefas Noise Modelling Report). This is restricted to modelling of sound pressure; the potential implications of acoustic particle displacement are discussed in this EIA Report but there is currently insufficient information to support particle displacement modelling, or the application of relevant effect thresholds.

9.33. Underwater noise has the potential to cause both physiological and behavioural impacts on fish. The potential impacts of underwater noise are dependent on the noise source characteristics (frequency [Hz] and decibels [dB]), the receptor species and the distance from the sound source and noise attenuation within the environment.

9.34. Sound measurements underwater are usually expressed using the dB scale, which is a logarithmic measurement of sound. Sound may be expressed in many different ways depending upon the particular type of noise, and the parameters of the noise that allow it to be evaluated in terms of biological effect. A detailed description of the measurement of underwater noise is beyond the scope of this EIA report but a brief summary is provided below.

9.35. Peak level is the maximum level of the acoustic pressure, and is usually used to characterise underwater blasts, where there is a clear positive peak, for example following the detonation of explosives. Peak to peak level is usually used in calculating the maximum variation in pressure from a positive to a negative within the sound wave. It represents the maximum change in pressure, and is often used to characterise the sound transients from impulsive sources such as percussive impact piling and seismic airguns. Sound pressure level (SPL) is normally used to characterise noise and vibration of a continuous nature such as drilling, boring or background noise levels. Sound exposure level (SEL) provides a measurement of the total acoustic energy, by summing the acoustic energy over a given period (being the time integral of the pressure squared for an event). It takes account of both the SPL and the duration of the presence of the sound in the acoustic environment. It measures the cumulative broadband noise energy and serves as an index for accumulated sound energy, by allowing the integration of sound energy across multiple sources such as pile driving.

9.36. Before underwater noise propagation modelling commenced, a number of key parameters had to be established which were discussed and agreed with Marine Scotland and SNH (Table 9.2) to take forward into the Noise Modelling Plan (Appendix 10C). Representative locations for noise propagation modelling were selected for the two potential driven wind turbine foundation options (monopiles and jacket pin piles) and installation scenarios representing parameters for pile driving (hammer energy, blow frequency etc.) together with potential build scenarios were identified. Throughout this process, the aim was to evaluate the most likely and worst case scenarios for fish receptors in terms of underwater noise from piling. Key piling parameters are summarised in Table 9.4 and modelled scenarios in Table 9.5.

9.37. Noise modelling locations are illustrated in the presentation of results (Figure 9.16 and Figure 9.17), but were selected as representative of the sensitivities of both fish and marine mammal receptors (Chapter 10 [Marine Mammals]), both assessments relying on common underwater noise modelling.

9.38. Underwater noise modelling to support the assessment was undertaken by Cefas. The Cefas noise propagation model (Farcas *et al*., 2016) is based on RAM (Collins, 1993), a widely applied parabolic equation method of sound propagation modelling. The Cefas model applies RAM to produce a series of transects around the noise source, each with range-dependent propagation loss, which varies with bathymetry, sediment type and water properties.

9.39. Modelled impact zones for selected effect thresholds for mortality, injury and temporary threshold shift (TTS) published by Popper *et al*. (2014) were then mapped to inform the impact assessment. Distances to effect thresholds were determined without assuming any avoidance response (fleeing) by fish on commencement of piling; the effect ranges are therefore likely to be relatively precautionary.

9.40. Source sound levels for piling (Table 9.6) were calculated using an energy conversion model (De Jong & Ainslie 2008), whereby a proportion of the expected hammer energy is converted to acoustic energy:

$$SL_E = 120 + 10log_{10}\left(\frac{\beta E c_0 \rho}{4\pi}\right)$$

Where E is the hammer energy in joules, SL_E is the source level energy for a single strike at hammer energy E,β is the acoustic energy conversion efficiency, c_0 is the speed of sound in seawater in m^{-1}, and ρ is the density of seawater in kg m^{-3}.

9.41. This yields an estimate of the source level in units of sound exposure level (dB re 1 μPa^2 s). This energy is then distributed across the frequency spectrum, based on previous measurements of impact piling (Ainslie *et al*. 2012).

9.42. Hammer energy profiles for the piling scenarios formed the basis of the source level estimates. The above equation was used to compute the source level energies, using an acoustic energy conversion efficiency of 0.5%, which assumes that 0.5% of the hammer energy is converted into acoustic energy. This energy conversion factor is in keeping with current understanding of how much hammer energy is converted to noise (Dahl & Reinhall 2013; Zampolli *et al*. 2013; Dahl *et al*. 2015). The above equation gives the source level energy for a single strike (single-strike SEL). The source level peak pressures, as well as the field peak SPL, were calculated using the empirical linear equations linking the peak SPL and the single-pulse SEL for pile driving sources reported by Lippert *et al*. (2015).

9.43. The assessment for behavioural effects is based on qualitative guidelines, also published by Popper *et al*. (2014).

9.44. The Cefas model has been validated and optimised using field data from pile driving and bespoke noise propagation measurements undertaken with a seismic source in the North Sea. The Cefas model has also been used for underwater noise modelling work for other offshore wind farms in Scottish waters.

Table 9.4 Worst Case Scenario piling parameters assumed in the noise modelling and resulting impact assessment

Foundation	Maximum Hammer Energy (kJ)	Max number of events within 24hr	Duration per pile (hrs)	Ramp up duration (min)	% max hammer energy	Strike rate (per min)
10m Monopile	3,000	1	4	1	13	7
				19	13 to 20 gradual ramp up	31
				100	20 to 100 gradual ramp up	35
				100	100	35
2m Pin pile	1,800	4	2.25	6	15	45
				4	35	45
				5	55	45
				30	75	45
				90	95	45

Table 9.5 Build scenarios that have been assessed

Scenario	Name	Description	Foundation Type(s)	Max Energy (kJ)
1	Alpha Worst Case (monopile)	Single monopile at Alpha	10m monopile	3,000
2	Alpha Most Likely (monopile)	Single monopile at Alpha	10m monopile	2,300
3	Bravo Worst Case (monopile)	Single monopile at Bravo	10m monopile	3,000
4	Bravo Most Likely (monopile)	Single monopile at Bravo	10m monopile	2,300
5	Alpha Worst Case (jacket)	Single jacket foundation at Alpha	2m pin pile	1,800
6	Bravo Worst Case (jacket)	Single jacket foundation at Bravo	2m pin pile	1,800
7	Alpha Worst Case (jacket & monopile)	Simultaneous jacket and monopile at Alpha	10m monopile and 2m pin pile	3,000 and 1,800
8	Bravo Worst Case (jacket & monopile)	Simultaneous jacket and monopile at Bravo	10m monopile and 2m pin pile	3,000 and 1,800

Table 9.6 Source noise levels used in propagation modelling

Hammer energy (kJ)	SEL (dB re 1 µPa²s @1m)	SL peak (dB re 1 µPa @1m)	Notes
270	202.2	243.1	Start energy pin pile (Scenarios 5, 6, 7, 8, and 9)
400	203.9	245.4	Start energy monopile (Scenarios 1, 3, 7, and 8)
1,710	210.2	254.3	Max energy pin pile (Scenarios 5, 6, 7, 8, and 9)
3,000	212.6	257.7	Max energy monopile (Scenarios 1, 3, 7, and 8)

Developments in Assessment Methods

9.45. The assessment has been completed in a manner which is consistent with the 2012 Offshore ES and equivalent definitions (for example of Study Area and receptor importance) have been adopted where possible. However, the approach taken has been updated to reflect current best practice, specifically:

- Modelling of underwater noise from hammer piling has been undertaken with reference to threshold effect levels in guidelines published by the Acoustical Society of America (ASA, Popper *et al*. 2014). Previously, the potential for effects upon fish receptors was evaluated using the dBht (species) metric (Subacoustech, 2012). Marine Scotland Science have agreed that the ASA guidelines should be used in the EIA Report; and
- Recently available EIA guidelines (CIEEM, in prep) have been referenced which has led to a change in the way receptor sensitivity has been defined. Previously, this was a combination of what is now separately termed receptor importance and sensitivity in this EIA Report.

9.46. Overall, while some changes to the assessment method (as set out above) have been introduced to conform to current best practice for the Natural Fish and Shellfish Resource assessment, the methodology is similar to that followed in the 2012 Offshore ES and conclusions from the respective assessments are comparable in terms of overall conclusions of significance.

Significance Criteria

9.47. The significance of potential impacts has been evaluated using a structured process, based upon identification of the importance of receptors and their sensitivity to the project activity (e.g. disturbance by underwater noise) together with the predicted magnitude of the impact.

9.48. The importance of receptors has been assessed using a hierarchical geographic frame of reference (CIEEM, 2010; CIEEM, in prep), as set out in Table 9.7.

9.49. The magnitude of a potential impact, which can be considered as its extent and severity, will depend upon whether the impact would cause a fundamental, material or detectable change. This takes into account the sensitivity of receptors as set out in Table 9.8, which follows updated CIEEM (in prep.) guidance. The criteria for assessing the magnitude of potential impacts are categorised as being high, medium, low or negligible, as outlined in Table 9.9.

Table 9.7 Hierarchical geographic frame of reference and importance of receptors

Geographic Frame of Reference	Importance	Criteria
International	Very High	Species which have been designated for their international importance, e.g. OSPAR designations/IUCN Red list/Annex II species
National	High	Species which have been designated for their national importance, e.g. Priority Marine Feature, or nationally important commercially targeted species
Regional	Medium	Species that have been designated for their regional importance. Species that are locally--regionally important commercial species
Local	Low	Species with no designated status or commercial importance

Table 9.8 Sensitivity criteria

Sensitivity	Criteria*
High	A receptor with a very limited ability to resist (or tolerate) a pressure and recover from any impacts induced by the pressure (resilience).
Medium	A receptor with a limited ability to resist (or tolerate) a pressure and recover from any impacts induced by the pressure (resilience).
Low	A receptor with some ability to resist (or tolerate) a pressure and recover from any impacts induced by the pressure (resilience).
Negligible	A receptor which can generally resist (or tolerate) a pressure and recover from any impacts induced by the pressure (resilience).

* Based on sensitivity as defined by Pérez-Domínguez *et al*., 2016.

Table 9.9 Criteria used to define the magnitude of impacts

Magnitude	Criteria
High	Fundamental and permanent/irreversible changes to the sum of influences acting on the conservation status of the receptor concerned that may affect its abundance and distribution within a given geographical area.
Medium	Material, permanent/irreversible changes to the sum of influences acting on the conservation status receptor concerned that may affect its abundance and distribution within a given geographical area.
Low	Detectable, temporary (throughout project duration) change to the sum of influences acting on the conservation status receptor concerned that may affect its abundance and distribution within a given geographical area.
Negligible	Detectable, temporary (for part of the project duration) change, or barely discernible change for any length of time, to the sum of influences acting on the conservation status receptor concerned that may affect its abundance and distribution within a given geographical area.

9.50. Probability and duration of potential impacts and proximity to infrastructure are also considered where they influence the magnitude of an impact. Determinations of impact magnitude are based on the best available information together with professional judgement, as explained in Chapter 6 (EIA Process) of this EIA Report.

9.51. A significant impact (positive or negative) is defined as "an impact that is sufficiently important to require assessment and reporting so that the decision maker is adequately informed of the environmental consequences of permitting a project" (CIEEM, in prep.).

9.52. The matrix used to determine the significance of an impact combines the importance of the receptor with magnitude of impact (Table 9.10). As set out in Chapter 6 (EIA Process), for the purposes of this EIA Report, potential impacts identified as major or moderate are generally considered to be significant in EIA terms and mitigation may be required, while impacts identified as minor or negligible are generally considered to be not significant in EIA terms.

Table 9.10 Criteria used to define the significance of impacts

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

Assessment Limitations and Uncertainty

9.53. The assessment of the impact of piling noise on receptor behaviour, notably during the spawning season, relies on information on the distribution of fish, their spawning areas and sensitivity to underwater noise. There is imperfect information in all of these areas, resulting from factors such as spatial and temporal variability in spawning patterns, challenges associated with sampling fish populations which occur unevenly over wide areas at different life stages (adults, juveniles, larvae and eggs) and difficulty understanding responses to external pressures such as underwater noise, which may be relatively subtle and variable.

9.54. Specifically in relation to underwater noise, there is relatively limited understanding of the importance of particle motion detection as a mechanism by which effects on fish and invertebrates may occur. This led MSS to advise that the following work be undertaken:

- Provide an overview of currently available information on particle motion within the vicinity of noise producing construction and operational activities, including, for example, pile driving, dredging and explosions – both within the water column and the sea bed. 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.
- Give consideration to the potential effects of particle motion on species known to occur around the Revised Development site, making use of information on species distribution from the Original Development ES and information which has become available since then. Particular attention should be given to potential effects on species of commercial or conservation concern.
- Provide information on opportunities that the Project may present to investigate effects of particle motion on fish and invertebrates.

BASELINE CONDITIONS

9.55. The Scoping Opinion confirms that the baseline presented in the 2012 Offshore ES remains largely valid. This information is summarised here with updates where pertinent to the impact assessment and additional baseline information relating to Atlantic salmon and certain commercially important shellfish (nephrops and scallops), as set out in the 2017 Scoping Opinion.

9.56. Information is presented on the current baseline for the ISA, RSA and then WSA. Individual species accounts for key species are included in the WSA section where sensitivities to underwater noise and, for nephrops and scallops, suspended sediments/smothering, are outlined. More detailed information on fish and shellfish sensitivity to underwater noise is provided in a summary section, following the baseline descriptions.

Immediate Study Area (Current Baseline)

9.57. Distribution patterns of fish and shellfish are subject to a number of influences including abiotic factors, such as water temperature, salinity, depth, local-scale habitat features and substrate type; biotic factors including predator-prey interactions and competition; and anthropogenic influences, such as the presence of artificial structures in the marine environment and type or intensity of commercial fisheries.

9.58. The ISA (Figure 9.1) is characterised by water depths ranging between 41m and 61m. The sediments across the ISA are described as ranging from gravelly sand and sandy gravel, to slightly gravelly sand from east to west across the Seagreen Project area.

9.59. As part of the 2011 benthic survey, 53 trawls were completed, the majority of these were from offshore areas relating to Projects Alpha and Bravo. These provided information on certain demersal fish and shellfish species present at the time of survey in March to April, as presented in Table 9.11.

9.60. Pogge *Agonus cataphractus*, dab *Limanda limanda*, goby *Pomatoschistus norvegicus/lozanoi*, lesser or Raitts sandeel *Ammodytes marinus*, and butterfish *Pholis gunnellus* were present in over 70% of the benthic trawls from offshore (wind farm area) stations. Dab, goby, and lesser sandeel were generally the most abundant species, with up to 558 individuals recorded in a single trawl. Other species of sandeel, such as the smooth sandeel *Gymnammodytes semisquamatus* and the greater sandeel *Hyperoplus lanceolatus* were also present in samples, but at lower frequency and abundance.

9.61. A number of commercially exploited species were present in addition to dab. These included plaice *Pleuronectes platessa*, whiting *Merlangius merlangus*, cod *Gadus morhua* and scallop (king scallop *Pecten maximus* and queen scallop *Aequipecten opercularis*).

9.62. While the trawl surveys provide a useful summary of fish and shellfish species in the ISA it is recognised that a wider range of species should be expected to occur since surveys were restricted from March to April and targeted smaller demersal species only. No elasmobranchs (sharks, skate and rays) were caught and pelagic species such as herring and sprat are unlikely to be captured. Broader scale information from the Regional and Wider Study Areas and desk based information collation is relevant in this respect and is summarised below.

Table 9.11 Fish species recorded during the benthic trawl survey program during March and April 2011 (IECS, 2011).

Common name	Scientific name	Number found	% of trawls	Protected status
Pogge	*Agonus cataphractus*	337	88	None
Dab	*Limanda limanda*	341	86	None
Goby	*Pomatoschistus norvegicus / lozanoi*	258	76	None
Lesser or Raitt's Sandeel	*Ammodytes marinus*	1214	72	UK BAP
Butterfish	*Pholis gunnellus*	181	70	None
Norwegian topknot	*Phrynorhombus norvegicus*	65	56	None
Reticulated Dragonet	*Callionymus reticulates*	93	54	None
Common dragonet	*Callionymus lyra*	83	54	None
Lemon sole	*Microstomus kitt*	63	52	None
Bull rout	*Myoxocephalus scorpius*	63	50	None
Plaice	*Pleuronectes platessa*	31	42	UK BAP
American Plaice	*Hippoglossoides platessoides*	32	40	None
Thick Back Sole	*Microchirus variegates*	27	32	None
Spotted dragonet	*Callionymus maculates*	60	30	None
Bib or Pouting	*Trisopterus luscus*	21	20	None
Northern rockling	*Ciliata septentrionalis*	21	18	None
Dragonets	*Callionymidae*	24	14	None
Whiting	*Merlangius merlangus*	13	14	UK BAP
Cod	*Gadus morhua*	8	14	UK BAP & OSPAR
Two-spotted clingfish	*Diplecogaster bimaculata*	7	14	None
Moustache sculpin	*Triglops murrayi*	9	10	None
Snake pipefish	*Entelurus aequoreus*	8	10	None
Smooth sandeel	*Gymnammodytes semisquamatus*	11	8	None
Red gurnard	*Aspitrigla cuculus*	9	8	None
Grey gurnard	*Eutrigla gurnardus*	5	8	None
Jeffrey's goby	*Buenia jeffreysii*	4	8	None
Sea snail	*Liparis Liparis*	4	8	None
Cuckoo ray	*Leucoraja naevus*	4	8	None
Yarrell's blenny	*Chirolophis ascanii*	4	6	None
Greater sand eel	*Hyperoplus lanceolatus*	2	4	None
Wolf fish or catfish	*Anarhichas lupus*	1	2	None
Diminutive goby	*Lebetus scorpioides*	1	2	None
King scallop	*Pecten maximus*	6	8	None
Queen scallop	*Aequipecten opercularis*	201	64	None

Regional Study Area (Current Baseline)

9.63. In order to gain an understanding of the relative importance, presence and abundance of fish and shellfish species in the RSA, commercial landings data for ICES rectangles were interrogated. The RSA consists of ICES rectangles 41E7, 41E8 42E7 and 42E8. Rectangles 42E7 and 42E8 include the ISA and Projects Alpha and Bravo are both located in Rectangle 42E8 (see Figure 9.1).

9.64. Landings data from 2011 to 2015, provided by MSS for those rectangles, were used to identify the species regularly landed. This information, outlined here, is presented fully in Chapter 11 (Commercial Fisheries). The Commercial Fisheries technical report (Appendix 11A) is also referenced.

9.65. The main fishing activities undertaken in the RSA, as detailed in Figure 2.5 of the commercial fisheries technical report (Appendix 11A) are:

- Scallop dredging (principally in rectangle 42E8 and 42E7);
- Creeling/potting for lobster and crab (largely in rectangles 42E7 and 41E7);
- Demersal trawling for nephrops (concentrated in rectangle 41E7) and squid (most important in rectangle 42E7); and
- Trawling for sandeels (principally in rectangle 41E8)

9.66. The most important fishing activity in the immediate area of Projects Alpha and Bravo is dredging for scallops *Pecten maximus*, with smaller values attributed to otter trawls targeting squid *Loligo sp*., as well as creelers/potters targeting lobster *Homarus gammarus* and crabs *Cancer pagurus* and *Necora puber*.

9.67. A whitefish fishery is present and targets species such as haddock *Melanogrammus aeglefinus* and cod *Gadus morhua*, but this has declined significantly over the years in the regional study area, with currently negligible activity in the immediate area of Projects Alpha and Bravo.

9.68. A range of other species can be expected to occur, including those presented in the summary of spawning and nursery areas and individual species accounts in the context of the wider study area, set out below.

Wider Study Area (Current Baseline)

9.69. A number of species of commercial importance are known to use all or part of the WSA as spawning and/or nursery grounds (Cefas, 2010, Coull *et al*., 1998). Those which overlap, or are in close proximity to the any of the study areas include cod, lemon sole, herring, nephrops, mackerel, plaice, sandeel, saithe, sprat, spotted ray, spurdog, tope, and whiting.

9.70. Table 9.12 identifies the main periods of spawning activity for important species in the WSA.

Table 9.12 Main periods of spawning activity for key fish species in the WSA (spawning periods are highlighted in yellow, peak spawning periods marked orange)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Herring*												
Cod												
Sandeel												
Sprat												
Whiting												
Mackerel												
Plaice												
Saithe												
Lemon Sole												
Spurdog												
Nephrops												
Scallops												
Edible Crab												
Lobster												
Squid												

Source: Adapted from Coull *et al.*, (1998); *Buchan stock

Individual species accounts – finfish

9.71. The following sections describe the current status, ecology and distribution of the key species of fish and shellfish identified in the study areas. These species are also discussed in relation to their sensitivity to anthropogenic change. Information on fish sensitivity to underwater noise as sound pressure is outlined below, with further detail presented in a summary of sensitivity, following the individual species accounts and baseline section.

9.72. The variability in hearing sensitivity amongst fish has led to recent guidelines being published by the Acoustical Society of America (Popper *et al.*, 2014). These guidelines are considered the most up to date and appropriate to inform this assessment. The guidelines divide fish into three broad groups, based on physiological differences, as related to hearing sensitivity:

- Group 1: Fish with no swim bladder, or other gas chamber (e.g. mackerel, dab and other flatfish). These species are less susceptible to barotrauma and only detect particle motion, not sound pressure. However, some barotrauma may result from exposure to extreme sound pressures;
- Group 2: Fish with swim bladders, but in which hearing does not involve the swim bladder, or other gas volume (e.g., Atlantic salmon). These species are susceptible to barotrauma, although hearing only involves particle motion, not sound pressure; and
- Group 3: Fish in which hearing involves a swim bladder or other gas volume (e.g. Atlantic cod, herring and relatives). These species are susceptible to barotrauma and detect sound pressure as well as particle motion.

9.73. The above groups are applied to fish receptors described in the following section.

Herring (Clupea harengus)

Status

9.74. Herring is a commercially important pelagic fish, common across much of the North Sea. The species was not recorded during surveys within the RSA (Appendix 9A) but as a pelagic shoaling species this is to be expected. Herring is a relatively large fishery; the most recently published figures for the UK share of the catch indicate 62,292 tonnes for the North Sea north of 53^{0}30'N (Scottish Government, 2015).

9.75. Herring stocks in the North Sea crashed as a result of over-fishing in the latter part of the 20th Century. Although there has since been a recovery, active management is required to prevent a recurrence (Dickey-Collas *et al.*, 2010). A herring recovery plan to reduce fishing mortality was implemented in 1996 for the North Sea and was revised in 2004. Although this was considered generally successful (Burd, 2011), it was not as successful for those herring stocks found in the northern North Sea (which includes the WSA). A ban on discards for pelagic fisheries such as herring started on 1 January 2015.

9.76. There are two herring fisheries certified as sustainable by the Marine Stewardship Council (MSC) in the North Sea (MSC, 2018). Herring are also a Scottish Priority Marine Feature.

Ecology

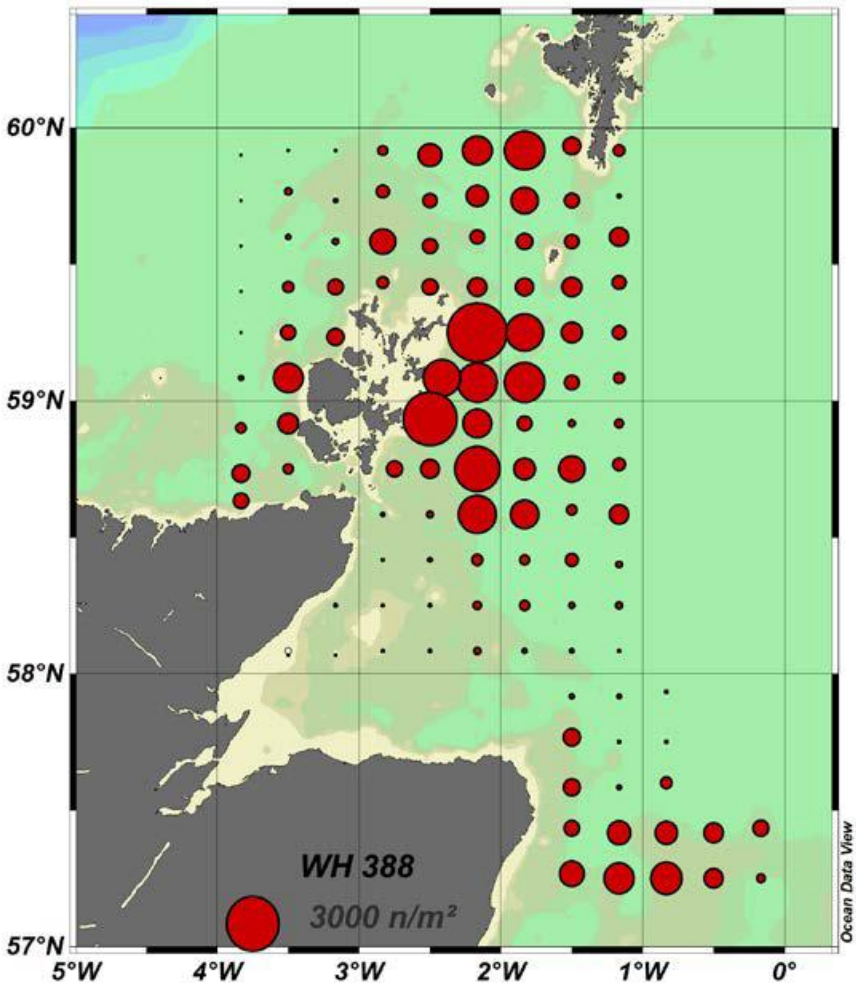
9.77. North Sea herring fall into a number of different 'races' or stocks, each with different spawning grounds, migration routes and nursery areas (Coull *et al.*, 1998). North Sea autumn-spawning herring have been divided into three, mainly self-contained stocks — the Buchan, Dogger and Downs herring,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

9.78. Herring deposit eggs on a variety of substrates from coarse sand and gravel to shell fragments and macrophytes; although gravel substrates have been suggested as their preferred spawning habitat. Once spawning has taken place (the peak spawning months being August and September for the Buchan group), the eggs take approximately three weeks to hatch after which the larvae drift in the plankton (Dickey-Colas *et al.*, 2010, and Cefas 2011).

Distribution in the study areas

9.79. Project Alpha and Project Bravo are not within any herring spawning grounds (as identified by Coull *et al.* [1998]). However, more recent Cefas data suggest spawning grounds are located approximately 6.3km to the north and 80km to the south of the project areas. However the main spawning areas for herring have been shown by Ellis *et al.* (2012) to be further to the north (Figure 9.2) and the main commercial fishing grounds are also in the same region. Recent work by the Working Group of International Pelagic Surveys (WGIPS) has similarly reported that the main concentration of herring larvae towards the end of the spawning period is to the north (Plate 9.1), consistent with this interpretation (ICES, 2016).

Plate 9.1 Abundance of herring larvae per square metre (all sizes, n/m²), as obtained by the German survey in the Orkney/Shetlands and Buchan area (second half of September 2015). The symbol size is equal to 3 000 larvae/m². WH 388 refers to the national cruise number. Source ICES, 2016.



9.80. Data provided by Marine Scotland for the 2012 Seagreen Offshore ES (unpublished) showed that herring larvae were present within the ISA and were found in relatively high abundance (between 1.2 to 2 per m²) in 2011 although it is not certain if these larvae were at the yolk sac stage which would be an indication of local spawning stock. These data indicate that although spawning activity was not found in the ISA, the larvae present may have originated from the more northern spawning areas.

9.81. Both Project Alpha and Project Bravo (within the ISA) and much of the WSA are within herring nursery grounds (Ellis *et al*, 2012), with the Firth of Forth considered to be a nursery ground of high intensity, with another area, of lower intensity, to the east (Figure 9.2).

Sensitivity

9.82. Herring is an important species within the North Sea in terms of being a food source for predators, such as seabirds and marine mammals, and acts as a regulator of zooplankton populations. It has also been suggested that they play a crucial role in the health of the North Sea ecosystem (Fauchald *et al.*, 2011 and Casini *et al.*, 2004). Therefore, significant changes to the spawning success, abundance and distribution of the species could have a negative impact on the populations of seabirds and marine mammals.

9.83. Herring spawning and nursery areas are vulnerable to anthropogenic influences, particularly activities which have an impact on the physical environment (seabed) since they are benthic spawners; however, no change in the nature of magnitude of seabed disturbance is expected as a result of the optimised Seagreen Project and such effects are therefore beyond the scope of this EIA Report.

9.84. Atlantic herring are hearing specialists, with an intimate connection between the swim bladder and hearing system, and are a 'Group 3' species after Popper *et al*., 2014.

Sandeel (Ammodytes marinus and other species)

Status

9.85. In the early 1990s there was a substantial industrial sandeel fishery on the Wee Bankie, Marr Bank and Berwick Bank sandbanks, all of which are within the WSA, to the south of the ISA. By 1993 landings from this area had peaked at over 100,000 tonnes (Greenstreet *et. al.*, 2010a).

9.86. In 2000, this industrial sandeel fishery was closed in response to concerns that the fishery was having a deleterious effect on top predators, particularly breeding bird colonies at Bass Rock and other colonies on the islands within the Firth of Forth. The fishery remains closed and sandeel abundance is monitored by Marine Scotland. The sandeel closure within this region (precautionary closure – Article 29a from Council Regulation No 850/88) had the effect of limiting sandeel fishing on most of the Firth of Forth sandeel grounds.

9.87. After the Firth of Forth sandeel fishery closed, high levels of recruitment, combined with a lack of any significant fishing activity resulted in an immediate and substantial increase in the biomass of sandeel on the Wee Bankie sandbank. However, since 2001, sandeel biomass has steadily declined to levels that are now similar to those observed when the sandeel fishery was active.

9.88. Two sandeel species, *Ammodytes marinus* & *A. tobianus*, are Scottish Priority Marine Features.

Ecology

9.89. Sandeel spend most of the year buried in the seabed, emerging in the winter to spawn (van der Kooij *et al*., 2008). Sandeel spawn a single batch of eggs in December to January, which are deposited on the seabed, several months after ceasing to feed. The larvae hatch after several weeks, usually in February to March, and drift in the currents for one to three months, after which they settle on the sandy seabed. During the spring and summer sandeel emerge during the day to feed in schools and at night return to bury in the sand. This is an adaptation to conserve energy and to avoid predation. There are indications that the survival of sandeel larvae is linked to the availability of copepod prey in the early spring, especially *Calanus finmarchicus* and that climate-generated shifts in the *Calanus* species composition can lead to a mismatch in timing between food availability and the early life history of lesser sandeel (Wright and Bailey, 1993; van Deurs *et al*., 2009). Sandeel is an important prey species for many marine predators.

9.90. Sandeel have a close association with sandy substrates into which they burrow. They are largely stationary after settlement and show a strong preference to specific substrate types. Recent work, in the laboratory (Wright *et al*., 2000) and in the natural environment (Holland *et al*., 2005) has focused on identifying the sediment characteristics that define the seabed habitat preferred by sandeel. Both approaches produced similar results, indicating that sandeel preferred sediments with a high percentage of medium-to-coarse-grained sand (particle size 0.25 to 2 millimetres [mm]), and avoided sediment containing >4% silt (particle size <0.063mm) and >20% fine sand (particle size 0.063 to 0.25mm). As the percentage of fine sand, coarse silt, medium silt and fine silt (particles <0.25mm in diameter) increased, sandeel increasingly avoided the habitat. Conversely, as the percentage of coarse sand and medium sand (particles ranging from 0.25 to <2.0mm) increased, sandeel showed an increased preference for this substrate.

9.91. Work by Greenstreet *et al*., (2010b) draws on the research by Holland *et al*., (2005), to define four sandeel sediment preference categories, using hydro-acoustic seabed surveys and nocturnal grab surveys. They merged fine sand, three silt grades and the two coarser sand grades, to define two particle size classes, silt and fine sand and coarse sand, and then examined the combined effect of these two size grades of sediment particles on the percentage of grab samples with sandeel present. Based on the results obtained, four sandeel sediment preference categories were defined; Prime, Sub Prime, Suitable and Unsuitable.

Distribution in study areas

9.92. Particle Size Analysis (PSA) was completed, as part of the 2011 benthic survey and used to map particle size composition across the Seagreen Project area. Using the four categories defined by Greenstreet *et al*., (2010b) (Prime, Subprime, Suitable, Unsuitable), it was possible to identify which areas within the Project Alpha and Project Bravo sites contained the most preferable habitat. The results indicated that the majority of the Project Alpha and Project Bravo sites contain Prime or Subprime habitat for sandeel (Figure 9.3).

9.93. The wider Firth of Forth region has long been known to support important sandeel populations. The highest density of this population is focused on the Wee Bankie, some 30km south of the Seagreen Project. However, sandeels do range across much of the wider study area.

9.94. Three species of sandeel were found to be present within the ISA during the 2011 benthic survey (Table 9.11). By far the most abundant was the lesser or Raitts sandeel *Ammodytes marinus*. Lesser sandeel was recorded in both the benthic trawl and the dropdown video surveys across both the ECR and the Project Alpha and Project Bravo areas, and was also recorded as part of the benthic grab survey.

9.95. The commercial fisheries technical report (Appendix 11A) identifies some limited sandeel trawling activity by Danish vessels to the south of the Project Area with very little activity in ICES rectangle 42E8, containing the ISA.

Sensitivity

9.96. Sandeel have a close association with specific substrates at the spawning and settlement phases in their lifecycle. The ecology, life cycle and slow growth rate of the most abundant sandeel *A. marinus* in Scottish waters (including the Firth of Forth) in comparison with other North Sea grounds (Boulcott *et al*., 2007) makes it particularly vulnerable to disturbances to its spawning and settlement phases. Disturbance of seabed substrates during construction and decommissioning could have a deleterious impact on the population and abundance. The slow growth rate also suggests that stock will also be slower to recover from a decline in the population.

9.97. Sandeels are considered to be of considerable importance in North Sea food webs. It is therefore considered important to maintain the population abundance to provide food for a number of predator species.

9.98. Sandeel have no swim bladder and are therefore classed as 'Group 1' (low sensitivity to sound pressure) after Popper *et al*. (2014) but have potential to detect acoustic particle motion (see also Appendix 9B).

Cod (Gadus morhua)

Status

9.99. Cod is widely distributed throughout the North Sea. Adult cod (>70cm) densities tend to be highest in the north, between Shetland and Norway, along the edge of the Norwegian Deep, in the Kattegat off the Danish coast, around the Dogger Bank and in the Southern Bight. Sub-adults (<70cm) are more widespread and occur throughout the North Sea, and Kattegat (ICES, 2010a).

9.100. There has been a gradual improvement in the stock status recently although fishing mortality is still considered to be above Maximum Sustainable Yield (MSY) and recent recruitment has been lower than expected, possibly due to changes in food availability for larvae and increased predation by seals (ICES, 2011). Cod is a Scottish priority marine feature.

Ecology

9.101. Spawning grounds appear to be widespread and not restricted to specific areas, with spawning aggregations found offshore all over the North Sea (Figure 9.4). Spawning itself can take place anywhere in the water column with eggs released in batches over a number of days. The eggs then take 10 to 30 days to hatch, depending on temperature (ICES, 2010a). Peak spawning in the southern North Sea occurs from the last week of January to mid-February (Daan *et al*., 1980). Results from plankton surveys and the distribution of mature cod in trawl surveys showed hot spots of egg production around the southern and eastern edges of the Dogger Bank, in the German Bight, the Moray Firth and to the east of the Shetlands (Fox *et al*., 2008).

Distribution in study areas

9.102. Cod is present within the ISA (Table 9.11) and spawning and nursery grounds are shown in Figure 9.4. The species is widely distributed throughout the North Sea.

9.103. Cod spawning grounds in the North Sea appear widespread (Coull *et al*., 1998 and Ellis *et al*., 2012), with spawning aggregation found all over the North Sea. This has led Cefas to categorise the majority of the North Sea as a cod spawning ground (Ellis *et al*., 2012). The ISA and RSA are located within low intensity spawning grounds but high intensity nursery grounds and data provided by Marine Scotland (Fox *et al*., 2008) indicate that cod eggs are present within the ISA and the RSA. Juvenile cod less than one year old are present within the ISA and have been found there in relatively high abundances (between 0.11 and 0.2 per km^2) (Gibb *et al*., 2007). Within the RSA, areas of high juvenile abundance have also been recorded in the outer Firth of Tay to the south west of the ISA. However, although the RSA may be used for spawning, in the wider context of the North Sea, it is less intense than seen elsewhere.

Sensitivity

9.104. Cod has an anterior part of the swim bladder that, although not connected to the inner ear, is in close proximity. As a result cod is relatively sensitive to underwater sound, though less so than herring. Cod is known to use low level grunting sounds to locate mates and coordinate spawning (Hawkins and Rasmussen, 1978). Anthropogenic noise sources may be audible for cod over long distances, potentially masking important communication and disturbing spawning behaviour (Hawkins and Rasmussen, 1978).

9.105. Popper *et al*. (2014) classify cod in 'Group 3' (high sensitivity to sound pressure) for which species acoustic particle displacement is believed to play a subordinate role in sound detection.

9.106. Cod, along with a number of other teleost fish species, are understood to be sensitive to electromagnetic fields (EMFs) (Gill *et al*., 2005). However, no significant change to EMFs are expected as a consequence of the optimised Seagreen Project. EMF effects were therefore scoped out of the assessment, in line with the 2017 Scoping Opinion and further consultation and are not discussed further in relation to cod or other species.

Sprat (*Sprattus sprattus*)

Status

9.107. There is a lack of data for this species, making it difficult to make a reliable assessment of its status, although it is considered an important prey species in the ecosystem of the North Sea.

9.108. International Bottom Trawl Survey (IBTS) data, collected between 1977 and 2005, indicate that sprat abundance in the North Sea is highest in the southern half, between southern England and southern Denmark. There is however, a local relatively high abundance of 1 and 2 year old sprat in the Firth of Forth (ICES 2010a).

Ecology

9.109. Sprat is a multiple batch spawner, with females spawning repeatedly throughout the spawning season (up to 10 times in some areas) (ICES, 2010a). Spawning occurs in both coastal and offshore waters, during spring and late summer, with peak spawning between May and June, depending on water temperature (ICES, 2010a). Sprat is an important food source for larger predatory fish, such as gadoids, and for seabirds such as kittiwake. It has also been suggested that sprat (and herring) fill a very important niche within the North Sea ecosystem by controlling zooplankton through predation (Fauchald, 2011).

Distribution in the study areas

9.110. Sprat is not landed in great quantities in commercial fisheries in the WSA. However, the eastern side of the ISA and a large part of the RSA are spawning grounds and the entire ISA and most of the RSA are nursery grounds (Figure 9.5).

Sensitivity

9.111. Sprat along with herring are thought to have relatively acute hearing. Popper *et al*. (2014) classify sprat in 'Group 3' (high sensitivity to sound pressure) for which species acoustic particle displacement is believed to play a subordinate role in sound detection.

Whiting (*Merlangius merlangus*)

Status

9.112. Whiting is a species of secondary commercial importance that is caught in large numbers throughout the entire North Sea, although large quantities are discarded. Since the late 1970s commercial landings have declined gradually to a historic minimum. Whiting is a Scottish priority marine feature.

9.113. Landings of whiting from the North Sea, particularly the northern North Sea, have been in decline in recent years (ICES 2010a) and landings data from the RSA support this (see Appendix 11A [Commercial Fisheries Technical Report]) suggesting that the population as a whole is declining.

Ecology

9.114. Whiting is a fish predator that feeds heavily on many commercially important species, including sandeel (ICES, 2012).

9.115. Spawning takes place in late spring and summer in the northern North Sea. Whiting and especially juvenile whiting, is an important prey for larger gadoids and other demersal fishes.

Distribution in study areas

9.116. Whiting is widely distributed throughout the North Sea and was recorded during the 2011 benthic trawl survey in the ISA.

9.117. IBTS data collected between 1977 and 2005 indicate that whiting are particularly abundant in the northern North Sea and in the waters off Shetland (ICES, 2010). Movements of whiting in the northern North Sea are directed mainly along the offshore waters adjacent to the Scottish coast.

Sensitivity

9.118. Detailed investigations into the auditory sensitivity of gadoid species, such as whiting, have been undertaken by Nedwell *et al*., (2004). This research showed that in cod, the swim bladder is in close proximity to the ear although it is not connected. Since whiting is a gadoid, it is suggested that this species will have a similar susceptibility to anthropogenic noise as cod.

9.119. On this basis whiting are assumed to be a 'Group 3' species after Popper *et al*. (2014) (high sensitivity to sound pressure) for which species acoustic particle displacement is believed to play a subordinate role in sound detection.

Mackerel (*Scomber scombrus*)

Status

9.120. The bulk of the catch in the North Sea is taken by pelagic trawlers each year and the large variation in annual catch relates to variable recruitment each year. Mackerel caught by the Scottish pelagic fleet belong to two different stocks, the North Sea and the Western stock. This separation is based on differences in the timing and the areas used for spawning. North Sea mackerel overwinter in the deep water, to the east and north of Shetland and on the edge of the Norwegian Deep.

9.121. Mackerel is a Scottish priority marine feature.

Ecology

9.122. Mackerel from the North Sea stock migrate south in spring to spawn in the central part of the North Sea from May until July. The Western mackerel stock is found in a wide area near to the continental slope. These fish spawn between March and July, mainly to the south and west of the UK and Ireland. After spawning fish move to the feeding grounds in the Norwegian Sea and the northern North Sea where they mix with the North Sea stock. Some western stock mackerel, predominantly small individuals, also enter the North Sea through the English Channel.

9.123. The Western stock mackerel travels long distances between the feeding grounds and the spawning areas. Over the past twenty years, the pattern of southerly migration has changed dramatically in both timing and route (ICES 2010a).

9.124. Mackerel mature at approximately 3 years old. Female mackerel shed their eggs in about twenty separate batches over the course of a spawning season. An average-sized fish produces around 250,000 eggs. Juvenile mackerel grow quickly and can reach 22cm after one year and 30cm after two years. Nursery grounds are shown in Figure 9.6.

9.125. The diet of mackerel can vary with the area and the season. By weight, almost half of the food consists of Crustacea (shrimps). The remainder is made up of juvenile fish such as sandeel, herring and Norway pout.

Distribution within the study areas

9.126. Mackerel is widespread throughout the North Sea. No mackerel spawning grounds overlap with the RSA, however, the majority of the RSA is within low intensity mackerel nursery grounds (Figure 9.6).

Sensitivity

9.127. Mackerel does not have a swim bladder and are therefore classed as 'Group 1' (low sensitivity to sound pressure) after Popper *et al*. (2014), but mackerel does have potential to detect acoustic particle motion (see also Appendix 9B). There have been anecdotal reports of shoals of mackerel remaining present in close proximity (10s of metres) to pile driving operations during offshore wind farm construction programmes, with no apparent behavioural response to the noise (NIRAS, pers. obs.).

Plaice (*Pleuronectes platessa*)

Status

9.128. Plaice populations are understood to be increasing with improved stock status due to increased spawning stock biomass since 2007 (ICES, 2017a).

9.129. Although not listed as a Scottish Priority Marine Feature plaice is a UK BAP priority marine species.

Ecology

9.130. Plaice spawn offshore in restricted areas from where the eggs and larvae are transported to coastal nurseries. Spawning can occur across much of the North Sea but the highest concentration of spawning occurs in the south (ICES 2010). Much of the RSA and the entire ISA is within low intensity spawning and nursery grounds (Figure 9.7).

Distribution in the study area

9.131. Plaice are widely distributed and were present throughout much of the ISA during the 2011 benthic trawl and video surveys (see Appendix 9A [Seagreen Phase 1 and ECR Benthic Survey]).

Sensitivity

9.132. Plaice, along with other flatfish, do not have swim bladders and are therefore classed as 'Group 1' (low sensitivity to sound pressure) after Popper *et al*. (2014) but do have potential to detect acoustic particle motion (see also Appendix 9B).

Saithe (*Pollachius virens*)

Status

9.133. Landings of saithe in the North Sea have declined since the 1970s (ICES 2010), however recent reductions in fishing mortality due to low market prices have led to a recovery of the stock. This species is slow to mature and can potentially be slow to recover from population crashes. Saithe is a Scottish priority marine feature.

Ecology

9.134. Saithe mature between the ages of four and six years. An adult female (approximately 75cm) can produce about 2.9 million eggs during a spawning season. Spawning takes place from January (in the southern part of the spawning distribution area) to May (further north) and generally occurs along the edge of the continental shelf, to the north and west of the Outer Hebrides and therefore at some distance from the Seagreen Project.

9.135. Young fish are initially found close to the surface but by June/July they move closer inshore and by the second year they live along the shoreline before moving offshore into deeper water in spring.

Distribution in the study area

9.136. This species uses much of the coastal waters of Scotland for nursery grounds (Coull *et al*., 1998). Part of the Project Alpha site lies within a lower intensity nursery area for this species (Figure 9.8). IBTS data indicate that this species generally occurs in higher abundances in the eastern North Sea than the west (ICES 2010).

Sensitivity

9.137. As saithe is a gadoid it is assumed that this species will have a similar susceptibility to anthropogenic noise as whiting and cod. On this basis saithe are assumed to be a 'Group 3' species after Popper *et al*. (2014) (high sensitivity to sound pressure) for which species acoustic particle displacement is believed to play a subordinate role in sound detection.

Lemon sole (*Microstomus kitt*)

Status

9.138. Lemon sole is a demersal species found in the shelf waters of the North Atlantic, from Iceland southward to the Bay of Biscay. Lemon sole is mainly a bycatch species in mixed fisheries and although the abundance of the stock is considered to be stable, landing data analysed for the 2012 Offshore ES suggest that there is a long-term decline in catch per unit effort.

Ecology

9.139. This species spawns in the northwest of the North Sea in April and spawning spreads north and east as the season progresses. Studies have shown that lemon sole has a widespread distribution and tends to spawn everywhere it is found (Rogers and Stocks, 2001), with a relatively long spawning period (from April to September). Eggs and larvae are planktonic, with post-larvae found in the mid water before becoming demersal, when reaching three centimetres (cm) in length (Wheeler, 1978).

9.140. Studies undertaken in the English Channel showed that lemon sole appeared to prefer sandy and gravelly sediments and tend to live at deeper depths, higher salinity and lower temperature than plaice or sole.

Distribution in the study area

9.141. Both the ISA and the RSA are within a large spawning and nursery ground for lemon sole (Figure 9.9).

9.142. During the 2011 benthic trawl survey lemon sole was recorded within the Project Alpha and Project Bravo areas within the ISA at several locations.

Sensitivity

9.143. Lemon sole, along with other flatfish, do not have swim bladders and are therefore classed as 'Group 1' (low sensitivity to sound pressure) after Popper *et al*. (2014), but lemon sole do have potential to detect acoustic particle motion (see also Appendix 9B).

Individual species accounts – elasmobranchs

9.144. This section describes the ecology and distribution of species of elasmobranch found in the study areas. Potential sensitivities of this group to activities associated with construction, operation and decommissioning of the Seagreen Project are described at the end of this section.

Spotted ray (*Raja montagui*)

Status

9.145. There is no stock assessment and therefore no estimate of biomass or numbers, but the population of this species is considered to be stable or even increasing in most of the OSPAR area, with an abundance which has fluctuated, but with no obvious trend (OSPAR, 2010a).

Ecology

9.146. The spotted ray inhabits inshore and shallow shelf seas, in depths of 8m - 283m, though it is most abundant in waters less than 100m deep. Juveniles tend to occur closer inshore on sandy sediments, whereas adults are more common offshore on sand and coarse sand-gravel substrates. Juveniles feed on small crustaceans, with adults feeding on larger crustaceans and fish (Ellis *et al*., 2005).

Distribution in the study area

9.147. The spotted ray has nursery grounds which are used at a low intensity across northern parts of the RSA (Figure 9.10).

Spurdog, or spiny dogfish (*Squalus acanthias*)

Status

9.148. The UK population is estimated to have declined by 95% and the species is now considered critically endangered (ICES 2010a). Although there is not a targeted spurdog fishery in Scotland they are still often caught as bycatch, particularly within otter trawls. A low fecundity, coupled with an extremely low growth rate makes spurdog vulnerable to commercial overexploitation.

9.149. At the beginning of the 20th century spurdog was abundant within the RSA, and often considered a nuisance by commercial herring fishermen, as they caused damage to the nets and catches. Landings increased rapidly during the late 1950s and early 1960s, but have since declined (ICES, 2010a).

9.150. Much of North Sea has been identified as nursery grounds of low intensity for the spurdog or spiny dogfish (Cefas, 2010). This area covers the WSA (Figure 9.11).

9.151. Spurdog are a Scottish Priority Marine Feature.

Ecology

9.152. Spurdog occurs mainly at depths between 10 and 100m. It tends to aggregate in large shoals of the same size or sex. Young are reliant on yolk reserves during embryonic development and fecundity increases with size. Spurdog produce live young, the size at birth ranges from 19cm to 30cm, though is more typically 26cm to 28cm. The pupping season is from August to December (ICES, 2010a). There is some evidence that they may undertake extensive migrations. Mature females migrate inshore to give birth to their young (Faber Maunsell, 2007).

Distribution in the study area

9.153. IBTS survey data for the years 1977 to 2005 indicate that spurdog is present across much of the North Sea with highest abundances found in the centre of the North Sea and offshore from the Moray Firth (ICES, 2010).

Tope (*Galeorhinus galeus*)

Status

9.154. Tope is widely distributed in the north-eastern Atlantic, occurring as far north as Norway. It is considered that there is a single stock of tope in the north-eastern Atlantic.

Ecology

9.155. Tope is viviparous and can produce between six to 52 pups per litter, but generally between 20 and 35. Their size at birth is between 30cm and 40cm. Males are sexually mature at an age of eight years with a length between 120cm and 170cm, and females mature at 11 years with a length of 130cm to 185cm. It is estimated that this species can reach an age of at least 55 years. The gestation period is approximately 12 months during which the females move inshore to nursery areas on the coast during the late summer to give birth.

Distribution in the study area

9.156. Much of the western part of the RSA and the entire ISA is within nursery grounds of low intensity for tope (see Figure 9.12).

Sensitivity of elasmobranch species

9.157. Elasmobranchs are known to be electrically and magnetically sensitive and therefore potentially susceptible to effects from EMFs associated with submarine power cabling (Gill *et al*., 2005). As noted previously, however, no significant change to EMFs are expected as a consequence of the proposed parameter variation. EMF effects are therefore scoped out of the assessment in line with the 2017 Scoping Opinion and further consultation.

9.158. Elasmobranchs do not have swim bladders and are therefore classed as 'Group 1' (low sensitivity to sound pressure) after Popper *et al*. (2014) but do have potential to detect acoustic particle motion (see also Appendix 9B).

9.159. The assessment of the potential impacts on elasmobranchs is particularly important as this group are generally slow to mature, produce small numbers of young and are already heavily impacted by fishing practices (targeted or as bycatch) and therefore are slow to recover from population decline.

Individual species accounts – shellfish and other fish species

9.160. A range of shellfish species occur in the WSA, including edible (brown) crab (*Cancer pagurus*), lobster (*Homarus gammarus*), velvet swimming crab (*Necora puber*), whelk (*Buccinium undatum*) and squid (*Loligo forbesi*). Information on the status of these species in terms of commercial value for fisheries is provided in the commercial fisheries technical report (Appendix 11A). In common with many other marine invertebrates, these species may be sensitive to the particle displacement component of underwater noise.

9.161. Other species of fish known to be present within the RSA (Table 9.10) include: pogge, dab, gobies, butterfish, Norwegian topknot, reticulated dragonet and common dragonet. The sensitivity of these species to underwater noise is considered in a grouped context.

9.162. Further details are provided below on identified key species, scallops and nephrops, which have been the subject of specific comments during scoping of the optimised Seagreen Project (2017), due to concerns about their potential sensitivity to elevated levels of suspended sediments and smothering associated with gravity base installation.

King scallop (*Pecten maximus*) and queen scallop (*Aequipecten opercularis*)

Status

9.163. King scallop in particular is a valuable fishery in Scottish waters. This is discussed further in Chapter 11 of this EIA Report (Commercial Fisheries).

Ecology

9.164. Scallops show a preference for areas of clean firm sand, fine or sandy gravel and may occasionally be found on muddy sand. Distribution of this species is invariably patchy (Marshal and Wilson 2009, Carter 2009) but the areas with greatest abundance tend to be areas of little mud and with good current strength.

9.165. In Scottish waters, scallops spawn for the first time in the autumn of their second year, and subsequently spawn each year in the spring or autumn. After settlement, scallops grow until their first winter, during which growth usually ceases. Thereafter, growth resumes each spring and ceases each winter, causing a distinct ring to be formed on the external surface of the shell.

Distribution in the study areas

9.166. King scallops were found to be present within Project Alpha and Project Bravo during the 2011 benthic trawl, video and grab surveys (Appendix 9A).

9.167. Queen scallops were far more numerous with 201 individuals found over 34 trawl locations in the 2011 benthic trawl survey.

9.168. Data provided by MSS (Figure 9.13) suggest that the key fishing grounds for scallops overlap with Project Alpha and extend to the north and west (inshore) of the Seagreen Project Area. This data set suggests relatively lower fishing effort in the Project Bravo area. Evidence in the commercial fisheries chapter (Chapter 11 [Commercial Fisheries], Figures 11.13 and 11.14) suggests that scallop fishing grounds overlap with the majority of both Project Alpha and Project Bravo.

Sensitivity

9.169. Scallops are filter feeders and plankton is their main food source. These species are therefore sensitive to changes in water quality, especially turbidity, which will affect the ability to source prey and which will in turn affect the abundance of food organisms. Scallops have numerous eyes around the shell margin each capable of forming an image, which along with other well developed sense organs make scallops highly sensitive to changes in their immediate surroundings. High levels of disturbance and turbidity can also affect larval development and subsequent cohort strength. High turbidity may also be detrimental to larval development (Shumway and Parsons, 2016).

9.170. Temporary increases in suspended sediments, or smothering, are expected to have a negligible effect on adult scallops owing to their ability to burrow and swim. The question remains, however, whether suspended sediment and smothering could affect juveniles. Scallops are affected by suspended sediment, with reduced growth rates from even modest increases (e.g. 11 to 37mg/l) and juveniles can suffer mortality if buried by a centimetre or so of sediment, but critically only when smothering occurs at low temperatures when scallops typically show low activity (Shumway & Parsons, 2016).

9.171. The technical note (Appendix 9C) on suspended sediments and smothering in relation to gravity base installation concluded that:

"Increases in suspended sediment levels are expected to be limited to hundreds of metres from the activity, with deposition, typically to a few mm in relation to excavation and a few cm in relation to disposal of any arisings, also expected to be limited to some hundreds of metres."

9.172. Given the above, and taking into account the lack of significant impact determined in the 2012 Offshore ES and reduction in the number of gravity base foundations potentially to be deployed in the proposed optimised Seagreen Alpha and Bravo OWFs, it was concluded unnecessary to undertake further work, such as physical processes modelling, to refine predictions of suspended sediment.

9.173. The potential for elevations in suspended sediments can also be compared to the same effect initiated through scallop dredging. Black and Parry (1999) studied the size, longevity and settling of sediment plumes created by scallop dredging. The gear used in the study was a small dredge 3.3 metres wide which was towed at 4 to 6 knots across a sandy seabed (typical mean gran size 220µm). The sediment plume was lifted 2m above the seabed and took approximately 120 minutes to settle out though this was the mud fraction; the sand fraction took only 3 to 4 minutes to settle out, akin to what is expected in the Seagreen Project area. Total suspended sediments peaked at 20m from the dredge at an equivalent of 4.77g/l (as compared to a background of 0.1g/l) which rapidly decreased to 2.68g/l at 50m from the dredge. Sedimentation from the plume was 2mm up to a few metres from the dredge, dropping to just 0.1mm at 20m from the dredge and then steadily decreasing to 0.001mm at 350m from the dredge.

9.174. The study indicates that only a short tow of a few hundred metres with a small dredge has the potential to liberate several tonnes of sediment into the water column. Outside the 12 nautical mile limit, vessels are permitted to tow up to 14 dredges per side, a considerably larger set of gear than that studied by Black and Parry (1999). This in turn suggests that the Seagreen Project area is already subject to periods of elevated suspended sediments, owing to scallop dredging, with smothered areas in the immediate vicinity of the activity.

9.175. Taking into account all of the above it is concluded that no further assessment of the potential impact of gravity base installation on scallops is required to update the information previously presented within the 2012 Offshore ES, where no significant adverse impact was determined.

9.176. Scallops, in common with other invertebrates, may have sensitivity to the particle displacement component of underwater noise and this is considered further below (impact assessment from paragraph 9.244, see also from paragraph 9.222).

Nephrops (*Nephrops norvegicus*)

Status

9.177. Nephrops is a valuable fishery in Scottish waters. This is discussed further in Chapter 11 (Commercial Fisheries).

Ecology

9.178. Distribution patterns of nephrops are determined by the presence of suitable habitats, i.e. muddy sediments. The sediment type determines the density of the population with greater densities seen on mud with a greater proportion of sand. Nephrops spend most of their time in burrows, only coming out to feed and look for a mate.

9.179. They are opportunistic predators, primarily feeding on crustaceans, molluscs and polychaete worms. Female nephrops usually mature at three years of age and reproduce each year thereafter. After mating in early summer, they spawn in September and the females carry eggs under their tails until they hatch in April or May. The larvae develop in the plankton before settling to the seabed six to eight weeks later (Scottish Government, undated).

Distribution within the study areas

9.180. Nephrops is a commercially important species within the RSA; however, the vast majority of landings are from ICES rectangle 41E7 to the south east of the ISA (Appendix 11A [Commercial Fisheries Technical Report]).

9.181. Much of the RSA has been identified as being nephrops spawning and nursery grounds which also incorporate all but half of the ISA, mainly in the Project Alpha site (Figure 9.14). However, nephrops were not recorded in any of the benthic surveys commissioned for this project. TV survey data provided by Marine Scotland for the 2012 Offshore ES showed that nephrops abundance was high in the inshore waters of the southern parts of this spawning and nursery ground.

9.182. Recent data forwarded by MSS (Figure 9.14) suggest that nephrops fishing effort is focused well to the south and inshore of the Seagreen Project area. This is consistent with understanding of ground conditions throughout the ISA which generally lack the muddy habitat required by this species (Appendix 9A [Seagreen Phase 1 and ECR Benthic Survey]).

Sensitivity

9.183. Adult nephrops are expected to be relatively tolerant of smothering because of their ability to burrow or swim. Research on the effects of suspended sediment and smothering on juvenile nephrops does not appear to have been carried out, but post-settlement individuals (with a carapace length of 3 to 7mm) are capable of forming burrows in mud (Cobb & Phillips, 1980). It is reasonable to conclude, therefore, that post-settlement nephrops are almost as tolerant of smothering as adults.

9.184. Irrespective of the limited sensitivity of this species to suspended sediments and smothering, its limited occurrence within the ISA and restricted range of effects of sediment dispersal and settlement from gravity base installation (see above in relation to scallops) lead to the conclusion that there is no potential for significant adverse impacts to occur. It is therefore concluded that no further assessment of the potential impact of gravity base installation on nephrops is required to update the information previously presented within the 2012 Offshore ES where no significant adverse impact was determined.

9.185. Nephrops, in common with other invertebrates, may have sensitivity to the particle displacement component of underwater noise.

Individual species accounts – migratory fish

9.186. The term migratory fish is used in this chapter to describe fish that migrate between fresh water and the marine environment. Five species of migratory, or diadromous, fish have been identified as relevant to the Seagreen Project and these are presented in Table 9.13, along with typical timings of their migrations. More detailed information on the baseline for Atlantic salmon is then provided, as requested within the 2017 Scoping Opinion and further consultation.

Table 9.13 Overview of life histories for migratory fish relevant to the Seagreen Project

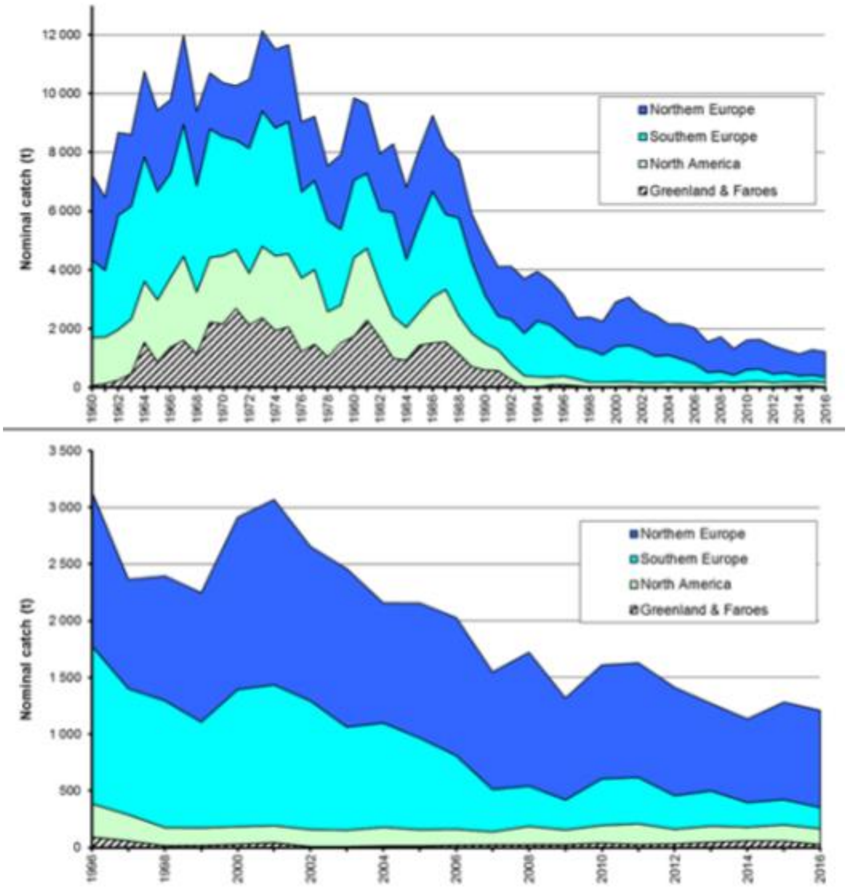
Species	Time spent in freshwater before downstream migration	Timing of downstream migration	Time spent at sea before first return	Timing of upstream migration
Salmon	2 to 3 years	April to May	1, 2 or 3 years	All year round with peak in late summer early autumn
Sea trout	2 to 3 years	Spring	2 or more	April to June
Eel	Males 7 to 20 yrs Females 9 to 50 yrs	Late spring	Many do not return to fresh water	January to June
Sea lamprey	3 to 4 years	July to September to open sea	18 to 24 months	April-May spawning in May/June
River lamprey	5 years or more. Remain in burrow in river silt beds until adults	July to September to feed in estuaries	2 years spent in estuaries	Winter and spring when temps are <10^{o}
Allis and Twaite Shad	Short period	-	Estuarine	April to May spawning in freshwater
Sparling (European smelt)	Short period	-	Estuarine	February to April spawning in freshwater

Atlantic salmon (*Salmo salar*)

Status

9.187. Salmon is of considerable cultural and conservation importance (Hindar *et al.*, 2010) and in Scotland represents an important part of the rural economy (Radford *et al.*, 2004). However, in recent decades, and especially the past thirty or so years, there have been declines across much of the species' range (Plate 9.2). There are many pressures on Atlantic salmon stocks in both marine and freshwater environments, including commercial and recreational exploitation of stocks, disease, impacts related to farmed salmon and climate change (ICES, 2017b).

Plate 9.2 Total reported nominal catch of salmon (tonnes round fresh weight) in four North Atlantic regions, 1960–2016 (top) and 1996–2016 (bottom). From ICES (2017b).



9.188. A Marine Scotland report on salmon fishery statistics (Marine Scotland, 2017) summarised rod and line, net and coble and fixed engine fisheries data for the period 1952 to 2016, based on completed fisheries returns. Rod caught spring salmon catches have declined since records began and are at a historically low level. The overall catch of salmon and, in later months, grilse, however, generally increased up to 2010, then fell sharply (second lowest on record in 2014) before recovering slightly in 2015 and 2016. By 2016 the reported catch and effort for the fixed engine and net & cobble fisheries were the lowest since records begin in 1952.

9.189. The Salmon Conservation Regulations which came into force in 2016 included measures to prohibit the killing of fish in coastal waters and in estuaries and rivers where the stocks were determined to be in poor conservation status. The great majority of rod and line caught salmon from the recreational fishery are returned to the water (90% of the annual catch in 2016).

9.190. Atlantic salmon is an Annex II species under the Habitats Directive and is a feature of various Special Areas of Conservation (SACs), although potential effects have been screened out of the Habitats Regulations Appraisal (Chapter 16) of this EIA Report.

9.191. Freshwater pearl mussel, which relies on migratory salmonids for part of its life cycle, is fully protected under Schedule 5 of the Wildlife and Countryside Act 1981 (as amended) and the freshwater pearl mussel is also listed on annexes II and V of the EU Habitats and Species Directive and Appendix III of the Bern Convention. The conservation status of the species is reflected in its listing as Endangered on the IUCN Invertebrate Red List.

9.192. Salmon are a Priority Marine Feature in Scotland, and an Annex III species under the Bern Convention.

Ecology

9.193. Following spawning by adult salmon in Scottish east coast rivers, the ova mature into fry and then parr before migrating to sea as smolts. At sea the smolts grow rapidly and after one to three years they return as adults to spawn, most commonly to their natal river. Many Atlantic salmon die after spawning, but some return to sea as kelts and may return again to rivers to spawn (Mills, 1989).

9.194. Malcolm *et al.* (2015) used metadata to assess the timing of smolt emigration across Scotland. This suggests that most fish leave rivers between around mid-April and the end of May. These results do not include the period spent by smolts in the coastal environment after leaving their native rivers. There was evidence that smolt emigration is becoming earlier (by around 1.5 days per decade over a period of around 50 years).

9.195. Migration of Atlantic salmon smolts through the Cromarty Firth and into the Moray Firth was tracked in a study undertaken for Beatrice Offshore Windfarm Ltd. by Glasgow University (BOWL, 2017). The study results indicated an eastwards migration of the tagged fish along the southern coast of the Moray Firth. Results also showed the majority of fish to remain predominantly within the upper 1m of the water column during migration. Mortality of smolts was considered to be mainly attributable to predation and there was a strong relationship between group survival, early migration and group size.

9.196. Atlantic salmon smolts were tracked using acoustic telemetry in the River Deveron (south coast of the Moray Firth) and adjacent coastal areas (Lothian *et al*., 2017). Deveron fish had higher swim speeds in the early marine phase compared with the river. The majority of fish left the river in darkness on a flooding tide. Early marine migration speed decreased with increased environmental noise levels. Fish movements in the marine environment appeared more influenced by water currents than geographical features.

9.197. It has been suggested that once in the marine environment the east coast Scotland ‘post smolts’, as they are known, are transported by North Sea currents firstly towards northern Norway and then into the Norwegian sea (Holst *et al*., 2000, Jonsson *et al*., 1993). Smolt emigration at sea is poorly understood, however, and Malcolm *et al*. (2010) outline a concept that fish from Scotland head west to feed and grow, utilising waters off West and East Greenland, as well as the Faroes, as evidenced by recaptures of Scottish fish in all these areas. This includes fish from the Aberdeenshire Dee, Tay and North Esk.

9.198. Adult returning fish are thus expected to arrive from broad sea areas, predominantly north and west of the British Isles. Multi-sea winter (MSW) salmon and grilse (one sea winter fish) may potentially utilise different areas and return from different directions; the picture is complex but Malcolm *et al*. (2010) propose the following conceptual model:

"Salmon and grilse return both to the north and west coasts of Scotland, and may even reach the north east coast directly, having passed Orkney and Shetland. After they reach the coast they move towards their home rivers, giving apparently variable patterns of migration. Given that MSW salmon rivers dominate the north and east coasts, the dominant direction of movement for MSW fish caught on the west will be north and east. However, for grilse, the pattern of movement would depend on where they reach the shoreline and where their native river was located. For the east coast rivers south of Aberdeenshire, the pattern appears clearer, with fish generally moving in a northward direction from the Northumberland coast."

9.199. Godfrey *et al*., (2014 and 2015) studied the swimming depths of adult salmon, predominantly fish on their first homing migration, returning to their natal rivers. The study focussed on the area around the Pentland Firth, between Orkney and the Scottish mainland on the north coast of Scotland (a region for the development of tidal energy [Shields *et al*., 2009, cited in Godfrey *et al*., 2014] and as an area which a large proportion of homing Scottish salmon may traverse [Malcolm *et al*., 2010]). Fish generally used surface waters (upper 5m) but all fish went below 10m and mean maximum depth was 67m (range 13 to 256m, reflecting available water depths in area) and it was therefore assumed that salmon may use the entire water column. Salmon swam in all possible directions from release points, up to 190km offshore but with a predominance of coastal locations. Most fish moved to rivers or coastal areas off the north coast; relatively few fish moved to east coast rivers. The study was also limited to larger (mainly two Season Winter) salmon, and the authors noted that the swimming behaviour of grilse (one-sea-winter salmon) remains unexplored.

Distribution in the study areas

9.200. Since 1994, data on numbers and weight of salmon caught and released in Scotland have been collected and published. However, for a number of important Scottish salmon rivers, rod catch data exists from as far back as 1952. The study areas for salmon and migratory fish are defined by rivers for which data are available. For salmon the WSA is defined as the whole of Scotland and the RSA includes all the east coast salmon rivers.

9.201. Rod catch data from rivers on the east coast of Scotland can provide insight into the general trends of salmon populations within the RSA. Data provided by Marine Scotland have been interrogated, with a focus on the following rivers relevant to the WSA: Tweed, Forth, Tay, South Esk and Dee. The Spey is also included as a major river just outside the WSA. At a simple level Figure 9.15) evidences that salmon migrate to/from a number of rivers in the vicinity of proposed development and therefore should be assumed very likely to pass through the ISA, either as smolts or returning adults.

9.202. The trends of rod caught salmon since the 1990s, shown in Figure 9.15, need to be considered in the context of marked declines in overall stocks of North Atlantic salmon shortly before this period began. The variable nature of rod and line fishing also needs to be taken into account. Overall, there is a mixed picture across rivers in the WSA, but generally consistent catch levels across the 26 year period within individual river systems, with catch returns typically varying by a few hundred to a thousand fish between periods. However, this represents up to around a 30% change where there are smaller fisheries, such as the decline seen in the River South Esk.

9.203. Overall it must be assumed that adult and juvenile salmon may pass through or close to the ISA. This is consistent with the assumptions made within the 2012 Offshore ES.

Sensitivity

9.204. Atlantic salmon have a swim bladder but this is not connected to the inner ear. They are therefore 'Group 2' species after Popper *et al*. (2014) and susceptible to barotrauma, although hearing only involves particle motion, not sound pressure.

Summary of Baseline

9.205. The baseline section has identified that a wide range of fish and shellfish species occur in the ISA, RSA and WSA, including many species of considerable commercial and/or conservation importance. In all cases there is considered to be potential susceptibility to effects due to underwater noise from foundation piling operations during wind farm construction which are scoped into the assessment because of the proposed optimised Seagreen Project (inclusion of piled foundations) and updated best practice guidance (notably Popper *et al*., 2014), which also recognises the potential importance of particle displacement in sound perception for some species.

9.206. This EIA Report has identified potential for impacts to occur a result of sound pressure changes for fish species with a swim bladder. Where the swim bladder is connected to the fish's hearing system and plays a part in hearing (e.g. cod and herring) effects of sound pressure could be physical (e.g. barotrauma) or behavioural; where the swim bladder is not connected to the hearing system (e.g. Atlantic salmon) only physical effects of sound pressure are considered possible and hearing relies on acoustic particle displacement. For fish species lacking a swim bladder, whilst barotrauma from extreme sound pressures is still possible, hearing only involves particle displacement. Particle displacement is also the mechanism via which effects on invertebrates (shellfish) could occur.

9.207. Further information on underwater noise effects is provided in the sensitivity section below, relevant aspects are then taken forward for assessment.

9.208. Following a review of the potential for suspended sediment to be mobilised and smothering to occur as a result of the installation of gravity base foundations there is considered to be no potential for increased effects on key shellfish receptors (scallops and nephrops). The expected magnitude and spatial scale of effects mediated by suspended sediments is too small. In addition, in the case of nephrops the receptor is also not present to any significant extent with the ISA for there to be cause to question the conclusions of the 2012 Offshore ES, which did not predict significant impacts in this regard. There is no proposed change to the gravity base design for the optimised Project, other than a reduction in the maximum number of turbines. Therefore, this matter is therefore not considered further within this EIA Report.

9.209. The baseline for Atlantic salmon has been updated in line with the Scoping Opinion and it is assumed that salmon could be present within the ISA.

Predicted Future Baseline

9.210. Information on the potential future baseline for key commercially exploited stocks such as scallop and whitefish is provided in the commercial fisheries chapter of this EIA Report (Chapter 11 [Commercial Fisheries]). This reflects some of the uncertainties which exist in relation to factors such as climate change and in fisheries management which is expected to be influenced by the withdrawal of the UK from the EU after 2019.

9.211. In summary, for scallop a relative decline in scallop fishing activity in the RSA is expected due to the need for a recovery period and there is potential for restrictions to be applied in relation to scallop dredging in Project Alpha and Project Bravo as a result of the implementation of conservation measures in the Firth of Forth Banks Complex MPA.

9.212. Squid is an increasingly important fishery in the RSA and is currently unregulated. As with scallop, future restrictions may be put in place in relation to the Firth of Forth Banks Complex MPA, although the highly mobile nature of this species may compromise the effectiveness of locally focused conservation measures. Notwithstanding fisheries pressures, the expected trend for squid is one of population increase, as this group exploits opportunities resulting from overfishing of other species and climate change (Doubleday *et al.*, 2016).

9.213. An increase in creel fishing for lobster and crab is anticipated, although, it is unclear to what extent this reflects increased stock levels as opposed to altered fishing effort.

9.214. Nephrops is not expected to increase in abundance within the ISA because of the limited habitat suitability and is therefore likely to remain of limited relevance to the Seagreen Project.

9.215. Herring and Atlantic salmon were highlighted in the 2017 Scoping Opinion and the following additional information on anticipated future baselines is provided.

9.216. Herring stocks are subject to active management and future condition of the stocks is expected to depend heavily upon the success of this management, particularly in relation to management of the commercial fishery. This includes future management which may potentially be outside the European Union Common Fisheries Policy and is currently subject to considerable uncertainty. In broad terms, it is noted that North Sea herring including the Buchan stock, are believed to be currently sustainable (Scottish Government, 2015) and would therefore be expected to remain so in the presence of successful fisheries management.

9.217. Salmon stocks have suffered long term decline and are under considerable pressure as noted above. Specifically in relation to climate change, ICES (2017c) have stated the following:

"Climate change (CC) can be expected to impact Atlantic salmon at both the regional and Atlantic Ocean scale. Numerous biotic and abiotic factors that affect salmon survival are likely to be modified by CC, but the relative impact and interactions among these factors are poorly understood. While there will be some negative impacts, some positive impacts can also be expected for some Atlantic salmon populations. CC has the potential to affect the distribution, productivity, migration patterns, genetic variation, and other biological characteristics of the species within the range of the populations."

9.218. It is hoped that in a national and regional context, the strong efforts made towards salmonid conservation will at least prevent further decline, but there is considerable uncertainty about future population levels. The future status of salmon stocks will depend in part upon the success of recently introduced conservation measures referred to above.

9.219. There is potential for change to the timing of migrations and the progressively earlier smolt run in recent decades have already been noted.

9.220. Spring salmon numbers have declined markedly since records began and it is unknown whether there may be further decline or future increases in this economically and ecologically important stock.

9.221. Improved understanding following projects such as the SALSEA-Merge Project (Holst, 2012) which has investigated the migration and distribution of salmon in the North-East Atlantic should allow improved fisheries management.

SENSITIVITY OF FISH AND SHELLFISH TO UNDERWATER NOISE

9.222. The following section sets out the basis for the assessment of effects from underwater noise, associated with foundation pile driving on fish and shellfish receptors. This relates to the assessment of the effects of sound pressure and acoustic particle displacement, which are both recognised as being potentially important, depending upon the physiology of individual species. More detailed information on current understanding of acoustic particle displacement in the mediation of effects from underwater noise is provided in the Technical Note, included as Appendix 9B of this EIA Report; however, it is recognised that there is relatively poor understanding of the effects of particle motion on fish and shellfish species (Hawkins *et al*., 2014b).

9.223. The passage of a sound wave underwater causes oscillatory pressure changes, as vibrating particles result in alternate rarefaction and compression. Detection of hydrostatic pressure changes may form the basis of hearing systems in fish species with a swim bladder (i.e. a compressible gas filled space) connected to their hearing system. This is also how sound is measured with hydrophones. However, it is the particle motion component which is the mechanism through which many organisms, including invertebrates and a large number of fish species, detect sound (Popper and Fay, 2011). In addition to this water-borne sound wave, vibrations within seabed sediments will occur, e.g. as a result of the physical interaction between a driven foundation and the seabed. This vibration is not distinct from noise but rather the particle displacement component of noise.

9.224. As noted previously, recent guidelines have been published by the Acoustical Society of America (Popper *et al*., 2014). In relation to developing metrics to support the assessment of impacts on fish receptors these authors note:

"It is especially important to develop metrics based on the functional hearing groups of fishes (e.g., fishes with swim bladders mechanically linked to the ear, fishes with swim bladders, and fishes without swim bladders). Metrics for fishes with swim bladders mechanically linked to the ear will likely be referenced to sound pressure, while those without swim bladders will likely be referenced to particle motion. It is possible that metrics for fishes with swim bladders that are not linked to the ear might be best characterized in terms of both acoustic pressure and acoustic particle motion."

9.225. The authors divide fish into three broad groups based on physiological differences as related to hearing sensitivity:

- Group 1: Fish with no swim bladder, or other gas chamber (e.g. mackerel, dab and other flatfish). These species are less susceptible to barotrauma and only detect particle motion, not sound pressure. However, some barotrauma may result from exposure to extreme sound pressures;
- Group 2: Fish with swim bladders in which hearing does not involve the swim bladder or other gas volume (e.g. Atlantic salmon). These species are susceptible to barotrauma although hearing only involves particle motion, not sound pressure; and
- Group 3: Fish in which hearing involves a swim bladder or other gas volume (e.g. Atlantic cod, herring and relatives). These species are susceptible to barotrauma and detect sound pressure as well as particle motion.

9.226. Popper *et al.* (2014) provide criteria for the onset of injury in relation to the above groups, together with broad vulnerability to non-injurial masking (impairment of hearing sensitivity by >6dB) and behavioural effects (defined as substantial change in behaviour such as a long term change in distribution, or altered migration pattern, but not small movements or effects to which habituation occurs). These are presented in Table 9.14. NB results are presented for sound pressure in all cases since no data for particle motion exist.

Table 9.14 Criteria for onset of injury, risk of masking and behavioural effects from pile driving (Popper et al., 2014).

Group	Mortality and potential mortal injury		Impairment				Behaviour*
			Recoverable injury		TTS (SEL_{cum} Weighted (dB re 1 µPa^2.s)	Masking*	
	SPL_{peak} Unweighted (dB re 1µPa)	SEL_{cum} Weighted (dB re 1 µPa^2.s)	SPL_{peak} Unweighted (dB re 1µPa)	SEL_{cum} Weighted (dB re 1 µPa^2.s)			
1. No swim bladder (particle motion detection)	>213	>219	>213	>216	>>186	N: Moderate I: Low F: Low	N: High I: Moderate F: Low
2. Swim bladder not involved in hearing (particle motion detection)	>207	210	>207	203	>186	N: Moderate I: Low F: Low	N: High I: Moderate F: Low
3. Swim bladder involved in hearing (pressure and particle motion detection)	>207	207	>207	203	186	N: High I: High F: Moderate	N: High I: High F: Moderate
Eggs and larvae	>207	>210	N: Moderate I: Low F: Low		N: Moderate I: Low F: Low	N: Moderate I: Low F: Low	N: Moderate I: Low F: Low

* Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as: near (N), e.g. 10s of metres; intermediate (I), e.g. 100s of metres; and, far (F), e.g. 1000s of metres.

9.227. The assessment of injury risk in fish is based on the thresholds presented above. Distance to threshold effect levels are predicted using the noise propagation modelling as previously described. As indicated in Table 9.14, behavioural effects, such as avoidance, and masking (blocking of biologically important sounds) are not related to quantitative criteria, but a relative risk scale is provided which has been adopted in the assessment.

9.228. Invertebrates are considered unlikely to detect, or otherwise be sensitive to, sound pressure changes, but particle motion detection may be important and allows sound detection via statocyst or other organs (Thomsen *et al*., 2015). It is believed that invertebrate sensitivity to particle motion may be around two orders of magnitude lower than in fish (Fay and Simmons, 1998). This would suggest that impacts resulting from particle motion should only occur at very close range for invertebrates. Consistent with this, Thomsen *et al.* (2015), noted that elevations in particle motion levels recorded 750m from a piling operation, considered to be detectable to fish, was unlikely to be detectable by marine invertebrates.

9.229. There is currently no evidence that particle motion can cause tissue damage to either invertebrates or fish, although information is limited (Popper *et al*., 2014). The assumption, in light of current evidence, is that particle motion sensitivity in fish and invertebrates is most likely associated with behavioural effects (Mueller-Blenkle *et al*., 2010; Hawkins *et al*., 2014a).

ASSESSMENT OF IMPACTS – WORST CASE SCENARIO

9.230. As identified within the 'Scope of Assessment' the impact assessment for natural fish and shellfish resource considers the potential impacts of the optimised Seagreen project on underwater noise, resulting from foundation pile driving. The potential for gravity base installation to give rise to significant impacts for scallop and nephrops as a result of suspended sediment mobilisation and deposition has been considered above and discounted. All other impacts have been scoped out of this EIA Report.

9.231. The assessment considers the potential impacts of Project Alpha alone; Project Bravo alone; Project Alpha and Project Bravo combined (the optimised Seagreen Project) and Project Alpha and Project Bravo in a cumulative scenario. The following sections set out the assessment of potential impacts during construction, operation and decommissioning phases of the Project. As set out in Chapter 6 (EIA Process), impacts reported are adverse unless stated otherwise.

9.232. The assessment considers only construction related impacts, as underwater noise generated from piling activities will only be generated during the construction phase. This is in line with the 2017 Scoping Opinion and further consultation (see Table 9.2). The proposed optimised Seagreen Project will not result in any differences in impacts to natural fish and shellfish resource receptors as a result of wind farm operation compared to the consented Project.

9.233. Similarly, the proposed optimised Seagreen Project will not result in any differences in impacts to natural fish and shellfish resource receptors as a result of wind farm decommissioning.

Worst Case Scenario

9.234. To inform the impact assessment on natural fish and shellfish resource, a worst case scenario has been defined using the information contained within the optimised design envelope for the optimised Seagreen Project, Chapter 5 (Project Description). The worst case represents, for any given impact, the scenario within the range of options in the design envelope that would result in the greatest potential for change to the receptors assessed.

9.235. Table 9.16, below, identifies the worst case scenario in relation to those issues scoped into the assessment and provides justification as to why no other scenario would result in a greater impact on the receptors considered. It should be noted that, while the WCS is defined for each impact for Project Alpha and Project Bravo in isolation, the WCS would be consideration of the projects combined (the optimised Seagreen Project). The impact assessment undertaken therefore considers the impacts of each project in isolation as well as the projects combined.

9.236. Both spatial and temporal WCS are considered within this assessment. The spatial worst case would represent the greatest area of impact and is associated with the highest energy pile driving, i.e. monopile foundation installation. The temporal worst case is the foundation installation scenario which would take the longest time, thus maximising the duration of impact, and is associated with installation of jacket foundations, as piling would take place over a longer period of time than for monopiles.

9.237. For injury and mortality the underwater noise modelling (Appendix 10B) provides predictions of the range of impact for each modelled scenario. The results in Table 9.15 represent the predicted distance to which a fish (herring or other Group 3 species) would be injured or killed if it was stationary throughout the duration of piling. The predicted impact ranges are relatively greater for jacket foundation installation because the cumulative energy from four events is greater than for the shorter monopile installations, despite the lower instantaneous hammer energy.

Table 9.15 Impact areas for mortality and recoverable injury according to the Popper *et al.* (2014) SEL_{cum} criterion for Group 3 fish including herring.

Scenario	Description	Recoverable injury area (km^2); range (m)	Mortality area (km^2); range (m)
1	Project Alpha Monopile, 3,000kJ,	1.98; 804	0.04; 141
3	Project Bravo Monopile, 3,000kJ	1.95; 822	0.01; 50
5	Project Alpha Jacket (4 pin piles), 1,800kJ	5.21; 1,354	1.64; 726
6	Project Bravo Jacket (4 pin piles), 1,800kJ	4.96; 1,312	1.58; 726
7	Project Alpha Simultaneous Monopile and Jacket (4 pin piles)	6.55	1.5
8	Project Bravo Simultaneous Monopile and Jacket (4 pin piles)	6.4	1.38
9	Projects Alpha & Bravo Simultaneous Jackets (2 x 4 pin piles)	8.83	2.83

9.238. Although impact ranges appear to be lower, monopile installation is believed to represent the realistic worst case for mortality and injury, because of the higher instantaneous energy levels. In practice, fish would be expected to move away from loud noise as piling energy ramped up though the soft start process. This is not assumed to serve as mitigation in the assessment but has been taken into account in the WCS selections summarised in Table 9.16.

Table 9.16 Worst Case Scenario Justification

Type of Impact	Worst Case Scenario (individual project)	Justification/Rationale of Selected Design Envelope Parameter
Construction		
Injury/disturbance from underwater noise	Project Alpha (spatial worst case): 70 x 3,000kJ monopile foundations.	Greatest effect range expected for highest energy piling (3,000kJ monopiles). In Project Bravo, remaining balance of 35 piled jacket foundations.
	Project Bravo (spatial worst case): 35 x 3,000kJ monopile and 35 x 1,800kJ, 2m diameter jacket foundations.	
	Project Alpha (temporal worst case): 70 x 1,800kJ, 2m diameter piled jacket foundations.	Each piled jacket involves four piling events. Total piling time and cumulative energy input into the marine environment is anticipated be greater than for 70 monopiles (Alpha) or 35 monopiles and 35 jackets (Bravo).
	Project Bravo (temporal worst case): 70 x 1,800kJ, 2m diameter piled jacket foundations.	
	Projects Alpha and Bravo Combined (spatial worst case): Concurrent piling of 70 x 3,000kJ monopile foundations at Alpha; 50 x 1,800kJ, 2m diameter piled jacket foundations at Bravo. It is assumed that monopiles and jacket pin piles are installed concurrently until all monopiles are installed, thereafter jacket pin pile installation continues alone until completion.	Project Alpha is closest to known area for herring spawning so greatest spatial overlap is with highest energy piling (3,000kJ monopiles). Remaining balance of WTGs is made up of jacket foundations at Project Bravo.
	Projects Alpha and Bravo Combined (temporal worst case): 70 x 1,800kJ, 2m diameter piled jacket foundations at Alpha; 50 x 1,800kJ, 2m piled diameter jacket foundations at Bravo.	Each piled jacket involves four piling events. Total piling time and cumulative energy input to the marine environment is anticipated be greater than for 70 monopiles (Alpha). Majority of foundation allocated to Alpha as closest to herring spawning area.
Operation		
No impacts scoped in to assessment.		
Decommissioning		
No impacts scoped in to assessment.		
Cumulative and in-combination		
Disturbance from underwater noise	Concurrent piling of 35 x 3,000kJ monopile foundations and 25 x 1,800kJ, 2m diameter piled jacket foundations at Alpha; 35 x 3,000kJ monopile foundations and 25 x 1,800kJ, 2m diameter piled jacket foundations at Bravo.	Maximum number of higher piling energy (monopile) foundations evenly split between Alpha and Bravo as spatial overlap with other projects is considered most likely to contribute to cumulative impacts. Balance of capacity allocated to piled jacket foundations.

ENVIRONMENTAL MEASURES INCORPORATED INTO THE PROJECT

9.239. Throughout the design evolution process and with consideration of the findings of the 2012 Offshore ES, measures have been taken to avoid potentially significant impacts wherever possible and practical to do so. Mitigation measures that are incorporated into the design of the project are referred to as 'environmental measures incorporated into the Project'. These measures are intended to prevent, reduce and where possible offset any significant adverse impacts on the environment. These are effectively 'built in' to the impact assessment and as such, the assessment includes consideration of these measures.

9.240. Mitigation measures that were identified and consent conditions applied to the originally consented project are provided within Chapter 7 (Scope of EIA Report). Measures relevant to the assessment of natural fish and shellfish resource are detailed below:

- A soft start to piling will be implemented which is anticipated to reduce the potential for injury or mortality of fish and shellfish from high levels of underwater noise associated with monopile installation:
  - For monopile installations, low hammer energies (approximately 400kJ or <15% of maximum energy) will be applied during the first phase of each piling operation, building up to 600kJ or 20% of maximum energy after 20 minutes. Hammer frequency will also increase steadily during the soft start, from around one blow every 10s in the first minute to around one every 2s between two and 20 minutes; and
  - For jacket pin pile installations, starting energy will be <15% of maximum energy, building up to 75% after a minimum of 15 minutes and 95% after not less than 45 minutes.
- This will allow mobile species to leave the area, reducing risk of injury as hammer energies increase; and
- Procedures will be incorporated into an Environmental Management Plan.

9.241. It is highlighted that underwater noise modelling has not assumed any avoidance response by fish during soft start which is considered a relatively precautionary assumption.

9.242. A number of consent conditions were attached to the original consents received for the Seagreen Project in 2014. These were defined to manage the environmental risk of the Project. Any future consents issued to Seagreen may include similar conditions to manage risk where necessary. Consent conditions applied to the originally consented project are provided within Chapter 7 (Scope of EIA Report).

9.243. Consent conditions relevant to the management of natural fish and shellfish resource include development and implementation of a Project Environmental Management Plan (PEMP), Condition 26, which requires pre-construction, construction and post-construction monitoring surveys for receptors, including sandeels, marine fish and diadromous fish. There is also a requirement for consideration of a lobster restocking programme under Condition 31, although this is tied to commercial fisheries impacts (see Chapter 11 of this EIA Report).

IMPACT ASSESSMENT – CONSTRUCTION PHASE

Project Alpha

Effects of noise – mortality and injury impacts

9.244. As stated previously, physical impacts including mortality and injury are only anticipated for those species which are sensitive to sound pressure, i.e. those that possess swim bladders. No such impacts are anticipated for species such as elasmobranchs, flatfish or mackerel which lack a swim bladder, or shellfish.

9.245. This assessment therefore relates to 'Group 2 and 3' fish species (after Popper *et al*., 2014) which includes key species highlighted during Scoping: Atlantic salmon and herring. Herring ('Group 3'), with a connection between their swim bladder and hearing systems, are relatively more sensitive than salmon ('Group 2') which lack such a connection but are still susceptible to barotrauma. The assessment therefore proceeds by first assessing the potential for impacts on Group 3 species, based on herring as a high importance and greater sensitivity species, before considering if it is appropriate to also assess Group 2 species.

9.246. Herring are an important species both in terms of commercial fisheries and in supporting other marine species such as marine mammals and seabirds. They are also a Priority Marine Feature and, as such, are considered as being of High importance.

9.247. Mortality, recoverable injury and TTS from pile driving for fish such as herring have been predicted based on the criteria presented by Popper *et al*. (2014) as summarised in Table 9.14. Contours for each of these three thresholds are indicated in Figure 9.16 and areas of influence in Table 9.15. This is based on underwater noise modelling completed for a worst case scenario of 3,000kJ monopile installation which is expected to represent the worst case for injury (maximum spatial effects from highest energy piling). The Worst Case for Project Alpha is installation of 70 monopiles using a 3,000kJ hammer. Figure 9.16 also presents equivalent thresholds for a monopile located in the northernmost part of Project Alpha, closest to the herring spawning area, which was modelled as a concurrent piling event with a jacket foundation to the south.

9.248. The range for potential impacts of recoverable injury (203dB SEL_{cum} threshold) for monopile installation is up to approximately 1km with a very much smaller range for potential mortality impacts (the latter is not discernible at the scale of reproduction in Figure 9.16, but is of the order of 200m).

9.249. It is important to note that noise modelling for this EIA Report has assumed that fish will not flee from piling noise but remain stationary. In practice it would be expected that adults of sound sensitive fish such as herring would move away from the highest magnitude sound, close to piling operations, and thereby reduce the practical range of impact for mortality and injury impacts. The noise modelling supporting this impact assessment is there precautionary in that it is assumed fish do not reduce their exposure by moving away.

9.250. Herring larvae would not be able to flee, however, recent research by Bolle *et al*. (2014) suggests that the 210dB SEL_{cum} threshold for mortality/injury (see Table 9.14) may be overly conservative (i.e. the true threshold may be higher). Sole, bass and herring larvae were exposed to pile driving noise reproduced at zero-to-peak sound pressure levels up to 210dB re 1 µPa, single pulse sound exposure levels up to 186dB re 1 µPa²s and cumulative sound exposure level (SEL_{cum}) up to 216 dB re 1 $\mu Pa^2 s$. Herring larvae were monitored over ten days with no significant difference in mortality levels to a control group. Boyle and New (2018) who reviewed a wide range of material relating to potential impacts of underwater noise on herring for ORJIP also concluded that significant impacts on herring eggs and larvae (and by implication those of other species) were unlikely, with a caveat that some literature suggests information is limited.

9.251. Herring are relatively fecund and have the ability to recover from population reductions, as evidenced by the improved status of stocks following previous overfishing in the wider North Sea area. An averagely sized female herring from the Buchan stock can produce 67,000 eggs and the species therefore has good resilience to localised mortality. Sensitivity is thus considered to be **Low**.

9.252. Monopile installation in Project Alpha is expected to take place over a period of up to around 18 months, focused between April and October, with up to 70 foundations installed within the overall construction period of approximately three years. This equates to up to around 280 hours of piling, 224 hours in the primary period between April and October (up to around 4% of this focal period would be active period, 96% no piling). It is assumed that herring will be present but even if they and other fish species do not move away from the highest levels of underwater noise associated with mortality and injury during piling soft start, which is believed to be a highly precautionary assumption, the spatial range of potential impact is limited. The overall magnitude of impact for herring is therefore concluded to be **Negligible** since no, or imperceptible, change to baseline condition of the community would be expected.

9.253. Whilst shellfish cannot move away as quickly as adult fish, and may not be mobile at all, as noted above, significant physical effects are not anticipated for groups sensitive to particle displacement rather than sound pressure. Whilst there is theoretical potential for extreme levels of particle displacement to result in injury, this has not been demonstrated in situ (Popper et al., 2014) and any risk of impacts occurring is believed to be limited to such short range that impacts would be **Negligible** (see also Appendix 9B).

9.254. The magnitude of impact is predicted to be **Negligible**, the sensitivity of herring is considered to be **Low** and therefore the overall impact is predicted to be **Negligible** which is **Not Significant** in EIA terms.

9.255. No other fish or shellfish species are expected to be more sensitive than herring or other Group 3 fish species to mortality or injury impacts from underwater noise.

Additional Mitigation

9.256. No additional mitigation is either required or proposed in relation to mortality or injury impacts on fish or shellfish as no adverse significant impacts are predicted.

Residual Impact

9.257. Impacts in relation to injury or mortality on fish or shellfish are predicted to be **Negligible**, no mitigation is required and therefore residual impact is also predicted to be **Negligible** and therefore **Not Significant** in EIA terms.

Effect of noise – behavioural impacts

9.258. Behavioural effects are here considered to be as defined in Popper *et al.* (2014), i.e. *"substantial change in behaviour for the animals exposed to a sound. This may include long-term changes in behaviour and distribution, such as moving from preferred sites for feeding and reproduction, or alteration of migration patterns. This behavioural criterion does not include effects on single animals, or where animals become habituated to the stimulus, or small changes in behaviour such as a startle response or small movements"*. Masking effects (impairment of hearing sensitivity by greater than 6dB) are also possible as a result of piling noise, but since effect ranges are expected to be similar (see Table 9.14), this is assessed here alongside behavioural consequences.

9.259. In contrast to mortality and injury, there are no proposed thresholds for behavioural impacts. Instead, Popper *et al*. (2014) suggest that there is a range (distance) related risk of impacts occurring with a relatively higher risk for herring and other fish species with swim bladders involved in hearing in the near to intermediate fields (tens to hundreds of metres) and a moderate risk in the far field (thousands of metres). The consequence of a substantial change in behaviour, such as movement away from suitable spawning areas, could be reduced breeding success which might have population level implications if it affected a sufficient area.

9.260. For species such as Atlantic salmon which relies on particle displacement for hearing Popper *et al.* (2014) suggests that there is a moderate risk in the mid-field (up to hundreds of metres) but a low risk of behavioural impacts beyond this. Given the relatively lower sensitivity of invertebrates to particle displacement effects it can be assumed that behavioural impacts would occur over shorter ranges than for fish species such as salmon, flatfish, elasmobranchs etc.

9.261. Jacket foundation installation which would take place over approximately 18 months within an overall construction programme of approximately three years is expected to represent the worst case scenario for behavioural impacts, as the period of disturbance would be maximised (Table 9.16). The worst case in this regard would be the installation of 70 jacket foundations (280 pin pile events). Total active piling duration for installation of 70 jacket piles is approximately 630 hours (or 4.8% of the overall installation period).

9.262. Pile driving for Project Alpha is expected to be focused between April and October with around 80% of piling events in this period. This encompasses the spawning season for herring which commences with aggregations of fish from around July, followed by principal spawning between August and September. The herring spawning grounds are located approximately 6.3km to the north and 80km to the southern boundaries of Project Alpha (Figures 9.2 and 9.16). An 18 month period of piling could encompass up to two herring spawning periods (and up to two spawning periods for other species although none are expected to be more sensitive to noise than herring).

9.263. Some limited information is available on the behavioural impacts of loud underwater noises from activities such as seismic airgun deployments. Pearson *et al.*, (1992) reported that caged rockfish *Sebastes spp*. exhibited no physiological stress when exposed to airgun noise and returned to normal behaviour within 14 to 30 minutes of the end of airgun operations. Experiments with caged fish need to be interpreted carefully (McCauley *et al.*, 2000) and thus the qualitative criteria suggested by Popper *et al*. (2014) are used here.

9.264. There is some suggestion that fish engaged in breeding activity may be less influenced by anthropogenic noise if their instinct to mate overrides the influence of the noise (e.g. Pena *et al*., 2013). Skaret *et al*. (2005) reported that the passage of a large vessel several times over a large shoal of spawning herring in Norwegian waters resulted in no evidence of disturbance, whereas avoidance had been noted outside the spawning period. The authors suggested that this is a 'risk-reward' situation where the animals needs to balance the risk of not moving away from a potential predator (or in this case disturbing level of noise) and continuing to engage in the spawning activity given the energy reserves put into reproduction and short 3 to 7 day window for spawning. Conversely, the authors noted that avoidance reactions seen at other times may be due to the adoption of a low-risk behaviour to potential predators, to maximise the chances of successful reproduction at a later date.

9.265. Overall, based on current guidelines (Popper *et al.*, 2014) it is expected that there is moderate risk of behavioural impacts occurring in the far field (thousands of metres) which suggests a likely overlap with a small proportion of the herring spawning area to the north, but not the spawning area to the south, of Project Alpha. The 2012 Offshore ES suggested that significant disturbance (strong avoidance reaction) was expected to affect up to 3% of the herring spawning area to the north and some 9% of the herring nursery grounds in the WSA. Comparative figures cannot be produced based on the more qualitative guidelines now applied (Popper *et al.*, 2014).

9.266. The magnitude of impact for herring is expected to be similar for monopile installation, since although there would be an estimated two year programme the total duration of piling is expected to be less (70 monopiles = approximately 280 hours of active piling, or 1.6% of the overall installation period compared to 630 hours/4.8% for jackets). Piling events would typically take place every 1 to 3 days during summer and autumn, including the herring spawning season, with more than 95% of time on average being 'quiet' (i.e. no piling).

9.267. Sensitivity of herring and other Group 3 species (after Popper *et al.*, 2014) to behavioural effects of underwater noise is considered to be **Medium**. There may be increased ability to tolerate noise during spawning and their fecundity, together with likely return to normal behaviour shortly after the cessation of each piling event, is likely confer resilience, but there is potential for an impact to occur. The relatively short periods of active piling compared to periods in between piling events have also been taken into account.

9.268. The magnitude of the impact is considered to be **Low,** i.e. potentially detectable, but taking into account the limited overlap with herring spawning and nursery areas, and relatively higher importance of spawning (and fishing) areas well to the north, it is not considered realistic that more than 10% of the population would be affected.

9.269. The magnitude of impact is predicted to be **Low**, the sensitivity of herring is considered to be **Medium** and therefore the overall impact is predicted to be **Minor** which is **Not Significant** in EIA terms.

9.270. Other Group 3 fish species include gadoids such as cod and whiting. Cod spawn very widely (Figure 9.4) with a peak in April which could overlap with the main period of piling, but lower levels of spawning take place between January and March when piling activity would be expected to be at a lower intensity. Whiting spawn between May and July, but across a very broad area offshore on the east coast of Scotland. Although also Group 3 species, their hearing sensitivity is not believed to be as acute as herring (Popper *et al.*, 2014). Both species are concluded to have no greater sensitivity to disturbance from foundation piling than herring.

9.271. Sprat, a clupeid like herring, also have relatively good hearing. They spawn through summer but over the majority of the UK shelf (Figure 9.4) and without known specific habitat requirements (being broadcast spawners). Intermittent localised disturbance (extending some thousands of metres from each Project) is considered very unlikely to represent more than a **Negligible** impact for this species.

9.272. No other fish or shellfish species are expected to be more sensitive than herring or other Group 3 fish to behavioural impacts from underwater noise. The impact for Group 1 and 2 fish, and all shellfish, is therefore considered to be **Negligible** and **Not Significant** in EIA terms.

Additional Mitigation

9.273. No additional mitigation is either required or proposed in relation to behavioural impacts on fish or shellfish as no adverse significant impacts are predicted.

Residual Impact

9.274. Behavioural impacts on fish or shellfish as a result of underwater noise are predicted to be **Minor**, no mitigation is required and therefore residual impact is also predicted to be not more than **Minor** and **Not Significant** in EIA terms.

Project Bravo

9.275. Fish and shellfish data collected for the ISA, RSA and WSA did not distinguish between those found in Project Alpha and Project Bravo. Therefore potential impacts for Project Bravo will be similar to those assessed for Project Alpha. As such, the impact assessment for Project Bravo described in the sections below makes reference to the preceding sections regarding Project Alpha and are a summary of the impacts.

Effect of noise – mortality and injury impacts

9.276. Receptor importance is considered to be High (based on an assessment for herring) and sensitivity **Low** (also based on herring) as determined for Project Alpha from paragraph 9.244.

9.277. The Worst Case for Project Bravo is the installation of 35 monopiles using a 3,000kJ hammer and 35 jacket foundations using a 1,800kJ hammer (refer to Table 9.2).

9.278. Impact ranges for mortality and injury from monopile and jacket pile installation are predicted to be slightly shorter for Project Bravo than Project Alpha (Table 9.15), but as this is based on modelling of single representative locations it is assumed that average impact ranges will be equivalent.

9.279. Monopile installation in Project Bravo is expected to take place over a period of up to around 18 months; however, it is assumed here on a precautionary basis that the small number of piling events (35) would occur over less than 12 months, focused between April and October. This is within an overall construction programme of approximately three years. Jackets would be installed within the same period (if concurrent), or over a further period of up to 12 months (total two years). The total time piling would be up to 427 hours, just under 5% of time if piling was condensed into 12 months.

9.280. The magnitude of impact for herring is not expected to be any greater than for Project Alpha and is therefore concluded to be **Negligible** since no, or imperceptible, change to baseline condition of the community would be expected.

9.281. The magnitude of impact is predicted to be **Negligible**, the sensitivity of herring is considered to be **Low** and therefore the overall impact is predicted to be **Negligible** which is **Not Significant** in EIA terms.

9.282. No other fish or shellfish species are expected to be more sensitive than herring or other Group 3 fish to behavioural impacts from underwater noise. The impact for Group 1 and 2 fish, and all shellfish, is therefore considered to be **Negligible** and **Not Significant** in EIA terms.

Additional Mitigation

9.283. No additional mitigation is either required or proposed in relation to mortality or injury effects on fish or shellfish as no adverse significant impacts are predicted.

Residual Impact

9.284. Impacts in relation to injury or mortality on fish or shellfish are predicted to be **Negligible**, no mitigation is required and therefore residual impact is also predicted to be **Negligible** and **Not Significant** in EIA terms.

Effect of noise – behavioural impacts

9.285. The potential effects of underwater noise from foundation installation and the sensitivity of receptors are as detailed from paragraph 9.258.

9.286. As for Project Alpha, the worst case for behavioural impacts is considered to be piling of maximum duration which is installation of up to 70 jacket foundations over approximately two years (280 pin pile events, total active piling duration approximately 630 hours or 4.8% of the overall installation period). There is a slight decrease in the area of overlap with the herring spawning area to the north (compared with Project Alpha) but in the context of the anticipated effect range which is expected to be 1000s of metres and the fact that the herring spawning area is representative, not absolute, this is assumed not likely to affect impact magnitude.

9.287. Impact magnitude for Project Bravo is considered to be equivalent to Project Alpha (**Low**), as a minor change to baseline condition (<10%) is not ruled out.

9.288. The magnitude of impact is predicted to be **Low**, the sensitivity of herring is considered to be **Medium** and therefore the overall impact is predicted to be **Minor** which is **Not Significant** in EIA terms.

9.289. No other fish or shellfish species are expected to be more sensitive than herring or other Group 3 fish to behavioural effects from underwater noise. The impact for Group 1 and 2 fish, and all shellfish, is therefore considered to be **Negligible** and **Not Significant** in EIA terms.

Additional Mitigation

9.290. No additional mitigation is either required or proposed in relation to behavioural impacts on fish or shellfish as no adverse significant impacts are predicted.

Residual Impact

9.291. Behavioural impacts on fish or shellfish as a result of underwater noise are predicted to be **Minor**, no mitigation is required and therefore residual impact is also predicted to be not more than **Minor** and **Not Significant** in EIA terms.

Project Alpha and Project Bravo Combined

9.292. This section draws together the impacts considered for Project Alpha and Project Bravo so that the impacts of the Seagreen Project as a whole can be understood.

9.293. Table 9.17 brings together information on impacts assessed within each project and evaluates whether there is potential for significant combined impacts in light of the worst case scenario considered. Seagreen have confirmed that there would not be simultaneous piling of monopiles at Project Alpha and Project Bravo. There could however be simultaneous piling of jackets in Project Alpha and Project Bravo (noise modelling Scenario 9 in Underwater Noise Technical Report, Appendix 10B). As stated in relation to

Project Alpha and Project Bravo, the WCS for physical injury and mortality impacts is considered to be associated with installation of monopile foundations because of the relatively high instantaneous energy levels compared to jacket pin piles.

9.294. As previously stated, the Offshore Transmission Asset Project is already licenced and is therefore considered alongside other projects and plans in the cumulative assessment below (paragraph 9.311).

Table 9.17 Confirmation of scenarios for assessment of combined impacts (Project Alpha and Project Bravo)

Impact	Project Alpha	Project Bravo	Worst Case Scenario (see also Table 9.16)	Potential for significant combined impact
Effect of noise-mortality and injury impacts	Negligible (all species)	Negligible (all species)	Spatial worst case: concurrent piling of 70 x 3,000kJ monopile foundations at Alpha; 50 x 1,800kJ, 2m diameter piled jacket foundations at Bravo.	No (combined impacts would not exceed Minor adverse). NB it is not considered realistic that simultaneous piling of monopile or piled jacket foundations at Alpha and Bravo would occur so closely (within approximately 1km) that injury zones would overlap.
Effect of noise-behavioural impacts	Minor (herring and other Group 3 species) Negligible (all other species)	Minor (herring and other Group 3 species) Negligible (all other species)	Temporal worst case: 70 x 1,800kJ, 2m diameter piled jacket foundations at Alpha; 50 x 1,800kJ, 2m diameter piled jacket foundations at Bravo	Yes (herring and other Group 3 species). No (all other species, combined impacts would not exceed Minor given limited expected range of effect [10s to 100s of metres]).

Effect of noise – mortality and injury impacts

9.295. As set out in Table 9.17, there is concluded to be no likelihood of significant adverse impact due to mortality or injury from foundation piling at Project Alpha and Project Bravo combined on any fish or shellfish species. Impact zones would not interact and the impact (not more than Minor for each Project individually) would therefore not be additive and not expected to exceed **Minor** overall significance, which is **Not Significant** in EIA terms. Therefore this impact is not considered further in relation to Project Alpha and Project Bravo in combination within this EIA Report.

9.296. The potential for behavioural impacts from foundation piling at Project Alpha and Project Bravo combined on fish behaviour, specifically Group 3 fish species (Popper *et al.*, 2014) with swim bladders connected to their hearing system, is considered below.

9.297. Significant behavioural impacts are not expected for other fish and shellfish species, including those with swim bladders, but relying on particle motion for hearing, and are not considered further in this EIA Report. This is because of the limited anticipated range of impact (moderate risk of behavioural impacts up to 100s of metres only, low risk in the far field) such that overlapping impact zones are not expected.

Effect of noise – behavioural impacts (herring and other Group 3 fish species)

9.298. Information on the sensitivity of receptors and magnitude of impacts are provided in paragraph 9.258.

9.299. Impacts of up to Minor significance were predicted for Project Alpha and Project Bravo in isolation (Table 9.17).

9.300. The worst case in relation to the overall duration of piling is assumed to be installation of 70 piled jacket foundations at Project Alpha and 50 piled jacket foundations at Project Bravo, installed consecutively. The installation programme would be expected to take approximately 24 months in total (within an overall offshore construction period of approximately four years) with 80% of piling events focused in the seven months between April and October (inclusive).

9.301. The above foundation installation programme represents 480 piling events (120 jackets x 4 pin piles) and 1,080 hours of active piling (135 minutes per pin pile). This is around 6% of the total installation programme (i.e. no piling for 94% of the time) but with 80% of events expected between April and October there would be expected to be piling for approximately 8.5% of the time in this period.

9.302. The potential for herring's normal response to anthropogenic noise to be overridden by spawning instincts was discussed previously. Together with the relative dominance of no-piling periods over periods of active piling, it is not considered likely that effects would combine to result in a significant impact for herring.

9.303. Other Group 3 fish species include gadoids such as cod and whiting. Cod spawn very widely (Figure 9.3) with a peak in April which could overlap with the main period of piling, but lower levels of spawning take place between January and March when piling activity would be expected to be at a lower intensity. Whiting spawn between May and July but across a very broad area offshore on the east coast of Scotland. Although also Group 3 species, their hearing sensitivity is not believed to be as acute as herring (Popper *et al*., 2014). Both species are concluded to have no greater sensitivity to disturbance from foundation piling than herring.

9.304. Sprat, a clupeid like herring, also have relatively good hearing. They spawn through summer but over the majority of the UK shelf (Figure 9.5) and without known specific habitat requirements (being broadcast spawners). Intermittent localised disturbance (extending some thousands of metres from each Project) is considered very unlikely to represent more than a **Negligible** impact for this species.

9.305. The magnitude of impact is predicted to be **Low**, the sensitivity of herring and other Group 3 fish species is considered to be up to **Medium** and therefore the overall impact is predicted to be **Minor** which is **Not Significant** in EIA terms.

9.306. No other fish or shellfish species are expected to be more sensitive than herring or other Group 3 fish to behavioural effects from underwater noise. The impact for Group 1 and 2 fish, and all shellfish, is therefore considered to be **Negligible** and **Not Significant** in EIA terms.

Additional Mitigation

9.307. No additional mitigation is either required or proposed in relation to behavioural impacts on fish or shellfish as a result of the combined impacts of Project Alpha and Project Bravo as no adverse significant impacts are predicted.

Residual Impact

9.308. Behavioural impacts on fish or shellfish as a result of underwater noise from the combined Project Alpha and Project Bravo is predicted to be not more than **Minor**, no mitigation is required and therefore residual impact is also predicted to be not more than **Minor** and **Not Significant** in EIA terms.

IMPACT ASSESSMENT – OPERATIONAL PHASE

9.309. The proposed optimised Seagreen Project will not result in any differences in impacts to natural fish and shellfish resource receptors as a result of wind farm operation compared to the consented Project. Operational effects were therefore scoped out of the assessment in line with 2017 Scoping Opinion and further consultation (Table 9.2).

IMPACT ASSESSMENT – DECOMMISSIONING

9.310. The proposed optimised Seagreen Project will not result in any differences in impacts to natural fish and shellfish resource receptors as a result of wind farm decommissioning. Decommissioning effects were therefore scoped out of the assessment in line with the 2017 Scoping Opinion and further consultation (Table 9.2).

IMPACT ASSESSMENT: CUMULATIVE

9.311. The EIA Regulations require the assessment of cumulative impacts. This requires consideration and assessment of existing projects, projects under construction and consented or proposed projects identified in relevant development plans and programmes that have the potential to impact cumulatively with the optimised Seagreen Project.

9.312. Cumulative impacts can occur when the impacts from one project on an identified receptor combine (through either spatial or temporal overlap) with similar impacts from other projects on the same receptor. The purpose of considering cumulative impacts is to understand if the impacts from the optimised Seagreen Project parameters (Project Alpha and Project Bravo), when considered together (combined), or cumulatively with other plans and projects are different, or more significant than from the individual projects in isolation. This enables additional mitigation to be identified, as appropriate.

9.313. Cumulative impacts are considered for all stages of the optimised Seagreen Project throughout construction, operation and decommissioning. However, in line with the scoping opinion for natural fish and shellfish resource only construction related effects are scoped into the assessment.

9.314. It should be noted that the Offshore Transmission Asset is already licenced and is unchanged, therefore this is considered alongside the other identified projects and plans. The Offshore Transmission Asset includes limited piling for up to five offshore sub-station foundations which is assumed to represent either five monopile or 20 jacket pin pile foundations as the worst case in terms of underwater noise. Construction of the Offshore Transmission Asset will also generate noise from rock dumping, vessel movement and cabling laying, but these will generate much lower levels of noise than piling and are not considered likely to interact with other plans or projects to give rise to a significant impact on fish or shellfish receptors.

9.315. Identification of relevant projects and developments has been informed by scoping and wider consultation, as set out within Chapter 7 (Scope of EIA Report). Potential cumulative impacts considered within the assessment are set out below. Projects were identified where construction programmes could overlap with Seagreen and there is considered to be potential for spatial or temporal overlap of impacts of at least Minor significance at the individual Project level.

9.316. In addition to the Offshore Transmission Asset, Neart na Gaoithe and Inch Cape Offshore Wind Farms are included in the cumulative impact assessment. Inch Cape is a consented scheme of up to 110 WTGs. There is an alternative Design for which scoping was submitted in May 2017 for up to 72 WTGs. Inch Cape is approximately 15km east of the Angus Coastline and approximately 10km west of the Project Alpha at its closest point (Figure 9.1).

Table 9.18 Confirmation of scenarios for assessment of combined impacts (Project Alpha and Project Bravo)

Project	Minimum distance from Seagreen (km)	Worst Case Scenario (see also Table 9.16)	Anticipated Period of Foundation Piling (duration)
Seagreen Alpha and Seagreen Bravo OWFs	0	70 x 1,800kJ, 2m diameter piled jacket foundations at Alpha; 50 x 1,800kJ, 2m piled diameter jacket foundations at Bravo. 480 piling events and 1,080 hours of active piling	January 2022 to December 2023 (24 months)
Seagreen Offshore Transmission Asset Project	0	5 x piled jacket foundations for offshore sub-stations (assumed equivalent to Seagreen Project piled jacket foundations) Assumed 20 events/45 hours piling	Assumed within period of Project Alpha and Project Bravo piling (or immediately before/after)
Neart na Gaoithe OWF consented (Mainstream, 2012, as varied)	30	64 WTG jackets x 4 pin piles (2.5 or 3.5m diameter), 1,635kJ max hammer, extensive drill-drive likely to be required and will reduce piling energy inputs. Estimated 213 hours piling (200 min per pile)	Assume as Neart na Gaoithe (alternative)
Neart na Gaoithe OWF alternative Design (Mainstream, 2018)	30	54 WTG jackets, 6 piles per jacket and 2 OSP jackets with 8 piles per jacket and one met mast with 4 piles per jacket. Total number of piles: up to 344 (1,635 kJ hammer) Pile Driving time for 6 piles: 6 to 21 hours. Pile driving to occur over a 15 month (maximum).	2021 (15 months)
Inch Cape OWF (Inch Cape Offshore Limited, 2013)	10	110 piled jackets (4 x 2.43m pin piles each) and 1,200kJ hammer.	Uncertain, assume overlap with Seagreen is possible
Inch Cape OWF alternative Design (Red Rock Power, 2017)	10	72 piled jackets (4 pin piles each) and 2,400kJ hammer	Uncertain, assume overlap with Seagreen is possible

9.317. Neart na Gaoithe is a consented installation of up to 64 WTGs. There is an alternative Design for Neart na Gaoithe of up to 54 WTGs. Neart na Gaoithe is approximately 15.5km from Fife Ness on the Fife coastline and approximately 30km south west of the Seagreen Project.

9.318. Other plans and projects are considered either too small (e.g. Forthwind) or distant (e.g. Moray Firth East and Moray Firth West OWFs) and it is not considered that there will be pathways for significant cumulative impacts between these and the optimised Seagreen Project.

9.319. Given the historic nature of the fishing industry, any impacts from fisheries upon the fish and shellfish communities are considered to be part of the baseline and are not considered within the cumulative assessment.

9.320. The worst case scenarios for Inch Cape, Neart na Gaoithe, the Offshore Transmission Asset Project and the optimised Seagreen Project are set out above in Table 9.18.

9.321. Mortality and injury impacts of underwater noise were not taken forward for assessment of the combined Project Alpha and Project Bravo because Project level impacts were predicted to be Negligible and are likewise not considered likely to combine in any significant manner with the wider projects, as impacts will be spatially limited to the optimised Seagreen Project Area and waters immediately adjacent. The cumulative assessment therefore focuses on the worst case scenarios for behavioural impacts which focuses on the likely duration of impact for each project.

9.322. As with the assessment of combined effects between Projects Alpha and Projects Bravo, significant cumulative impacts are only considered possible for those species susceptible to behavioural disturbance over greater ranges, i.e. Group 3 fish (Popper *et al.*, 2014) which are potentially at risk of disturbance over distances of thousands of metres from the piling noise source. There is therefore considered to be no risk of significant cumulative impacts for other species of fish and shellfish where the risk of impact is expected to be limited to hundreds of metres.

Effect of Noise – Behavioural Impacts (Herring and Other Group 3 Fish Species)

9.323. Information on the sensitivity of receptors and magnitude of impacts are provided from paragraph 9.258.

9.324. Impacts of up to Minor Significance were predicted for Project Alpha and Project Bravo in combination.

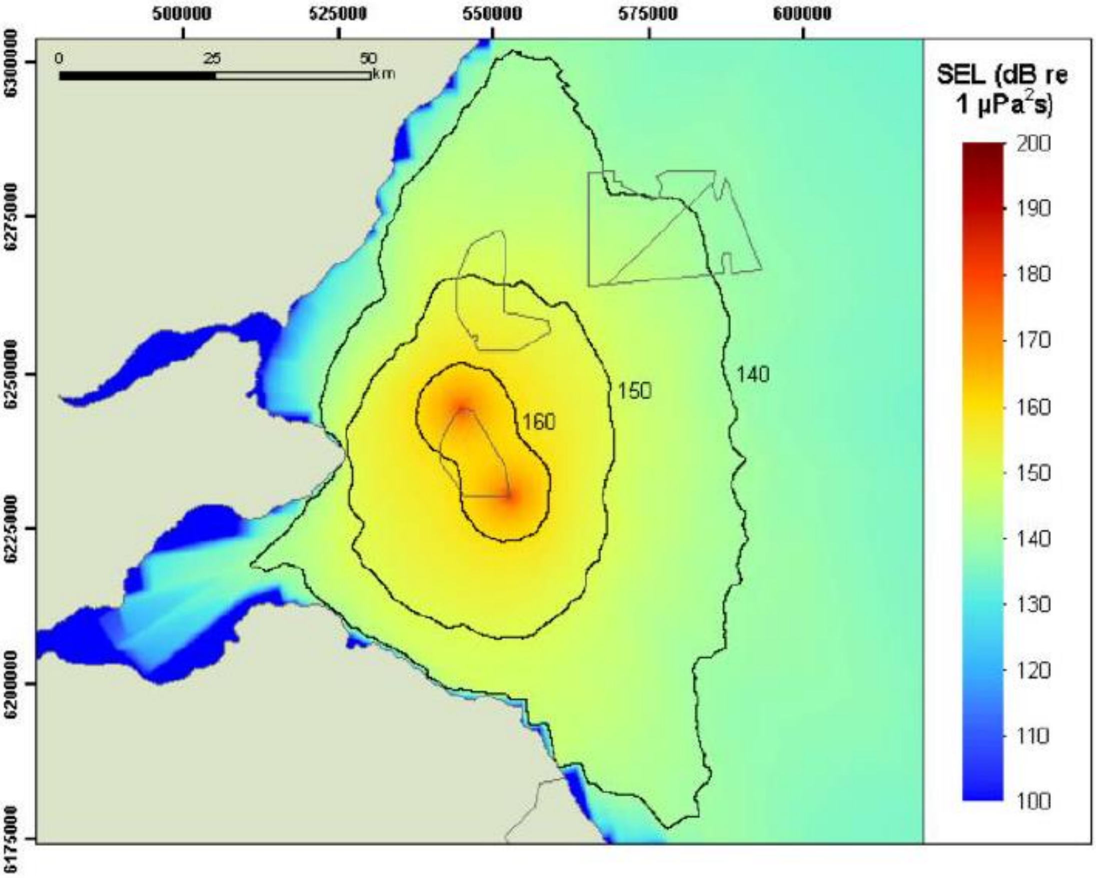
9.325. The worst case scenarios for the Inch Cape and Neart na Gaoithe projects are considered to be the consented schemes in each case. These both comprise greater numbers of WTGs than the proposed alternative designs and with jacket foundations planned in all cases it is assumed that total piling duration would more likely be greater.

9.326. The combined programme for all projects represents approximately 1,000 separate piling events over an anticipated minimum two year period. It is highly unlikely that there would be overlap between all projects. It is however assumed that the worst case would be consecutive piling (no overlap but minimal gaps between projects) which is also highly unlikely but believed to be a conservative assumption.

9.327. Inch Cape is more distant from herring spawning grounds to the north, closer to those around the south of the Firth of Forth. Neart na Gaoithe is a similar distance from herring spawning grounds as the optimised Seagreen Project (Figure 9.2). Whilst these projects may extend the duration of disturbance to herring and other species, the relatively close proximity of the optimised Seagreen Project and Neart na Gaoithe suggest that both will have no impact on herring spawning grounds to the south and similar impacts on the grounds to the north, potentially affecting <10% of the spawning area based on evidence presented previously (paragraph 9.268). If piling did occur simultaneously at these projects it is not expected that the resultant impact ranges would be larger, or areas affected greater to a significant degree; rather, it is the duration of impact which would increase.

9.328. The recent ORJIP report on impacts on fish of piling at offshore wind farms (Boyle and New, 2018) adopted the TTS threshold for herring and other Group 3 fish species (186dB SEL_{cum} unweighted) as a threshold for disturbance to adult herring and applied noise modelling for a 4,000kJ hammer to arrive at a predicted disturbance effect range of 15.4km. Whilst TTS is not used here as a surrogate for disturbance (Popper *et al*. (2014) guidelines are adopted which suggest a moderate risk of disturbance to herring in the far field/1000s of metres) it is interesting to note that the predicted range to 186dB SEL_{cum} is less than 11km for monopiles at Project Alpha or Project Bravo and a maximum of 16.9km for jacket foundation piling (4 pin piles) (Figures 9.16, Figure 9.17 and Appendix 10B, Table 3.5). Comparable distances would be expected for jacket pile installation at Inch Cape or Neart na Gaoithe; the latter project modelled jacket foundation installation and results suggest that there would be no overlap of the 186dB SEL contour with other regional wind farm projects (Plate 9.3).

Plate 9.3 Predicted unweighted SEL during concurrent pile driving at Neart na Gaoithe OWF (from Mainstream, 2018).



9.329. The cumulative impacts of these projects are not considered likely to combine in a manner which would cause the impact magnitude to increase above that which was concluded for Project Alpha and Project Bravo in combination. Depending on construction schedules, the combined effect of construction of the three wind farms would be to extend the duration of disturbance impacts, not to increase the proportion of herring or other fish spawning/nursery areas affected by the individual projects to any significant degree.

9.330. There is some uncertainty in this conclusion because of the potential for limited areas of herring spawning grounds (north of the Seagreen Project) to be disturbed over multiple consecutive years, potentially five to six years if all projects were constructed sequentially.

9.331. The magnitude of impact is predicted to be **Low**, the sensitivity of herring and other Group 3 fish species is considered to be up to **Medium** and therefore the overall impact is predicted to be **Minor** which is **Not Significant** in EIA terms.

9.332. No other fish or shellfish species are expected to be more sensitive than herring or other Group 3 fish to behavioural effects from underwater noise.

Additional mitigation

9.333. No additional mitigation is either required or proposed in relation to behavioural effects on fish or shellfish as a result of the combined effects of Projects Alpha and Bravo as no adverse significant impacts are predicted.

Residual impact

9.334. Behavioural impacts on fish or shellfish as a result of underwater noise from the combined Project Alpha and Project Bravo is predicted to be not more than **Minor**, no mitigation is required and therefore residual impact is also predicted to be not more than **Minor** and **Not Significant** in EIA terms.

INTERRELATIONSHIPS

9.335. Interrelationships describe the potential for impacts to arise through the interaction of multiple project impacts upon one receptor and can have a spatial and/or temporal component.

9.336. Impacts may occur throughout different phases of the project (construction, operation or decommissioning). An example would be underwater noise from piling, operational turbines, vessel noise and decommissioning interacting to create a more significant impact on one or more receptors than the individual phases. Alternatively, different project impacts may have spatial overlap and interact to create a more significant impact on a receptor than when considered in isolation. An example of this would be the combined impacts of underwater noise, habitat loss, EMF etc. resulting in a greater impact on natural fish and shellfish resource receptors than the same impacts considered in isolation. Resultant impacts may be short term, temporary or longer term over the lifetime of the Project.

9.337. No potentially significant inter-relationships have been identified in relation to natural fish and shellfish resource. Only construction related impacts have been scoped into the assessment. It is also noted that operational noise impacts will be at a much lower level than construction noise and therefore spatially restricted and not anticipated to interact in such a way as to result in significant combined impacts. Likewise, Negligible or Minor impacts from effects such as habitat loss, EMF etc. would not be expected to combine with construction noise in a significant manner.

TRANSBOUNDARY IMPACTS

9.338. No transboundary impacts are predicted for natural fish and shellfish resource because impacts are not expected to extend beyond Scottish waters.

MITIGATION AND MONITORING

9.339. There is acknowledged to be some uncertainty relating to the assessment of disturbance impacts on fish, specifically herring spawning and the potential for cumulative impacts with Inch Cape and Neart na Gaoithe wind farms, if there are consecutive foundation piling installation programmes. Whilst it is relatively unlikely that there will be consecutive foundation installation programmes, which could extend the effective period of disturbance to five or six years, should such a situation arise Seagreen would explore appropriate monitoring of herring spawning stocks. This is considered to be a regional issue and so a collaborative approach with other projects would be investigated.

9.340. No other mitigation or monitoring requirements have been identified as a result of the assessment for natural fish and shellfish resource.

IMPACT ASSESSMENT SUMMARY – THE OPTIMISED SEAGREEN PROJECT

9.341. This chapter has assessed the potential impacts on natural fish and shellfish resource of the construction, operation and decommissioning phases of the optimised Seagreen project, both in isolation and cumulatively. Where significant impacts have been identified, additional mitigation has been considered. Table 9.19 summarises the impact assessment undertaken and the conclusion of residual impact significance.

9.342. The 2012 Offshore ES predicted equivalent Negligible or Minor adverse mortality and injury impacts, due to underwater noise for all species and scenarios.

9.343. For all species other than herring the 2012 Offshore ES predicted equivalent Negligible or Minor adverse behavioural impacts due to underwater noise for all scenarios.

9.344. However, the following Significant impacts were predicted in relation to behavioural impacts on herring from pile driving of wind turbine jacket foundations:

- Project Alpha, Moderate adverse;
- Project Bravo, Moderate adverse;
- Projects Alpha and Bravo combined, Major adverse; and
- Cumulative with other Projects, Major adverse.

9.345. The above predictions of significant adverse impacts were arrived at in the 2012 Offshore ES because of predicted spatial overlap between modelled levels of underwater noise, impacts and mapped herring spawning and nursery grounds. This EIA Report uses the same information on herring spawning and nursery areas and so differences relate to the developments made in underwater noise modelling and guidelines used to inform the assessment.

9.346. The 2012 Offshore ES used the dB_{ht} (species) metric (Subacoustech, 2012). Marine Scotland Science have advised that the ASA guidelines should be used in this EIA Report.

Table 9.19 Summary of Predicted Impacts for the optimised Seagreen project

Receptor	Potential Impact	Phase (C, O or D)	Impact Significance	Additional Mitigation Measures	Residual Impact Significance
Project Alpha					
All fish and shellfish	Noise – mortality and injury	C	Negligible adverse (Not Significant)	n/a	Negligible
Group 3 Fish, including herring	Noise – behaviour	C	Minor adverse (Not Significant)	n/a	Minor
Other fish and shellfish species	Noise – behaviour	C	Negligible adverse (Not Significant)	n/a	Negligible
Project Bravo					
All fish and shellfish	Noise – mortality and injury	C	Negligible adverse (Not Significant)	n/a	Negligible
Group 3 Fish, including herring	Noise – behaviour	C	Minor adverse (Not Significant)	n/a	Minor
Other fish and shellfish species	Noise – behaviour	C	Negligible adverse (Not Significant)	n/a	Negligible
Projects Alpha and Bravo Combined					
All fish and shellfish	Noise – mortality and injury	C	Negligible adverse (Not Significant)	n/a	Negligible
Group 3 Fish, including herring	Noise – behaviour	C	Minor adverse (Not Significant)	n/a	Minor
Other fish and shellfish species	Noise – behaviour	C	Negligible adverse (Not Significant)	n/a	Negligible
Cumulative Impact Assessment					
All fish and shellfish	Noise – mortality and injury	C	Negligible adverse (Not Significant)	n/a	Negligible
Group 3 Fish, including herring	Noise – behaviour	C	Minor adverse (Not Significant)	n/a	Minor
Other fish and shellfish species	Noise – behaviour	C	Negligible adverse (Not Significant)	n/a	Negligible
Key: C = Construction, O = Operational, D = Decommissioning					

Fish groups after Popper *et al.* (2014)

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