CHAPTER 12: NATURAL FISH AND SHELLFISH RESOURCE

Technical Summary

Data from benthic trawl surveys of the Seagreen Project areas were supplemented with publicly available commercial fish landings data. The lesser sandeel was the most numerous species caught during the survey, followed by dab, goby, pogge and butterfish. The landings data indicated the commercial importance regionally of scallops, crab, lobster and nephrops.

The main impact on fish and shellfish in the area of the Seagreen Project is considered to be due to noise generated from construction activities, in particular from pile driving. Sound sensitive species such as herring are likely to be particularly vulnerable. The Seagreen Project areas overlap with a herring spawning ground and significant impacts on herring are predicted for Project Alpha and Project Bravo individually. No significant impacts are predicted as a result of potential disturbance of sensitive fish species by electromagnetic fields effects from the array cables in Project Alpha and Project Bravo or from the high voltage export cables in the Transmission Asset Project.

Significant cumulative impacts on herring are predicted for the full Seagreen Project and for the Seagreen Project cumulatively with other projects. The cumulative impacts on all other fish and shellfish species are predicted to be not significant.

INTRODUCTION

12.1. This chapter of the Environmental Statement (ES) describes the existing environment with regard to the natural fish and shellfish resource within the Seagreen Project area, as well as across the wider North Sea. Other aspects of marine ecology are covered elsewhere in this ES, for example, Chapter 11: Benthic Ecology and Intertidal Ecology, and Chapter 13: Marine Mammals.

12.2. This chapter provides a description of the distribution and seasonal abundance of fish and shellfish species which are known to occur, or which have been recorded (during Seagreen baseline studies) in the study areas (as defined in Existing Environment) and/ or across the wider region. This description draws upon data collected through site specific and/ or regional surveys, both in the published and grey literature, and as a result of original data collection. Subsequent to this, the assessment of potential impacts of the construction, operation and decommissioning phases of the Seagreen Project on the existing environment are presented and details of the proposed mitigation that may be considered by Seagreen are also outlined. Finally, outline approaches to monitoring are presented.

12.3. This chapter of the ES was produced by Royal Haskoning and should be read in conjunction with Chapter 14: Commercial Fisheries as the two chapters are interlinked. All figures can be found in ES Volume II: Figures. All appendices can be found in ES Volume III: Appendices.

CONSULTATION

12.4. Table 12.1 summarises issues that were highlighted by the consultees in the Scoping Opinion (Marine Scotland, January 2011) and indicates which sections of the chapter addresses each issue.

Table 12.1 Summary of consultation and issues

Date	Consultee	Issue	Relevant chapter section
January 2011	Joint Nature Conservation Committee (JNCC), Scottish Natural Heritage (SNH) and Marine Scotland	Impacts on fish (e.g. sandeels, *Ammodytes marinus*) should be considered in the context of species of conservation concern and those which are important for sustaining other important species (e.g. birds and marine mammals).	Construction Impacts and Operation Impacts sections of this chapter
January 2011	JNCC and SNH	Fish of conservation concern include qualifying interests of adjacent Special Areas of Conservation (SACs) (i.e. Atlantic salmon, sea lamprey and river lamprey, sparling, Allis and Twaite shad) and species listed as a priority on UK Biodiversity Action Plan (UKBAP), International Council for the Exploration of the Sea (ICES) and International Union for Conservation of Nature (IUCN) Red lists (i.e. European eels).	Individual species accounts - migratory fish In this chapter
January 2011	Marine Scotland	The ES will need to consider potential impacts on migratory fish including salmon, sea trout, lamprey and European eel during all phases of the project.	Operation Impacts: Disturbance effects of electromagnetic fields, of this chapter
January 2011	JNCC and SNH	A recent review by Marine Scotland (Malcolm *et al*., in prep) summarises available information on the migratory routes and behaviour of Atlantic salmon, sea trout and European eel which may help inform assessment of the movement of some key species on the east coast of Scotland.	Construction noise impacts; Death or injury and Behaviour, of this chapter
January 2011	JNCC and SNH	The levels of noise production (from construction of the foundations) that can be expected should be set-out and, using published literature (including SNH report (Gill *et al*., in prep)), the impact, if any, this will have on fish movements and behaviour should be considered.	Construction noise impacts; Death or injury and Behaviour, of this chapter
January 2011	Marine Scotland	Noise assessments should take into consideration background noise.	Construction noise impacts; Death or injury and Behaviour, of this chapter
January 2011	JNCC and SNH	The levels of operational noise that is expected to be generated should be set-out, and the impact this may have on fish should be considered.	Impact Assessment- Operation, Noise In this chapter
January 2011	Scottish Environment Protection Agency (SEPA)	There is a need to ensure that the native oyster (*Ostrea edulis)* is not present where works are proposed in the marine environment.	Construction Impacts and Operation Impacts of this chapter

Date	Consultee	Issue	Relevant chapter section
January 2011	Association of Salmon Fishery Boards (ASFB)	The proposed developments should be conducted in full consultation with the local District Salmon Fishery Boards and Fishery Trusts. The Trusts may have a particular interest in assessing potential impacts and monitoring the interactions between fish and developments such as these.	Operation Impacts section of this chapter
January 2011	ASFB	Construction impacts to be considered: Physiological and behavioural effects of underwater noise and vibration Direct effects on fish of water quality Indirect effects of water quality changes through effects on food	Construction Impacts and Operation Impacts sections of this chapter
January 2011	ASFB	Operational impacts to be considered: Physiological and behavioural effects of underwater noise and vibration Electrical or magnetic field effects Indirect effects on fish of permanent changes in habitat	Construction Impacts and Operation Impacts sections of this chapter
January 2011	Marine Scotland	In cases where there is uncertainty over potential impacts it may be necessary for the developer to implement a monitoring strategy to assess the impacts on salmonid fish populations.	Construction Impacts and Operation Impacts sections of this chapter
January 2011	Marine Scotland	The fisheries sensitivity maps were compiled from a variety of sources, in some cases historical data, and although they are a useful source of information, they are only indicative. For several species, there is more recent and/ or site specific information available.	Individual species accounts - migratory fish in this chapter
January 2011	Marine Scotland	Species ecology and migratory behaviour should be considered.	Operation Impacts section of this chapter
January 2011	Marine Scotland	The scoping report identifies considerable uncertainty associated with export cable routes and the significance of electromagnetic field (EMF) impacts. Given the potential for cumulative and in combination effects in the area, these should remain in scope	Operation Impacts section of this chapter
January 2011	Forth Estuary Forum (FEF)	The importance of the proposed site for sandeel spawning will have to be addressed.	Construction Impacts and Operation Impacts sections of this chapter
January 2011	FEF	More information on elasmobranchs may be required and the effect of EMF on these as well as on fish and shellfish populations	Operation Impacts: Disturbance effects of electromagnetic fields, of this chapter
January 2011	Scottish Anglers National Association Limited (SANA) and Sea Trout Group (STG)	SANA have concerns regarding potentially large changes in scouring and deposition of soft sea bed caused by turbine placement that could change sandeel spawning dynamics and even encourage fish and bird predation due to vortices in tidal streams.	Construction Impacts and Operation Impacts sections of this chapter

Date	Consultee	Issue	Relevant chapter section
January 2011	SANA and STG	Concerned about the impact of noise and increased shipping transport on fish during the construction phase.	Operation Impacts section of this chapter
January 2011	SANA and STG	Major concerns about the impact of EMFs around subsea cables on the migratory behaviour of salmon.	Operation Impacts: Disturbance effects of electromagnetic fields, of this chapter
January 2011	SANA	Developers must produce an account of the mitigating measures that they propose, accompanied by peer reviewed evidence of the efficacy of such measures	Construction Impacts and Operation Impacts sections Table 12.24 in this chapter
February 2012	Marine Scotland	In response to the HRA screening: Consider the potential impacts of noise, EMF and perceived barrier effects. The potential for noise to affect migration should also be considered.	Construction Impacts and Operation Impacts sections of this chapter
February 2012	JNCC/ SNH	In response to HRA screening: Cumulative impacts in respect to SAC fish need to be considered.	Cumulative Impact Assessment of this chapter

ASSESSMENT METHODOLOGY

Study Area

12.5. Three areas of study have been identified, within which potential impacts on natural fish and shellfish resources will be considered, the Immediate Study Area (ISA), the Regional Study Area (RSA) and the Wider Study Area (WSA). For reasons of data coverage the study relates to ICES rectangles and these are displayed in Figure12.1 (all figures can be found in ES Volume II: Figures).

- the Immediate Study Area (ISA) – Includes the Project Alpha, Project Bravo and Transmission Asset Project areas (including the Export Cable Route (ECR) corridor). Relevant ICES rectangles are shown on Figure 12.1;
- 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 on Figure 12.1.

12.6. The rationale for choosing three separate study areas is due to the large variation in the mobility of the species considered and the likelihood of their presence within the projects at any one time. Therefore, different study areas will be applied to different species according to their ecology and geographical range. The study areas are approximately aligned with, but not identical to those presented in Chapter 14: Commercial Fisheries, in this ES and follow the ICES rectangle system which is used for reporting of fishing data.

12.7. The coastal boundary for all three study areas is delineated by the Mean High Water Spring (MHWS) tidal limit. All onshore works are being assessed as part of a separate Environmental Impact Assessment (EIA) which will terminate at Mean Low Water Spring (MLWS). This results in an overlap of study areas between the offshore and onshore developments. This approach follows that adopted for some previous Round 1 and Round 2 offshore wind farms.

Data Collection, Survey and Analysis

12.8. All key data sources that have been utilised and commissioned by Seagreen to characterise the baseline environment and inform subsequent impact assessment are listed in Table 12.2

12.9. It was agreed with Marine Scotland that as there are existing data spanning several years available for the study area that no further specific fish surveys for commercial species were necessary (Letter from Marine Scotland 2nd March 2011 to Seagreen). However, as part of the epibenthic trawl surveys undertaken by The Institute of Estuarine and Coastal Studies (IECS), as presented in Chapter 11: Benthic and Intertidal Ecology in this ES and detailed below, all fish species encountered were recorded and a measurement of the length of each individual was recorded. These fish data are considered in this chapter and summarised in Table 12.2.

Table 12.2 Summary of key data and surveys

Title	Source	Year(s)	Reference
EC 2009 -2011	Marine Scotland Science (MSS)	2009-2011	East Coast Scallop surveys 2009 - 2011
MIK 2009	MSS	2009	Mackerel egg survey 2009
Sandeel Presence all Demersal Gears	MSS	1927-2010	Sandeels present during Marine Scotland surveys
Scottish Sandeel grounds	MSS	undated	Marine Scotland FOI
Fishing Grounds_lat_long	MSS	undated	Marine Scotland FOI
Firth of Forth Nephrops TV surveys	MSS	2008-2010	Nephrops TV survey 2008 - 2010
North Sea survey for Juvenile cod (Cod 0-group)	MSS	2007	Gibb *et al* 2007
North Sea survey for Cod eggs (Cod stage I eggs)	MSS	2008	Fox *et al* 2008
Discards from demersal fishing	MSS	2008-2010	Demersal discard survey work, 2008 - 2010
Discards from pelagic fishing.	MSS	2008-2010	Pelagic discard survey work, 2008 - 2010
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
Landings data	MSS	2006-2010	Marine Scotland FOI request
Seagreen Benthic Survey- Grab samples – Phase 1	IECS	2011	IECS, 2011
Seagreen Benthic Survey- Grab samples – Export Cable route	IECS	2011	IECS, 2011

Title	Source	Year(s)	Reference
Seagreen Benthic Survey- Benthic Trawl samples Phase 1	IECS	2011	IECS, 2011,
Seagreen Benthic Survey- Benthic Trawl data – Export Cable route	IECS	2011	IECS, 2011
Seagreen Benthic Survey- Video Trawl samples Phase 1	IECS	2011	IECS, 2011
Seagreen Benthic Survey- Video Trawl data – Export Cable route	IECS	2011	IECS, 2011
Seagreen Fish length data- from Benthic Trawl Phase 1	IECS	2011	IECS, 2011
Seagreen Fish length data- from Benthic Trawl ECR	IECS	2011	IECS, 2011
Seagreen Winter fish survey Inch Cape	AMEC Environment and Infrastructure Ltd.	2012	AMEC Ltd 2012.
Construction Noise modelling 2012	Subacoustech Ltd	2012	Nedwell *et al.*, 2012

12.10. Key species for assessment were selected based upon the landings data, species which have nursery or spawning grounds in the area, conservation importance and whether they were raised in the stakeholder consultation.

Video sampling

12.11. A drop down video camera was deployed prior to each beam trawl. The system was a VideoRay Pro 3 XE Professional Remotely Operated Vehicle (ROV), connected to a control panel with a 15 inch colour display via an umbilical cable, allowing real time analysis of video footage. Footage was also captured on mini digital video cassette and external hard drive.

12.12. Field notes were taken recording sediment type, epifauna (including potential biogenic reefs) and any observed obstructions at each deployment. The video footage was then analysed and the species present, sediment type and any other points of interest were recorded. Each sample station was assigned biotope codes using The Marine Habitat Classification for Britain and Ireland v04.05 (Connor *et al*, 2004). A preliminary classification of habitats was made by IECS; this was then used to inform the habitat mapping work of Envision described below. Further detail of the equipment and methodology used during video sampling are presented in Appendix G1 found in ES Volume III: Appendices.

Epibenthic trawl sampling

12.13. A total of 53 epibenthic sample stations were identified by Royal Haskoning within the ISA, 50 within the original Seagreen Phase 1 area (encompassing Project Alpha and Project Bravo) and a further three in the Export Cable Route (ECR) corridor.

12.14. Following the deployment of the VideoRay system, a 2m beam trawl with a 5m long net, 40mm mesh liner inside, and a 5mm (knot to knot) square mesh cod end liner was deployed in close proximity to the video line. The trawl was lowered from the survey vessel to the seabed at the predetermined start point and towed for approximately 10 - 20 minutes over a path of approximately 500m while maintaining a speed of between 1 - 1.5 knots.

12.15. The trawl line was logged using Differential Global Positioning System (DGPS) at the start (lock of the winch) and end of the trawl (engagement of the winch). The 1m cod end with 5mm mesh was hauled aboard with the aid of a lifting rope to ensure the cod end was lifted independently of the beam. A single tow was carried out at each identified trawl line.

12.16. Any large specimens were identified on board the vessel, recorded, photographed and then returned to the water. The remaining catch was transferred to a clean, labelled bucket and fixed using 4% formo-saline solution and transported to the laboratory for taxonomic identification. All fish were measured and rounded down to the nearest millimetre (total length or an appropriate measure in case of species with extreme body shape; i.e. skates and rays) and these measurements form a separate data source that is used in this chapter. Further details of the equipment used and the methodology can be found in Appendix G1 in ES Volume III: Appendices.

Noise Modelling

12.17. The modelling of noise from piling operations was undertaken by Subacoustech Environmental using a sub-sea acoustic modelling software package called the Impulse Noise Propagation and Impact Range Estimator (INSPIRE). The INSPIRE model shows the range at which different species are affected by underwater sound from the source of the noise (i.e. pile driving) by calculating noise contours.

12.18. The model is validated against a large existing database of measurements of piling noise. The unit of measurement used throughout the study for underwater sound is the decibel scale (dB) which uses a unit of one microPascal (µPA) as a reference unit.

12.19. In order to take into account the changes in sound transmission relating to local bathymetry and physical conditions, 180 transects were modelled for each pile location spaced at two degree intervals for 360 degrees around the pile location. Tidal states have also been taken into account, as too has a worst case water depth of Mean High Water Springs (MHWS). For full details of the methodology please refer to Appendix H6, in ES Volume III: Appendices.

Approach to Assessment

12.20. The impact assessment follows the standard methodology as presented in Chapter 6 EIA Process in this ES and the description of the Seagreen Project as presented in Chapter 5 Project Description in this ES. The existing environment has been described using the data sources above and the impacts identified and assessed in terms of their significance.

12.21. Project details have been used to establish the worst case development scenario for the assessment of impacts. The worst case scenario for the receptor varies depending on the sensitivity of the receptor and the type of impact being considered. The worst case scenario is set out in Table 12.14a – 12.14c and is assessed within the specific sections of the impact assessment.

12.22. Table 12.3 defines the sensitivity and conservation value or importance of fish and shellfish receptors to potential impacts, based on the degree to which the receptors are valued nationally, regionally, or locally as well as their capacity to accommodate impacts.

Table 12.3 Definition of terms relating to the sensitivity of fish and shellfish receptors

Receptor sensitivity / value	Marine fauna and flora importance	Receptor characteristics
High	International/ National	Species which have been designated for their internationally or national importance i.e. UK BAP species / OSPAR designations/ IUCN Red list/ Annex II species. Sensitivity: The receptor has no or very limited capacity to accommodate the proposed form of change and the impact may cause death or permanent damage.
Medium	Regional	Species that have been designated for their regionally important biodiversity or habitat (Local BAP species). Sensitivity: Receptor has limited capacity to accommodate the proposed form of change or it may result in behavioural changes.
Low	Local	Species that have been designated as having local importance Sensitivity: Receptor has some tolerance to accommodate the proposed change.
Negligible	N/ A	Species with little or no local importance Sensitivity: Receptor is generally tolerant and can accommodate the proposed change

12.23. The level of magnitude of an impact on each receptor is defined in Table 12.4 and can be described in terms of the extent, duration, frequency, severity and probability.

Table 12.4 Definition of terms relating to the magnitude of potential impacts on fish and shellfish

Magnitude of impact	Definition
High	Fundamental change to the baseline condition of fish and shellfish ecology, resulting in major alteration to the population density, diversity or abundance. The change affects the majority (>50%) of the population.
Medium	Detectable but non-fundamental temporary or permanent consequential changes to the baseline condition resulting in noticeable alteration of the size and/ or quality of habitats, species or biodiversity. The change affects >10% proportion of the population.
Low	Minor change with only slight detectable changes, which do not (or only temporarily) alter the baseline condition of the receptor. Small proportion (<10%) of the population only is affected.
Negligible	An imperceptible or no change to the baseline condition of the fish community

12.24. The significance of an impact whether positive or negative can be determined by a consideration of both magnitude of the impact and the sensitivity of the receptor. This is based on the data available and a judgement on the potential interaction that will occur between the receptor and the impact. The significance will also capture the spatial extent and duration of the interaction between impact and receptor as well as the probability that the impact will occur and that the receptor will be present at the same time. Where there is less confidence in predictions based on evidence available a precautionary approach will be taken. Table 12.5 defines the significance prediction matrix used in the impact assessment.

Table 12.5 Significance Prediction Matrix

Value / Sensitivity	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

EXISTING ENVIRONMENT

12.25. Distribution patterns of fish are determined by a number of factors including abiotic factors such as water temperature, salinity, depth, local-scale habitat features and substrate type and biotic factors including predator-prey interactions, competition and anthropogenic factors (e.g. the presence of artificial structures in the marine environment and type and intensity of commercial fisheries). This section describes the ecology, distribution and sensitivities of the key species of fish and shellfish.

Immediate Study Area (ISA)

12.26. The ISA (see Figure 12.1) is characterised by water depths ranging between 41 metres (m) and 61m. The sediments across the ISA were described by Envision Mapping (as presented in Chapter 11: Benthic and Intertidal Ecology in this ES). From east to west across the Seagreen Project area the sediments range from gravelly sand and sandy gravel, to slightly gravelly sand. Along the ECR corridor, at its western end the substrate consists of slightly gravelly muddy sand, changing to slightly gravely sand further east and then to cobble and sand adjacent to where it enters the Project Alpha site.

12.27. At the landfall for the Transmission Asset Project the sediments are characterised by gentle gradients (maximum 2.5°), comprising mainly fine or silty fine sands. However, the gradient steepens (≤9.5°) towards bathymetric depressions which are typically marked by a series of gravelly ridges. Some irregular rock outcrops occur just to the north of the ECR, suggesting that the finely granular sediment cover is relatively thin in that area, as presented in Chapter 7: Physical Environment in this ES.

12.28. As part of the benthic survey, designed to sample benthic epifauna and flora within the ISA, 53 trawls were completed within the survey area (see Figure 11.2 and 11.3 in ES Volume II: Figures), 50 within the original Phase 1 area and a further three in the ECR corridor. Although this survey regime was not designed to sample all fish species, any fish species collected in the trawls were identified and the length of each specimen was also recorded, providing a species list for the Seagreen Project area. The results of this are displayed in Table 12.6 below. (The equivalent species list for the ECR survey can be found in Table 12.7).

Table 12.6 Fish species recorded during the benthic trawl survey program (Original Phase 1 area) 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

12.29. The species list displayed in Table 12.6 is unlikely to include all species in the area, as the surveys were carried out over a relatively short time period and only sampled demersal (bottom dwelling) species. It must be assumed that other species are also present within the ISA.

12.30. Pogge, dab, goby, lesser or Raitts sandeel, and butterfish were present in over 70% of the benthic trawls (Table 12.6) and 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 and the greater sandeel were also present in samples but at lower frequency and abundance.

12.31. A number of commercially exploited species such as dab, plaice, whiting, cod and scallop were also present during the benthic trawl surveys, and these are discussed in greater detail below.

12.32. Species of particular relevance to the proposed development as a result of their likely presence within the ECR corridor, combined with an ecology and physiology which may lead them to be affected by the development, are considered within this section.

12.33. The ECR corridor is included within the ISA and its associated species are discussed below. The only available data set that that focuses specifically on the fish resource within the ECR corridor is the fish length data set, recorded as part of the benthic trawl survey (see Data collection and survey).

12.34. The results of the trawl survey within the ECR are displayed in Table 12.7 and indicate that dab and plaice were the most abundant species within the ECR survey corridor. These are both commercially exploited species and their importance as a natural resource at both local and regional spatial scales is discussed below.

Table 12.7 Fish species recorded during the benthic trawl survey of the ECR as part of the benthic survey program during March and April 2011

Common name	Scientific name	Number found	% of trawls	Protected status
Dab	*Limanda limanda*	76	100	None
Plaice	*Pleuronectes platessa*	33	100	UK BAP
Pogge	*Agonus cataphractus*	9	66	None
American Plaice	*Hippoglossoides platessoides*	5	66	None
Goby	*Pomatoschistus norvegicus / lozanoi*	7	66	None
Lesser or Raitt's Sandeel	*Ammodytes marinus*	1	33	UK BAP
Spotted dragonet	*Callionymus maculatus*	3	33	None
Grey gurnard	*Eutrigla gurnardus*	1	33	None
Cod	*Gadus morhua*	3	33	UK BAP and OSPAR
Whiting	*Merlangius merlangus*	1	33	UK BAP
Bull rout	*Myoxocephalus scorpius*	3	33	None

Regional Study Area (RSA)

12.35. 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 (see Figure 12.1). Landings data from 2006 to 2010, provided by MSS for those rectangles, were used to identify the species regularly landed.

12.36. All species in the RSA, for which more than 100 kilograms (kg) were landed, are listed in Table 12.8. The value of landings from each rectangle is displayed for each species as well as a total landing across this area by species. The top 5 species landed by weight are shown in blue (see key below).

Table 12.8 Species landed from the RSA (ICES rectangles 41E7, 41E8, 42E7 42E8) between 2006 and 2010

Common Name	Scientific Name	Landings (kg)				
		41E7	41E8	42E7	42E8	Total
Total		12910792	772417	4734171	2859876	
Count		52	30	36	26	
Nephrops	*Nephrops norvegicus*	7953411	107868	255505	8425	8325209
King scallop	*Pecten maximus*	1473677	565064	2303224	2723504	7065469
Edible crab	*Cancer pagurus*	931389	1391	972368	2339	1907486
Lobsters	*Homarus gammarus*	801701	1143	446359	377	1249581
Velvet swimming crab	*Necora puber*	576397	358	555383	209	1132347
Squid	*Loligo forbesi*	356040	44095	121231	30200	551566
Surf clams	*Spisula solida*	359741	0	0	0	359741
Razor clam	*Ensis*	287478	670	71	0	288219
Haddock	*Melanogrammus aeglefinus*	27492	33337	8954	78317	148100
Mackerel	*Scomber scombrus*	37856	4593	35871	3908	82228
Whelk	*Buccinium undatum*	55074	525	9119	0	64718
Whiting	*Merlangius merlangus*	8055	6050	3933	7846	25884
Other demersal		18406	708	709	202	20025
Cod	*Gadus morhua*	7274	444	7528	358	15604
Plaice	*Pleuronectes platessa*	2292	2381	7189	1921	13783
Anglerfish (Monks)	*Lophius*	3080	866	563	459	4968
Lemon sole	*Microstomus kitt*	1913	1167	279	1187	4547
Queen scallop	*Aquinopecten opercularis*	182	305	2400	0	2887
Saithe (Coalfish)	*Pollachius virens*	1142	0	1668	0	2810
Green crab	*Carcinus maenas*	2045	0	142	0	2187
Halibut	*Hippoglossus hippoglossus*	1239	196	192	74	1701

Common Name	Scientific Name	Landings (kg)				
		41E7	41E8	42E7	42E8	Total
Witche	*Glyptocephalus cynoglossus*	476	215	56	70	817
Crawfish	*Astacoidea sp.*	613	0	177		790
Red gurnards	*Aspitrigla cuculus*	66	704	1	15	786
Hake	*Merluccius merluccius*	551	80	31	74	736
Mussel	*Mytilus edulis*	726	0	0	0	726
Other flatfish		457	0	140	114	711
Dab	*Limanda limanda*	200	0	388	100	688
Skates & rays	*Raja spp.*	241	31	226	12	509
Sprat	*Sprattus sprattus*	420	0	0	0	420
Ling	*Molva molva*	271	50	29	7	357
Turbot	*Psetta maxima*	204	55	12	0	271
Red mullet	*Mullus surmuletus*	33	60	40	104	237
Spinous spider crab	*Maja squinado*	64	0	170	0	234
Pollack (Lythe)	*Pollachius pollachius*	17	0	164	0	181
Spur dogfish -	*Squalus acanthius*	130	0	0	50	180
Grey gurnard	*Eutrigla gurnardus*	150	0	0	0	150
Number of Species landed		52	30	36	26	

Source: Marine Scotland Science.

Note: Species for which less than 100 kg were landed are not included. The top five species landed are represented by the following shades:

1	2	3	4	5

12.37. Species landed, within the RSA, from ICES rectangles 42E7 and 42E8 are shown in Table 12.8. Rectangle 42E8, the location for Project Alpha and Project Bravo is considered to be of moderate to low importance on a national scale and of moderate importance locally for king scallops (78.6%), haddock (13.5%) and squid (3.0%) by value (see Chapter 14 Commercial Fisheries) Other species caught include nephrops, edible crab, prawns, lobster and velvet swimming crab all of which are also abundant within rectangle 42E7 (the ECR corridor). Within the RSA nephrops, scallops, edible crab lobster and velvet swimming crab form 92% of the total landings.

12.38. The majority of landings came from rectangle 41E7, with 41 more species landed from this rectangle than from any other rectangle (Table 12.8). Rectangle 42E8 is the least diverse with landings of only 22 different species being recorded. Species, for which less than 100kg were landed during years 2006 to 2010, are listed in Table 12.9 below.

Table 12.9 Species recorded in the landings data for which less than 100kg landed (2006 – 2010)

Common Name	Scientific Name	Common Name	Scientific Name
Bass	*Dicentrarchus labrax*	Other Lobster - Squat	Unidentified
Brill	*Scophthalmus rhombus*	Mullet – Other	Unidentified
Brown Shrimp	*Crangon crangon*	Redfish	Unidentified
Catfish	*Anarhichas lupus*	Roes	Unidentified
Cockles	*Cerastoderma edule*	Sharks	Selachimorpha
Conger eel	*Conger conger*	Sole or Dover Sole	*Solea spp.*
Dogfish - Spotted	*Scyliorhinus canicula*	Wrasse	Labridae
John Dory	*Zeus faber*	Gurnards (and latchets)	Unidentified
Megrim	*Lepidorhombus whiffiagonis*		

12.39. It is important to set the species identified from commercial landings in the RSA within the context of the WSA (see Figure 12.1). Thus data for ICES rectangles: 40E7, 40E8, 40E9, 41E7, 41E8, 41E9, 41E7, 41E8, 41E9, 42E7, 42E8 and 42E9 were interrogated, and are summarised in Table 12.10.

12.40. As well as the shellfish species identified as commercially important for the RSA, (scallops, lobster, nephrops and crab species) as presented in Chapter 14 Commercial Fisheries in this ES, other species within the WSA include haddock (the third most landed species) and herring (the fourth most landed species). These two species made up nearly 36% of the total landings. In total 73 species were recorded in landings data for the WSA, 53 of which were also recorded in the RSA and 32 were also in the ISA.

Table 12.10 Landings from the WSA from 2006 to 2010

Species (Common Name)	Landings per ICES rectangle (tonnes)												
	40E7	40E8	40E9	41E7	41E8	41E9	42E7	42E8	42E9	43E7	43E8	43E9	Total
Total	3458.6	1190.2	941.4	0.0	12910.8	772.4	422.5	2859.9	2148.6	834.4	366.7	4623.0	14195.3
Count	41	38	34	52	30	29	36	26	32	28	48	46	46
Species													
Nephrops (Norway Lobster)	2522.3	424.5	166.1	7953.4	107.9	90.1	255.5	8.4	30.7	6.0	17.3	119.3	11701.5
King scallop	214.6	115.1	0.0	1473.7	565.1	3.6	2303.2	2723.5	34.9	76.8	2021.6	181.4	9713.6
Haddock	24.8	32.7	68.1	27.5	33.3	235.5	9.0	78.3	1843.3	3.6	560.0	6159.3	9075.5
Herring	0.0	0.0	645.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	768.8	6874.9	8289.1
Brown (edible)crabs	269.7	333.5	0.1	931.4	1.4	0.0	972.4	2.3	0.0	235.3	540.5	0.0	3286.5
Lobster	121.7	112.2	1.2	801.7	1.1	0.0	446.4	0.4	0.0	7.6	35.1	0.0	1527.4
Velvet (swimming) crab	75.8	110.4	0.7	576.4	0.4	0.0	555.4	0.2	0.0	4.5	113.9	0.0	1437.6
Mackerel	59.2	3.9	7.6	37.9	4.6	2.0	35.9	3.9	0.2	9.0	399.4	314.3	877.9
Squid	119.9	9.8	6.2	356.0	44.1	9.0	121.2	30.2	12.0	14.0	19.9	28.3	770.6
Whiting	11.7	25.6	32.0	8.1	6.1	46.0	3.9	7.8	132.1	1.3	39.2	267.7	581.4
Surf clams	0.0	1.1	0.0	359.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	360.9
Razor fish	8.3	4.2	0.0	287.5	0.7	0.0	0.1	0.0	0.0	0.0	0.0	0.0	300.8
Plaice	2.4	2.0	1.8	2.3	2.4	10.0	7.2	1.9	38.0	1.3	16.0	43.5	128.7
Cod	5.3	3.7	1.9	7.3	0.4	3.5	7.5	0.4	6.0	1.5	21.8	31.0	90.2
Lemon sole	2.2	1.7	2.7	1.9	1.2	8.9	0.3	1.2	24.0	1.1	11.5	27.7	84.2
Hake	0.1	0.1	0.2	0.6	0.1	0.8	0.0	0.1	2.7	0.0	5.0	57.0	66.8

Species (Common Name)	Landings per ICES rectangle (tonnes)												
	40E7	40E8	40E9	41E7	41E8	41E9	42E7	42E8	42E9	43E7	43E8	43E9	Total
Whelks	0.1	0.01	0.0	55.0	0.5	0.0	9.1	0.0	0.0	0.0	0.4	0.0	65.2
Other or mixed demersal	10.1	4.9	0.6	18.4	0.7	0.7	0.7	0.2	2.1	0.2	3.6	16.2	58.4
Anglerfish (Monks)	2.0	2.7	2.5	3.0	0.9	4.9	0.6	0.5	8.7	0.5	6.6	21.5	54.4
Saithe (Coalfish)	0.1	0.1	0.06	1.2	0.0	0.1	1.7	0.0	3.7	0.6	1.9	6.8	16.2
Red gurnard	4.9	0.3	1.4	0.1	0.7	3.0	0.0	0.1	1.7	0.0	1.1	1.2	14.7
Clams	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.7	0.0	13.6
Witches	0.5	0.3	0.9	0.5	0.2	1.8	0.1	0.1	3.3	0.1	0.5	5.1	13.2
Halibut	0.8	0.6	0.8	1.2	0.2	1.03	0.2	0.1	0.9	0.02	0.6	4.8	11.2
Green crab	0.0	0.0	0.0	2.1	0.0	0.0	0.2	0.0	0.0	0.0	8.4	0.0	10.6
Ling	0.3	0.1	0.3	0.3	0.1	0.4	0.03	0.01	0.8	0.1	0.9	6.8	9.9
Norway pout	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	0.0	7.8
Skates & rays	0.01	0.0	0.02	0.3	0.03	0.1	0.2	0.01	0.6	0.3	3.2	2.6	7.3
Blue whiting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	6.2
Pollack (Lythe)	0.0	0.0	0.0	0.02	0.0	0.0	0.2	0.0	0.1	0.1	1.0	4.5	5.9
Other flatfish	0.05	0.1	0.1	0.5	0.0	0.1	0.2	0.1	0.7	0.03	0.6	2.6	4.9
Spur Dogfish	0.0	0.01	0.3	0.1	0.0	0.1	0.0	0.1	0.3	0.4	0.6	2.9	4.7
Red mullet	0.05	0.2	0.4	0.03	0.1	0.6	0.1	0.1	0.7	0.0	0.1	0.7	3.0
Queen scallop	0.0	0.0	0.0	0.2	0.3	0.0	2.4	0.0	0.0	0.0	0.0	0.0	2.9
Dab	0.04	0.01	0.0	0.2	0.0	0.0	0.4	0.1	0.0	0.0	1.1	0.9	2.8
Catfish	0.0	0.0	0.01	0.0	0.0	0.0	0.03	0.0	0.1	0.0	0.5	2.1	2.7

Species (Common Name)	Landings per ICES rectangle (tonnes)												
	40E7	40E8	40E9	41E7	41E8	41E9	42E7	42E8	42E9	43E7	43E8	43E9	Total
Other crab	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.6	0.0	0.01	2.6
Turbot	0.2	0.2	0.1	0.2	0.1	0.2	0.01	0.0	0.5	0.0	0.2	0.8	2.4
Pouting (Bib)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	2.1
White skate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.8	1.1
Crawfish	0.3	0.0	0.0	0.6	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	1.1
Megrims	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.8	1.0
Cuckoo ray	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.7	0.9
Mussels	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7
Sprat	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.5
Sole or Dover sole	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.1	0.1	0.4
Grey gurnards	0.0	0.2	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Bass	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.4
Scabbardfish - black	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.3
Other dogfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.3
Brown shrimps	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3
Spinous spider crab	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2
Other mullet	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.1	0.1	0.2
Brill	0.01	0.03	0.01	0.01	0.0	0.02	0.0	0.0	0.03	0.0	0.01	0.04	0.2
Sharks	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2
Redfish	0.02	0.01	0.01	0.02	0.02	0.04	0.0	0.0	0.0	0.0	0.0	0.01	0.1

Species (Common Name)	Landings per ICES rectangle (tonnes)												
	40E7	40E8	40E9	41E7	41E8	41E9	42E7	42E8	42E9	43E7	43E8	43E9	Total
Other gurnards (and latchets)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Conger eels	0.03	0.0	0.0	0.0	0.03	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.1
John dory	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.1	0.1
Roes	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.	0.0	0.03	0.0	0.04
Spotted dogfish	0.0	0.0	0.0	0.03	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0.02	0.04
Squat lobster -	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.04
Oysters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.03
Tope	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.02
Cockles	0.0	0.0	0.0	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.02
Periwinkles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.01
Roundnose grenadier	0.0	0.0	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.01
No catch	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
Bream	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01
Wrasse	0.0	0.0	0.0	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
Bream - Ray's	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cuttlefish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bluemouth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Spawning and Nursery Areas

12.41. A number of species of commercial importance are known to use all or part of the WSA as spawning and/ or nursery grounds (Cefas, 2010a, 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.

12.42. Table 12.11 identifies the main periods of spawning activity for important species in the WSA.

Table 12.11 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*							yellow	orange	orange			
Cod	yellow	yellow	yellow	orange								
Sandeel	yellow	yellow										
Sprat				yellow	orange	orange	yellow	yellow	yellow			
Whiting					yellow	yellow	yellow					
Mackerel					yellow	yellow	yellow	yellow				
Plaice	orange											yellow
Saithe		yellow	yellow	yellow	yellow							
Lemon Sole				yellow	yellow	yellow	yellow	yellow	yellow			
Spurdog	yellow	yellow									yellow	yellow
Nephrops									yellow			
Scallops			yellow	yellow	yellow				yellow	yellow		
Edible Crab					yellow	yellow	yellow	yellow				
Lobster						yellow	yellow					
Squid	orange	orange	yellow	yellow	yellow	yellow	yellow	yellow	yellow	yellow	orange	orange

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

INDIVIDUAL SPECIES ACCOUNTS – FINFISH

12.43. 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 will also be discussed in relation to their sensitivity to anthropogenic change. There is little commercial finfish fishing within either Project Alpha or Project Bravo and a very small amount of haddock landed from within the ECR corridor (as presented in the Existing Environment section of Chapter 14 Commercial Fisheries).

Herring (*Clupea harengus*)

Status

12.44. Herring is a commercially important pelagic fish, common across much of the North Sea although it was not recorded during surveys within the RSA (see Table 12.8). Herring has the largest Total Allowable Catch (TAC) allocation for the UK in the North Sea (currently 29,832 tonnes (Scottish Government, 2011).

12.45. Herring stocks in the North Sea have fluctuated in recent years due to factors such as overfishing, poor recruitment, bycatch of the stock in general and specifically bycatch of larvae in the sprat fishery (as presented in Chapter 14: Commercial fisheries in this ES). 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).

Ecology

12.46. 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 from July to September off the Scottish east coast are most relevant to the Seagreen Project.

12.47. 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 (the peak spawning months being August and September for the Buchan group) has taken place 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

12.48. Project Alpha and Project Bravo are not within any herring spawning grounds (as identified by Coull *et al*. (1998). However, recent Cefas data suggest spawning grounds are located approximately 6.3km to the north and 80km to the south of those project areas. The ECR corridor passes to the southernmost extent of the northern herring spawning grounds. However the main spawning areas for herring have been shown by Ellis *et al*. (2012) to be further to the north and the main commercial fishing grounds are also in the same region (Figure 12.2) (HAWG, 2011).

12.49. Data provided by Marine Scotland (unpublished) show that herring larvae are present within the ISA and were found in relatively high abundance (between 1.2 - 2 per m^2) as recently as 2011 (Figure 12.2) 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 in the more northern spawning areas. This is of relevance to the project as northern North Sea herring stocks have been experiencing poor recruitment in recent years (Burd, 2011).

12.50. 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 12.2).

Sensitivity

12.51. 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). Herring spawning and nursery areas are vulnerable to anthropogenic influences especially activities which have an impact on the physical environment (seabed) since they are benthic spawners. 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 (as presented in Chapter 10: Ornithology and Chapter 13: Marine Mammals in this ES).

12.52. Sensitivity to noise (i.e. underwater sound and vibration) varies greatly among fish species. Herring is a species with particularly high sensitivity to noise due to their physiology and the extension of the swim bladder (bulla) which ends in the middle ear (ICES, 2010 and Nedwell, 2003). Significant underwater sound and vibration would have an impact on this species including physiological damage (and death) and behavioural changes which could disrupt spawning behaviour and recruitment. Herring are not thought to be sensitive to electromagnetic fields (Hvidt *et al*., 2003).

Sandeel (*Ammodytes marinus*)

Status

12.53. In the early 1990s there was a substantial industrial sandeel fishery on the Wee Bankie, Marr Bank and Berwick's 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) and as presented in the Existing Environment section of Chapter 14: Commercial Fisheries.

12.54. 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, as presented in Chapter 10 Ornithology. 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.

12.55. 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.

Ecology

12.56. 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-January, which are deposited on the seabed, several months after ceasing to feed. The larvae hatch after several weeks, usually in February-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 (such as seabirds and marine mammals as presented in Chapter 10: Ornithology and Chapter 13: Marine Mammals in this ES).

12.57. 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 0.25–2 millimetres (mm)), and avoided sediment containing >4% silt (particle size <0.063mm) and >20% fine sand (particle size 0.063–0.25mm). 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.

12.58. 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

12.59. Particle Size Analysis (PSA) which has been completed as part of the wider benthic mapping work, as presented in Chapter 7: Physical Environment and Chapter 11: Benthic and Intertidal Ecology in this ES, was 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 produce a map highlighting which areas within the Project Alpha and Project Bravo sites contain the most preferable habitat. The results indicate that the majority of the Project Alpha and Project Bravo sites is Prime or Subprime habitat for sandeel. Within the ISA there with small areas, mainly around the western perimeter of the original Phase 1 area and across Scalp Bank which are considered Unsuitable (Figure 12.3). Most of the ECR corridor is considered to be Suitable or Subprime habitat the only Prime area occurs to the west of Scalp Bank (Figure 12.4).

12.60. 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 as indicated in data provided by Marine Scotland and displayed in Figure 12.3.

12.61. Three species of sandeel were found to be present within the ISA during the benthic survey (Table 12.6); by far the most abundant was the lesser or Raitts sandeel *Ammodytes marinus*. Lesser sandeel was recorded in both the benthic trawl and the drop down 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.

12.62. Sandeel presence recorded during the Seagreen commissioned benthic surveys (Appendix G1) is displayed in Figure 12.3 and Figure 12.4. This shows that sandeel is present across much of the Seagreen Project area but is only found in the offshore locations within the ECR corridor. Analysis of the benthic trawl data indicates that sandeel was the most abundant species within the ISA (Table 12.9).

Sensitivity

12.63. 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.

12.64. 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 (as presented in Chapter 10: Ornithology, and Chapter 13: Marine Mammals).

12.65. Sandeel have no swimbladder and are therefore classed as hearing generalists with a low sensitivity to noise. However, studies have shown that this species can detect particle acceleration at a distance of 10m from a sound source. The detection of particle motion caused by noise is greater for species which have direct contact with the seabed although this would not be great enough to cause injury (Andersson, 2011). The literature review for this chapter has not found any specific work regarding sandeel sensitivity to EMF.

Cod (*Gadus morhua*)

Status

12.66. 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).

12.67. 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 UK BAP priority marine species.

Ecology

12.68. Spawning grounds appear to be widespread and not restricted to specific areas, with spawning aggregations found offshore all over the North Sea (Figure 12.5). 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

12.69. Cod is present within the ISA (Table 12.9) and spawning and nursery grounds are shown in Figure 12.5. Cod is present across all ICES rectangles within the RSA and WSA (Table 12.8 and 12.10) and is widely distributed throughout the North Sea.

12.70. 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 (Figure 12.5). 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

12.71. 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). A review conducted by the U.S. Department of the Interior (2011) suggests that cod may have some behavioural sensitivity to EMF, whilst work by DONG Energy and Vattenfall (2006) was inconclusive.

Sprat (*Sprattus sprattus*)

Status

12.72. 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.

12.73. 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

12.74. 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 (see Chapter 10: Ornithology). 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

12.75. Sprat is not landed in great quantities from either the RSA (Table 12.8) or the WSA (Table 12.10). 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 12.6).

Sensitivity

12.76. Sprat along with herring is thought to have acute hearing, which will be significant in relation to the effects of underwater noise during construction and decommissioning of the wind farm. Impacts could range from severe physiological damage to displacement and avoidance of specific areas. The literature review for this chapter has not found any specific work regarding sprat sensitivity to EMF.

Whiting (*Merlangius merlangus*)

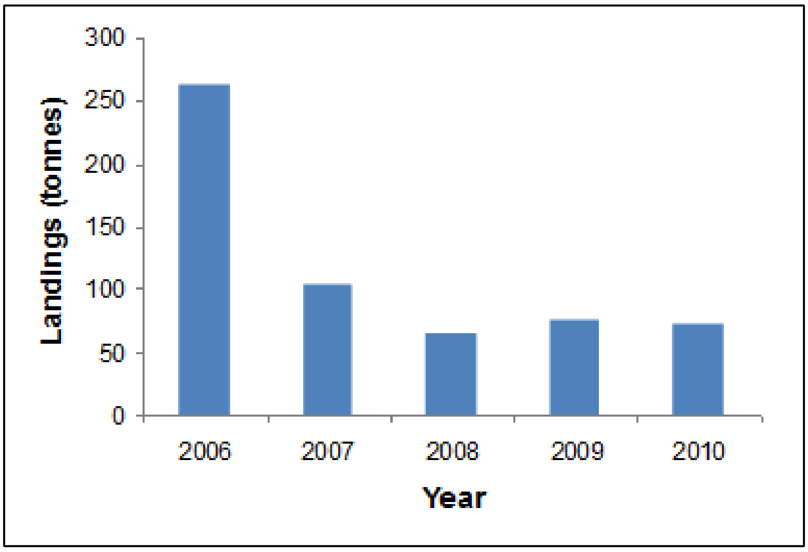
Status

12.77. 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 fish predator that feeds heavily on many commercially important species including sandeel and juvenile whiting (ICES, 2012). Whiting is a UK BAP priority species.

12.78. 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 (Plot 12.1) suggesting that the population as a whole is declining. Despite mortality due to fishing being stable over the last four years recruitment has been very low between 2003 and 2007 although increasing slightly in 2008 and 2009 (ICES, 2010a).

12.79. The change in abundance has been estimated from the IBTS Q1 and Q3 surveys. These show different trends in recruitment between the northern and southern North Sea and it is clear that from 2005 the northern component of the stock has been in decline whereas the southern component is either increasing or stable. The geographical differences would therefore skew the overall picture for the North Sea.

Plot 12.1 Landings of whiting from the WSA by year (source: Marine Scotland Science)



Ecology

12.80. 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

12.81. Whiting is widely distributed throughout the North Sea with high densities of both small and large whiting found almost everywhere, with the exception of the Dogger Bank approximately 450km southeast of the ISA. Whiting was recorded during the benthic trawl survey in the ISA. The species was recorded in eight trawls (Figure 12.7).

12.82. Analysis of landing data shows that whiting is an important species across both the RSA and the WSA (Tables 12.8 and 12.10). Within the RSA this species is landed from all ICES rectangles, with a greater proportion of landings from the two offshore rectangles where they are the fourth most landed species (Table 12.8).

12.83. 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

12.84. 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. A review conducted by the U.S. Department of the Interior (2011) suggests that whiting may have some behavioural sensitivity to EMF; however this is based upon extrapolation from results from cod.

Mackerel (*Scomber scombrus*)

Status

12.85. 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.

Ecology

12.86. 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.

12.87. 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).

12.88. 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 12.6.

12.89. 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.

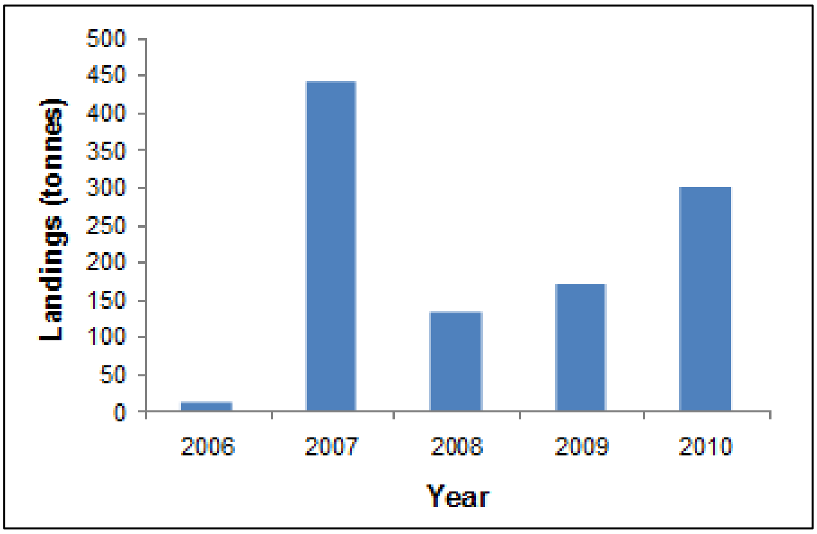
Distribution within the study areas

12.90. No mackerel spawning grounds overlap with the RSA, however, the majority of the RSA is within low intensity mackerel nursery grounds (Figure 12.6).

12.91. Mackerel is landed from every ICES rectangle within both the RSA and the WSA. It is the eighth most landed species from the WSA (Table 12.10) and the tenth most landed from the RSA (Table 12.8) indicating it is an important resource for the area.

12.92. Mackerel is widespread throughout the North Sea. IBTS data collected between 1977 and 2005 indicate that the Firth of Forth area is relatively low in abundance compared to the central North Sea. However, in recent years 1991 to 2004, landings from the Firth of Forth area have increased relative to the rest of the North Sea (ICES, 2010a). This increasing trend can also be seen in the landings data for the RSA (Plot 12.2) where, with the exception of the high landings seen in 2007, the trend is one of steady increase.

Plot 12.2 Landings of Mackerel from the WSA by year (source: Marine Scotland Science)



Sensitivity

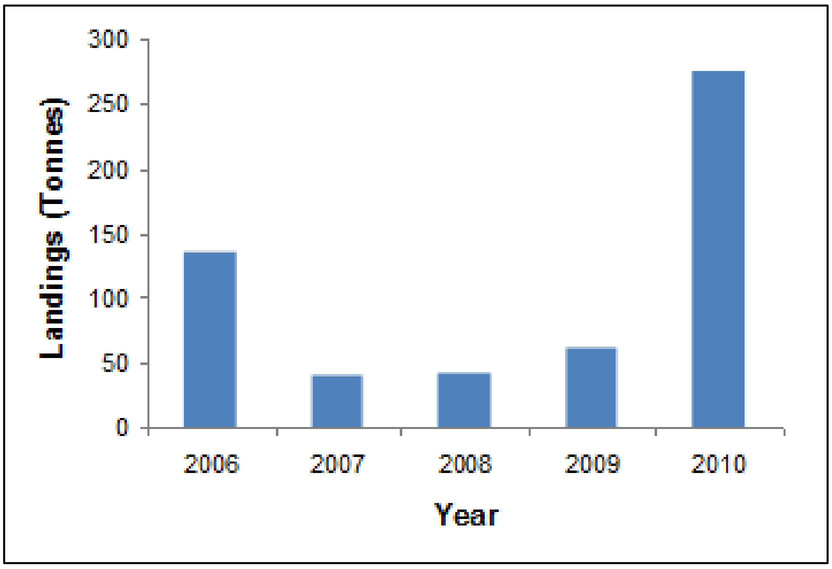
12.93. Mackerel does not have a swim bladder and is therefore less sensitive to noise than other species such as herring and sprat. They are described as having medium sensitivity to noise by Nedwell *et al*. (2004). Mackerel is a highly migratory species and may enter any of the project study areas. Noise during construction and decommissioning may affect migration patterns as may the presence of electromagnetic fields within the ECR corridor. A review conducted by the U.S. Department of the Interior (2011) suggests that mackerel may have some sensitivity to EMF affecting navigation.

Plaice (*Pleuronectes platessa*)

Status

12.94. Landings data for the RSA shows a marked increase in landings of plaice in 2010 (Plot 12.3 below) which indicates that the populations within the study area are increasing. Plaice is also a UK BAP marine priority species.

Plot 12.3 Landings of plaice from the Wider Study Area by year (source: Marine Scotland Science)



Ecology

12.95. 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 12.7).

Distribution in the study area

12.96. Plaice was present throughout much of the ISA from the benthic trawl (Figure 12.7) and video surveys. Plaice is also a feature of the landings from both the RSA and the WSA. It is the thirteenth most landed species from the RSA and the fifteenth most landed species from the WSA (Tables 12.8 and 12.10 respectively).

Sensitivity

12.97. Sediment characteristics are thought to be of importance during larval settlement and positive relationships have been found between grain size and plaice densities. Preference is for sandy sediments remains during the entire lifespan, although older age groups may sometimes be found on coarser sand.

12.98. Flatfish do not have swim bladders therefore plaice is considered to be of low sensitivity to noise, following Nedwell *et al*., (2004). Metcalfe *et al*., (1993, cited in U.S. Department of the Interior (2011)) suggest plaice may utilise external magnetic cues for orientation although they note that plaice have no known physiological mechanism to detect magnetic fields.

Saithe (*Pollachius virens*)

Status

12.99. 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.

Ecology

12.100. Saithe mature between the ages of four and six years. An adult female (approximately 75 cm) 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 some distance from the Seagreen Project.

12.101. 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

12.102. This species uses much of the coastal waters of Scotland for nursery grounds (Coull *et al*., 1998). Part of the Project Alpha and the ECR corridor lies within a lower intensity nursery area for this species (Figure 12.6). Saithe appear to hold the same relative importance in the RSA as they do in the WSA (nineteenth and twentieth most landed species, respectively (Table 12.10). The general trend in the RSA is that they are caught in the inshore ICES rectangles of 41E7 and 42E7 (Table 12.8). IBTS data indicate that this species generally occurs in higher abundances in the eastern North Sea than the west (ICES 2010).

Sensitivity

12.103. Detailed investigations into the auditory sensitivity of gadoid species such as cod have been undertaken by Nedwell *et al*. (2004) and have found that the swimbladder is in close proximity to the ear although it is not connected. As saithe is a gadoid it can be assumed that this species will have a similar susceptibility to anthropogenic noise as whiting and cod. The literature review for this chapter has not found any specific work regarding saithe sensitivity to EMF.

Lemon sole (*Microstomus kitt*)

Status

12.104. Lemon sole is a demersal species found in the shelf waters of the North Atlantic, from the White Sea and 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 show that there is a long-term decline in catch per unit effort.

Ecology

12.105. 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), and the spawning period is relatively long period (from April to September). Eggs and larvae are planktonic, with post-larvae found in the mid water before becoming demersal, when reaching 3 centimetres (cm) in length (Wheeler, 1978).

12.106. 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

12.107. Both the ISA and the RSA are within a large spawning and nursery ground for lemon sole (Figure 12.8). In addition, lemon sole is a relatively important commercial species landed from both the RSA and the WSA where they are the seventeenth and fifteenth most landed species by weight, respectively (Table 12.8 and 12.10)

12.108. During the benthic trawl survey lemon sole was recorded within the Project Alpha and Project Bravo areas within the ISA at several locations (Figure 12.8).

Sensitivity

12.109. As a flatfish without a swim bladder, lemon sole is considered to be of low sensitivity to noise, following the noise sensitivity system published by Nedwell (2004). The literature review for this chapter has not found any specific work regarding lemon sole sensitivity to EMF. Sediment disturbance during construction will need to be assessed in terms of impact on spawning habitat.

INDIVIDUAL SPECIES ACCOUNTS - ELASMOBRANCHS

12.110. This section describes the ecology and distribution of species of elasmobranch found in the study areas. The final paragraph describes the potential impact development activities will have on all species described in this section.

Spotted ray (*Raja montagui*)

Status

12.111. 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

12.112. 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

12.113. The spotted ray has nursery grounds which are used at a low intensity across northern parts of the RSA (Figure 12.6).

Spurdog (*Squalus acanthias*)

Status

12.114. 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 especially in otter trawls. A low fecundity coupled with an extremely low growth rate makes spurdog vulnerable to commercial overexploitation.

12.115. Much of North Sea has been identified as nursery grounds of low intensity for the spurdog or spiny dogfish (Cefas, 2010). This area covers all three study areas. (Figure 12.8).

Ecology

12.116. Spurdog occurs mainly at depths between 10 and 100m. It tends to aggregate in large shoals of the same size or sex. It is viviparous and produces live young of between 20 and 30cm in length. The pupping season is from August to December (ICES, 2010a). Young are reliant on yolk reserves during embryonic development and fecundity increases with size. 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

12.117. Landings data from both the WSA and the RSA indicate that this species is present within these areas (Table 12.10 and Table 12.8 respectively) and is relatively abundant.

12.118. IBTS survey data for the years 1977-2005 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). 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).

Tope (*Galeorhinus galeus*)

Status

12.119. 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

12.120. Tope is viviparous and can produce 6 to 52 pups per litter but generally between 20 and 35. Their size at birth is between 30 cm and 40 cm. Males are sexually mature at an age of 8 years and a size between 120cm and 170cm, and females mature at 11 years with a length of 130 cm to 185 cm. 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

12.121. Much of the western part of the RSA and the entire ISA is within nursery grounds of low intensity for tope (see Figure 12.8).

Sensitivity of elasmobranch species

12.122. Elasmobranchs are known to detect and capture their prey through the electric outputs of organisms in saltwater (Gill and Taylor, 2001). Electrosensitivity can also be used for orientation using the electrical differences in the resistance of various objects as well as interpreting the effect of the earth's electromagnetic current on the electric field (MMO *et al.*, 2010). Electrosensitive species can therefore potentially detect and respond to the electromagnetic fields produced by offshore power installations. There is growing evidence from physiological, behavioural, and anatomical research that elasmobranchs are able detect EMF (Gill and Bartlett 2010, Normandeau *et al.*, 2011) and this is discussed further in the Impact Assessment-Operation section. However, the assessments of elasmobranch responses to cable EMF are based on a small number of data sets and the interpretations are limited or inconclusive.

12.123. Responses to electric and magnetic stimuli are reported for only a few elasmobranch species, thus variation is expected among species, sex and age classes (Normandeau *et al.*, 2011). In addition, electromagnetic stimuli associated with cabling for offshore wind farms may affect feeding and distribution patterns.

12.124. Elasmobranchs do not have swim bladders therefore are hearing generalists and not considered sensitive to noise (Fänge, 1966).

12.125. The assessment of the potential impacts on elasmobranchs is particularly important as this class of fish 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

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

Status

12.126. King scallop is the second most valuable commercial fish species in Scotland with total landings in 2009 being 9850 tonnes with a value of £19 million almost 50% of the total UK landings. Queen scallops are also marketed in the UK, but are less valuable. The value of the scallop fishery in the Firth of Forth area and within the Seagreen Project area (ICES rectangle 42E8) is currently approximately £700,000 per annum (average 2000-2009 as presented in Chapter 14: Commercial Fisheries in this ES). The main fishery for scallop within the Seagreen Project occurs on the western edge of the Project Alpha Site. There are some landings within the ECR corridor but this is concentrated in areas adjacent to the western edge of Project Alpha and landings reduce along the ECR to the landfall area (as presented in Chapter 14: Commercial Fisheries).

Ecology

12.127. Scallops show a preference for areas of clean firm sand, fine or sandy gravel and may occasionally be found on muddy sand. Distribution in this species is invariably patchy (Marshal and Wilson 2009, Carter 2009) but the areas with greatest abundance tend to be areas of little mud but with good current strength. High turbidity is known to be detrimental to larval development (Shumbray and Parsons, 2006).

12.128. 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

12.129. King scallops were found to be present within Project Alpha and Project Bravo during the benthic trawl, video and grab surveys (Figure 12.9) with single individuals recorded at each of four different sites during the trawl survey. Single king scallops were also recorded during the ECR benthic trawl survey at the eastern most sample station. They are also the most landed species from three of the four ICES rectangles that make up the RSA (Table 12.8), including rectangles 42E7 and 42E8 which include Project Alpha and Project Bravo sites and the ECR corridor (Figure 12.1).

12.130. Queen scallops were far more numerous with 201 individuals found over 34 trawl locations in the Seagreen benthic trawl survey (IECS, 2011) but were not recorded in any of the other survey data sets or within the ECR component of the ISA.

12.131. Data provided by MSS (see Table 12.2) indicate that scallops are present in greater abundance in the northern and southern areas of the ISA as well as in the vicinity of the ECR corridor (Figure 12.9). Although abundance fluctuates between years the general areas of high abundance have been consistent over the past three years. This is in slight contrast to fisheries data provided by Marine Scotland and the Marine Management Organisation (MMO) which indicate that landings and dredging activity from the ISA are high in comparison with the surrounding areas (as presented in Chapter 14: Commercial Fisheries in this ES).

Sensitivity

12.132. 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 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.

12.133. Although scallops have limited mobility it is unlikely that they will be able to avoid large operations that impact the seabed such as the placement of gravity base structure foundations and cable installation. In addition, disturbance of sediment in which scallops are found is likely to have the effect of displacement, loss of habitat, reduced spawning activity, and effects upon filter feeding mechanisms.

Nephrops (*Nephrops norvegicus*)

Status

12.134. The nephrops fishery contributes 0.4% of the total value of the commercial fishery in ICES rectangle 42E8 and is of negligible importance on a national scale (see Table 12.8 and the Existing Environment section of Chapter 14 Commercial Fisheries). In the Firth of Forth the ICES management recommendation was that the stock was not overexploited and could be managed through the Total Allowable Catch (TAC) (ICES 2010a). Most nephrops fishing is carried out to the south west of the Forth and Tay areas and there is no fishing for this species by over 15m vessels within the Seagreen Project (as presented in Chapter 14 Commercial Fisheries).

Ecology

12.135. 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.

12.136. 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 b).

Distribution within the study areas

12.137. As described above nephrops is a commercially important species within the RSA however 95% of these landings are from ICES rectangle 41E7 to the south east of the ISA (Figure 12.11).

12.138. Nephrops is equally important to the WSA as it is the most landed species, accounting for over 24% of the entire landings for this area of sea (Table 12.10). Much of the RSA has been identified as being nephrops spawning and nursery grounds which also incorporate all but half of the ISA and mainly in the Project Alpha site (Figure 12.11). However, nephrops were not recorded in any of the benthic surveys commissioned for this project. TV survey data provided by Marine Scotland illustrates that nephrops abundance is high in the inshore waters of the southern parts of this spawning and nursery ground (Figure 12.11).

Sensitivity

12.139. The main limiting factor for nephrops distribution is the extent of suitable muddy sediment in which the animals construct burrows. Areas containing this sediment type are limited within the ISA (as presented in Chapter 7 Physical Environment and Chapter 11 Benthic and Intertidal Ecology in this ES).

Edible (brown) crab (*Cancer pagurus*)

Status

12.140. Brown crab is the most commercially important species of crab with landings in 2008 in excess of 9,000 tonnes and a first-sale value of over £10.8M (Mesquita *et al*., 2011). Currently the species is thought to be fished above MSY in Scottish waters (Mesquita *et al*., 2011).

Ecology

12.141. Edible crab is found all around the Scottish coast from the shallow sub-littoral into offshore waters to depths exceeding 100m. The species inhabits rocky reefs, mixed coarse grounds and soft sediments particularly on the offshore grounds. Small crabs are rarely caught in offshore areas which suggest that crabs only move into deeper water as they grow and approach maturity. They are known to undertake extensive migrations at rates of 2-3km per day during migrations of up to 200 nautical miles (370km) (Pawson, 1995).

12.142. Edible crabs feed mainly on benthic invertebrates, particularly bivalves, small decapods and barnacles as well as scavenging on dead animal matter. Mating occurs in spring and summer shortly after the female has moulted. Females are berried (carrying their eggs beneath their tail segments) for 6-9 months after copulation and release the larvae in late spring/ early summer (Neal and Wilson, 2008). Once hatched, crab larvae are planktonic for up to approximately 90 days (Pawson, 1995). Juvenile crabs are more commonly found in shallow inshore waters (Scottish Government undated c).

Distribution in the study areas

12.143. Edible crab is the third most landed species from the RSA (Table 12.8) with the majority of landings coming from within the two inshore ICES rectangles 42E7 and 41E7. The majority of crab fishing is done by smaller vessels (under 15m) which set gear predominantly inshore, several miles from the coast although a few larger vessels fish further out (see Chapter 14: Commercial Fisheries). The importance of edible crab as a resource is also reflected in the landings from the WSA, where it is the fifth most landed species. Edible crab is also present within the ISA (Figure 12.10) but with no clear pattern in distribution emerging.

Sensitivity

12.144. Edible crab is thought to be relatively tolerant to changes in its environment; however, evidence to support this conclusion is limited. They are also known to be sensitive to synthetic compound contamination (Neal and Wilson, 2008). The disturbance to sediments and benthic habitats along the ECR corridor during construction and possibly decommissioning will need to be considered in the assessment of impacts as would construction within migration routes.

Lobster (*Homarus gammarus*)

Status

12.145. The tonnage of lobster caught is lower than that of the edible crab but this species is of much higher value therefore and an important component of the fishery. Currently the stock is overfished according to length cohort analysis (LCA) (Scottish Government, undated d).

Ecology

12.146. Lobster is found all around the coast of Scotland, typically on hard ground in relatively shallow waters and on the fringes of kelp beds. It is unlikely to be abundant within the Project Alpha and Project Bravo area of the ISA as the main substrates consist of sand and gravel (as presented in Chapter 10: Benthic and Intertidal Ecology in this ES) and water depths are between 41 and 61m. The diet of the adult lobster consists mainly of benthic invertebrates such as crabs, molluscs, sea urchins, polychaete worms and starfish, but may also include fish and plants. Mating occurs just after moulting which happens in June or July (Scottish Government undated d).

12.147. Lobster is a sedentary animal with home ranges varying from 2 to 10km (Bannister *et al*., 1994). Lobsters do not make extensive migrations when berried and hatching takes place in spring and early summer on the same grounds (Pawson, 1995).

Distribution in the study areas

12.148. Lobster was the sixth most landed species from the WSA (Table 12.10) and the fourth most landed species from the RSA (Table 12.8) making it an important resource. However the majority of the landings came from the inshore areas of ICES rectangles 41E7 and 42E7 the latter rectangle includes the ECR corridor. Lobster was recorded at one station in the benthic trawl survey, at two locations in the video survey of the ECR and at three locations in the video survey of the Project Alpha and Project Bravo areas. Generally lobster landings are negligible within rectangle 42E8 (as presented in the Existing Environment section, Chapter 14: Commercial Fisheries).

Sensitivity

12.149. The key limitation for lobster is the availability of suitable habitat and disruption of biological processes such as breeding and moulting, when the species is most vulnerable and will therefore be sensitive to effects which could also cause displacement or disruption in migratory habits. Lobsters have not been found to be sensitive to either noise or EMF (Ueno *et al*., 1986 in Normandeau *et al*., 2011).

Velvet swimming crab (*Necora puber*)

Status

12.150. The velvet crab industry in Scotland has rapidly developed within the last 30 years in Scotland as a result of the Spanish fishery crashing. The majority of Scottish caught velvet crab is shipped to southern Europe. Due to the increased demand for velvet crab in recent years landings have increased over a very short time period and therefore it is unclear how this species is reacting to the current levels of fishing pressure (Marine Scotland, 2012a).

Ecology

12.151. Velvet crabs are most commonly found on rocky substrates down to depths of about 25m and are therefore unlikely to be abundant across Project Alpha and Project Bravo area as here depths range from 41-61m. Velvet crabs feed on both animal and algal material, with brown algae being the dominant item found in gut content analysis (Wilson, 2008).

Distribution in the study areas

12.152. Velvet crab was the seventh most landed species from the WSA (Table 12.10) and the fifth most landed species from the RSA (Table 12.8). The majority (approximately 99%) of the landings from within the RSA came from the inshore ICES rectangles 41E7 and 42E7. A single velvet swimming crab was recorded in the western part wind farm area of the ISA (outside of Project Alpha) and two individuals were recorded at a single location within the ECR corridor (Figure 12.10) during the benthic trawl surveys.

Sensitivity

12.153. As for edible crab.

Whelk (*Buccinium undatum*)

Status

12.154. The whelk is common in the North Sea and is distributed extensively around the UK coastline (Jacklin, 1998).

Ecology

12.155. This species inhabits mainly muddy gravel or mud mixed with shell. Whelks spawn when they reach maturity at approximately two to three years of age. Fertilisation occurs in late autumn followed by spawning in November. After four months development, the fully formed juveniles emerge from the egg capsules during February to March (Jacklin, 1998).

Distribution in the study areas

12.156. Whelks were recorded at six sites during the benthic trawl survey (Figure 12.10). Landings data (Table 12.8 and Table 12.10) indicate that whelks are a relatively important resource in the inshore areas of the RSA and WSA respectively.

Sensitivity

12.157. The sensitivity of whelk with respect to disturbance from noise is unknown but studies have shown that they are useful as bio-indicators of tributyl tin (TBT) contamination due to changes in sexual characteristics at certain levels of the contaminant in seawater (Poloczanska and Ansell 1999). Whelk is a bottom dwelling species and therefore high levels of suspended solids which may occur during construction may affect their distribution and feeding behaviour.

Squid (*Loligo forbesi*)

Status

12.158. In the last decade, total squid landings from the NE Atlantic were between 10,000– 18,000 tonnes. The most frequently caught species in UK waters is *Loligo forbesi*, and this species is the basis of significant by-catch fisheries, with annual landings as high as 3,500 t. Of the total Scottish squid landings between 50-70% are caught in the Moray Firth, where a seasonal, targeted fishery operates during summer-autumn. The fleet size directly involved in this fishery has ranged from 20–65 vessels in recent years. Many of the fishing crews target squid for several weeks, when large numbers of small squid recruit to the fishery. The applicability of assessment methods for these stocks is limited by inadequate and inaccurate statistical information, and because nearly all of the catch arises as a by-catch from fin fisheries (Pierce *et al*., 2009).

Ecology

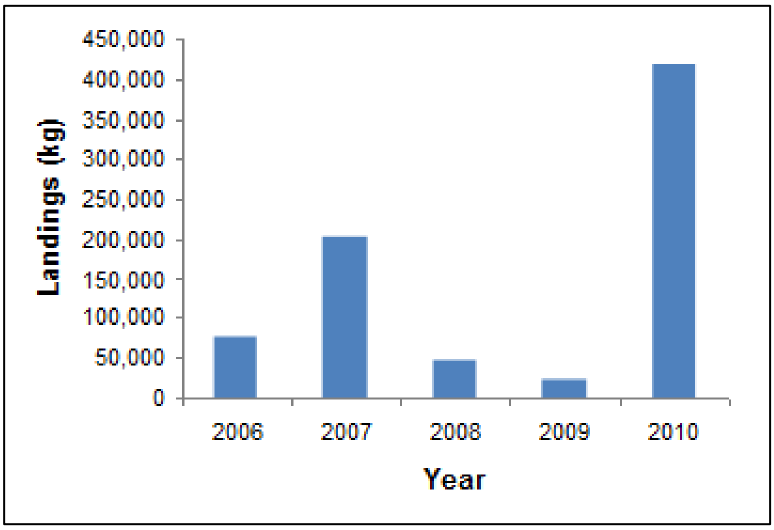
12.159. Squid species are found over sandy and muddy bottoms (Wilson 2006) and are mostly demersal in nature and are therefore often bycatch in demersal fisheries (Bellido *et al*., 2001). Research on squid has determined that they are probably batch spawners. Males grow to a larger size than females and mature a month earlier and are therefore recruited earlier into the fishery. Both males and females mature sexually at two distinct sizes although this is more distinct in the males. There is a peak breeding period in the winter (December–May) throughout the geographical range, and one or more seasonal peaks of recruitment (Boyle and Pierce 1994).

12.160. The main food of squid is fish, including many commercially important species, and crustacean, however as size increases the proportion of fish in the diet increases. Squid is a prey species for larger finfish, seals, cetaceans and seabirds.

Distribution in the study areas.

12.161. *Loligo forbesi* is the most important fished cephalopod in Scottish waters and the only cephalopod for which there is a reliable market. It is a fishery gaining in importance in the Forth and Tay areas (as presented in Chapter 14: Commercial Fisheries). Squid are the sixth most landed species from the RSA (Table 12.8) and the ninth most landed species from the WSA (Table 12.10). The main Scottish fishery for squid occurs in coastal waters and usually exhibits a marked seasonal peak between June and September corresponding to the occurrence of pre-breeding squid (Young *et al.*, 2006) although in 2010 fishing for squid continued into November (see Chapter 14: Commercial Fisheries). Landings of squid within the RSA by year do not show a clear trend but landings in 2010 were 450 tonnes which was far greater than in any of the previous 4 years (Plot 12.4).

Plot 12.4 Landings of Squid from the WSA by year (source: Marine Scotland Science)



Sensitivity

12.162. Squid tend to spawn in a single episode (Boyle and Pierce, 1994 where many individuals gather together in a single location. If this spawning episode were to be disrupted recruitment to the following year stock may be adversely impacted. However, there is evidence that occasional incidental spawning may occur all year round.

Other species

12.163. The other species of fish known to be present within the RSA (Table 12.8) include: pogge, dab, gobies, butterfish, Norwegian topknot, reticulated dragonet and common dragonet. All species were present in over 50% of the benthic trawls (Table 12.6).

INDIVIDUAL SPECIES ACCOUNTS - MIGRATORY FISH

12.164. The term migratory fish is used in this chapter to describe fish that migrate between fresh water and the marine environment. This includes diadromous species; truly migratory fish which migrate between the sea and fresh water. These include anadromous species, which spend most of their lives in the sea and migrate to fresh water to breed, and catadromous species, which spend most of their lives in fresh water and migrate to the sea to breed. Five species of migratory fish have been identified as relevant to the development and these are presented in Table 12.12 along with timings of migrations.

Table 12.12 Timings and durations 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	2-3 years	April- May	1, 2 or 3 years	All year round with peak in late summer early autumn
Sea trout	2-3 years	Spring	2 or more	April- June
Eel	Males 7-20 yrs Females 9-50 yrs	Late spring	Many do not return to fresh water	January to June
Sea lamprey	3-4 years	July to September to open sea	18-24 months	April-May spawning in May/ June
River lamprey	5 yrs 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°.
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

Source: Maitland 2003

Salmon (*Salmo salar*)

Status

12.165. A Marine Scotland report on salmon and sea trout fisheries for 2009 indicated that the fishing effort in both net fisheries was "*the lowest since records began in 1952*". In addition to this catch rates for both net fisheries were under 5% of maximum recorded catch. Total rod catches declined by 18% from the average of the previous 5 years. However although catches of spring salmon have declined gradually since records began, catches of grilse have increased and catches of summer salmon show little trend over the same period. (Marine Scotland 2010). Salmon are a protected species being a UK BAP priority species, an Annex II species under the EU Habitats Directive and Annex III species under the Bern Convention.

Ecology

12.166. 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 to their natal river as adults to spawn. Post smolt migration at sea is poorly understood (Malcolm *et al.*, 2010), but there is evidence to suggest 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).

Distribution in the study areas

12.167. Atlantic salmon was not recorded during any of the site specific surveys or included in the landings data. This is unsurprising as salmon are rarely caught at sea, especially in the offshore environment. Therefore, the baseline environment for salmon and indeed all migratory fish must be established using other means.

12.168. 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 is available. For salmon the WSA is defined as the whole of Scotland and the RSA includes all the east coast salmon rivers.

12.169. There is a growing body of evidence showing that salmon populations across Scotland have been rapidly decreasing in the last 25 years (Youngson *et al*, 2002). These downward trends have been particularly true of the spring running salmon on the east coast of Scotland and rivers relevant to the RSA. Salmon run Scottish rivers all year round, but recently there has been large decrease in the amount of salmon running east coast rivers in February to April (Marine Scotland 2012b).

12.170. Conversely, there is evidence that in recent years (since 1990) catch rates on east coast rivers have actually increased in May and particularly in June. The latest review of the salmon fishery reported that "*Total reported rod catch (retained and released) for 2011 is 86,655 salmon. It is the sixth highest rod catch on record, and is 97% of the previous 5-year average. The proportion of the rod catch accounted for by catch and release continues to increase. In 2011, 91% of rod caught spring salmon was released, as was 73% of the annual rod catch*" (Marine Scotland 2012b).

12.171. It has been suggested that the decline in Scottish salmon populations and in other populations around the North Sea and north east Atlantic is due to factors such as increasing mortality at sea (Hansen *et al*., 2000).

12.172. 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 RSA: Tweed, Forth, Tay, South Esk, Dee, Ness and Spey (Figure 12.12).

12.173. The results of these analyses are displayed in Figure 12.12 illustrating that salmon do migrate to a number of rivers in the vicinity of proposed development and therefore may pass through the ISA. Although catch rates from all the rivers within the study area fluctuate (Figure 12.12) they do not appear to show the obvious declines seen in Plot 12.5 above.

12.174. Catches from the coastal and estuary net fisheries should also be considered. In the 1960s for example, an average of almost 400,000 salmon were caught by netsmen each year, mostly on the east coast. Over the last few decades netting effort has fallen dramatically. This should have allowed many more fish to enter the rivers Marine Scotland 2012b. There are corresponding increases in rod caught salmon in rivers such as the Tay and the Spey as the net fisheries start to decline in the 1970s. However this is followed by downward catch trends in the 1980s.

Sensitivity

12.175. It is thought that salmonids use chemoreceptor clues to locate their natal rivers when migrating in coastal waters, although they are also thought to use electromagnetic fields (EMF) during offshore migrations. Salmon may, therefore, be sensitive to the effects of EMF generated from wind farm cables although they are a pelagic species and effects will mainly be perceived near the seabed. The impact of EMF may therefore be greater in the shallower areas.

12.176. Studies have shown that salmon also respond to low frequency sounds (Gill and Bartlett, 2010). Construction noise may also need to be assessed for impact on migration patterns and routes in terms of displacement and avoidance behaviour which may impact the return to natal rivers.

Sea trout (*Salmo trutta*)

Status

12.177. The latest report released by Marine Scotland (2012b) for rod catch of sea trout for the whole of Scotland states that "*despite declining for much of the period since 1952, the catch in 2011 increased by 8% compared to the previous 5-year average. In 2011 the total rod catch for east coast fisheries increased by 12% compared to the previous 5-year average, while west coast fisheries showed little change. Overall west coast sea trout catch remains at historically low levels*".

Ecology

12.178. Sea trout is known to migrate to a number of rivers on the east coast of Scotland and could potentially pass through or in close proximity to the ISA. Their life cycle is similar to that of salmon (Harris & Milner, 2006), but there are two significant differences. In contrast to salmon, the majority of sea trout survive spawning which occurs in late autumn, and will return to their natal spawning river on numerous occasions during their life time. The other significant difference is that they do not appear to undertake the same migration at sea but remain in coastal waters, probably close to their natal river.

Distribution in the study areas

12.179. There were no recorded capture of sea trout in the benthic surveys but since this species is migratory it can be assumed that a proportion of this species will cross the ISA at some point.

Sensitivity

12.180. As discussed above with regard to salmon, trout are thought to be sensitive to both EMF and low frequency noise (Gill and Bartlett, 2010).

European eel (*Anguilla anguilla*)

Status

12.181. World-wide, eel species are in decline, both in terms of juvenile stocks and adult catches. In Europe glass eels (juvenile stage) were formerly used for direct consumption or for stocking rivers, but the number of juveniles arriving from the Atlantic has steadily fallen since 1980 and is now at perhaps just 5%-10% of its average level in the 1970s (Dekker 2003). In 1998, ICES declared that "*the European eel stock is outside safe biological limits and the current fishery is not sustainable*." This species is also a UK BAP priority species and listed as Critically Endangered on the IUCN Red List and a species of principal importance for the purpose of conserving of biodiversity under the Natural Environment and Rural Communities Act 2006.

12.182. In September 2007 the European Union issued Council Regulation (EC) No 1100/2007 establishing measures for the recovery of the stock of the European eel, requiring member states to produce Eel Management Plans setting measures to reduce fishing mortalities of adult eels sufficiently to ensure that at least 40% of the stock escape capture. In practice this will involve the reduction or closure of many European eel fisheries. The European eel is listed on Appendix II of CITES, and all trade of eels from the EU to the rest of the world now require a statement of non-detriment from a competent scientific authority. (Marine Scotland 2011).

Ecology

12.183. Eel is the only European fish to leave the European coast to spawn in the sea. Depending upon growing conditions (i.e. temperature and food availability) male eels spend anywhere between seven and 20 years, and females between nine and 50 years, in fresh water before returning to the sea and maturing. Body condition may be the stimulus to migrate. The eels become silver in colour (silver eels), and migration is greatest on dark, moonless nights (Marine Scotland 2011).

12.184. European eel spawn in the Sargasso Sea, the larvae are transported by the Gulf Stream to North Africa and Europe and the juvenile eel enter coastal areas and freshwater as glass eel (ICES, 2010b). They quickly transform into yellow eel and stay in Europe for 5 to 15 years or more (ICES, 2010b). Growth and age at maturity are linked to regional temperature (maturity occurs later at colder temperatures). Mature eels begin the downstream spawning migration usually from late spring to winter and migrate back to the Sargasso Sea. Although no eels were recorded during sampling within the ISA, it is possible eels pass through the site on their seaward migrations and also on their return to the coastline as elvers.

Sensitivity

12.185. Little specific information relating to the acoustic ability of eels has been found as they do not appear to possess a specific link between the swim bladder and the ear (Gill & Bartlett, 2010). As such they could be regarded as hearing generalists (Nedwell *et al*., 2003). They are thought to be sensitive to EMF although research on this is inconclusive as to whether the effect causes a significant change in migratory behaviour (Gill & Bartlett, 2010).

Sea lamprey (*Petromyzon marinus*)

Status

12.186. Scotland represents the northern extent of lamprey distribution in Europe, with few populations found north of the Great Glen (JNCC, undated a). This may be due to the cold temperatures in more northerly rivers which restrict or may prevent breeding altogether. The Scottish populations of lamprey are therefore important in maintaining the natural range of the three species (Sea, River and Brook lamprey) both within the UK and Europe.

12.187. Because of its decline across Europe, the sea lamprey is now given legal protection. It is listed in Annexes IIa and Va of the Habitats Directive, Appendix III of the Bern Convention, and as a Long List Species in the UK Biodiversity Action Plan.

Ecology

12.188. Like other species of lamprey, sea lamprey need clean gravel for spawning and marginal silt or sand for the burrowing juvenile ammocoetes. Sea lampreys have a preference for warm waters in which to spawn and spawning occurs in late May or June when the temperature reaches approximately 15°C in British rivers. The sea lamprey is reasonably widespread in UK rivers. In some places it is still common, but it has declined in parts of its range and has become extinct in a number of rivers.

Distribution in study areas

12.189. The sea lamprey was not recorded during any of the site specific surveys although it is known to be present within a number of nearby rivers (Table 12.12) and therefore may travel through the ISA during its migration.

Sensitivity

12.190. The sea lamprey does not have a swim bladder and is therefore likely to have a low sensitivity to noise. There is some evidence that the sea lamprey is sensitive to EMF (Gill and Bartlett, 2010).

River lamprey (*Lampetra fluviatilis*)

Status

12.191. The river lamprey is similar to the sea lamprey and is found in coastal waters, estuaries and accessible rivers. Although this species was not recorded during any of the site specific surveys it is known to be present within a number of nearby rivers (Table 12.13) and therefore may travel through the inshore area of the ISA during migrations.

12.192. The river lamprey is widespread in the UK, occurring in many rivers from the Great Glen in Scotland southwards and populations are currently thought to be in a healthy state (JNCC undated b).

Ecology

12.193. River lampreys are anadromous and migrate upstream from the sea at night to spawning grounds in autumn/ winter. Spawning takes place between April-May on substrates of pebble and gravel. Ammocoetes (juveniles) also spend several years in soft sediment before migrating to sea as adults. It is not currently known how long they spend in marine habitats before making the return trip to spawn.

Sensitivity

12.194. The river lamprey does not have a swimbladder and is therefore likely to have a low sensitivity to noise. There is some evidence that the river lamprey is sensitive to EMF (Gill and Bartlett, 2010).

Allis and Twaite Shad (*Alosa fallax and Alosa alosa*)

Status

12.195. Both species have declined across most of Europe and are absent from many rivers in which they once thrived and in Britain it is now illegal to fish for shad. Due to the decline in numbers the allis shad is now protected under schedule 5 of the Wildlife and Countryside Act 1981, Annex II and V of the EU habitats Directive, Appendix III of the Bern Convention and as a UK BAP Priority Species.

Ecology

12.196. These species live most of their lives in the shallow coastal waters and only return to freshwater to spawn in late spring. The main rivers where they are still found include the River Usk and the Solway and good water quality is an important factor in spawning success. Not much is known about the life of shad in the sea but it is known that they require good water quality for spawning and juvenile survival, and they are mainly found in pelagic waters.

Distribution in the study area

12.197. Neither species was found or are expected to be found in any of the study areas therefore it is not thought that the development poses a risk to their habitat.

Sensitivity

12.198. Shad are members of the herring family and therefore likely to have similar sensitivities, i.e. they will be sensitive to noise but there is no evidence of these species being sensitive to EMF.

Sparling (European smelt) (*Osmerus eperlanus*)

Status

12.199. This species was once widely found in the rivers Dee, Esk, Tay and Forth but currently are now only found in the latter two rivers where they spawn in February to April. The species has declined to such an extent that it is now a Priority Species under the UK BAP and a conservation feature in SSSI.

Ecology

12.200. This species spends most of its life in coastal areas and estuaries only travelling up the rivers to spawn.

Distribution

12.201. None were found in any of the study areas.

Relevant sites designated for migratory fish

12.202. A number of Special Areas of Conservation (SACs) on the east coast of Scotland have been designated for the protection of migratory species. These are included in Table 12.13 below. Further information regarding SACs and in particular those relevant to the development is presented in Chapter 9: Nature Conservation Designations in this ES.

Table 12.13 SACs relevant to the development that are designated for migratory fish

SAC	Migratory Species (Primary reason for designation)	Migratory Species (Qualifying feature)	Approximate distance (km) from Immediate Study Area (ISA) by water
South Esk	Salmon	None	75
Tay	Salmon	Sea lamprey, River Lamprey	135
River Dee	Salmon	None	175
Tweed	Salmon	Sea lamprey, River Lamprey	285
Teith	Sea lamprey, River Lamprey	Salmon	200

Source: JNCC http://jncc.defra.gov.uk/ProtectedSites/SACselection/SAC_species.asp

ASSESSMENT OF IMPACTS – WORST CASE SCENARIO

12.203. The assessment of potential impacts is based on the worst case scenarios for each receptor and as a result the maximum potential impact has been calculated. Therefore, no impacts of greater adverse significance would arise, should any other development scenario (as described in Chapter 5: Project Description) be taken forward in the final scheme design. Full details on the range of options being considered for the Seagreen project are provided throughout Chapter 5: Project Description. For the purpose of the fish and shellfish resource assessment, the worst case scenario, taking into consideration these options, is described in Tables 12.14a which defines the worst case for Project Alpha, 12.14b for Project Bravo and 12.14c for Transmission Asset Project.

12.204. All options considered for project design are as presented in Chapter 5: Project Description in this ES, where any range exists (such as pile diameter), these are considered realistic and therefore, assessing the worst case option is considered most practicable and conservative. It is considered that if residual impacts on the worst case scenario are acceptable then this will apply to all options within the range.

12.205. It is noted that only those design parameters detailed under each specific impact have the potential to influence the level of impact experienced by the relevant receptor. Therefore, if the design parameter is not discussed then it is considered not to have a material bearing on the outcome of the assessment.

12.206. The worst case scenarios identified below are also applied to the assessment of cumulative impacts. In the event that the worst case scenarios for the project in isolation do not result in the worst case for cumulative impacts, this is addressed within the cumulative assessment section of this chapter.

12.207. The worst case scenarios for Project Alpha, Project Bravo and the Transmission Asset Project are defined in detail in Tables 12.14a to 12.14c. As previously stated the OSPs have been considered only within the detailed assessments for Project Alpha and Project Bravo respectively. The outcome of the OSP assessments is then cross referenced where appropriate when describing the potential impacts of the Transmission Asset Project.

Table 12.14 a Worst case scenario for Project Alpha assessment

Impact	Worst case scenario	Justification
Construction		
Effect of noise – death or injury	Maximum 75 WTGs with jacket piles (4 piles per jacket). A total of 348 piles installed using impact piling with 3 OSP and 3 meteorological masts. The worst case would be scenario GM1. Construction is assumed to take place over the full year. The duration of the piling programme at Alpha will be a maximum of two years, with only one piling event at any time. In the worst case it is possible that pile installation is undertaken in Bravo concurrently. Given the short duration of piling it is unlikely that two piling events will coincide.	The 'worst case' scenario is the maximum level of noise and duration created by hammer blows on the pile being driven through bedrock which could have a lethal or damaging effect on the receptors present.
Effect of noise – behaviour	As above	The maximum level of noise that would cause changes to behaviour such as spawning and feeding periods, spatial distribution and displacement in receptors present.
Seabed habitat disturbance	The worst case scenario is the maximum area of disturbance on sensitive habitats; calculations are based on disturbance due to array cable installation, gravity based structures (GBS) foundations for wind turbine generators (WTGs), meteorological masts and offshore platforms (OSPs). The total quantifiable construction disturbance (Area of Influence) is 375.27ha (see Appendix G4).	The worst case scenario is established by defining the maximum amount (spatial extent) of habitat disturbance that Project Alpha could have resulting from the installation of structures and array cables with the largest footprint. This is termed the Area of Influence. The worst case would be if the entire wind farm was built within sensitive habitats e.g. sandeel prime habitat,
Permanent loss of habitat	The worst case scenario is represented by the maximum permanent loss of habitat for the most sensitive species based on the GBS foundations and OSP structures above. The total maximum habitat loss will be 88.80ha (see Appendix G4).	The worst case scenario is therefore, represented by the largest footprint from the foundation structures (and associated scour protection) under consideration. In addition, if the entire wind farm was built within the one single most sensitive habitat that has the greatest sensitivity e.g. sandeel habitats that would represent the worst case scenario

Impact	Worst case scenario	Justification
Increased of suspended sediments and remobilisation of contaminants.	The worst case scenario would be the maximum amount of sediment released in the shortest amount of time. This would also be the worst case for contaminant release. Release of up to 695,700m^3 of seabed during seabed preparation. The greatest possible amount of material release will be 2,932,200m^3 which could occur over a maximum of a 36 month period. (see Appendix G4 Table 1 for detail)	The 'worst case' scenario is represented by that which could result in the maximum volume of arisings (and therefore, maximum volume of material that could brought into suspension. Assuming conical GBS foundations 72m diameter, 3 OSP and 3 meteorological masts
Operation		
Disturbance effects of Electromagnetic Fields (EMF)	Array cabling with 355km of 66kV array cabling with an minimum burial depth of 0.5m	EMF impacts are governed by depth of (cable) burial and not the number of turbines or their layout or location within the site. Therefore, the worst case scenario is represented by the shallowest burial depth for all cables. Because the burial depth achieved varies greatly an average minimum burial depth is applied.
Operational noise	Noise or vibrations from the operation of 75 WTGs on GBS foundations.	Provides maximum extent of operational noise based on number of turbines and greater radiation efficiency compared to smaller piles associated with jackets.
Disturbance of seabed habitats	It is not possible to determine the number of maintenance activities that will disturb the seabed. Scour hole formation around GBS and OBS structures in 1 in 50yr storm = 35.61ha	Maintenance activity may impact on species which inhabit the seabed such as shellfish and sandeels, if the plant used interacts with the seabed. The scenario therefore, provides for the maximum level of seabed disturbance from anchor and jack-up vessels. Assuming no scour protection for structures and the use of GBS foundations which cause the greatest potential scour during a 1 in 50 year storm. Assumes a 72m diameter GBS structure at 8 locations and 52m elsewhere
Creation of new habitat fish aggregation	The worst case scenario for the area created habitat created will be approximately the same as the worst case scenario for the area of habitat loss. This was calculated as 88.80ha see *Loss of potential habitats due to construction activities* above	Aligned with seabed footprint (see loss of habitat in construction phase). The scenario provides for the maximum available surface area for colonisation. Any other scenario will result in a lower surface area.

Impact	Worst case scenario	Justification
Increased of suspended sediments and remobilisation of contaminants	The worst case scenario would be the maximum amount of sediment released in the shortest amount of time. This would also be the worst case for contaminant release. Greatest amount of material release is 345,522m^3.	The worst case scenario for scour formation assumes no scour protection is provided and scour occurs during a 1 in 50 year storm condition with 4877m^3 per foundation of 73m diameter. Increased suspended sediments may affect filter feeding mechanisms and respiratory functions for species inhabiting the seabed
Decommissioning		
Seabed habitat disturbance and loss	Removal of all cabling and built structures (based on worst case assumptions detailed under construction).	Arrangements associated with decommissioning will be determined prior to construction and a full Decommissioning Plan for the project will be drawn up and agreed with DECC. Until the arrangements have been clarified, the worst case scenario is that all structures will be removed.

Table 12.14 b Worst case scenario for Project Bravo assessment

Effect	Worst case scenario	Justification
Construction		
Effect of noise – death or injury	Maximum 75 WTGs with jacket piles (4 piles per jacket). A total of 324 piles installed using percussive impact piling with 2 OSP and 3 meteorological masts. The worst case would be scenario GM1 Construction is assumed to take place over the full year. The duration of the piling programme at Bravo will be a maximum of two years, with only one piling event at any time In the worst case it is possible that pile installation is undertaken in Alpha concurrently. Given the short duration of piling it is unlikely that two piling events will coincide	As for Project Alpha except 2 OSP
Effect of noise – behaviour	As above	As for Project Alpha except 2 OSP
Seabed habitat disturbance	The worst case scenario is the maximum area of disturbance on sensitive habitats e.g. prime sandeel habitats. The calculations are based on disturbance due to array cable installation, GBS foundations for WTGs, meteorological masts and OSPs. The total quantifiable construction disturbance (Area of Influence) is 374.84ha	As for Project Alpha except 2 OSP
Permanent loss of habitat	The worst case scenario is represented by the maximum permanent loss of habitat for the most sensitive species based on the structures above. The total maximum habitat loss will be 87.71ha	As for Project Alpha except 2 OSP
Increased of suspended sediments and remobilisation of contaminants	The worst case scenario would be the maximum amount of sediment released in the shortest amount of time. This would also be the worst case for contaminant release. Greatest amount of material release over a 36 month period 2,894,700m^3	As for Project Alpha except 2 OSP

Effect	Worst case scenario	Justification
Operation		
Disturbance effects of Electromagnetic Fields (EMF)	Array cabling with 355km of 66kV array cabling with an minimum burial depth of 0.5m	As for Project Alpha
Operational noise	Noise or vibrations from the operation of 75 WTGs on GBS foundations.	As for Project Alpha
Disturbance of seabed habitats	It is not possible to determine the number of maintenance activities that will disturb the seabed. Scour hole formation around structures in 1 in 50yr storm = 35.42ha	As for Project Alpha except 2 OSP
Creation of new habitat fish aggregation	The worst case scenario for the area created habitat created will be approximately the same as the worst case scenario for the area of habitat loss. This was calculated as 87.71ha see *Permanent loss of habitat due to construction activities*	As for Project Alpha except 2 OSP
Increased of suspended sediments and remobilisation of contaminants	The worst case scenario would be the maximum amount of sediment released in the shortest amount of time. This would also be the worst case for contaminant release. As for Project Alpha except 2 OSP resulting in 341,490m^3 scour material	As for Project Alpha except 2 OSP
Decommissioning		
Seabed habitat disturbance and loss	Removal of all cabling and built structures (based on worst case assumptions detailed under construction).	As for Project Alpha except 2 OSP

Table 12.14 c Worst case scenario for Transmission Asset Project assessment

Effect	Worst case scenario	Justification
Construction		
Underwater noise	Noise from rock dumping, vessel movement and cabling laying	Noise levels from these activities assessed in Appendix H6
Seabed habitat disturbance	Infrastructure within the Project Alpha and Project Bravo site boundaries (assessed within Alpha and Bravo) Habitat loss =1.27ha ECR corridor Six export cables with a combined length of 530 km. The area of influence has been calculated as 10m. Therefore maximum disturbance = 795ha	The worst case scenario is established by defining the maximum area of habitat disturbance that the Transmission Asset Project could have.
Permanent loss of habitat	Within the Project Alpha and Project Bravo site boundaries (assessed within Alpha and Bravo) Maximum area of habitat loss = 4.8ha ECR Corridor Rock placement or mattresses to protect export cables will in a worst case scenario and would cause a habitat loss of 37.1ha.	The loss of seabed habitat will result from the placement of built structures (and associated scour protection material) on the seabed.
Increased of suspended sediments and remobilisation of contaminants	Within Project Alpha and Project Bravo site boundaries (assessed within Alpha and Bravo) Worst case is material release of 69,500m^3 over 36 months ECR Corridor Worst case is material release of 4,770,000m^3 over 24 months	The worst case scenario is represented by that which could result in the maximum volume of arisings (and therefore, maximum volume of material that could be brought into suspension) and the method by which the material is re deposited on the seabed. This assumes jetting of 237.5m/hr for installation, up to 6 cables of 275kv (HVAC) within the ECR corridor Within Project Alpha and Project Bravo site boundaries worst case is structures with no scour protection for up to 5 OSP with 49m baseplate

Effect	Worst case scenario	Justification
Operation		
Effect of electromagnetic fields (EMF) (export cables)	6 (HVAC) 132 kV export cables with a combined length of 530 km and a minimum depth of 0.5m.	The worst case scenario for the impact of electromagnetic fields on sensitive receptors.
Creation of new habitats – fish aggregation	The maximum increase in habitat due to ancillary structures and rock protection will 4.8ha within the Project Alpha and Bravo Boundaries (assessed in Alpha and Bravo) and 37.1ha within the ECR corridor	Aligned with seabed footprint (see loss of habitat in construction phase). The scenario provides for the maximum available surface area for colonisation, any other scenario will result in a lower surface area.
Increased suspended sediments and mobilisation of contaminants	Unplanned maintenance operations requiring vehicular plant access to the buried cable during low water. Maximum potential area of disturbance would be as specified for construction phase.	Any maintenance activity required on the intertidal section of the export cables could require vehicular access. The worst case area of impact is therefore in line with that provided for under construction.
	Conical GBS with no scour protection, maximum scour volume of 6,420m^3	This assumes that no scour protection is used around rectangular/square baseplate GBS. This assumes a 1 in 50 year storm condition. Total 5 OSP and 49m diameter base plate
Decommissioning		
Seabed habitat disturbance due to OSP and cable removal	Removal of all cabling and built structures (based on worst case assumptions detailed under construction). Note OSP removal covered in Project Alpha and Project Bravo assessments	Arrangements associated with decommissioning will be determined prior to construction. Until the arrangements have been clarified, the worst case scenario is that all structures will be removed.

IMPACT ASSESSMENT CONSTRUCTION PHASE

12.208. This section assesses the potential impacts which may occur during construction of the Seagreen Project. The section begins with an impact investigation on the potential effects of noise on fish and shellfish and will be used to inform the impact assessment for Project Alpha, Project Bravo and the Transmission Asset Project.

Background to construction noise

12.209. "*The extent to which intense underwater sound might cause an adverse environmental impact in a particular species is dependent upon the incident sound level, frequency content, duration and/or repetition rate of the sound wave*" (Nedwell *et al.*, 2011). It is also dependent on the sensitivity of the species to noise in terms of their hearing ability. The variation in sensitivity of different fish species to sound is directly related to the variations in anatomy and physiology of the auditory structures and the swim bladder. The swim bladder is used for buoyancy, hearing and sound production. Noise can cause the swim bladder to either rupture causing death or expand and contract rapidly causing tissue damage. Popper and Fay (1993) showed that there is considerable variation in the way in which various species 'hear' and process incident sound and vibration. Fish species can be classified as:

- hearing generalists which have either no swim bladder or one that is poorly developed or not connected to the inner ear. These can be of medium sensitivity such as cod which has a swim bladder in close proximity to the inner ear but with no direct connection, or Atlantic salmon which has a swim bladder which is not connected to the skull nor is it always filled. There are also those classed as low sensitivity e.g. flatfish and elasmobranchs which have no swim bladder; and
- hearing specialists which have a mechanical connection between the swim bladder and inner ear (bulla auditoria in clupeids such as herring and sprat) have high sound pressure sensitivity.

Table 12.15 Hearing specialisms for selected fish species

Common name	Swim bladder connection to inner ear	Sensitivity
Herring	Prootic auditory bullae	High
Sprat	Prootic auditory bullae	High
Cod, pollock, haddock	Close proximity	Medium
Atlantic salmon	Not close proximity	Medium
Plaice	No swim bladder	Low
Thornback ray	No swim bladder	Low
Dab	No swim bladder	Low
Sandeel	No swim bladder	Low
European eel	No swim bladder	Low

Information based on Nedwell *et al.*, (2012)

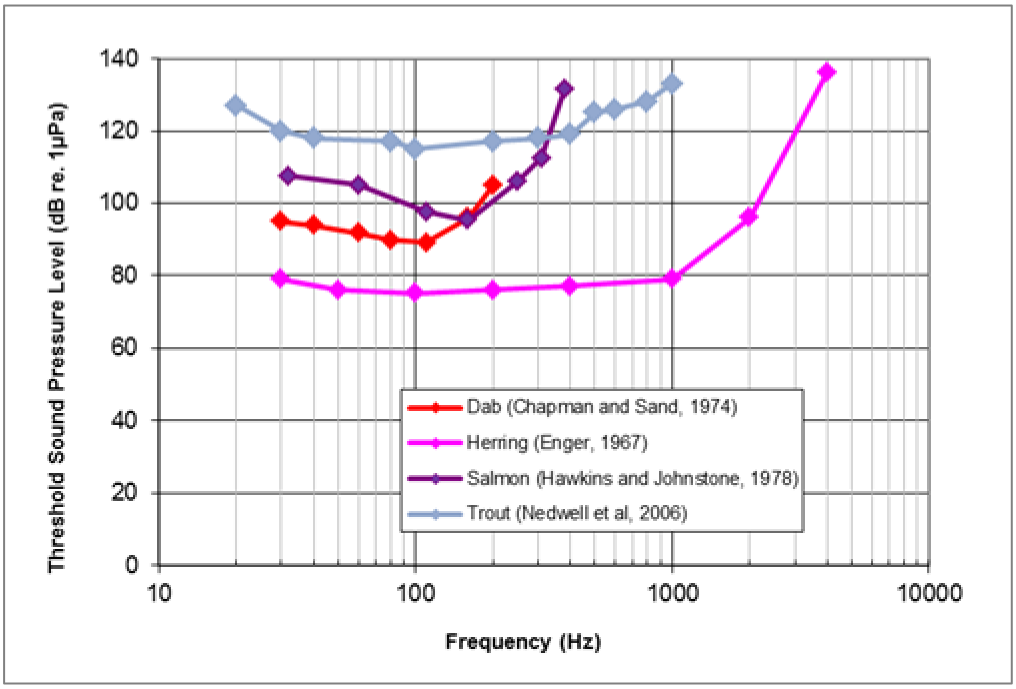
12.210. Underwater noise can have several impacts on marine species from causing death, physiological and auditory damage. Other impacts include disturbance to spawning and feeding patterns, disruption to breeding and displacement from normal habitats. Such impacts on the natural assemblages of fish species also have an impact on the food chain with the potential loss of prey species for birds, marine mammals and other predatory species of fish. There are various ways of measuring the effect on marine species of noise on above the normal hearing threshold. The following paragraphs describe how noise is characterised in relation to marine species.

12.211. Decibels are units commonly describing sound intensity and can only be compared when a standard reference pressure is used. For underwater sounds the reference pressure is generally a pressure of 1µPa (sound intensity of one micro pascal). Thus units for decibels are given as dB re 1µPa. Nedwell *et al.*, (2007a) reported background levels of sea noise in coastal waters could be approximately 130dB re 1µPa which would be considered hazardous in air but since sound travels much faster in water and marine animals have evolved to adapt to such levels.

12.212. There are various ways of characterising the relative pressure of a sound signal:

- the peak pressure, is the range in pressure between zero and the greatest pressure of the pressure wave signal.
- the peak-to-peak pressure is the range in pressure between the lowest and highest point of the wave. Peak to peak levels of noise are often used to characterise sound originating from sources such as percussive impact piling and seismic airgun sources. Currently available information suggests that lethality to fish may occur where peak to peak levels exceed 240dB re 1µPa , and physical injury may occur where peak to peak levels exceed 220dB re 1µPa (Nedwell *et al.*, 2011). Nedwell *et al.*, (2007b) has suggested that the use of a 130dBht level provides a suitable criterion for predicting the onset of traumatic hearing damage, which recognises the varying hearing sensitivity of differing species.
- sound pressure level (SPL) – is a measure of sound levels over a specific time period. It is therefore the average unweighted level of the sound. SPL is used to measure sound from continuous noise such as drilling or background underwater sound levels. Yelverton *et al.* (1975) showed that, for a given pressure wave, the severity of the injury is related to the duration of the pressure wave. The Yelverton model also indicated that smaller fish were generally more vulnerable than larger ones.
- sound exposure level (SEL) – effectively takes account of both the SPL of the sound source and the duration of the sound present in the acoustic environment through determining the energy of the sound over a measurement period. SELs are useful in making predictions about the physiological impact (such as hearing damage) of noise as this can be modelled as a function of the acoustic energy of a stimulus (Southall *et al.*, 2007). However SEL is also limited with respect to short loud pulses of sound as it remains unadjusted (unweighted) to any reference point in contrast to SEL's in air for human hearing.
- dB_{ht}*(species)* – an assessment of hearing ability is an important consideration when assessing the effect of underwater noise. Perceived noise levels measured in dB_{ht} is lower than the unweighted levels as described above because there are frequency components in the sound that fish cannot detect. Noise levels should be weighted in relation to the way sound is perceived in different species. The dB_{ht} metric is a measure of perception i.e. the amount a certain noise is above the hearing threshold (ht) of various species and is termed dB_{ht} (s*pecies*). $0dB_{ht}$ *(species)* is the hearing threshold where 'sound' starts being heard and this is obtained through developing 'audiograms for various species'. The hearing thresholds for species with regional significance are shown in Plot 12.6. A certain level of sound will have a different effect on different species depending on their sensitivity thus using this measure the effect of noise on different species can be compared.

Plot 12.5 Comparison of Hearing thresholds for species of fish (Nedwell *et al*., 2012)



12.213. Nedwell *et al*., (2007b) suggest that a perceived level of 130 dB_{ht} (*Species*) will cause instant hearing damage from a short exposure to a single piling event. The assessment criteria shown in Table 12.16 below were compiled from a large body of evidence of fish and marine mammal responses to underwater sound and published by the Department of Business Enterprise and Regulatory Reform (BERR) (Nedwell *et al*., 2007b).

Table 12.16 Assessment criteria used in this study to assess the potential impact of underwater noise on marine species (Nedwell *et al*., 2007b)

Level in dB_{ht} (*Species*)	**Impact**
0-50	Low likelihood of disturbance
50-75	Avoidance is unlikely
75 and above	Significant avoidance reaction by the majority of individuals but habituation or context may limit effect
90 and above	Strong avoidance reaction by virtually all individuals
Above 130	Possibility of traumatic hearing damage from single event

Source: Appendix H6 (Section 3)

12.214. Subacoustech Ltd undertook a noise modelling study to determine the extent of the propagation of underwater noise from the pile driving operations, using the Impulse Noise Sound Propagation and Impact Range Estimator (INSPIRE) model. This was used to determine the impact ranges of noise for key species of fish and shellfish (for details of the methodology used in modelling see Appendix H6). Four source locations were modelled:

i. Project Alpha;

ii. Project Bravo;

iii. Inch Cape; and

iv. Neart na Gaoithe.

12.215. The proposed Scottish Territorial Waters OWF sites at Inch Cape and Neart na Gaoithe were included for cumulative impact modelling. Cumulative and in-combination impacts are assessed in Impact Assessment-Cumulative and In-Combination.

12.216. Two piling scenarios were modelled at 2 noise source positions within the Seagreen Project area, one location at each of Project Alpha and Project Bravo. Noise source positions were selected in terms of proximity to key species populations of marine mammals and fish. The scenarios used a WTG with jacket substructure, each consisting of 4 piles up to a diameter of 3m.

12.217. Sensitivity analysis carried out during the noise propagation modelling showed that when blow force or hammer energy remained constant, the diameter of the pile had little influence on the range of potential impact. The worst case scenario was selected based on two criteria; maximum noise output and maximum duration of noise exposure, created from a range of piling scenarios tested. During the initial phase of the assessment the sensitivity analysis was carried out using the INSPIRE model to test which parameters most affected the extent of the noise propagation. This concluded that the only parameter that directly influenced the extent of the noise outputs is the hammer energy force. The other parameters indirectly affect the extent of the noise outputs, e.g. the 3m pile required a lesser depth of penetration and did not encounter harder bed rock which therefore required lower hammer energy and produced less noise. There was little difference between the noise from piling of 2m and 3m diameter piles.

12.218. Based on this premise a worst case scenario was selected consisting of a fully driven single piling operation with an installation time of 55 minutes to install a 2m pile up to 27m in length. This worst case is referred to as WC GM1 in the remainder of this assessment, and in the relevant technical appendices. The worst case scenario takes assumes that: only one pile is installed per day in Project Alpha and Project Bravo: piling will take place over a period of up to 2 years: a maximum of 75 WTGs will be installed on each site and each substructure/ foundation will use a jacket with 4 piles giving 300 piles for each site. A maximum of three OSPs will be installed in Project Alpha, one with up to 12 legs and two with up to 6 legs. A maximum of two OSPs will be installed in Project Bravo with up to 6 legs each. Assuming two piles will be installed at each OSP leg, this entails 48 piles for Project Alpha and 24 piles for Project Bravo. A total of up to 348 piles will therefore be installed for project Alpha and a total of 324 piles for Project Bravo. Note that whilst the assessment for marine mammals presented in Chapter 13 of this ES uses a combination of most likely and worst case parameters for the assessment, given the small differences between the values a simpler approach was considered to be more appropriate for this chapter.

12.219. Using this worst case scenario, the species of fish and shellfish used in the study are those considered to be commercially or environmentally important by consultees and/ or where spawning and nursery grounds are in relative close proximity to the development. Knowledge of hearing thresholds are crucial for dB_{ht} analysis thus species selected required peer reviewed audiograms. Using the INSPIRE model the maximum range at which either lethal and auditory damage or behavioural impacts for dab, salmon, herring, trout and sandeel were determined and the impact on other similar key species could be suggested. Noise contours were used with maps of spawning and nursery areas for the same species to illustrate the spatial impacts of different sound pressures (see Figures 12.13 to 12.17).

Project Alpha

Effect of noise – death or injury

12.220. Parvin *et al.* (2007) suggested that the lethal effects of underwater noise may occur where peak to peak noise levels exceed 240 dB re 1µPa and physical injury or death may occur at level above 220 dB re 1µPa. Based on the GM1 scenario the range of lethal effect is 40m and the range for non-auditory physical injury is 60m (Nedwell *et al*, 2012). Given the very small range, the magnitude of this potential impact is considered negligible for all species. The conclusion of a review of data on auditory injury to marine fish exposed to underwater noise, concluded that it is very unlikely that fish would experience auditory injury unless constrained in a very high level continuous sound field for prolonged periods (Nedwell *et al*., 2011). Based on behavioural reactions to noise, fish will swim away from the source and therefore are unlikely to be exposed to these high noise levels for any length of time (Maes *et al.*, 2004), therefore for this impact, the sensitivity of all species is considered to be low. Therefore, for lethal or non-auditory physical injury the significance of impact for all species of fish is considered to be negligible.

12.221. There is little research on the potential lethal or damaging effect of noise on various species of shellfish although the few studies undertaken have shown that clams, oysters and shrimp are not sensitive to noise, including that of seismic prospecting (Tollefson and Marriage 1949, and Andriguetto-Filhoa *et al*., 2005). Therefore, it is considered that there will be no impact upon these species with regard to lethality and physical injury.

12.222. Nedwell *et al.* (2012) used the weighted species specific 130 dB_{ht} perceived level as an indicator of traumatic hearing damage. While temporary hearing loss is an injury that is recoverable over a period of time, permanent hearing loss results in the death of sensory hair cells in the inner ear and is irreversible.

12.223. The estimated ranges out to which hearing damage may occur in key species of fish for the worst case scenario are shown below in Table 12.17.

Table 12.17 Range of auditory injury at 130 dB_{ht} (*species*) for key species

Seagreen – GM1 (Alpha)	Range to 130dB_{ht} (km)			
	Max	Min	Mean	Area
Dab	0.04	0.02	0.03	0
Herring	0.26	0.24	0.25	0.2
Salmon	0.04	0.02	0.03	0
Sandeel	below level of detection	n/ a	n/ a	n/ a
Trout	below level of detection	n/ a	n/ a	n/ a

12.224. JNCC, SNH, FEF and Marine Scotland expressed concerns (see Table 12.1) about the impact of construction on the sandeel population and especially spawning behaviour. In terms of noise, several studies have concluded that as this species lacks a swim bladder they are hearing generalists with a low sensitivity to noise from piling. Nedwell *et al*., (2004) and Hassel *et al*., (2004) concluded that sandeel species reacted more to pulsed sound than continuous soundwaves. Research using underwater seismic air guns providing a sound level of 256.9 dB_{ht} re 1µPa indicated there was no lethal effect on caged lesser sandeel. The only reaction noted was greater tailbeat frequency and some movement away from the noise source, there was little evidence of fish trying to escape from the source of noise (Hassel *et al*., 2005).

12.225. Limited research has been carried out on the direct effect of piling noise on spawning behaviour in sandeel and there is uncertainty about how vulnerable fish eggs and larvae are to piling noise. Bolle *et al*. (2011) identified a maximum SEL of 183dB re $1\mu Pa^2s$ for small fish <2g and Booman *et al*. (1996) found that mortality of eggs and larvae of cod, saithe and herring occurred within 5m of the source of seismic airgun noise. This suggests that the effects of noise from piling would be very localised and since piling activity will be restricted to one installation per day (see Chapter 5: Project Description in this ES) and the area of prime habitat is relatively large in Project Alpha only a small proportion of eggs and larvae, which are planktonic would be affected.

12.226. The range at which hearing damage would occur for species with low sensitivity to noise (see Table 12.17) such as sandeel were found during the modelling study to be too small to measure. This supports the conclusion that any auditory injury effects are very localised and would only affect a small proportion of the population. The evidence suggests sandeel have a low sensitivity to noise and considering the small range at which noise at this level the magnitude of the potential impact of noise on sandeel is considered to be low and the impact is therefore negligible.

12.227. The sensitivity of other hearing generalist species such as plaice, thornback ray and dab is considered to be low. The magnitude of the potential impact is also considered to be low, considering the localised nature of the impact based on the assessment done by Subacoustech (Appendix H6) for hearing generalists such as dab. The impact of auditory injury from noise for these species is therefore considered to be negligible.

12.228. The modelling results show that the range over which auditory injury could occur for salmon is 0.04km. The extent of the impact is therefore fairly localised and given that salmon are migratory species the likelihood of large numbers of salmon being in the area for significant amounts of time and being in close proximity to during piling operations is low. It is also likely that fish, if present, will move away from the source of noise and out of the area of exposure to high levels of noise, therefore the magnitude of the impact would is considered to be negligible. The sensitivity with respect to conservation importance is considered to be medium since salmon are a protected species; however, the extent of the species range within the area reduces this to low. The impact of noise with respect to auditory damage and death is therefore considered negligible.

12.229. The maximum range for auditory injury for herring was predicted to be at a distance of 0.26km. Clupeids of regional commercial significance such as herring and sprat are considered to be highly sensitive to noise and therefore impacts would have the greatest potential impact on these species. The noise contours at 130 dB_{ht} level for herring is shown in Figure 12.13 and shows the overlap with the southernmost spawning ground for the Buchan stock. Herring larvae are present within the ISA and were found in relatively high abundance (between 1.2 - 2 per m^2) as recently as 2011 (Figure 12.2) 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 since spawning activity was not found in the ISA, the larvae present may have originated in the more northern spawning areas. Herring are benthic spawners and although it is uncertain whether herring eggs would become unviable as a result of piling noise, other studies on eggs and larvae of cod, herring saithe found that mortality from seismic gun noise was very localised and only a small proportion of the eggs and larvae would be affected (Booman *et al*., 1996).

12.230. Whilst there is a potential for auditory injury to affect a large number of individuals, as the population is widely dispersed in the North Sea and since fish would exhibit natural avoidance behaviour to underwater noise is not thought likely that a large proportion of the population would be affected. Although the sensitivity of individual herring to noise is high it is important to consider the impact on the population as a whole. In population terms the magnitude of potential lethal and physical injury is considered to be low. The sensitivity is considered high for individuals based on the species ability to detect noise but medium in terms of the population distribution and the proportion affected. The impact of death and injury from construction noise is assessed as being minor adverse and **not significant** for fish.

12.231. Studies on the effect of explosive charges at varying distances from the American lobster (*Hommarus americanus*) showed there was little reaction from the species to this noise (Knight 1907 in Nedwell *et al*., 2011). Similar results were found for the Atlantic white shrimp (*Penaeus setiferous*) and the oyster (*Ostrea virginica*) at a distance of 15m from the epicentre of the blast (Gowanloch and McDougal, 1945). More recent studies on penaeid species (white shrimp, southern brown shrimp and the Atlantic seabob) showed that there was no impact on any of the species from the noise from four synchronised airguns each with a peak pressure of 196 dB re 1µPa (Andriguetto-Filhoa 2005).

12.232. It can be concluded that for the species of crustacean found in the study areas (nephrops, velvet crab, edible crab and lobster) any impact will be negligible and **not significant**.

12.233. It should be noted that although all of the above impacts are only based on a single piling event that, given the short term and highly localised nature of lethal or injurious impacts, the significances presented provide a fair representation of the potential impact over the duration of the construction period.

Mitigation

Mitigation

At this stage, until further design work is carried out no mitigation is assumed.

12.234. Soft start piling (in which the energy used to drive the piles into the sediment is slowly ramped up) has been incorporated in to the noise assessments. This creates an increasing level of noise from low levels and will allow noise sensitive species such as herring and sprat to vacate the area and can reduce the risk to injury. This is an industry standard mitigation.

12.235. Following further detailed design, it is likely that many of the parameters used in the assessment (such as hammer energy, turbine loadings, etc.) will be refined and noise impacts be reduced. Although no commitment can be made at this stage, Seagreen will endeavour to reduce noise outputs during detailed design.

Residual Impact

12.236. Considering the potential reduction in noise outputs following detailed design, impacts could potentially be significantly reduced and are likely to be negligible and not significant for all species. The use of the above mitigation measures for piling may reduce the impact on high sensitivity species such as herring, however, at this stage it is not possible to determine what this reduction may be. Therefore on a precautionary basis the impact remains minor adverse but still **not significant.**

Effect of noise - behaviour

12.237. Studies have shown that behavioural changes in fish may occur at relatively low sound levels. Catches of haddock and cod were significantly lower for several days after the fish were exposed to seismic gun noise (Engas and Lokkeborg, 2002) and similar results were seen for herring and blue whiting (Slotte *et al*., 2004). Although fish can 'hear' underwater noise over a low frequency range (10Hz to 100Hz) the reactions vary due to physiological differences as described in the individual species accounts, as well as other factors such as age, size, reproductive rate and feeding states. The dB_{ht} (*species*) metric has been developed to enable the potential for behavioural responses to sound to be quantified (Nedwell *et al*., 2007b). Table 12.16 shows the potential impact various levels of noise may have on marine species.

12.238. As part of the modelling study a level of 90 dB_{ht} (*species*) has been proposed as the level at which there is a strong probability that all individuals would be disturbed and 75 dB_{ht} (*species*) is used as a level at which 50 - 85% of individuals will react (Nedwell *et al*., 2011). Although there will be a variation in avoidance ranges based on the location of piling, the largest impact ranges shown in the modelling from both perceived levels for different species in Project Alpha are shown in Table 12.18.

Table 12.18 Impact range for 90 dB_{ht} (*species*) and 75 dB_{ht} (*species*) perceived levels for different species of fish for Project Alpha (GM1)

Species	Range to 90 dB_{ht} (km/km^2)				Range to 75 dB_{ht} (km/km^2)			
	Max	Min	Mean	Area	Max	Min	Mean	Area
Dab	2.9	2.7	2.8	24.8	16	15	16	785
Herring	28	25	26.5	2100	77	33	55	10014
Salmon	1.3	1.3	1.3	5.5	8.4	8.0	8.2	211
Sandeel	0.2	0.2	0.2	0.1	1.4	1.4	1.4	6.1
Trout	0.3	0.2	0.3	0.2	1.8	1.7	1.8	9.7

(Source: Nedwell *et al*., 2012)

12.239. The modelling results show that for some species the impact ranges could affect behaviour in spawning and nursery grounds. Therefore, the noise contours representing the impact ranges for the species in Table 12.18 were overlain onto maps of spawning and nursery grounds developed by Coul *et al*., (1998) and updated by Ellis *et al*., (2005) and shown in Figures 12.13 to 12.18.

12.240. The study showed that for hearing generalists (sandeel, dab, trout and salmon) the distances of disturbance are generally small for all these species and would be very localised.

12.241. Areas within Project Alpha are considered to be prime substrate for spawning and feeding of sandeel are shown in sandeel habitat maps (Figure 12.3). Sandeel are substrate spawners and spend much of their life buried in the seabed only emerging to spawn and feed. They are considered important to the North Sea ecosystem and are key prey species for a number of marine bird species (see Chapter 10 Ornithology). Considering this and the fact that prime spawning habitat is found within Project Alpha the sensitivity is considered to be medium. However, the magnitude is considered to be low given the small range of predicted disturbance and therefore the impact of the noise is considered to be minor adverse and **not significant**.

12.242. The potential impact on salmon migratory behaviour in response to noise was raised during consultation (see Table 12.1). The range at which behavioural changes could occur in migratory species such as salmon was small (1.3 km). Halvorsen *et al*., (2011) found that Chinook salmon in experimental conditions showed no effects on hearing sensitivity to tidal turbine noise between 155 to 163 dB re 1μPa using electrophysiological testing of the auditory system. This suggested that as Chinook salmon pass very near to a turbine they would not experience changes in their hearing sensitivity and thus there would be little behavioural changes. This study also showed that as the fish move further away from a turbine there is less risk to the auditory system as the sound level would decrease on an order of 6 dB per doubling of distance from the turbine.

12.243. It is assumed however that migratory species will pass through the site during their migration (salmon, sea trout and sea lamprey) although there is no evidence of the numbers of fish this constitutes. Of these, salmon is considered to have medium sensitivity to noise and as a BAP priority species the sensitivity is considered medium (Gill and Bartlett, 2010, Nedwell *et al*., 2007). Given the relatively small range of impact, it is likely that the proportion of the population affected by noise would be small and therefore the magnitude of the impact is considered to be negligible. As such the significance of noise impacts is considered to be negligible and **not significant** for salmon.

12.244. No specific modelling study was conducted for eel species by Subacoustech, therefore, there are no data for the range of potential behavioural impacts. However, whilst the European eel may pass in close proximity to or through Project Alpha during certain life stages, its passage would be transient and there are no key habitats within the vicinity of Project Alpha which are required as part of its lifecycle. Therefore, there is little scope for the species being affected and the magnitude of any impact is considered to be negligible or low. The impact of noise during construction is not considered to pose a disturbance to migratory patterns of eels. Eels are considered hearing generalists and are thought to have a low sensitivity to noise (Nedwell *et al.*, 2004, see Table 12.15). Therefore, this impact would be considered negligible and **not significant** for eels.

12.245. Species considered to have medium sensitivity to noise, such as cod and whiting, have spawning areas that include the ISA and RSA and are BAP UK priority species. Cod is known to use low frequency grunting during spawning and it could be suggested that construction noise may affect this behaviour by masking communications. Peak spawning for cod is February to April and May to September in the northern North Sea thus piling activities over 2 years would potentially affect only two spawning seasons. Both species are pelagic broadcast spawners with spawning grounds that cover wide areas in the North Sea (Figure 12.5). The widespread distribution of potential spawning grounds for these species and their spawning behaviour indicate that only a very small proportion of the population would be affected thus the magnitude of the impact is considered to be low to negligible. Sensitivity to noise is considered to be medium as an individual but low in terms of the population. The impact assessment will be similar to other gadoid species such as whiting which are also broadcast spawners without specialised spawning substrates. As a result behavioural disturbance due to noise from pile driving at Project Alpha is not considered to be significant and the impact is considered negligible and **not significant**.

12.246. Species of high sensitivity to noise include clupeids, of which, the commercially important species in the North Sea is herring which is also a specialist substrate spawner with a peak spawning period in August and September. Herring spawning grounds are located approximately 6.3km to the north and 80km to the southern boundaries of Project Alpha (see Figure 12.13). Noise modelling study predicted that a behavioural response in individuals could occur up at to 77km for 75 dB_{ht} (*species*) behavioural response and 28km for the more severe 90dB_{ht} (*species*) response from the source of the noise in the worst case scenario GM1 (see Table 12.18). These impacts will result in 24% of the high intensity herring spawning grounds in the WSA (see Figure 12.13) affected by predicted 75 dB_{ht} noise levels or higher, with 3% of the spawning area predicted to be affected by noise levels of 90dB_{ht} or higher. Some 40% of the herring nursery area within the WSA are predicted to be affected by noise level greater than 75dB_{ht}. Predicted noise levels exceed 90dB_{ht} within 9% of the WSA herring nursery grounds.

12.247. During the construction phase up to 348 piling events will occur within Project Alpha potentially resulting in noise disturbance for approximately an hour every day throughout the herring spawning season and juvenile development stages. The assumption is that the worst case scenario for herring would be piling activity over the full 2 year period which would disrupt two consecutive spawning periods.

12.248. The urge to spawn in herring is particularly strong; the response recovery time following noise disturbance is unknown but is likely to be relatively rapid. Skaret *et al* (2005) suggest that during spawning herring will give priority to reproduction with spawning overruling noise avoidance responses.

12.249. Noise impacts from piling affect a significant portion of both the high intensity spawning and nursery areas within the WSA. Piling will take place intermittently, for 342 short (hour long) bursts over the two year construction period. Given the large area, but small temporal nature of the impact would suggest an impact magnitude of low on a high sensitivity receptor species. With respect to the herring population within the WSA the impact is predicted to result in a moderate adverse and **significant** impact on spawning herring.

12.250. Considering the wider picture with respect to herring spawning grounds in the North Sea, the latest spawning maps produced by Ellis *et al.* (2012) show that the main spawning grounds for the Buchan herring stock are concentrated off the north east coast of Scotland (Figure 12.2). Commercial catch data for herring (Figure 12.2) also show that the majority of adult herring is caught to the northwest of Scotland off Peterhead and acoustic surveys indicate that the greatest biomass of adult spawning herring are also located in this area (ICES, 2011). However, since the noise contours overlap with a significant portion of the southern extent of the spawning areas and given the high sensitivity of the species to noise the impact of noise would be considered to be minor adverse and **not significant** in a North Sea context.

12.251. There is little research on the potential impact of noise on shellfish although the few studies undertaken (during seismic prospecting) have shown that shellfish are not sensitive to noise (Tollefson and Marriage, 1949, and Andriguetto-Filhoa *et al.*, 2005). The modelling study undertaken did not include species of shellfish but as they are considered to be insensitive to noise the potential for behavioural impact on these species is considered negligible and **not significant.**

Mitigation

Mitigation
At this stage, until further design work is carried out no mitigation is assumed.

12.252. Soft start piling (in which the energy used to drive the piles into the sediment is slowly ramped up) has been incorporated in to the noise assessments. This creates an increasing level of noise from low levels and will allow noise sensitive species such as herring and sprat to vacate the area and can reduce the risk to injury. This is an industry standard mitigation.

12.253. Following further detailed design, it is likely that many of the parameters used in the assessment (such as hammer energy, turbine loadings, etc.) will be refined and noise impacts be reduced. Although no commitment can be made at this stage, Seagreen will endeavour to reduce noise outputs during detailed design.

Residual Impact

12.254. Considering the potential reduction in noise outputs following detailed design, impacts could potentially be significantly reduced and are likely to be negligible and **not significant** for all species. On a precautionary basis the impact remains at moderate adverse and **significant** for the high sensitivity species.

Seabed habitat disturbance

12.255. The installation of the wind farm infrastructure (cables and substructure/ foundations) by jack-up barges and ploughs or jetting tools will result in the temporary disturbance to the benthic habitats and those species of fish, shellfish and crustacean which are closely associated with the seabed, such as sandeel, molluscs and crustacean species. Details on the impact of construction on benthic habitats are presented in Chapter 11: Benthic and Intertidal Ecology of this ES.

12.256. Disturbance will take the form of displacement of sediment, depressions in the seabed and damage to or loss of the benthic habitat directly within the footprint of the works (Table 12.14a). Calculations of the greatest potential area of direct disturbance in Project Alpha are given in (Table 12.14a). The worst case scenario for cable installation is that cables will be installed via ploughing which will result in a maximum disturbance of 355ha of the seabed along the array cables in Project Alpha with the additional disturbance due to the installation of foundations taking the total area to approximately 375ha. This area has been calculated to be 1.9% of the total consent envelope area of 197km^2.

12.257. Temporary disturbance to the seabed during construction could impact fish and shellfish in a number of ways. Shellfish species which are bottom dwellers or have limited mobility, such as scallops, would be directly affected by disturbance to the seabed and a small proportion would be damaged by the installation activity. As a result there may be an increase in scavenging species of fish and crustacean attracted to the area of disturbance. These disturbance impacts are, however, anticipated to be temporary and reversible and are not anticipated to result in any long term changes in fish or shellfish communities.

12.258. The tolerance of scallops to an increase in suspended sediment is low although in this case the levels are only temporarily increased. Studies have shown that scallop recoverability is high as is their tolerance to loss of substrate since they have ability, albeit limited, to move away from adverse environments (Carter, 2009). The sensitivity to temporary disturbance is therefore considered to be low. The abundance of scallops across the Project Alpha site has varied between the years 2008 to 2010 (Figure 12.9) but the majority are found on the western edge of the site and form an important fishery. Significant disturbance to their natural habitat could affect the recruitment into the population. However considering that the scale of the disturbance, as a percentage of the total area of the site (1.9%), is small and temporary (see Table 12.14a) and the fact that scallops are broadcast spawners and not reliant on the substrate for spawning success it is considered that the magnitude of the impact will be low. The impact must also be considered in the context of the scallop fishery, which also causes regular disturbance to the seabed in the area. This impact is therefore seen as negligible and **not significant** for scallops.

12.259. The abundance of adult nephrops and other crustaceans within the Project Alpha site was low although the site is within the nephrops spawning and nursery grounds. However the main population of adult nephrops is found further south from the Project Alpha site within the Firth of Forth (Figure 12.11). Nephrops are able to move away from adverse environments and are tolerant of loss of substrate. Combined with this and the large size of the spawning grounds described by Coull *et al*., (1996) the sensitivity is considered to be low (Sabatini and Hill, 2008). Although much of Project Alpha is within nephrops spawning grounds the disturbance would affect a relatively small area of site and would be temporary and localised (Appendix G1 Table 12.14a) therefore the magnitude of the impact is considered to be low and the overall impact of physical disturbance is considered to be negligible and **not significant.**

12.260. The impact on fish species of disturbance to the seabed during construction is related to loss of spawning substrate, loss of prey resources or loss of prime habitats. Few pelagic species will be directly affected by temporary loss of habitat as they have the ability to move away during construction. Indirect effects will be due to loss of prey resources and spawning areas for benthic spawners such as herring. Fish predators have been classed as 'flexible' meaning that they are opportunistic in prey selection, for example, whiting will feed on sprat when there is a shortfall in availability of sandeel (Mackinson and Doskalov, 2007) therefore there will not be significant effects. Since Project Alpha is not within herring spawning grounds and temporary loss of feeding areas is not considered to be significant, the magnitude of the impact is low as is the sensitivity of this species to temporary habitat loss. The potential impact is therefore considered negligible and **not significant** for most of the fish species.

12.261. The main fish species directly affected by such disturbance at the Project Alpha site is potentially sandeel. Sandeel spawning takes place on the seabed as a single batch in December to January and within Project Alpha significant areas (approximately 64%) of seabed have been defined as prime habitat (Figure 12.3). The calculations from the worst case scenario indicate that the temporary disturbance to the seabed for the Project Alpha site is approximately 1.9% of the area, which on a worst case assumption would all fall within prime habitat. However considering that the wider area covered by the sandeel spawning and nursery grounds in the North Sea is large compared to the footprint for Project Alpha, plus the fact that the impact would be temporary, the magnitude on this scale would be low. Recent studies carried out after the construction and operation of the Horns Rev wind farm has shown that the sandeel population was not affected by the wind farm (Leonhard *et al.*, 2011), but given the ecological importance of the species, it's sensitivity is considered to be medium. The significance of impact will therefore be minor adverse and **not significant.**

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.262. For the majority of species the impact will remain negligible and **not significant**. For sandeel, given that the prime habitat covers so much of the site (and given that this classification is modelled and thus only indicative) it will not be possible to avoid such habitat, therefore micro-siting of infrastructure is not practical, therefore the residual impact will remain of minor adverse and **not significant**.

Permanent loss of habitat

12.263. The worst case scenario has been detailed in (Table 12.14a) which identifies the structures which will result in the maximum loss of seabed, including: WTG foundations (GBS) and associated scour protection, OSPs, cable protection and meteorological masts. The maximum loss of seabed is anticipated to be approximately 89ha (see Appendix G4, for a breakdown of the different components). The total area affected will therefore constitute 0.45% of the total area of the Project Alpha site and the majority of seabed lost will be as a result of the foundations and associated scour protection.

12.264. Loss of habitat will directly affect sandeel and bottom dwelling species such as scallops or potentially oysters. The impact on the latter species was mentioned as a concern by SEPA for the consultation phase (see Table 12.1). It should be noted that no native oysters were found during the benthic survey and none were identified in data collected during the desk study therefore this species has been scoped out from the assessment.

12.265. The total loss of seabed due to construction activities from the Project Alpha site has been calculated to be approximately 89ha. Prime sandeel habitat (Figure 12.3) covers approximately 64% of the site. If all the structures proposed for Project Alpha were placed on prime sandeel habitat the percentage habitat loss would be 0.7%. Considering the small percentage loss as well as the wider area available for sandeel spawning and nursery grounds in the North Sea compared to the footprint for Project Alpha, the magnitude of impact is considered to be negligible. The sensitivity of this species, being ecologically important is considered to be medium, therefore this impact is considered to be negligible and **not significant**.

12.266. Scallops have limited movement and as such would have the ability to move only a short distance from adverse conditions. Scallops are of high commercial importance and there is a significant scallop fishery to the west of Project Alpha and the annual value of this species to the industry is high, however, the area of loss is relatively small considering the total area of the site and the magnitude of any impact would be low to negligible. Scallops are also broadcast spawners so the impact of habitat loss on larval stages would be negligible. The impact is considered to be of negligible and **not significant**.

Mitigation

Mitigation
At this stage, until further design work is carried out no mitigation is assumed.

Residual Impact

12.267. Use of jacket substructure/ foundations could reduce the overall footprint and therefore the magnitude of impact but given the sensitivity of the key species affected and the already low to negligible magnitude the impact will remain negligible and **not significant**.

Increased levels of suspended solids and remobilisation of contaminants

12.268. Increased suspended sediment load has the potential to impact on demersal species of fish and shellfish through blockage of sensitive filter feeding apparatus, gill filaments or through smothering. This is likely to impact more upon limited mobility species (i.e. bivalves) since the majority of fish potentially affected would move away from any adverse conditions. It is considered that the sensitivity of fish species will therefore be low.

12.269. Installation of foundations and array cables would lead to localised increases in suspended sediment concentration (SSC) intermittently over the 36 month offshore construction window. The worst case scenario would be a release of sediments during installation of GBS with a release of 695,700m^3 of sediments during seabed preparation works and 2,236,500m^3 for cabling. Whilst these headline numbers are high, it should be noted that the release of sediment during construction activities will be phased over time. As presented in Chapter 7: Physical Environment, and Chapter 8: Water and Sediment Quality, the increase in suspended sediments will be short term and will become indistinguishable from background levels over a short period of time (order of days).

12.270. Given the temporary and phased nature of increased suspended sediment levels the magnitude of the impact is considered to be low. Given the low sensitivity of fish species, the impact upon them will be negligible. Mobile crustaceans will also have low sensitivity to increased suspended sediments (Neal and Wilson, 2008) and likewise the impact will be negligible. Bivalves have the ability to withstand such increased levels for short periods of time (days) (Gibbs and Hewitt 2004, Marshall and Wilson, 2008, Tyler-Walters, 2007) and therefore their sensitivity is low. Therefore for these species the impact is also considered to be negligible and **not significant**.

12.271. As presented in Chapter 8 Water and Sediment Quality in this ES, sediment analysis has indicated that contaminant conditions for the Project Alpha site are below levels at which adverse impacts on benthic species would be seen therefore the magnitude of the impact is considered to be low to negligible. Fish species will have a low sensitivity to increased contaminants as they are likely to move away from any disturbance of the seabed, in addition, work by Taylor *et al*. (1985) suggests that fish may be less sensitive to the acute effects of trace metals than are shellfish, however given the lack of specific information from a precautionary standpoint, the sensitivity of fish and shellfish is considered to be low. Therefore the significance of this potential impact upon fish is considered to be negligible.

Mitigation

Mitigation
No mitigation is proposed at this stage.

12.272. Site selection or the use of smaller diameter foundations for conical GBS could reduce the requirement for ground preparation and thus reduce the volume of re-suspended sediments and remobilised contaminants. However, at this stage until further detailed design is complete is carried out it is not possible to make any commitments.

Residual Impact

12.273. Whilst site selection for foundations and choice of foundation could reduce the magnitude of impact, given the already low magnitude of impact the residual impact will remain negligible and **not significant**.

Project Bravo

12.274. Fish and shellfish data collected for the ISA, RSA and WSA did not distinguish between those found in Project Alpha and Project Bravo. Therefore most 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 – death or injury

12.275. The discussion on the background research to the impact of noise and noise modelling from the worst case scenario is given in paragraphs 12.208 to 12.219. The worst case scenario in terms of noise for Project Bravo is almost identical to that of Project Alpha and is detailed in (see Table 12.14b). The major difference is the boundary for Project Bravo which is located a greater distance from the coast (31km) and has two OSP instead of three.

12.276. Estimated ranges for lethal and physical injury are 40m and 60m respectively as per Project Alpha (see Appendix H6). Based on behavioural reactions to noise fish will swim away from the source and therefore are unlikely to be exposed to these high noise levels for any length of time (Maes *et al*., 2004), therefore for this impact, the sensitivity of most species is considered to be low. Therefore for lethal or non-auditory physical injury the significance of impact for all species of fish is considered to be negligible. For shellfish it is considered that that there will be **no impact** upon these species with regard to lethality and physical injury.

12.277. The ranges of auditory injury for modelled species are the same as for Project Alpha (see Table 12.17). The range at which hearing damage would occur for hearing generalists such as sandeel and trout was too small to measure during the modelling studies, therefore impacts are considered to be negligible. For other species with low sensitivity to noise including plaice and thornback ray the range and therefore magnitude of impact is considered to be low therefore the impact on these species is considered to be negligible. Research suggests that the effect on juvenile stages would be very localised (Booman *et al*., 1996) and given the planktonic and transient nature of many of the juvenile species found in Project Bravo the impact would also be negligible. For salmon, the potential impact magnitude is negligible and given their low sensitivity (as discussed in paragraph 12.243) the significance of impact will be negligible and **not significant**.

12.278. The range for auditory injury to herring is 0.26km. Noise from piling is therefore localised and although the impact on individuals in close proximity would be high the impact on such widely distributed population as a whole is considered to be low. The sensitivity is considered high for individuals based on the species ability to detect noise but medium in terms of the population distribution and the proportion affected. The potential for auditory injury impact is therefore assessed as being minor adverse and **not significant**.

Mitigation

Mitigation

At this stage, until further design work is carried out, no mitigation is assumed.

12.279. Soft start piling (in which the energy used to drive the piles into the sediment is slowly ramped up) has been incorporated in to the noise assessments. This creates an increasing level of noise from low levels and will allow noise sensitive species such as herring and sprat to vacate the area and can reduce the risk to injury. This is an industry standard mitigation.

12.280. Following further detailed design, it is likely that many of the parameters used in the assessment (such as hammer energy, turbine loadings, etc.) will be refined and noise impacts be reduced. Although no commitment can be made at this stage, Seagreen will endeavour to reduce noise outputs during detailed design.

Residual Impact

12.281. Considering the potential reduction in noise outputs following detailed design, impacts could potentially be significantly reduced and are likely to be negligible and **not significant** for all species. The use of the above mitigation measures for piling may reduce the impact on high sensitivity species such as herring however at this stage it is not possible to determine what this reduction may be, therefore on a precautionary basis the impact remains minor adverse and **not significant**.

Effect of noise - behaviour

12.282. Behavioural impacts upon fish and shellfish species are discussed in paragraphs 12.208 to 12.219. Overall for Project Bravo impacts are similar to those for Project Alpha, as can be seen in Table 12.19. There are small differences between the two projects due to bathymetry differences and thus noise propagates differently.

Table 12.19 Impact range for 90 dB_{ht} (*species*) and 75 dB_{ht} (*species*) perceived levels for different species of fish for Project Bravo (GM1)

Species	Range to 90 dB_{ht} (km/km^2)				Range to 75 dB_{ht} (km/km^2)			
	Max	Min	Mean	Area	Max	Min	Mean	Area
Dab	2.9	2.8	2.9	25.5	17	16	16	810
Herring	28	25	26	2164	74	43	60	11458
Salmon	1.3	1.3	1.3	5.5	8.4	8.2	8.3	217
Sandeel	0.2	0.2	0.2	0.1	1.4	1.4	1.4	6.2
Trout	0.3	0.2	0.3	0.2	1.8	1.8	1.8	9.8

(Source: Appendix H6)

12.283. Project Bravo is sited within spawning and nursery grounds of several species of fish and shellfish (Figures 12.2 to 12.11), many of which are broadcast spawners (e.g. cod, whiting, plaice) for which spawning grounds are relatively widely dispersed. For those hearing generalist species with low sensitivity the impact of noise on behaviour is considered to be negligible. For medium sensitivity species such as cod and whiting with spawning areas including the ISA the significance of impact is considered to be minor adverse to negligible.

12.284. For shellfish species, given their relative insensitivity to noise the impacts upon behaviour are considered to be negligible (see paragraph 12.251).

12.285. Species of high sensitivity to noise include clupeids, of which, the commercially important species in the North Sea is herring which is also a specialist substrate spawner with a peak spawning period in August and September. Noise modelling study predicted that a behavioural response in individuals could occur up to 74km for 75 dB_{ht}(*species*) behavioural response and 28km for the more severe 90dB_{ht} (*species*) response from the source of the noise in the worst case scenario GM1 (see Table 12.19) These impacts will result in 27% of the high intensity herring spawning grounds in the WSA (see Figure 12.13) affected by predicted 75 dB_{ht} noise levels or higher, with 1% of the spawning area predicted to be affected by noise levels of 90dB_{ht} or higher. Some 41% of the herring nursery area within the WSA is predicted to be affected by noise level greater than 75dB_{ht}. Predicted noise levels exceed 90dB_{ht} within 9% of the WSA herring nursery grounds.

12.286. As discussed with reference to Project Alpha, noise impacts from piling affect a significant portion of both the high intensity spawning and nursery areas within the WSA. Piling will take place intermittently, for 324 short (hour long) bursts over two year construction period. Herring are highly sensitive to noise disturbance but during spawning there is some evidence which suggests the urge to spawn overrides the noise responses. As for Project Alpha the magnitude of impact is judged to be low on a highly sensitive receptor species. With respect to the herring population within the WSA the impact is predicted to result in a moderate adverse impact on spawning herring.

12.287. Considering the wider picture with respect to herring spawning grounds in the North Sea, the latest spawning maps produced by Ellis *et al*., (2012) show that the main spawning grounds for the Buchan herring stock are concentrated off the north east coast of Scotland (Figure 12.2). Commercial catch data for herring (Figure 12.2) also show that the majority of adult herring is caught to the northwest of Scotland off Peterhead and acoustic surveys indicate that the greatest biomass of adult spawning herring are also located in this area (ICES 2011). However, since the noise contours overlap with a significant portion of the southern extent of the spawning areas and given the high sensitivity of the species to noise the impact of noise would be considered to be minor adverse significance in a North Sea context.

12.288. The Project Bravo site covers prime substrate for sandeel (Figure 12.4), thus the sensitivity in conservation terms is considered to be medium but as a hearing generalist it is low. However, the range of effect for behavioural impacts for the species is only 0.2km (see Table 12.17). The small range of predicted disturbance means the magnitude of impact will be low. Thus the impact with respect to noise is considered minor adverse.

12.289. Whilst it is assumed that eel, salmon, sea trout and sea lamprey will pass through the site at any one time during their migration all are considered to be hearing generalists (Nedwell *et al*., 2003) and the noise of construction is not considered to pose a threat to their migratory patterns. Considering the conservation status of the species the sensitivity is considered to be medium but the magnitude low since a low proportion of the population would be affected. The impact was assessed as minor adverse.

Mitigation

Mitigation
At this stage, until further design work is carried out, no mitigation is assumed.

12.290. Soft start piling (in which the energy used to drive the piles into the sediment is slowly ramped up) has been incorporated in to the noise assessments. This creates an increasing level of noise from low levels and will allow noise sensitive species such as herring and sprat to vacate the area and can reduce the risk to injury. This is an industry standard mitigation.

12.291. Following further detailed design, it is likely that many of the parameters used in the assessment (such as hammer energy, turbine loadings, etc.) will be refined and noise impacts be reduced. Although no commitment can be made at this stage, Seagreen will endeavour to reduce noise outputs during detailed design.

Residual Impact

12.292. Considering the potential reduction in noise outputs following detailed design, impacts could potentially be significantly reduced and are likely to be negligible for all species. Use of the above mitigation measures for piling may reduce the impact on high sensitivity species such as herring however at this stage it is not possible to determine what this reduction may be, therefore on a precautionary basis the impact remains at moderate adverse.

Seabed habitat disturbance

12.293. The installation of the wind farm infrastructure (cables and foundations) by jack-up barges and ploughs or jetting tools will result in the temporary disturbance to the benthic habitats and those species of fish, shellfish and crustacean which are closely associated with the seabed, such as sandeel, molluscs and crustacean species. As the worst case scenario for construction in Project Bravo is very similar to Project Alpha the impacts are very similar with a maximum disturbance of approximately 375ha of seabed habitat, the majority of disturbance created by the excavation for 355km for array cabling. This constitutes approximately 1.9% of the 194km^2 of the Project Bravo area.

12.294. Disturbance impacts for invertebrates and the majority of fish species are discussed in paragraphs 12.255 to 12.262 and the impact is considered to be negligible and **not significant.**

12.295. 91.65km^2 (47%) of Project Bravo is prime sandeel habitat (Figure 12.3). In the worst case scenario where all infrastructure from Project Bravo was placed upon prime sandeel habitat, this would constitute at most a disturbance of approximately 4% of this area. Therefore the magnitude of this impact is considered to be low. Studies have shown that sandeel recover quickly from habitat disturbance (Leonhard *et al*, 2011, see paragraph 12.261) and therefore their sensitivity is considered to be medium, therefore the significance of this impact will be minor adverse and **not significant**.

12.296. In addition, any impact to demersal species should be considered in relation to the disturbance of habitat due to commercial fishing in the area, including scallop dredging, which creates regular disturbance to the seabed within site.

Mitigation

Mitigation
No mitigation measures are suggested for this impact

Residual Impact

12.297. For the majority of species the impact will remain negligible. For sandeel, given that the prime habitat covers so much of the site (and given that this classification is modelled and thus only indicative) it will not be possible to avoid such habitat, therefore micro-siting of infrastructure is not practical, therefore the residual impact will remain of minor adverse and **not significant**.

Permanent loss of habitat

12.298. Using the worst case scenario the permanent habitat loss from construction of foundations for WTGs and meteorological masts, scour and cable protection for Project Bravo (Table 12.14b) has been calculated to be approximately 88ha which is 0.44% of the total site area. The loss of habitat will be for the duration of the 25 years life of the Seagreen Project.

12.299. Given the small area covered by the infrastructure and the ubiquity of the habitats across the ISA as shown from the benthic survey, the impact for most species will be of negligible magnitude; therefore for most species this impact would be negligible and **not significant**.

12.300. The total area of prime sandeel habitat has been calculated to be 47% of the total area of Project Bravo. The total area of Project Bravo which would be covered by wind farm structures would be 0.44%. Therefore even if, in the worst case scenario, all structures were placed on prime sandeel habitat this would represent less than 1% coverage. The magnitude of the impact is therefore considered negligible. The sensitivity of this species, being ecologically important is considered to be medium, therefore this impact is considered to be of negligible and **not significant**.

Mitigation

Mitigation
No mitigation is proposed at this stage.

Residual Impact

12.301. Use of jacket substructure/ foundations could reduce the overall footprint and therefore the magnitude of impact but given the sensitivity of the key species affected and the already low to negligible magnitude the impact will remain negligible.

Increased levels of suspended sediment and remobilisation of contaminants

12.302. As discussed for Project Alpha, the increases in suspended sediments (and associated remobilisation of contaminants) will be a phased process over the 36 month build period of Project Bravo. Increases to suspended sediment load will be temporary (a few days) and intermittent over the construction period therefore the magnitude is considered low. The species potentially affected will either move away from the area of disturbance or have a low sensitivity to the increased suspended sediments. The significance of the impact of increased suspended sediments for all species will therefore be negligible and **not significant**.

12.303. The low magnitude of re-suspended sediments combined with measured levels of contaminants which are below those likely to have an adverse effect means that the potential impact due to re-suspension of contaminants is of low to negligible magnitude. Using a precautionary sensitivity of low for both fish and shellfish, the significance of impact will be negligible and **not significant**.

Mitigation

Mitigation
No mitigation is proposed at this stage.

12.304. Site selection or the use of smaller diameter foundations for conical GBS could reduce the requirement for ground preparation and thus reduce the volume of re-suspended sediments and remobilised contaminants. However, at this stage until further detailed design is complete is carried out it is not possible to make any commitments.

Residual Impact

12.305. Whilst site selection for foundations and choice of foundation could reduce the magnitude of impact, given the already low magnitude of impact the residual impact will remain of negligible significance.

Transmission Asset Project

Transmission Asset Project Infrastructure within the Project Alpha and Project Bravo site boundaries

12.306. The Transmission Asset infrastructure within Project Alpha and Project Bravo is limited in scale and footprint, and restricted to a maximum of five OSPs, as presented in Chapter 5: Project Description in this ES. Therefore all potential impacts due to construction within the boundary of Project Alpha and Project Bravo have been considered in the preceding sections and represent a small subset of the overall impacts from Project Alpha and Project Bravo (a total of 1.27ha of disturbance and 4.8ha of habitat loss).

ECR Corridor

12.307. The ECR corridor covers an area of 97.9km^2 and passes through ICES rectangles 42E7 and a small area of rectangle 42E8. The orientation is approximately east to west (as presented in Chapter 5: Project Description in this ES) with a landfall at Carnoustie, a total distance of 70km from the indicative OSP location in the Project Alpha site. The worst case scenario for export cable installation assumes the use of jetting and a cable burial depth of 0.5m to 3m, dependent on ground conditions.

Underwater noise

12.308. As part of the noise modelling conducted by Subacoustech, noise from rock dumping, vessel movement and cabling laying was assessed using the SPEAR model (see Appendix H6 and Chapter 5: Project Description). Using the 90dB_{ht} impact ranges, for all species modelled (cod, dab, herring, salmon) the range of impact was either nil or less than 10m. The magnitude of this impact is therefore considered to be negligible. Based on behavioural reactions to noise, fish will swim away from the source and therefore are unlikely to be exposed to these high noise levels for any length of time (Maes *et al*., 2004), therefore for this impact, the sensitivity of most species is considered to be low. Therefore for lethal or non-auditory physical injury the significance of impact for all species of fish is considered to be negligible and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.309. Given the negligible magnitude of this impact, no practical mitigation is possible and therefore the residual impact will remain of negligible and **not significant**.

Seabed habitat disturbance and permanent loss

12.310. The installation of the export cables will result in the temporary disturbance to benthic habitats and the species associated with them. As the remotely operated vehicle (ROV) which is installing the cable moves over the seabed it will disturb a corridor up to 10m wide and 3m depth and a temporary disturbance to the seabed of 795ha (as presented in Chapter 5: Project Description in this ES, the total length of 6 export cables in Scenario 4). Other disturbance will take the form of displacement of sediment, depressions in the seabed and damage to or loss of the species directly within the footprint of the equipment used to install the cables and scour protection. As the total area of the ECR is 9,790ha, this disturbance represents approximately 10% of the area. Sedimentary habitats are naturally dynamic and the communities are tolerant of disturbance, it is expected that disturbed seabed will quickly recover to its previous state. As such the magnitude of this impact will be low.

12.311. The worst case scenario for habitat loss is for the installation of 6 cables with the placement of cable protection along 5% of the length, this gives an area of habitat loss of approximately 37ha, this is equivalent to less than 1% of the ECR area. Given this small footprint, the magnitude of impact for all species is considered to be negligible.

12.312. Species found within the RSA including the ECR corridor are shown in Table 12.7 and those specifically caught during the benthic survey are indicated in Table 12.11. The more sensitive species associated with benthic habitats are discussed below.

12.313. The ECR corridor passes through ICES rectangles which have significant landings of scallops, a species which is considered of high commercial importance on a regional scale. The density of this species is highest immediately adjacent to Project Alpha but is lower along the cable route towards the landfall area (as presented in Chapter 14: Commercial Fisheries). Scallops have limited mobility to avoid disturbance but are generally tolerant of disturbance (Marshall and Wilson, 2009) and are considered as being of low sensitivity to these impacts. Also, this impact should be considered in the context of the disturbance to sediments and seabed habitats from the scallop fishery in this area. The impact of the loss or disturbance of seabed habitats is therefore considered to be negligible and **not significant**.

12.314. Benthic commercial species such as crab and lobster were not found in the ECR benthic survey although they are known to be caught in the area (as presented in Chapter 14: Commercial Fisheries in the ES). These species would respond by moving away from the area of disturbance thus the sensitivity to the impact is considered to be low. Given the low magnitude of impact, the significance of impact is therefore considered to be negligible and **not significant** for more mobile species.

12.315. Species of demersal fish found within the ECR include plaice, goby and sandeel. During disturbance most fish would swim away from the affected area, however species such as sandeel which are closely associated with the seabed are of more concern. As can be seen in Figure 12.4, most of the ECR is considered as suitable or subprime, with the prime area concentrated west of Scalp Bank. The ECR survey data was interrogated for suitable sandeel habitats and the resultant map is shown in Figure 12.4. Of the 9,790ha covered by the ECR corridor 1,030ha is considered to be prime sandeel habitat which is 10.5% of the total area. Given that the cables will only pass through this area once there will be limited habitat loss within this prime habitat and the impact will be temporary (see Chapter 7: Physical Environment) the magnitude is considered negligible. The sensitivity of sandeel as an important prey species is considered medium. The overall impact is assessed as minor adverse to negligible.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.316. The residual impact will remain negligible and **not significant** for all species.

Increased suspended sediments and remobilisation of contaminants

12.317. The worst case scenario for export cable installation assumes the use of jetting and a burial depth of 0.5m to 3m, depending on ground conditions, for 95% of the cable route. This assumes a total of 6 export cables will be installed and each will be buried in a separate trench with a total length of 530km. The assessment presented is based on an expert assessment of suspended sediment plume dynamics and potential sediment deposition as presented in Chapter 7: Physical Environment in this ES.

12.318. The dispersal of sediment will arise during installation, but elevated concentrations will be short-term (a few days). This is on the assumption that installation activities occur over a minimum 6 months construction period, as described in Chapter 7: Physical Environment in this ES. The installation period could be extended as a consequence of poor weather, though it would be expected that any change in weather conditions prolonging the duration of works would serve to further disperse any sediment plume. Consequently, natural background conditions will be restored within a short timescale after the ECR installation.

12.319. The sediment mobilised by jetting will be deposited on the seabed close to the works with the level of deposition being dependent upon the sediment grain size and the strength and orientation of tidal currents. Sediment deposition is predicted to be greatest for larger size fractions (>187µm) which typify the seabed and which will settle more rapidly and be less prone to re-mobilisation (as presented in Chapter 7: Physical Environment in this ES).

12.320. It is anticipated that any material deposited on or close to the shoreline (from export cable installation) will be rapidly dispersed by wave action and sediments will return to normal within a short space of time. The magnitude of the impact is considered to be negligible due to the short time period in which suspended sediment levels are higher than background levels. As discussed previously fish and crustaceans are likely to move away from areas of disturbance and less mobile species have a low sensitivity to increased suspended sediments (Marshall and Wilson, 2008, Neal and Wilson, 2008, Tyler-Walters, 2007). The sensitivity of all species to increased suspended sediments is therefore low and the significance of impact is considered to be negligible and **not significant**.

12.321. With increased sediment loads there is also the possibility of mobilisation of contaminants. Within the ECR levels of contaminants were found to be below Cefas Action Level 1 standard (as presented in Chapter 8: Water and Sediment Quality in this ES) and therefore the magnitude of the impact is considered to be low. The sensitivity of bivalves, crustaceans and fish present in the area is considered to be low (see paragraph 12.268). Therefore for all species the impact from remobilised contaminants is considered to be negligible and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.322. The residual impact will remain of **negligible** significance.

IMPACT ASSESSMENT - OPERATION

Project Alpha

Disturbance effects of electromagnetic fields (EMF)

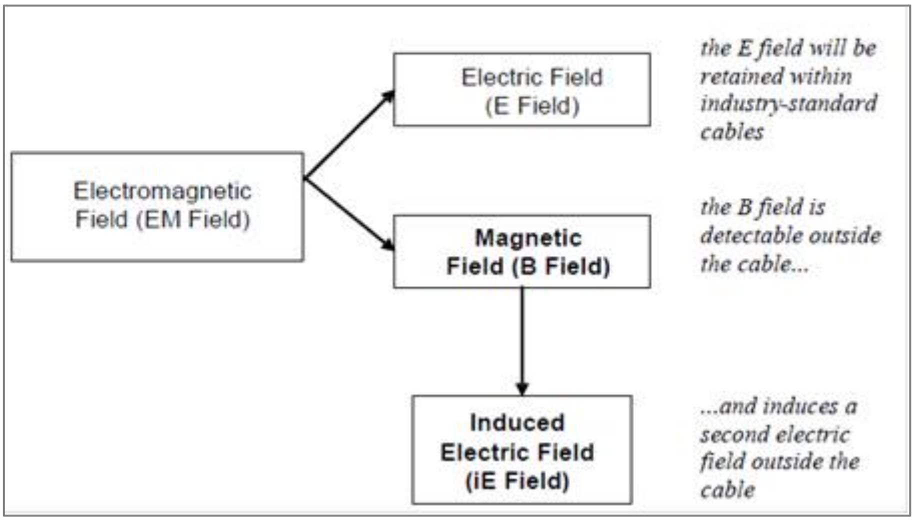
12.323. This section describes the current knowledge on EMF and its impact on marine species. This background information will also be used to inform the impact assessment for both the Project Alpha and Project Bravo sites as well as the Transmission Asset Project.

12.324. Both high voltage direct current and high voltage alternating current (HVDC and HVAC) cables emit EMF but in different ways as discussed below. The worst case scenario set out in Table 12.14a establishes that there will be up to 335km of 66kV HVAC array cables within Project Alpha with an estimated burial depth of 0.5 to 2.1m, depending on ground conditions. There may be locations when ground conditions prevent cable burial and cables will be surface laid and covered either by rock dumping or concrete mattresses (see Chapter 5: Project Description).

12.325. The natural source of EMF in the marine environment is generated by the earths geomagnetic field (E field), as a result of processes within an organism (bioelectric fields) or the interaction of the organism or sea water with the geomagnetic field. Organisms will detect magnetic fields through chemical or sensitive material (magnetite) within the body (e.g. European eel (Berge, 1979)) or through responding to an induced electric field (iE field). Both responses are related to navigation or direction finding and are especially important for migratory species (Gill and Bartlett, 2010).

12.326. Subsea cables generate EMF which has two constituent fields; electric (E field), magnetic (B field) and associated induced electric fields (iE) - the latter is produced by an organism or tidal movement through the B field. A simplified overview of how induced electrical fields are produced by HVAC power cables is presented in Plot 12.1. Most subsea cables are sheathed in a coating which will contain the E field thus EMF from both AC and DC power cables are the B field and the resultant iE field.

Plot 12.6 Simplified overview of how induced electrical fields are produced by AC power cables



Source: Gill *et al*., (2009)

12.327. HVAC cables can induce a magnetic field (an iE field) outside the cable through the B field rotating with the alternating current. Studies have found that the intensity of the magnetic field was approximately a direct function of the voltage (ranging from 33 to 345 kV) on the cables. The other factors affecting field strength included separation of the cables and burial depth. The strength of the magnetic field was greatest directly above the cable and decreased rapidly with vertical and horizontal distance (Gill *et al*., 2009).

12.328. The shielding material for HVDC cables can contain the E field unlike HVAC cabling however this is still not enough to contain the B field. Tidal movement or fish swimming though the B field creates an induced iE field. It is thought that magnetic fields from HVDC cables can be minimised by placing the cables close together allowing the fields from each cable to cancel each other out (Normandeau, 2011).

12.329. EMF modelling of cables at a series of wind farms (Gill *et al*., 2005) also demonstrated that there was a linear relationship between current load and resultant B and iE fields. Therefore, when the wind farm is operating below maximum capacity (i.e. at average wind speeds) the resultant B and iE fields will be less than at full capacity.

12.330. A recent review on the detection of B and E field by fish species has shown that this is closely related to the location of spawning grounds or long distance navigation (Gill and Bartlett, 2010). Table 12.20 shows seven EMF sensitive teleost fish species found in UK waters. In addition a number of elasmobranchs species are known to be sensitive to EMF as are juvenile trout.

Table 12.20 Evidence based list of electromagnetic sensitive teleost fish species and their conservation status (according to the IUCN Red list) in UK coastal waters.

Species	Conservation status	Frequency in UK Waters	Evidence of response to E fields	Evidence of response to B fields
European eel Anguilla anguilla	Critically Endangered	Common	✓ 1,2	✓ 3,4
Atlantic salmon Salmo salar	Least Concern	Common	✓ 5,6	✓ 5,6
Sea trout Salmo trutta	Least Concern	Occasional		✓ 7
European plaice Pleuronectes platessa	Vulnerable	Common	✓ 8	✓ 8
Yellowfin tuna *Thunnus albacares*	Least Concern	Occasional		✓ 9-12
European river lamprey *Lampetra fluviatilis*	Near Threatened	Common	✓ 13,14	
Sea lamprey *Petromyzon marinus*	Least Concern	Occasional	✓ 5-17	

[1]Berge (1979); [2] Vriens & Bretschneider (1979); [3] Enger *et al*. (1976); [4] Westerberg (1999); [5] Moore *et al*. (1990); [6] Rommel & McCleave (1973); [7] Formicki *et al*. (2004) – juvenile fish; [8] Metcalfe *et al*. (1993); [9] Kobayashi & Kirschvink (1995); [10] Walker *et al*. (1984); [11] Walker (1984); [12] Yano *et al*. (1997); [13] Gill *et al*. (2005); 14 Akeov & Muraveiko (1984); [14] Bodznick & Northcutt (1981); [15] Bodznick & Preston (1983); [16] Bowen *et al*. (2003); [17] Chung-Davidson *et al*. (2004)

Key: Superscript numbers show reference sources

Source: Gill & Bartlett (2010)

12.331. Specific concerns about the effect of EMF on elasmobranchs were raised during the consultation process (see Table 12.1). Much of the information available to date comes from studies on elasmobranchs. Elasmobranchs are known to respond to magnetic fields 25-100 µTesla (Meyer *et al*., 2005) and are thought to use the Earth's magnetic field (approximately 50 µTesla) for migration. They also respond behaviourally to electric fields emitted by prey species and conspecifics and this has raised concerns they may waste time and energy hunting E fields instead of their prey (Kimber, 2008). Such effects could reduce reproductive success and have wider population effects (Kimber, 2008). However the conclusions from the most recent COWRIE mesocosm studies into EMF effects (Gill *et al*., 2009) proved inconclusive. There was no evidence to suggest any positive or negative effect of EMF on the elasmobranch species studied (Gill and Bartlett, 2010).

12.332. Studies of thornback ray egg cases have also demonstrated that upon sensing artificial E fields embryonic rays cease body movement that facilitates critical ventilatory movement of water for respiration. This suggested the rays were employing detection minimisation behaviour (i.e. keeping still) as E fields were mimicking predatory animals (small, adult elasmobranchs and teleosts (Ball, 2007).

12.333. Salmonids and eels are known to be particularly sensitive to EMF during migration. Other fish species that are regarded as EMF sensitive do not possess specialised receptors, but are able to detect induced voltage gradients associated with water movement or geomagnetic emissions (Gill & Bartlett, 2010) (see Table 12.20). The physiology of these sensory mechanisms for the detection of EMF is poorly understood, and is likely to vary on a species by species basis (Pals *et al*., 1982 as cited in Gill & Bartlett, 2010). It is likely that the species listed in Table 12.20 will respond to natural levels of EMF that are associated with peak tidal movements, which can create fields in the range of 8-25µV/m and are thus likely to be affected by EMF generated by anthropogenic sources (Barber & Longuet-Higgins, 1948; Pals *et al*., 1982 as cited in Gill & Bartlett, 2010). However the implications of this response and the magnitude of the effect on migratory behaviour are not yet determined.

12.334. An unpublished study on migrating silver eels across a 130kV AC cable in Sweden by Westerberg and Lagenfelt (as cited in Öhman *et al*., 2007) found swimming speeds to be significantly lower in proximity to the cable with, on average, a 30 minute delay in migration. Brown shrimp have also been recorded as being attracted to the B fields of the magnitude expected around wind farms (ICES, 2003).

12.335. Research on the migratory routes of salmon, has determined that adults return to the Scottish coast from a range of directions (Malcolm *et al*., 2010) and thus are likely to cross the area at some time during the operational phase of the wind farm. Knowledge of eel migration patterns on the Scottish coast is limited although potentially a significant proportion of the total European eel population may pass through Scottish coastal waters. From a precautionary standpoint it is therefore assumed that European eels, sea trout and perhaps sea lamprey will also pass through Project Alpha at some point. However, it is likely the bulk of migratory movements will be in coastal waters.

12.336. Although fish can detect EMF the magnitude and extent of the B and iE fields generated by the array cables in Project Alpha are anticipated to be highly localised. Furthermore, while the duration of the impact will be for the lifetime of the project, the intensity of EMF will vary depending on the operating capacity of the wind farm. Sensitive species would, therefore, not always be exposed to the highest levels of EMF as these may fluctuate depending on wind conditions. In addition impacts will only be detected by fish swimming close to the cables, the overall magnitude is therefore considered to be low.

12.337. Research on whether or not electromagnetic forces from array or export cables will have a negative impact on migration is, at present, inconclusive. There is uncertainty associated with the actual behavioural response to EMF and scientific understanding of the effect of EMF at the individual, population and the ecosystem level is limited (Gill and Bartlett 2010, Normandeau, 2011). However for those species which are of conservation interest (as detailed in Table 12.19) and given the ability of elasmobranchs and migratory species to detecting EMF the precautionary assessment of receptor sensitivity is medium.

12.338. However, given the negligible magnitude of the impact combined with the medium sensitivity of the receptor the overall impact of EMF on sensitive species within the wind farm site would be of minor adverse and **not significant** from a precautionary standpoint.

12.339. Evidence for sensitivity of invertebrates to EMFs comes from physiological and behavioural studies on a small number of marine or aquatic invertebrate species. Normandeau *et al*., (2011) reviewed research carried out to date and stated that "*No direct evidence of impacts to invertebrates from undersea cable EMFs exists. Few marine invertebrates have ever been evaluated for sensitivity to electric or magnetic fields; and the available data for those that have been studied are limited. In addition, these magneto-orientation studies are focused on the behaviour of mobile adults and the effects on their pelagic larval stages are poorly studied".* Given the current lack of information on the sensitivity of invertebrates to EMF and the low magnitude of the effect the overall impact is considered negligible and **not significant**.

Mitigation

Mitigation

As the impacts of EMF are poorly understood, mitigation measures are difficult to recommend. However, burial depths of 0.5m to 2.1m are estimated and the arrangement of the array cable layout will be considered with respect to mitigating the impacts of EMF.

Residual Impact

12.340. With appropriate burial depth it may be possible to reduce the impacts of EMF, however, given the uncertainties around this impact from a precautionary standpoint this will remain minor adverse and **not significant** for the most sensitive species.

Operational noise

12.341. During the operation of a wind farm the main source of underwater noise will be the vibration from WTGs which is transmitted from the tower and the foundations into the sea and seabed (Nedwell *et al*., 2003). Sound levels are significantly lower than those produced during the construction phase. In studies on the Kentish Flats Wind Farm it was found that the operational noise was only a few decibels over that of background noise (Nedwell *et al*., 2007b). Additionally there will be noise from vessel movements; this was modelled for several fish species using the SPEAR model (see Appendix H6). Using the 90dBht impact ranges, for all species modelled (cod, dab, herring, salmon) the range of impact was below detectable range.

12.342. The small increase in noise levels (above background) during operation of a wind farm is considered to be of negligible magnitude. The sensitivity is low considering the results of the Horns Rev research which showed little impact on the fish population seven years after the construction and operation of a wind farm (Leonhard *et al*., 2011). Therefore it is considered that the longer term impacts of operational noise will remain of low magnitude and the potential impact on marine species within Project Bravo assessed as negligible and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.343. The residual impact will remain negligible and **not significant**.

Disturbance of seabed habitats

12.344. During the operational phase there will be disturbance to habitats due to maintenance activities but these will be localised and small scale and thus be of low magnitude.

12.345. A recent study, undertaken seven years after the construction of the Horns Rev Offshore wind farm located in the Danish North Sea, investigated changes in fish community structure and distribution and changes in sandeel population (Leonhard *et al*., 2011). Acoustic surveys showed that there were no significant changes in the abundance or distribution patterns, density or biomass of either pelagic or demersal fish species. The research also concluded that the operation of the wind farm had no detrimental long term effect on the sandeel population or on any other fish species assemblages. Considering the localised nature of operational disturbance the magnitude of the impact is considered to be low and the sensitivity low considering the results of the Horns Rev research. Therefore it is considered that the longer term operational impact will be negligible and **not significant.**

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.346. The residual impact will remain of negligible and **not significant**.

Creation of new habitats – fish aggregation

12.347. Structures within the wind farm made of concrete and steel will be colonised by a range of benthic species (as discussed in Chapter 11: Benthic and Intertidal Ecology in this ES). This in turn will increase productivity in seabed communities as well as provide shelter and a source of food for predators. This was found to be the case at Horns Rev Wind farm in Denmark where colonisation of wind farm structures was rapid (Leonhard *et al*., 2010). Within Project Alpha there is estimated to be a maximum of approximately 89ha of new habitat that could be created, which approximately 0.45% of the seabed area within Project Alpha.

12.348. Wilhelmsson *et al*. (2006) investigated fish abundance at wind farms using underwater visual census techniques. This study found that although fish abundance was higher next to substructure/ foundation structures for some species there was no increase in species richness. This suggested that such structures were acting as both an artificial reef and fish aggregating device for smaller demersal fish species.

12.349. Foundations can have the effect of increasing habitat complexity to benefit productivity in the local area of the structure, but given that these foundations are not in close proximity to one another it is not likely that there will be a significant increase in fish abundance or a major change to the benthic ecology on a wider scale (i.e. there is unlikely to be a significant reef effect). This impact is considered to be negligible and **not significant.**

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.350. The residual impact will remain negligible and **not significant**.

Increased suspended sediments and mobilisation of contaminants

12.351. The effect of the operational phase of Project Alpha on the sediment regime is discussed in detail in Chapter 7: Physical Environment and impacts on the benthos are presented in Chapter 11: Benthic and Intertidal Ecology in this ES.

12.352. The worst case scenario for increased suspended solids during the operational phase is based on a 1 in 50 year storm event and assumes that no scour protection is provided. The calculated the total scour volume for 81 structures (75 WTGs, 3 OSP, and 3 meteorological masts) would be 345,522m^3 of sediment (as presented in Chapter 7 Physical Environment). This impact is considered to be of low magnitude given the length of the operational phase of 25 years.

12.353. As discussed previously for construction impacts, fish and shellfish species are either tolerant of or will move away from the site of increased suspended sediment levels and therefore their sensitivity is considered to be low. Therefore, for all species the significance of impact will be negligible.

12.354. Increased suspended solids may cause remobilisation of contaminants. Contaminant conditions for the Project Alpha site are below levels at which adverse impacts on the benthic communities are seen, with only elevated levels of arsenic detected from the sampling program as presented in Chapter 8: Sediment and Water Quality in this ES. The levels of all contaminants are below Cefas Action Level 1 standard and therefore the magnitude of the impact is considered to be negligible. The sensitivity of bivalves, crustaceans and fish present in the area is considered to be low (see paragraph 12.268). Therefore for these species the potential impact is considered to be negligible and **not significant.**

Mitigation

Mitigation
Placement of scour protection should reduce the amount of re-suspended material during operation.

Residual Impact

12.355. With effective scour protection and reduced sediment load the residual impact will be negligible and **not significant**.

Project Bravo

Disturbance effects of electromagnetic fields (EMF)

12.356. The background informing the assessment on EMF has been provided in paragraphs 12.323 to 12.339 for Project Alpha. The information available indicates that fish may respond to EMF but the range of any effect is localised and there is little evidence of the impact of EMF on invertebrate species. The duration of the potential impact will relate to the operating capacity of the wind farm thus sensitive species will not always be exposed to the greatest level of EMF. Research to date has shown that the most sensitive species are elasmobranch and migratory species which use geomagnetism to direct their migratory pathways. However, there is little evidence to suggest there is a positive or negative effect of EMF on elasmobranchs (Gill *et al*., 2009).

12.357. In relation to migratory species which are assumed to cross the Project Bravo site at some point in their migration (Malcolm *et al*., 2010) the effects of EMF on the migratory routes is unclear and requires further research and monitoring to demonstrate whether or not there is a negative impact on returning species to natal or spawning rivers. The strength of EMF is also known to be related to burial depth and since salmon are pelagic species it is thought that the effect of EMF may only be discernible in the shallow waters of estuaries. As discussed in Project Alpha although the overall magnitude of EMF on behaviour is considered to be low given the uncertainty of the overall response to EMF the precautionary assessment of the sensitivity of the receptor is considered medium. The potential impact is therefore considered minor adverse and **not significant**.

Mitigation

Mitigation

The impacts of EMF are poorly understood mitigation measures are difficult to recommend. However burial depths of 0.5m to 2.1m are estimated and the arrangement of the array cable layout will be considered with respect to mitigating the impact of EMF.

Residual Impact

12.358. With appropriate burial depth and intelligent array cable layouts it may be possible to reduce the impacts of EMF, however given the uncertainties surrounding this impact and from a precautionary standpoint the impact will remain minor adverse and **not significant** for the most sensitive species.

Operational noise

12.359. As discussed in paragraphs 12.341 to 12.342 for Project Alpha operational noise originates from vibrations of WTGs transmitted to the seabed through their foundations (Nedwell *et al*., 2003) and from vessel movements during maintenance activities. Noise levels will much lower than those emitted by piling during construction.

12.360. Considering the localised nature of operational disturbance the magnitude of the impact is considered to be low. The sensitivity is low considering the results of the Horns Rev research which showed little impact on the fish population seven years after the construction and operation of a wind farm (Leonhard *et al*., 2011). Therefore it is considered that the longer term impacts of operational noise will remain of low magnitude and the potential impact on marine species within Project Bravo is assessed as negligible and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.361. The residual impact will remain negligible and **not significant**.

Disturbance of seabed habitats

12.362. Although during the operation of Project Bravo there will be disturbances due to maintenance activities the effect will be localised and of low or negligible magnitude as discussed in previous sections for Project Alpha. Recent studies have shown that there had been no significant changes to the distribution patterns or biomass of fish assemblage at the Horns Rev windfarm (Leonhard *et al*., 2011). Given that any disturbance would be temporary the sensitivity of all species is considered to be low. The potential impact of operational disturbance is therefore assessed as negligible and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.363. The residual impact will remain negligible and **not significant**.

Creation of new habitats – fish aggregation

12.364. The discussion of this impact can be found in above in the discussion for Project Alpha. Whilst there is potential for some localised increases in diversity and abundance (with a total potential area of approximately 88ha across the 19400ha area of Project Bravo), it is not considered that this is a significant impact and therefore the impact whilst potentially beneficial is considered to be negligible and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.365. The residual impact will remain negligible and **not significant**.

Increased suspended sediments and mobilisation of contaminants

12.366. The worst case scenario for increased suspended solids during the operational phase is based on a 1 in 50 year storm event and assumes that no scour protection is provided. The calculated the total scour volume for 81 structures (75 WTGs, 2 OSP, and 3 meteorological masts) would be 341,490m^3 of sediment (as presented in Chapter 7: Physical Environment). This impact is considered to be of low magnitude given the length of the operational phase of 25 years. As discussed previously for construction impacts, fish and shellfish species are either tolerant of or will move away from the site of increased suspended sediment levels and therefore their sensitivity is considered to be low. Therefore, for all species the significance of impact will be negligible and **not significant**.

12.367. Investigations on sediment contamination levels for Project Bravo indicate that conditions are below that which could cause and adverse impact on benthic species. Elevated levels of arsenic are below Cefas Action Level 1 standard. The sensitivity of bivalves, crustaceans and fish present in the area is considered to be low (see paragraph 12.268). Therefore for these species the impact is considered to be negligible and **not significant**.

Mitigation

Mitigation
Placement of scour protection should reduce the amount of re-suspended material during operation.

Residual Impact

12.368. With effective scour protection the residual impact will remain negligible and **not significant**.

Transmission Asset Project - Export Cable Route

Disturbance effects of Electromagnetic fields (EMF)

12.369. The export cable has the potential to produce EMF throughout its length including up to and between OSPs. The current knowledge on EMF for species of fish and shellfish found in the study area is discussed above in detail for Project Alpha. It is not intended to reproduce the sections above but an assessment of the potential impact the ECR will have on species found in benthic surveys along the ECR and in coastal areas associated with the Transmission Asset Project is provided below.

12.370. The worst case scenario will be that up to six AC 275kV export cables will be installed in trench 3m wide within a 1km wide cable corridor and the maximum combined length of cable will be 530km. The current knowledge of possible impacts on marine fish and shellfish from power cables used to connect wind farms to the onshore connector stations is limited and relatively inconclusive (Gill and Bartlett 2010, Hvidt *et al*., 2006). Populations of some species of decapod crustaceans (e.g. lobsters, crabs) could experience a moderate level of effects from EMF as their epibenthic habitat and relatively low mobility would expose individual organisms to the highest field strengths although research on this is limited and inconclusive (Normandeau *et al*., 2011).

12.371. It is known that elasmobranchs and eels (in particular) are considered to be sensitive to the effects of EMF, as are other migratory species such as the Atlantic salmon, The impact of EMF due to cabling is also dependent of their type (AC or DC), the depth of burial and distance of the cable from the receptor.

12.372. Studies carried out on the Nysted Offshore Wind farm in Danish waters monitored impacts on fish species of the 132kV power cable connecting the wind farm to the shore (Hvidt, 2006). The study found evidence that the cable affected the eel, Baltic herring, Atlantic cod and flounder more than any other species, but the effects were very localised and temporary according to the power production in the cable. Eels were seen to migrate out of the area along the cable which suggested a barrier effect. However the correlation between this behaviour and EMF could not be substantiated and it was thought that the cable trench which was not backfilled completely may have created a guideline for the eels (Hvidt 2006).

12.373. Normandeau *et al*. (2011) conducted a review of research on migration of salmonids. Juveniles and adults, both rely partially on the geomagnetic field to reach their destinations. Although modelling suggested that magnetic fields emitted by AC cables might be detectable by salmon, the fish would have to be within several meters of the cable to do so. Since both adult and the juvenile salmonids (i.e. those ready to leave the coastal areas) are pelagic and will travel well above the bottom, the potential for effect from the magnetic field will be reduced for most of its length due to the distance from the cable. In areas of shallower water such as the area of cable landfall at Carnoustie, the effect of EMF may be greater.

12.374. There is evidence that sockeye salmon also rely on other senses such as sight and smell during migration and as such may be able to compensate for localised changes in the geomagnetic signals due to EMF. Other species of salmonid are expected to show similar compensatory mechanisms with respect to EMF (Normandeau *et al*., (2011).

12.375. It can be concluded that, although there is a large body of information that can either demonstrate or imply that marine species use geomagnetic forces and may be affected on some way by EMF, there is limited work which can provide a quantifiable impact analysis. The magnitude of this impact is therefore considered to be low with several species considered to be of medium sensitivity.

12.376. In general the impacts of EMF on sensitive species caused by export cable(s) are still very poorly understood and therefore a precautionary approach would be to assess this as likely to be a minor adverse and **not significant** impact given that the coastal portion of the ECR corridor will cross likely migration routes for several species.

Mitigation

Mitigation
The impacts of EMF are poorly understood and mitigation measures are difficult to recommend. However burial depths up to 3m and cable sheaths may mitigate some of the impacts.

Residual Impact

12.377. Sufficient burial depth and cable protection may reduce the impact however from a precautionary standpoint this impact remains minor adverse and **not significant**.

Creation of new habitats – fish aggregation

12.378. The colonisation of structures within the boundary of Project Alpha and Project Bravo has been considered in the respective sections above. Within the ECR it has been estimated that in the worst case up to 5% of the cables will not be buried and require cable protection (rock dump or concrete mattresses). A combined length of 530km may be incorporated into the Transmission Asset Project and therefore a maximum of 26.5km will be protected. The maximum width of the cable protection will be 7m and therefore the maximum area of habitat created would be 37.1ha. This area represents a negligible magnitude of impact and needs to be considered in context, i.e. if the cable is not able to be buried, there is a good chance that the seabed has hard substrate and therefore the cable protection would not represent a great change in seabed conditions. Given the range of habitats across the ECR corridor it is considered that the sensitivity of fish and shellfish to habitat change would be low. Therefore with regard to the creation of new habitat the impact would be negligible and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.379. The residual impact will remain negligible and **not significant**.

Increased suspended sediments and mobilisation of contaminants

12.380. Unless cables are excavated due to failure, there will be no requirement for maintenance to the cables and therefore no pathway through which there would be disturbance of the sediments and potential remobilisation of contaminants. In this case there would be **no impact**.

12.381. If cables do need to be raised or replaced the impacts will be similar as those for construction albeit with a lower magnitude of impact. As discussed previously for construction impacts, fish and shellfish species are either tolerant of or will move away from the site of increased suspended sediment levels and therefore their sensitivity is considered to be low. Therefore, for all species the significance of impact will be negligible and **not significant**.

12.382. Within the ECR levels of contaminants were found to be below Cefas Action Level 1 standard (as presented in Chapter 8 Water and Sediment Quality in this ES) and therefore the magnitude of the impact is considered to be low. The sensitivity of bivalves, crustaceans and fish present in the area is considered to be low (see paragraph 12.268). Therefore for all species the impact from remobilised contaminants is considered to be negligible and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.383. The residual impact will remain negligible and **not significant**.

IMPACT ASSESSMENT – DECOMMISSIONING

12.384. A decommissioning plan will be agreed with DECC in consultation with Scottish Ministers. These plans will cover the methodology for when and how the Seagreen Project will be decommissioned. A high level decommissioning programme is set out in Chapter 5: Project Description of this ES.

Project Alpha

Seabed habitat disturbance and permanent loss

12.385. The assumption is that all substructure/ foundations structures will be removed. Piled foundations will be cut off just below the seabed and jackets removed. If GBS are used, then decommissioning will involve removal of ballast and refloating of the GBS. Each substructure/ foundation will then be towed to an approved destination for recycling or disposal as appropriate (see Chapter 5: Project Description). For both activities a heavy lift vessel will be needed.

12.386. If cables are to be removed the worst case scenario would be that removal involved a grapnel to pull the cable from the seabed, using an under-runner to pull the cable from the seabed or jetting seabed material from above the cable. The impacts would be similar to those described in the construction phase although of potentially smaller magnitude. The impact would also be temporary with the benefit of those habitats lost during construction returning to their original state. Given the low sensitivity of most species in the area and the negligible magnitude the impact is considered to be negligible and **not significant**.

12.387. For sandeel, the worst case scenario would be that all infrastructure lies within prime sandeel habitat giving a low magnitude of impact. Given the ecological importance of sandeel and the direct nature of this impact, the sensitivity of sandeel is considered to be medium. The significance of impact will therefore be minor adverse and **not significant**. This would be limited to the duration of the decommissioning works.

12.388. In addition the removal of infrastructure would also remove the new habitats formed on these structures which often act as fish and crustacean aggregating devices. However since the species associated with such structures are of low sensitivity and there is evidence that after decommissioning the habitats would return to baseline status this impact significance is negligible and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.389. For the majority of species the impact will remain negligible and **not significant**. For sandeel, given that the prime habitat covers so much of the site the residual impact will remain of minor adverse and **not significant**.

Project Bravo

Seabed habitat disturbance and permanent loss

12.390. The disturbance will be as detailed above for Project Alpha. Removal of infrastructure will have a negligible impact upon all species with the exception of the more sensitive sandeel for which the impact will be minor adverse and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.391. For the majority of species the impact will remain negligible and **not significant**. For sandeel, given that the prime habitat covers so much of the site the residual impact will remain of minor adverse and **not significant**.

Transmission Asset Project

Seabed habitat disturbance due to removal of OSPs

12.392. The expected impacts of the decommissioning of Project Alpha and Project Bravo are detailed above and any impacts for OSPs are included as a subset of these. Overall the significance of impact will be negligible and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.393. The residual impact will remain negligible and **not significance**.

Seabed habitat disturbance due to cable removal

12.394. Discussions will be held with stakeholders and regulators to determine if cables will be left in situ if considered appropriate, or wholly or partially removed. Feasible methods for cable removal include pulling the cable out of the seabed using a grapnel, pulling an under-runner using a steel cable to push the electrical cable from the seabed, or jetting the seabed material (see Chapter 5: Project Description).

12.395. The magnitude of the impact of cable removal is considered low as such activity will have the same footprint as installation. However there is a potential for decommissioning activities to affect migratory species during peak periods of migration but it is also expected that these species will be able to avoid areas of disturbance therefore the sensitivity is considered low. Thus the impact can be considered negligible and **not significant**.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.396. If cables are left in situ there will be **no impact**, otherwise the residual impact will remain of negligible significance.

IMPACT ASSESSMENT – CUMULATIVE AND IN-COMBINATION

12.397. In addition to identifying the potential impacts of Project Alpha, Project Bravo and the Transmission Asset Project on sensitive receptors in isolation, it is also important to consider the cumulative impacts of the elements of the Seagreen Project together and with other existing, consented or proposed development activity in the Firth of Forth region and beyond.

The Seagreen Project cumulative impacts

12.398. This section draws together the impacts considered for Project Alpha, Project Bravo and the Transmission Asset Project so that the impacts of the Seagreen Project as a whole can be seen. Table 12.21 brings together information on impacts assessed within each project and provides an overall summation of impacts.

Table 12.21 Identification of Key Cumulative impacts of Seagreen (Project Alpha, Project Bravo and Transmission Asset Project)

Impact	Alpha	Bravo	Transmission Asset Project	Identification of key Cumulative impacts to be assessed	Justification
Construction					
Effect of noise – death or injury	Minor adverse (for herring) Negligible (all other species)	Minor adverse (for herring) Negligible (all other species)	Negligible (all species)	Maximum of 2 simultaneous piling events, other noise impacts negligible	The potential effect of piling noise from both sites being developed at one time
Effect of noise – behaviour	Moderate adverse (for herring) Minor adverse (for sandeel) Negligible (all other species)	Moderate adverse (for herring) Minor adverse (for sandeel) Negligible (all other species)	Negligible (all species)	Maximum of 2 simultaneous piling events, other noise impacts negligible	The potential effect of piling noise from both sites being developed at one time
Seabed habitat disturbance	Minor adverse (for sandeel) Negligible (all other species)	Minor adverse (for sandeel) Negligible (all other species)	Negligible (all species)	Total Area of disturbance 1546.38ha This equates to 3.1% of the overall consent area	The total area of disturbance of the worst case scenarios of all three projects
Permanent loss of habitat	Negligible (all species)	Negligible (all species)	Negligible (all species)	Total Area of Habitat loss = 213.61ha This equates to 0.43% of the overall consent area	The total area of habitat loss of the worst case scenarios of all three projects.
Increased suspended sediment and remobilisation of contaminants	Negligible (all species)	Negligible (all species)	Negligible (all species)	Intermittent release over 3 year construction,	

Impact	Alpha	Bravo	Transmission Asset Project	Identification of key Cumulative impacts to be assessed	Justification
Operation					
Disturbance effects of Electromagnetic Fields (EMF)	Minor adverse (for sensitive species)	Minor adverse (for sensitive species)	Minor adverse (for migratory species)	The effect of EMF is dependent on burial depth, distance from the cable and current. Limited evidence from research on the exact responses and whether beneficial or adverse.	Increased levels of disturbance due to EMF with all cables active
Operational noise	Negligible (all species)	Negligible (all species)	Negligible (all species)	Total noise from 150 WTGs and maintenance vessel movements	
Disturbance of seabed habitats	Negligible (all species)	Negligible (all species)	Negligible (all species)	Limited to vessel feet/anchors unless major failure of infrastructure	
Creation of new habitat - fish aggregation	Negligible (all species)	Negligible (all species)	Negligible (all species)	Total area of habitat creation = 213.61ha	Equivalent to the total area of habitat loss of the worst case scenarios of all three projects.
Increased of suspended sediments and remobilisation of contaminants	Negligible (all species)	Negligible (all species)	Negligible (all species)	Intermittent release from scour	
Decommissioning					
Seabed habitat disturbance	Minor adverse (for sandeel) Negligible (all other species)	Minor adverse (for sandeel) Negligible (all other species)	Minor adverse (for sandeel) Negligible (all other species)	Total area of disturbance 1546.38ha This equates to 3.1% of the overall consent area	Without a decommissioning plan it is difficult to assess the magnitude of impact it has been assumed that they will be similar to that of construction.

Noise - disturbance or (construction and operation)

12.399. Initial studies using the SPEAR programme which compared the impact of noise from various activities showed that impact piling is the dominant noise source and hence the activity that will have the greatest impact.

12.400. There are no significant impacts (i.e. moderate or above) for any species at the project level and given the precautionary nature of the assessment for herring, it is not considered that the cumulative impact for that species would exceed minor adverse and not significant. Therefore with regard to lethal or physical injury the cumulative impact of the Seagreen Project is minor adverse and **not significant** for herring and negligible and **not significant** for all other species.

12.401. The Applicants have planned to restrict piling to the installation of one pile at any one time on each site as described in Chapter 5: Project Description in this ES. At the $90dB_{ht}$ level the contours only overlapped for herring, therefore for all other species the impact is additive.

12.402. Noise contours were plotted for both Project Alpha and Project Bravo at the $90dB_{ht}$ impact ranges (the sound level at which behavioural changes could occur). Figures 12.16 to 12.18 show the noise contours for sound in herring, sandeel, dab, trout, salmon and dab. The modelling indicates that disturbance from piling noise will have a negligible and **not significant** impact cumulatively for most species. Given the precautionary nature of the assessments for sandeel, it is not considered that the cumulative impact would exceed minor adverse and **not significant**.

12.403. Previous studies assessed the cumulative noise dose for piling at two locations and used a fleeing animal noise dose model to assess the impact (Nedwell *et al*., 2011). The study showed that animals would tend to flee the area once piling started although the concern would be that spawning is continually disrupted over a longer period of time. Herring are substrate spawners and hearing sensitivity is high although the main spawning population is located further north as discussing paragraphs 12.246 to 12.250. The cumulative impact of piling events occurring at Project Alpha and Project Bravo simultaneously have not been modelled as it is considered unlikely to occur given the comparatively short duration of piling within the build programme. Consequently the magnitude of the impact of cumulative noise is considered to increase above medium in view of the area of spawning ground affected within the WSA and doubling of the impact. The cumulative impact of Project Alpha and Project Bravo being developed at the same time is primarily to increase the number of piling events within the area affected by noise levels in excess of 75dBht. This corresponds to a maximum of 27% of the high intensity herring spawning grounds and 41% of herring nursery grounds. Therefore in accordance with Table 12.5 the impact noise impact on herring behaviour during construction, is considered to be major adverse and **significant**. All operational noise impacts were considered to be negligible and **not significant**.

Mitigation

Mitigation
At this stage, until further design work is carried out, no mitigation is assumed.

12.404. Soft start piling (in which the energy used to drive the piles into the sediment is slowly ramped up) has been incorporated in to the noise assessments. This creates an increasing level of noise from low levels and will allow noise sensitive species such as herring and sprat to vacate the area and can reduce the risk to injury. This is an industry standard mitigation.

12.405. Following further detailed design, it is likely that many of the parameters used in the assessment (such as hammer energy, turbine loadings, etc.) will be refined and noise impacts be reduced. Although no commitment can be made at this stage, Seagreen will endeavour to reduce noise outputs during detailed design.

Residual Impact

12.406. Considering the potential reduction in noise outputs following detailed design, impacts could potentially be significantly reduced and are likely to be negligible and **not significant** for all species. Use of the above mitigation measures for piling may reduce the impact on high sensitivity species such as herring however at this stage it is not possible to determine what this reduction may be, therefore on a precautionary basis the impact remains at major adverse and **significant.**

Seabed habitat disturbance and loss (Construction and Operation)

12.407. The maximum cumulative area that will be disturbed as part of the construction of Project Alpha, Project Bravo and the Transmission Asset Project is approximately 1,550ha. This area represents just 3.1% of the total area within the Seagreen Project boundary (Appendix G4 and as presented in Chapter 11: Benthic Ecology and Intertidal Ecology). Construction of Projects Alpha and Bravo and the Transmission Asset Project will overlap during the overall construction programme although impacts will be episodic and temporary (see Chapter 5: Project Description). Therefore the magnitude of the impact is considered low. The sensitivity of most species is considered to be low as they can either move or have some tolerance; therefore for most species the cumulative impact is negligible and **not significant**.

12.408. Sandeel, given their association with the seabed and ecological importance are considered to have a medium sensitivity, however the magnitude of impact (even if all infrastructure was placed within prime habitat) would be low. Given the precautionary nature of the project level assessments, it is not considered that the cumulative impact upon sandeel would be higher than minor adverse and **not significant**.

12.409. With regard to disturbance of seabed habitat during operation, the impacts for all species are negligible. It is considered that, given the very low magnitude of impact during operation, this would remain negligible cumulatively.

12.410. The maximum cumulative area of habitat that will be lost due to the construction of Projects Alpha, Bravo and the Transmission Project is 218.41ha. The area calculated as loss represents 0.4% of the total area within the ISA. This impact will be permanent lasting for the 25 year duration of the Seagreen Project life. Given the negligible magnitude of this impact it is not considered that cumulatively the impact should be higher – the key affected species is sandeel and given the extent of the seabed lost within the site compared to the known area of sandeel habitat within the North Sea this area is not significant. Therefore for all species the cumulative impact of habitat loss will be negligible and **not significant**.

12.411. Therefore cumulatively, there are no significant impacts from seabed habitat disturbance and loss.

Mitigation

Mitigation
Use of piled jacket structures would reduce the overall footprint and the consequent habitat loss.

Residual Impact

12.412. The residual impact will remain negligible and **not significant**.

Creation of new habitat and fish aggregation (Operation)

12.413. With regard to the creation of new habitat and potential for aggregation of fish, given the area of potential new habitat and the fact that this will be fragmented across a relatively large area, it is unlikely that there will be a major change to the benthos or a noticeable aggregation effect or increases in numbers or diversity – it is unlikely that there will be a 'reef' effect. Therefore for all species the cumulative impact of creation of new habitat and potential for aggregation of fish will be negligible and **not significant.**

12.414. Therefore cumulatively, there are no significant impacts from habitat loss and the creation of new habitat and potential for aggregation.

Mitigation

Mitigation
Use of piled jacket substructure/ foundations would reduce the overall footprint with a proportionate reduction in the creation of any new habitat.

Residual Impact

12.415. Use of jacket substructure/ foundations could reduce the footprint foundations and therefore the overall impact, however, given the already small magnitude the residual impact will remain negligible and **not significant**.

Electromagnetic fields (EMF) (Operation)

12.416. There is potential for both array cabling and export cabling to influence the behaviour of sensitive species especially migratory species. However research to date has been fairly limited and inconclusive as to the degree of impact cabling will have on such species. This is the subject of on-going study. EMF are only likely to be detected close to the cables – within 10 – 20m (Gill *et al*, 2008). In general the impacts of EMF on sensitive species are still very poorly understood and although the magnitude is considered low the species sensitivity is potentially medium. Therefore a precautionary approach would be to assess this as likely to be a minor adverse and **not significant** impact for demersal species or for migratory species in shallow waters.

12.417. Therefore cumulatively, there are no significant impacts from EMF.

Mitigation

Mitigation
As the impacts of EMF are poorly understood mitigation measures are difficult to recommend, dependent upon the layout chosen it may be possible (using paired DC cables) to cancel out the effects of export cables. Burial depths of 0.5m to 2.1m and cable sheaths may mitigate some effects and the arrangement of the array cable layout will be considered with respect to mitigating the impact of EMF.

Residual Impact

12.418. Given the low level of understanding of EMF, from a precautionary standpoint the cumulative impact remains of minor adverse and **not significance**.

Seabed habitat disturbance (decommissioning)

12.419. It is expected that the impacts caused during decommissioning of the Seagreen Project will be equivalent to (or less than) the magnitude of those seen during construction (see paragraphs 12.407 to 12.412 above) therefore the magnitude of disturbance is considered negligible and **not significant** for all species.

12.420. Therefore there will be no significant cumulative impacts from disturbance during decommissioning.

Mitigation

Mitigation
The level of disturbance will depend upon whether some or all of the cables are left in situ.

Residual Impact

12.421. If cables are left in situ there will be a significant reduction in the area of disturbance of the seabed, however the residual impact will remain negligible and **not significant**.

The Seagreen Project cumulative impact with other schemes

12.422. Cumulative impacts related to the Seagreen Project are assessed in this section with reference to other wind farms and industries in the area. There are few other industries in the region (see Chapter 20: Other Marine Users and Activities) and few activities or developments that could have a cumulative impact on fish and shellfish species 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.

12.423. With regard to other wind farms, several may be of relevance. The wind farms in the Moray Firth (Beatrice Offshore Wind Farm and Moray Firth Offshore Wind Farm) are over 200km from the Seagreen Project. It is not considered that there will be pathways for cumulative impacts between these projects and the Seagreen Project. There are also a number of small demonstrator projects which are in the planning and development phase at the time of writing. These are the Hywind Demonstration site, European Offshore Wind Development Centre, and Methil Offshore Wind Farm. It is expected that these projects would involve the installation of up to 11 wind turbine generators (WTGs). Given the anticipated build schedules, scale of development and distance (see Table 20.5, Chapter 20: Other Marine Users and Activities) it is not considered that there will be pathways for cumulative impacts between these projects and the Seagreen Project.

12.424. There are two other offshore wind farms currently in the planning process and are considered relevant in terms of cumulative impact, these are the Inch Cape Offshore Wind Farm (Inch Cape) and Neart na Gaoithe Offshore Wind Farm which will both, if consented, be located within the Firth of Forth inshore of the Seagreen Project. Inch Cape will be located approximately 10km west of the Project Alpha and Neart na Gaoithe will be located approximately 30km south west.

12.425. The main impacts during construction, operation and decommissioning phases which have the potential to result in cumulative impacts and are considered to be: the potential for noise from construction activities to influence the behaviour of sensitive species such as herring; disturbance and loss of benthic habitats and EMF effects. These are shown on Table 12.21.

Noise - disturbance or injury (construction and operation)

12.426. With regard to lethal effects and injury, Inch Cape and Neart na Gaoithe have similarly small ranges of potential impact to the Seagreen Project. Lethal effects for both projects are estimated to have a maximum range of 40m, whilst physical injury will have a range of up to 80m for Inch Cape and 60m for Neart na Gaoithe (see Table 6-8, Appendix H6). Given these small ranges and the fact that it is likely that most fish would flee from the noise as the piling energy is ramped up under soft-start, it is likely the magnitude of this impact is negligible at the cumulative scale. Given the precautionary nature of the assessment for herring (i.e. high sensitivity), it is not considered that the cumulative impact for that species would exceed minor adverse and **not significant**. Therefore with regard to lethal or physical injury the cumulative impact of the Seagreen Project is minor adverse and **not significant** for herring and negligible and **not significant** for all other species.

12.427. With regard to auditory injury the range and areas of effect for Inch Cape and Neart na Gaoithe are shown in Tables 12.22 and 12.23 (also see Tables 6-25a and 6-27a, Appendix H6). Again the ranges and areas of potential injury are small and the magnitude of impact would again be low. Given the precautionary nature of the assessment for herring (i.e. high sensitivity), it is not considered that the cumulative impact for that species would exceed **minor** adverse and **not significant**. Therefore with regard to auditory injury the cumulative impact of the Seagreen Project is minor adverse and **not significant** for herring and negligible and **not significant** for all other species.

12.428. With regard to behavioural impacts, it is clear that for most species that the impacts are short range and that there is little potential for overlap (the exceptions being salmon, dab and herring). For most species therefore impacts will be additive but contained within the respective project boundaries. Previous studies used a fleeing animal model to assess the impact of noise on herring swimming at a speed of 1m/s from the installation of 7m piles, using a maximum hammer blow of 1100kj, and 14km apart. The study found that the critical range between piles at which herring would receive a noise dose above $90dB_{ht}$ was 7km, closer than this they would be expected to receive auditory damage (Nedwell *et al*., 2011). Hammer energy for pile driving for all four wind farms being assessed were slightly higher than the study described above but the results can used as a guide to the assessment here. Both Inch Cape and Neart na Gaoithe are over 8km from the Seagreen Project therefore a cumulative noise dose from piling with respect to auditory damage is unlikely to occur. The modelling indicates that disturbance from piling noise will have a negligible and **not significant** impact cumulatively for most species (excluding salmon, herring and sandeel). Given the precautionary nature of the assessments for sandeel (having a medium sensitivity due to its ecological importance) there is considered to be a greater impact, it is not considered that the cumulative impact would exceed minor adverse and **not significant** across the four projects (see Figure 12.17).

12.429. For salmon (Figure 12.18) it appears that there is some potential for barrier effects (when considering the $75dB_{ht}$ significant avoidance modelling) should all projects undertake simultaneous piling and given the medium sensitivity of this species this may be considered to be a significant impact cumulatively. However, given that the cumulative impact is offshore and away from the coastal areas likely to be used for the bulk of migratory movements it is not considered the this impact has a magnitude greater than low, therefore the cumulative impact upon salmon will be minor adverse and **not significant**.

12.430. With regard to herring, it is clear (Figure 12.16) that the cumulative impact has the potential to cover large areas of the WSA some of which contain potential nursery and spawning grounds, the percentage of coverage of these areas is shown in Table 12.24. The tables show a worst case assessment of cumulative noise impact assessment of 38% of high intensity spawning and 51% of nursery area within the WSA has been predicted to receive noise impacts of 75dB_{ht} or higher. At a North Sea herring population context the area of herring spawning ground affected are a very small percentage of the overall area. Given the ecological importance of herring and their sensitivity to noise impacts their overall sensitivity is considered to be high. A key cumulative impact arises from the concurrent development of two or more wind farm sites. Whilst the area affected will not change the duration of piling and number of piling events will increase. The potential to affect the spawning behaviour of key species over a period of years would occur if piling driving activities took place concurrently and over consecutive spawning periods which would then inevitably create longer term disruption. Given the area of spawning and nursery grounds affected by piling noise magnitude of impact is likely to be high, although it should be noted that each piling event will be of short duration (<2 hours) and the chances of having simultaneous piling events will be limited. Therefore the cumulative impact would be major adverse and **significant**. It should be noted however, that the spawning and nursery ground data do not represent discrete or accurate boundaries and therefore some caution should be used when using these for assessment. However, given that if all projects use jackets there will be in excess of 1000 piling events, it is considered that this impact could be major adverse and **significant**.

Table 12.22 Range of auditory injury at 130 dB*ht* (*species)* for key species for Neart na Gaoithe and Inch Cape

	Range to 130dBht (km/ km^2)			
	Max	Min	Mean	Area
Neart na Gaoithe				
Dab	0.04	0.02	0.03	0
Herring	0.26	0.24	0.25	0.2
Salmon	0.04	0.02	0.03	0
Sandeel	below level of detection	n/ a	n/ a	n/ a
Trout	below level of detection	n/ a	n/ a	n/ a
Inch Cape				
Dab	0.04	0.02	0.03	0
Herring	0.28	0.26	0.27	0.23
Salmon	0.04	0.02	0.03	0
Sandeel	below level of detection	n/ a	n/ a	n/ a
Trout	below level of detection	n/ a	n/ a	n/ a

Table 12.23 Impact range for 90 dB_{ht} (*species*) and 75 dB_{ht} (*species*) perceived levels for key species for Neart na Gaoithe and Inch Cape

Species	Range to 90 dB_{ht} (km/km^2)				Range to 75 dBht (km/km^2)			
	Max	Min	Mean	Area	Max	Min	Mean	Area
Neart na Gaoithe								
Dab	3.7	3.7	3.7	42.8	20	16	19	1131
Herring	27	19	25	1899	65	19	47	7588
Salmon	1.5	1.4	1.5	6.6	9.2	8.8	9	252
Sandeel	0.2	0.1	0.2	0.1	1.3	1.3	1.3	5.4
Trout	0.3	0.2	0.3	0.2	1.8	1.8	1.8	9.8
Inch Cape								
Dab	3.9	3.8	3.9	47.4	21	16	19	1177
Herring	28	20	25	2003	70	21	48	8099
Salmon	1.6	1.6	1.6	7.7	9.6	8.5	9.3	272
Sandeel	0.2	0.2	0.1	0.1	1.5	1.4	1.5	6.6
Trout	0.3	0.3	0.3	0.2	1.9	1.9	1.9	11.5

Table 12.24 Impacts upon herring nursery and spawning grounds for the Seagreen Project, Neart na Gaoithe and Inch Cape, showing percentages of areas impacted 90 dB_{ht} (*species*) and 75 dB_{ht} (*species*) perceived levels

	Seagreen (Alpha and Bravo)		Neart na Gaoithe		Inch Cape		Seagreen, Neart na Gaoithe & Inch Cape	
	$75dB_{ht}$	$90dB_{ht}$	$75dB_{ht}$	$90dB_{ht}$	$75dB_{ht}$	$90dB_{ht}$	$75dB_{ht}$	$90dB_{ht}$
Herring Spawning grounds (% impacted)	27.24	3.03	16.99	0.06	18.42	1.74	37.67	4.02
Herring Nursery grounds (% impacted)	42.79	11.89	32.45	8.18	34.56	8.45	51.52	19.62

Mitigation

Mitigation

At this stage, until further design work is carried out, no mitigation is assumed.

12.431. Soft start piling (in which the energy used to drive the piles into the sediment is slowly ramped up) has been incorporated in to the noise assessments. This creates an increasing level of noise from low levels and will allow noise sensitive species such as herring and sprat to vacate the area and can reduce the risk to injury. This is an industry standard mitigation.

12.432. Following further detailed design, it is likely that many of the parameters used in the assessment (such as hammer energy, turbine loadings, etc.) will be refined and noise impacts be reduced. Although no commitment can be made at this stage, Seagreen will endeavour to reduce noise outputs during detailed design.

Residual Impact

12.433. Considering the potential reduction in noise outputs following detailed design, impacts could potentially be significantly reduced and are likely to be negligible for all species. Use of the above mitigation measures for piling may reduce the impact on high sensitivity species such as herring however at this stage it is not possible to determine what this reduction may be, therefore on a precautionary basis the impact remains at major adverse.

Seabed habitat disturbance and loss (Construction, Operation and Decommissioning)

12.434. With regard to habitat disturbance, it is likely that whilst there will be some overlap in the construction periods of the Seagreen Project, Inch Cape and Neart na Gaoithe there will not be any spatial overlap of activities. Given the distances between the developments and the localised nature of disturbance impacts (whether physical disturbance of habitats or increases in suspended sediments) there are no pathways for interactions (as discussed in Chapter 7: Physical Environment). Therefore any impacts will be additive but not interactive. Whilst the exact footprint of cumulative habitat disturbance cannot be calculated at the present time due to insufficient data from Inch Cape and Neart na Gaoithe, it is likely that any impacts will be similar to those for the Seagreen Project and proportionate to those developments. Therefore impacts will be relatively small scale, localised and temporary and occur episodically as the construction phases are undertaken. Therefore, the magnitude of the cumulative impact will be minor or negligible. Given the ubiquity of species across the region and their ability to either tolerate or move away from disturbance the sensitivity of all species to this impact is considered to be low. Therefore cumulatively the impact will be negligible.

12.435. As described in Chapter 11: Benthic Ecology and Intertidal Ecology in this ES the maximum cumulative area of habitat that will be lost due to the construction of the Seagreen Project, Inch Cape and Neart na Gaoithe is 485ha. This represents less than 0.25% of the total area for development (Table 12.21). This impact will be permanent, lasting for the duration of the projects' lifespan but the magnitude is low. The concern regarding habitat loss is the potential decrease in prime sandeel habitat and that for other benthic species. Data for suitable sandeel habitat within the Inch Cape wind farm site is not available at this point in time. Site specific survey analysis for Neart na Gaoithe indicated that habitats within the Neart na Gaoithe footprint were unlikely to be suitable for sandeel or scallop populations although nephrops burrows were seen in the sediments (Mainstream, 2012).

12.436. Since the full extent of the prime habitat for sandeel in the wider area around the developments is not known without extended habitat mapping the magnitude of habitat loss in terms of substrate specific species i.e. sandeel and scallop and the low percentage of habitat loss in comparison with the total developed area (0.25%) is considered to be negligible. However a precautionary standpoint should be taken as data are not available and therefore the sensitivity of the receptor is considered to be medium. Consequently under a worst case scenario the cumulative impact of habitat loss caused by the three wind farms is considered to be negligible.

12.437. Therefore cumulatively, there are no significant impacts from habitat disturbance or loss.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.438. Whilst the use of jacket substructure/ foundations would reduce the total area of habitat loss, the residual impact will remain of negligible significance.

Electromagnetic fields (EMF) (Operation)

12.439. The cumulative impacts associated with cabling for all wind farms is not expected to be significant mainly because the effects of EMF from HVAC cabling is thought to be very localised and reduces with distance from the cable and with burial depth. Research on European eel in Swedish waters found no changes in migratory behaviour beyond 500m from the wind farm sites (Ohman *et al*., 2007 in Gill and Bartlett, 2010). Other studies on a range of fish species including salmon showed that although EMF was detected at a distance of 1m from the cable no effect on migratory patterns emerged (Westerberg and Langenfelt, 2008). There is a limited amount of information on the impact on migratory behaviour for species of fish of conservation or commercial importance. The sensitivity of the receptor considered to be high in terms of the conservation and commercial importance of migratory species although the magnitude of the cumulative impact is low because of the localised nature of the effect. The overall impact is therefore minor adverse.

12.440. Therefore cumulatively, there are no significant impacts from EMF.

Mitigation

Mitigation
As the impacts of EMF are poorly understood mitigation measures are difficult to recommend, dependent upon the layout chosen it may be possible (using paired DC cables) to cancel out the effects of export cables.

12.441. Burial depths of 0.5m to 2.1m and cable sheaths may mitigate some impacts and the arrangement of the array cable layout will be considered with respect to mitigating the effect of EMF.

Residual Impact

12.442. Given the low level of understanding of EMF, from a precautionary standpoint the cumulative impact remains of minor adverse significance.

Creation of new habitat and fish aggregation (Operation)

12.443. With regard to the creation of new habitat and potential for aggregation of fish, given the area of potential new habitat and the fact that this will be fragmented across a relatively large area, it is unlikely that there will be a major change to the benthos or a noticeable aggregation effect or increases in numbers or diversity – it is unlikely that there will be a reef effect. Therefore for all species the cumulative impact of creation of new habitat and potential for aggregation of fish will be negligible.

Mitigation

Mitigation
No mitigation measures are suggested for this impact.

Residual Impact

12.444. The residual impact will remain of negligible significance.

Seagreen cumulative impact Phases 2 and 3

12.445. There will be five proposed offshore wind farms within Phases 2 and 3 of the Firth of Forth Zone with a combined output of 2.6GW, three export cables with a landing near Torness and agreements are in place for connection to the National Grid, electricity transmission network near Branxton, East Lothian.

12.446. Applications for consents for Phases 2 and 3 are expected to be submitted in 2014 and 2016 respectively. The Applicants believe that the design and development with these Phases must be adaptive and take into account lessons learned from Phase 1 development and other projects currently being developed in Scottish Territorial Waters (STW) as well as other offshore wind farm projects across the UK.

12.447. In terms of presenting cumulative impacts of Phases 2 and 3 within this document the Applicants believe that the best way to present information at this stage would be to use a high level qualitative approach rather than detailed work.

12.448. Available data is already present in the scoping exercise undertaken already (Seagreen 2011) which includes a present status report for Phases 2 and 3. This is based on the best currently available evidence. Further work will be undertaken during the period leading up to submission in 2014 and 2016. This work will include:

- detailed geophysical work to determine the surface topography and underlying geology of the Phases;
- physical process modelling once detailed design information is available to determine likely effects of Phases 2 and 3;
- benthic survey (grabs, trawls and video sampling) designed with regard to the results of the geophysical survey to determine the nature of the benthic community, composition of surface sediments and presence of any contaminants; and
- desk based assessment and some site specific survey to determine the baseline conditions of the human environment.

12.449. The details above indicate that there is a large amount of data yet to be collected and assessed. Any baseline assessment at this stage will be given a low level of confidence when included in Phase 1 EIA.

12.450. Considerable changes to the original design and location of the Phase 1 projects during the detailed development work have occurred as environmental concerns (both ecological and human) have emerged that have shaped the projects going forward within the EIA. For some receptors (e.g. ornithology, marine mammals etc.) it is possible that a development of this magnitude could give rise to significant cumulative impacts. However given the size of the Zone and the development process the Applicants intend to follow, an optimal layout and approach should be developed to deliver the maximum power output without causing a significant impact upon the receiving environment. The Applicants are committed to progressing the development of Phases 2 and 3 to ensure environmental impacts and in particular cumulative environmental impacts can be minimised and significant impacts avoided.

12.451. The Applicants wish to use best available evidence and best practice in order to follow a responsible approach to the development of Phases 2 and 3. Therefore, to a great extent, the design refinement for Phases 2 and 3 will be dependent upon the on-going process with regard to Phase 1, the STW sites and other offshore wind developments in Scotland. Of particular importance will be any limitations in capacity, layout, location or construction methodologies and infrastructure technologies (e.g. turbine sizes and foundation types) which are detailed in the final consent(s). Clearly the progress of the post-submission process and decisions taken will be a crucial influence on how Phases 2 and 3 are taken forward and ultimately what form these developments take.

ENVIRONMENTAL STATEMENT LINKAGES

12.452. The inter-relationships between fish and shellfish ecology and other physical, environmental and human parameters are inherently considered throughout the assessment of impacts as a result of the receptor lead approach to the assessment. For example fish and shellfish ecology has the potential to be influenced by increases in suspended sediments as a result of effects on physical processes from the proposed development construction and operational phases. The potential impacts as a result of this indirect effect have been discussed within this chapter based on the findings of the assessments made in Chapters 7: Physical Environment, Chapter 8: Water and Sediment Quality and Chapter 11: Benthic Ecology. Linkages considered in this chapter are detailed in Table 12.25.

Table 12.25 Environmental Statement Linkages

Inter-relationship	Relevant Section	Linked Chapter
Construction		
Indirect impacts due to the loss of habitat and benthic prey resource during construction	Impact Assessment - Construction	Chapter 11 Benthic and Intertidal Ecology Chapter 10 Ornithology
Indirect impacts to fish and crustacean from physical disturbance to intertidal and subtidal habitats	Impact Assessment - Construction	Chapter 11 Benthic and Intertidal Ecology Chapter 7 Physical Environment Chapter 8 Water and Sediment Quality
Indirect impacts from loss of fish as a prey resource	Impact Assessment - Construction	Chapter 10 Ornithology Chapter 13 Marine Mammals Chapter 14 Commercial Fisheries
Impact on fish resource from changes in water quality	Impact Assessment - Construction	Chapter 8 Water and Sediment Quality Chapter 7 Physical Environment
Operation		
Indirect impact of loss of prey resource resulting from changes in current regime and indirect effects on subtidal ecology during the operational phase	Impact Assessment- Operation	Chapter 7 Physical Environment Chapter11 Benthic and Intertidal Ecology

OUTLINE MONITORING

12.453. The Applicants make a commitment to development of monitoring plan if appropriate and requested by the regulators. This is likely to form part of the conditions for consent of the Marine Licence.

12.454. Any monitoring survey programs will be agreed with Marine Scotland and SNH to ensure that they provide suitable data to answer the appropriate questions. It is suggested that monitoring of natural fish is more suited to a regional approach to monitoring building upon strategic work being conducted at the wider Scottish and UK levels.

SUMMARY

12.455. Tables 12.26, 12.27 and 12.28 summarise the predicted significance of each impact assessed within the EIA and provide the suggested mitigation and residual impact.

Table 12.26 Summary of Project Alpha Impacts

Description of Effect	Impact	Potential Mitigation Measures	Residual Impact
Construction Phase			
Effect of noise – death or injury	Minor adverse	Use of non-piled substructures/foundations would significantly reduce noise impacts. Energy needed to drive piles should be minimised to reduce peak noise impacts. Soft start piling (in which the energy used to drive the piles into the sediment is slowly ramped up) creates an increasing level of noise from low levels and will allow noise sensitive species such as herring and sprat to vacate the area and can reduce the risk to injury. This is an industry standard mitigation. Physical mitigation methods may lead to a modest reduction in source level although this is untested in deeper water or tidal conditions. Investigation will continue regarding other technical mitigation solutions to reduce noise impacts.	If non-piled foundations are used then impact would be negligible. The use of the mitigation methods suggested for piling may reduce the impact on high sensitivity species such as herring however at this stage it is not possible to determine what this reduction may be. Therefore on a precautionary basis the impact remains minor adverse and **not significant.**
Effect of noise – behaviour	Moderate adverse (herring)	Use of non-piled substructure/foundations would significantly reduce noise impacts. Energy needed to drive piles should be minimised to reduce peak noise impacts. Soft start piling (in which the energy used to drive the piles into the sediment is slowly ramped up) creates an increasing level of noise from low levels and will allow noise sensitive species such as herring and sprat to vacate the area and can reduce the risk to injury. This is an industry standard mitigation. Physical mitigation methods may lead to a modest reduction in source level although this is untested in deeper water or tidal conditions. Investigation will continue regarding other technical mitigation solutions to reduce noise impacts.	If non-piled substructures/foundations are used then impact would be negligible. The use of the mitigation methods suggested for piling may reduce the impact on high sensitivity species such as herring however at this stage it is not possible to determine what this reduction may be. Therefore on a precautionary basis the impact remain moderate adverse and **significant.**

Description of Effect	Impact	Potential Mitigation Measures	Residual Impact
Seabed habitat disturbance	Negligible	No mitigation methods advised for this impact	**Not significant.**
Permanent loss of habitat	Negligible	Use of piled jacket structures would reduce the overall footprint and the consequent habitat loss	If prime sandeel habitats are avoided or use of them minimised and jacket substructure/foundations used then the impact could be reduced but given the high sensitivity of the receptor the impact will remain Negligible and **not significant**.
Increased of suspended sediments and remobilisation of contaminants	Negligible	No mitigation methods advised for this impact	**Not significant.**
Operation Phase			
Disturbance effects of Electromagnetic Fields (EMF)	Minor adverse	The effects of EMF are poorly understood mitigation measures are difficult to recommend. However burial depths of 0.5m to 2.1m are estimated and the arrangement of the array cable layout will be considered with respect to mitigating the effect of EMF.	With appropriate burial depth and intelligent array cable layouts it may be possible to reduce the impacts of EMF, however given the uncertainties around this impact from a precautionary standpoint this will remain minor adverse for the most sensitive species and **not significant.**
Operational noise	Negligible	No mitigation methods advised for this impact	**Not significant.**
Disturbance of seabed habitats	Negligible	No mitigation methods advised for this impact	**Not significant.**
Creation of new habitats – fish aggregation	Negligible/beneficial	No mitigation methods advised for this impact	**Not significant.**

Description of Effect	Impact	Potential Mitigation Measures	Residual Impact
Increased of suspended sediments and remobilisation of contaminants	Minor adverse	Where scour protection is used for conical GBS to ensure structural stability, visual dive surveys or bathymetric surveys will be undertaken at selected locations with Project Alpha to assess the effectiveness of scour protection on reducing scour and resultant sediment release (see Chapter 7 Physical Environment) Site selection or the use of smaller diameter foundations for conical GBS will aim to reduce the requirement for ground preparation and thus reduce the volume of resuspended sediments and remobilised contaminants.	**Not significant.**
Decommissioning Phase			
Seabed habitat disturbance and loss	Negligible	No mitigation methods advised for this impact.	**Not significant.**

Table 12.27 Summary of Project Bravo Impacts

Description of Effect	Impact	Potential Mitigation Measures	Residual Impact
Construction Phase			
Effect of noise – death or injury	Minor adverse	Use of non-piled substructure/foundations would significantly reduce noise impacts Energy needed to drive piles and to minimise peak noise impacts Soft start piling will allow noise sensitive species such as herring and sprat to vacate the area and can reduce the risk to injury. Physical mitigation methods such as bubble curtains may lead to a modest reduction in source level although this is untested in deeper water or tidal conditions. Investigation will continue regarding other technical mitigation solutions to reduce impacts.	If non-piled substructure/foundations are used then impact would be negligible. The use of the mitigation methods suggested for piling may reduce the impact on high sensitivity species such as herring however at this stage it is not possible to determine what this reduction may be. Therefore on a precautionary basis the impact remain minor adverse and **Not significant**.
Effect of noise – behaviour	Moderate adverse (herring)	Use of non-piled substructure/foundations would significantly reduce noise impacts Energy needed to drive piles and to minimise peak noise impacts Soft start piling will allow noise sensitive species such as herring and sprat to vacate the area and can reduce the risk to injury. Physical mitigation methods such as bubble curtains may lead to a modest reduction in source level although this is untested in deeper water or tidal conditions. Investigation will continue regarding other technical mitigation solutions to reduce impacts,	If non-piled substructure/foundations are used then impact would be negligible. The use of the mitigation methods suggested for piling may reduce the impact on high sensitivity species such as herring however at this stage it is not possible to determine what this reduction may be. Therefore on a precautionary basis the impact remain moderate adverse and **Significant**.
Seabed habitat disturbance	Negligible	No mitigation methods advised for this impact	**Not significant**.

Description of Effect	Impact	Potential Mitigation Measures	Residual Impact
Permanent loss of habitat	Negligible	Use of jacket substructure/foundations would reduce the overall footprint of habitat loss Siting of turbines to avoid prime sandeel habitats could be considered if practicable	If prime sandeel habitats are avoided or use of them minimised and jacketsubstructure/ foundations used then the impact could be reduced but given the high sensitivity of the receptor the impact will remain negligible and **not significant.**
Increased of suspended sediments and remobilisation of contaminants	Negligible	No mitigation methods advised for this impact	**Not significant.**
Operation Phase			
Disturbance effects of Electromagnetic Fields (EMF)	Minor adverse	The effects of EMF are poorly understood mitigation measures are difficult to recommend. However burial depths of 0.5m to 2.1m are estimated and the arrangement of the array cable layout will be considered with respect to mitigating the effect of EMF	With appropriate burial depth and intelligent array cable layouts it may be possible to reduce the impacts of EMF, however given the uncertainties around this impact from a precautionary standpoint this will remain minor adverse for the most sensitive species, and **not significant.**
Operational noise	Negligible	No mitigation methods advised for this impact	**Not significant.**
Disturbance of seabed habitats	Negligible	No mitigation methods advised for this impact	**Not significant.**
Creation of new habitats – fish aggregation	Negligible	No mitigation methods advised for this impact	**Not significant.**
Increased suspended sediment and mobilisation of contaminants	Negligible	Placement of scour protection should reduce the amount of re-suspended material during operation.	**Not significant.**
Decommissioning Phase			
Seabed habitat disturbance and loss	Negligible	No mitigation methods advised for this impact	**Not significant.**

Table 12.28 Summary of Transmission Asset Project Impacts

Description of Effect	Effect	Potential Mitigation Measures	Residual Impact
Construction Phase			
Underwater noise	Negligible	No mitigation methods advised for this impact	**Not significant.**
Seabed habitat disturbance	Negligible	No mitigation methods advised for this impact	**Not significant.**
Permanent loss of habitat	Negligible	No mitigation methods advised for this impact	**Not significant.**
Impacts of increased suspended sediment and remobilisation of contaminants .	Negligible	No mitigation methods advised for this impact	**Not significant.**
Operation Phase			
Effect of electromagnetic fields (EMF) (export cables)	Minor adverse	As the effects of EMF are poorly understood mitigation measures are difficult to recommend. It is thought that burial depths and use of appropriate patterns in the cable layout may help reduce EMF and environmental) along the route and set out target burial depths in accordance with the associated risks.	Burial depths to be investigated to lessen the impact of EMF to minor adverse or negligible depending on species. This is assessed as **Not significant.**
Creation of new habitats – fish aggregation	Negligible	No mitigation methods advised for this impact	**Not significant.**
Increased suspended sediments and mobilisation of contaminants	Negligible	No mitigation methods advised for this impact	**Not significant.**
Decommissioning Phase			
Seabed habitat disturbance due to OSP and cable removal	Negligible	No mitigation methods advised for this impact	**Not significant.**

REFERENCES

Andersson M H. (2011). *Offshore wind farms – ecological effects of noise and habitat alteration on fish.* Doctoral dissertation 2011, University Stockholm, Sweden

Andriguetto-Filhoa, J.M., Ostrenskya, A., Pieb, M.R., Silvac, U.A. & Boegerb, W.A. (2005). *Evaluating the impact of seismic prospecting on artisanal shrimp fisheries*. Continental Shelf Research. 25: 1720–1727.

Ball, R.E. (2007). *Electroreception in embryos of the thornback ray, Raja clavata.* Unpublished MSc thesis. Department of Natural Resources, Integrated Earth System Sciences Institute, Cranfield University.

Barnes, M. (2008). *Scomber scombrus. Atlantic mackerel. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line].* Plymouth: Marine Biological Association of the United Kingdom. [cited 15/ 10/ 2011]. Available from: <http:/ / www.marlin.ac.uk/ speciesinformation.php?speciesID=4310>

Barber, N.F. and M.S. LonguetHiggins (1948). *Water movements and Earths currents: Electrical and magnetic effects,* Nature 161, 192 - 193

Berge, J. A. (1979). *The perception of weak electric AC currents by the European eel, Anguilla anguilla.* Comparative Biochemistry and Physiology A, 62, 915-919

Bannister, R.C.A., Addison J.T and Lovewell, S.R.J (1994). *Growth movement recapture rate and survival of hatchery reared lobster (Homarus gammarus) (Linnaeus 1758) released into the wild on the English east coast*. Crustaeana, 67:156-172.

Bellido. J.M, Pierce. G.J and Wang.J (2001). *Modelling intra-annual variation in abundance of squid Loligo forbesi in Scottish waters using generalised additive models.*

Bolle LJ, de Jong CAF, Biermans S, de Haan D, Huijer, T, Kaptein D, Lohman M, Tribuhl S, van Beek P, van Damme CJG, van den Berg FHA, van der Heul J, van Keeken O, Wessels P, Winter E (2011). *Shortlist Masterplan Wind. Effect of piling noise on the survival of fish larvae* (pilot study).IMARES report.

Booman, C., Dalen, H., Heivestad, H., Levsen, A., van der Meeren, T. & Toklum, K. (1996). *Effekter av luftkanonskyting pa egg, larver og ynell.* Undersekelser ved Hauforskningstituttet ogtoclgisk Laboratorium, Universitet; Bergen. Fisken og Havet, 3.

Boulcott P., Wright P.J., Gibb F., Jensen H. and Gibb 1. (2007) *Regional variation in the maturation of sandeels in the North Sea.* ICES journal of Marine Science, 64: 369-376

Boyle, R. R., and G. J.Pierce (1994). *Fisheries biology of Northeast Atlantic squid: An overview*. Fisheries Research vol. 21; issues 1-2.pp 1-15.

Burd, A.C. (2011). *Recent Changes in the Central and Southern North Sea Herring Stocks*. Canadian Journal of Fisheries and Aquatic Sciences, 1985, 42 (S1), s192-s206

Camphuysen C. J., (2000) (Ed). *Understanding marine foodweb processes: An ecosystem approach to sustainable sandeel fisheries in the North Sea.* IMPRESS Final Report Project Q5RS-2000-30864.

Carter, M (2009). *Aequipecten opercularis. Queen scallop. Marine Life Information Network: Biology and* Sensitivity *Key Information Sub-programme [on-line].* Plymouth: Marine Biological Association of the United Kingdom. [cited 15/ 10/ 2011]. Available from: <http:/ / www.marlin.ac.uk/ speciesinformation.php?speciesID=2390>

Casini, M., Cardinale, M., and Arrhenius, F. (2004). *Feeding preferences of herring (Clupea harengus) and sprat (Sprattus sprattus) in the southern Baltic Sea.* e ICES Journal of Marine Science, 61: 1267e1277.

Cefas (2009). *Herring in the North Sea* (ICES Division IV, VIId and IIIa)

Cefas (2011). *Herring in the North Sea* (ICES Division IV, VIId and IIIa)

CMACS (2003). *A baseline assessment of electromagnetic fields generated by offshore windfarm cables.* COWRIE Report EMF - 01-2002 66.

Coull, K.A., Johnstone, R., and S.I. Rogers (1998). *Fisheries Sensitivity Maps in British Waters.*

Daan, N., Hislop, J.R.G., Lahn-Johannessen, J., Parnell, W.G., Scott, J.S., and Parre, P. (1980). *Results of the International O-group Gadoid Survey in the North Sea*, 1980. ICES CM, G:5.

Dekker, W., (2003). *Did lack of spawners cause the collapse of the European Eel, Anguilla anguilla.* Fisheries Management and Ecology Vol 10 (6). 365-375.

Dickey-Collas, M.,G.H. Engelhard and C. Möllmann (2010) In: Rijnsdorp AD, Peck MA, Engelhard GH, Möllmann C, Pinnegar JK (eds). *Resolving climate impacts on fish stocks*. ICES Coop. Res. Rep. No. 301, pp 121-129.

DONG Energy and Vattenfall A/ S (2006). *Review Report 2005 The Danish Offshore Wind Farm Demonstration Project: Horns Rev and Nysted Offshore Wind Farms Environmental Impact Assessment and Monitoring.* Prepared for The Environmental Group of the Danish Offshore Wind Farm Demonstration Projects.

Ellis, J.R., Cruz-Martinez, A., Rackham, B.D. and Rogers, S.I. (2005). *The distribution of chondrichthyan fishes around the British Isles and implications for conservation*. Journal of Northwest Atlantic Fishery Science, 35: 195–213

Ellis, J.R., Milligan, S.P., Readdy, L.,Taylor, N. and Brown, M.J. (2012). *Spawning and nursery grounds of selected fish species in UK waters*. Sci. Ser. Tech. Rep., Cefas Lowestoft, 147: 56 pp.

Engås, A. and S. Løkkeborg (2002). E*ffects of seismic shooting and vessel-generated noise on fish behaviour and catch rates*. Bioacoustics 17:313-316.

Faber Maunsell (2007). *Marine renewables SEA environmental report*. Section C7 Fish and shellfish.

Fänge R., (1966). *The Physiology of the Swimbladder*. Physiol Rev April 1, 1966 vol. 46 no. 2 299-322

Fauchald P, Skov H, Skern-Mauritzen M, Johns D, Tveraa T (2011). *Wasp-Waist Interactions in the North Sea Ecosystem*. PLoS ONE 6(7): e22729.doi:10.1371/ journal.pone.0022729

Fisheries Research Services (FRS) (undated). *The Changing Abundance of Spring Salmon*. Available from: http:/ / www.scotland.gov.uk/ Uploads/ Documents/ FW02SpringSalmon.pdf (accessed 10/ 9/ 12)

Fisheries Research Services (FRS) (undated). *Catches of Summer and Autumn Salmon in Scotland.* Available from http:/ / www.erft.org.uk/ uploads/ CATCHES%20OF%20SUMMER%20AND%20AUTUMN%20SALMON%20IN%20SCOTLAND.pdf (accessed 10/ 9/ 12)

Fox.C.J,, Taylor.M, Dickey-Collas. M, Fossum. P, Kraus. G, Rohlf.N , Munk.P, van Damme C.J. G., Bolle.L.J, Maxwell. D.L and Wright.PJ (2008). *Mapping the spawning grounds of North Sea cod (Gadus morhua) by direct and indirect means.* Proc Biol Sci. 275(1642):1543-8.

Furness, R.W. (2002). *Management implications of interactions between fisheries and sandeel-dependent seabirds and seals in the North Sea.* Ices Journal of Marine Science, 59 (2), 261-269. ISSN 1054-3139.

Gibb .F.M, Gibb. I. M. Wright. P.J., (2007). *Isolation of Atlantic cod (Gadus morhua) nursery areas*. Mar Biol. 151 (3), 1185-1194,.

Gibbs, M., and Hewitt, J., (2004). *Effects of sedimentation on macrofaunal communities: a synthesis of research studies.* Auckland Regional Council. Technical Publication 264.

Gill, A.B. & Bartlett, M. (2010). *Literature review on the potential effects of electromagnetic fields and subsea noise from marine renewable energy developments on Atlantic salmon, sea trout and European eel.* Scottish Natural Heritage Commissioned Report No.401.

Gill, A. B., Gloyne-Phillips, I., Neal, K. J. & Kimber, J. A. (2005). *The potential effects of electromagnetic fields generated by sub-sea power cables associated with offshore wind farm developments on electrically and magnetically sensitive marine organisms - a review*. In: Report to Collaborative Offshore Wind Research into the Environment (COWRIE) group, Crown Estates (unpublished report).

Gill, A.B., Huang, Y., Gloyne-Philips, I., Metcalfe, J., Quayle, V., Spencer, J. & Wearmouth, V. (2009). *COWRIE 2.0* Electromagnetic *Fields (EMF) Phase 2: EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the type used by the offshore renewable energy industry*. Commissioned by COWRIE Ltd (project reference COWRIE-EMF-1-06).

Gill, A.B., & Taylor, H. (2001). *The potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon elasmobranch fishes*. .CCW Science Report No. 488, September 2001.

Gowanlock J.N., and McDougall J.E (1945). *Effects of the detonation of explosions on certain marine life.* Oil 4:13-16

Greenstreet. S, Fraser. H, Armstrong.E, and Gibb. I (2010a). *Monitoring* the *Consequences of the Northwestern North Sea Sandeel Fishery Closure*. Scottish Marine and Freshwater Science Vol.1 No.6

Greenstreet, S. P. R., Holland, G. J., Guirey, E. J., Armstrong, E., Fraser, H. M., and Gibb, I. M. (2010b). *Combining hydroacoustic seabed survey and grab sampling techniques to assess "local" sandeel population abundance*. ICES Journal of Marine Science, 67: 971–984.

Halvorsen, M.B., Casper, B.M., Woodley, C.M., Carlson, T.J., and Popper, A.N. (2011). *Predicting and mitigating hydroacoustic impacts on fish from pile installations.* NCHRP Research Results Digest 363, Project 25-28, National Cooperative Highway Research Program, Transportation Research Board, National Academy of Sciences, Washington, D.C.
http://www.trb.org/Publications/Blurbs/166159.asp

Hammar, L., Andersson, S., and Rosenberg, R. (2010). *Adapting offshore wind power foundations to local environment*. Published by the Swedish Environmental Protection Agency.

Hansen.L.P, Freidland.K.D, Holm.M, Holts. J.C and Jacobsen.J.A (2000). *Temporal and Spatial Migration and Distribution of Atlantic Salmon, Salmo salar* L., *in the Northeast Atlantic Ocean*.

Harris G.S. and Milner N.J. (2006). *Sea Trout: Biology, Conservation and Management*. Proceedings of First International Sea Trout Symposium, Cardiff, July 2004. Blackwell Scientific Publications, Oxford, 499pp.

Hassel, A ., Knutsen, T., Dalen, J., Løkkeborg, S., Skaar,K., Østensen,O., Haugland, E.K., Fonn,M., Høines, A., Misund O.M. (2004). I*nfluence of seismic shooting on the lesser sandeel (Ammodytes marinus)*. ICES Journal of Marine Science, 61: 1165e1173 (2004).

HAWG (2011) *Herring* Assess*ment Report of the Herring Assessment Working Group for the Area South of 62 deg. N*. ICES HAWG Report 2011, ICES Advisory Committee ICES CM 2011/ACOM:06
http://www.ices.dk/reports/ACOM/2011/HAWG/HAWG%20Report%202011.pdf

Hawkins A.D., and Rasmussen, K.J. (1978). *The calls of gadoid fish*. Journal of the Marine Biological Association 58: 891-911

Holland, G. J., Greenstreet, S. P. R., Gibb, I. M., Fraser, H. M., and Robertson, M. R. (2005). *Identifying sandeel Ammodytes marinus sediment habitat preferences in the marine environment*. Marine Ecology Progress Series, 303: 269–282.

Holst, J. C., Shelton, R., Holm, M. & Hansen, L. P. (2000). *Distribution and possible migration routes of post-smolt Atlantic salmon in the north-east Atlantic. The Ocean Life of Atlantic Salmon*: Environmental and biological factors influencing survival. Fishing News Books, Blackwells Scientific Publishing Ltd, Oxford, 65 – 74.

Humway S. E., and Parsons, G. J.,(eds) (2006). *Scallop Biology Ecology and Aquaculture, Developments in Aquaculture and* Fisheries *Science*. Volume 35. Second Edition. Elsevier.

Hvidt C.B, Bech M & Klaustrup M (2003). *Monitoring Programme- status Report 2003. Fish at the cable trace. Nysted offshore wind farm at Rodsand*.

Hvidt CB, Brünner L, Knudsen FR, Balk H, Klaustrup M, Leonhard SB, Jensen BS (2006). *Hydroacoustic monitoring of fish communities around offshore wind farms*. Conference paper, 27-29 November 2006.

ICES (2003). *Report of the Benthos Ecology Working Group*. Fort Pierce, Florida, USA 28 April–1 May 2003. Available from: http://www.ices.dk/products/CMdocs/2003/E/E0903.PDF (accessed 10/9/12)

ICES (2010a). *ICES fish maps*. Available from: http://www.ices.dk/marineworld/ices-fishmap.asp (accessed 10/9/12)

ICES (2010b). *Advice November, Revised December 2010. Widely Distributed and Migratory Stocks. European eel*.

ICES (2011). *North Sea Cod Advice note*. Available from http://www.ices.dk/committe/acom/comwork/report/2011/2011/cod-347.pdf (accessed 10/9/12)

Jacklin, (1998). *Exploratory fishing trials for Buccinum undatum around the Islands of Barra and South Uist in the Western Isles*. Consultancy Report No. CR144 June 1998. Sea Fish Industry Authority Technology Division (SeaFish).

JNCC, (undated a). *1095 Sea lamprey*. Available from: http://jncc.defra.gov.uk/protectedsites/sacselection/species.asp?FeatureIntCode=S1095 (accessed 10/9/12)

JNCC (undated b). *1099 River Lamprey*. Webpage available from: http://jncc.defra.gov.uk/protectedsites/sacselection/species.asp?FeatureIntCode=S1099 (accessed 10/9/12)

Jonsson, N., Hansen, L. P., and Jonsson, B. (1993). *Migratory behaviour and growth of hatchery-reared post-smolt Atlantic salmon Salmo salar*. Journal of Fish Biology, 42: 435–443.

Kimber J. A. (2008). *Elasmobranch Electroreceptive Foraging Behaviour: Male-Female Interactions, Choice and Cognitive Ability*. School of Applied Sciences. Phd Thesis Cranfield University Academic Years 2005-2008

Kioerboe T, Frantsen E, Jensen C & Nohr, O (1981). *Effects of suspended sediment on development and hatching of herring (Clupea harengus) eggs*. Estuarine, Coastal and Shelf Science, vol. 13, 107-111.

Leonhard, S B , Stenberg, C and J Støttrup, (2011) (Eds). *Effect of the Horns Rev 1 Offshore Wind Farm on Fish Communities Follow-up Seven Years after Construction*. DTU Aqua Report No 246-2011 National Institute of Aquatic Resources, Denmark.

Le Pennec, M., Paugam, A., and Le Pennec, G. (2003). *The pelagic life of the pectinid Pecten maximus a review*. ICES Journal of Marine Science, 60: 211–223.

Leverone, JR.(1993). *Environmental requirements assessment of the bay scallop Argopecten irradians concentricus. Tampa Bay National Estuary Program*. Report no 01-93. Mote Marine Laboratory Technical Report no 253. 61 p and appendices.

Mackinson S. and Daskalov. G. (2007). An *ecosystem model of the North SEA to support an ecosystem approach to fisheries management description and parameterisation*. Sci.Ser. Tech. rep. Cefas Lowestoft 142:196pp

Maes, J., A.W.H., Turnpenny, D., Lambert, J.R., Nedwell, A Permentier, and F.Ollevier (2004). *Field evaluation of a sound system to reduce estuarine fish intake rates at a power station cooling water inlet*. J. Fish Biology, V64, pp. 938-946.

Maitland, P., (2003). *Ecology of the River, Brook and Sea Lamprey*. *In*; Conserving Natura 2000 rivers, Ecology series No.5. English Nature.

Mainstream Renewable Power (2012). *Neart na Gaoithe Offshore Wind Farm Environmental Statement*

Malcolm. I.A, Godfrey.J and Youngson.A.F (2010). *Review of migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: implications for the development of marine renewables.*

Marine Management Organisation (MMO), JNCC, Natural England, Countryside Council for Wales and Cefas (2010). *Draft Guidance on the Assessment of Effects on the Environment and Cultural Heritage from Marine Renewable Developments*.

Marine Scotland (2010). *Salmon fishery statistics 2009*. Topic sheet No. 68 V1.

Marine Scotland (2012a). *Velvet Crab Fishery Information sheet*. Available at: http://www.scotland.gov.uk/Topics/marine/marine-environment/species/fish/shellfish/VelvetCrab

Marine Scotland (2012b). *Provisional Salmon Fishery Statistics 2011 Season*. Topic Sheet No. 94 VI 2012.

Marine Scotland (2012). *Marine Protected Areas and Sandeels (A. marinus & A. tobianus)*. Position paper 2012

Marine Scotland Science (2010). *Fishing Effort and Quantity and Value of Landings* by ICES Rectangle. Web page available at: http://www.scotland.gov.uk/Topics/Statistics/Browse/Agriculture-Fisheries/RectangleData (accessed 10/9/12)

Marshall. C and Wilson. E (2009). *Pecten maximus. Great scallop. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. Plymouth: Marine Biological Association of the United Kingdom. [cited 15/10/2011]. Available from: <http://www.marlin.ac.uk/speciesinformation.php?speciesID=4056> (accessed 10/9/12)

Mesquita, C., Dobby, H. and A. McLay (2011). *Crab and Lobster Fisheries In Scotland:- Results of Stock Assessments 2006 – 2008*. Scottish Marine and Freshwater Science Volume 2 No 11

Meyer, C.G., K.N. Holland, and Y.P. Papastamatiou. (2005). *Sharks can Detect Changes in the Geomagnetic Field*. Journal of the Royal Society Interface 2:129-130

Neal K and Wilson. E (2008). *Cancer pagurus*. Edible *crab. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*. Plymouth: Marine Biological Association of the United Kingdom. [Cited 15/10/2011]. Available from: <http://www.marlin.ac.uk/reproduction.php?speciesID=2872> (accessed 10/9/12)

Nedwell.J.R, Edwards. B, Turnpenny. W.H and Gordon. J (2004). *Fish and Marine Mammal Audiograms: A summary of available information*. Subacoustech Report ref: 534R0214

Nedwell J R, Langworthy J and Howell D (2003). *Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during construction of offshore windfarms, and comparison with background noise*. Subacoustech Report ref: 544R0423, published by COWRIE, May 2003

Nedwell J.R., Mason, T.I., Collett, A. (2012). *Modelling of noise during impact piling operations at the Firth of Forth Phase 1 Offshore Wind Farm*. Subacoustech Environmental Report No E297R0204.

Nedwell J R, Parvin S J, Edwards B, Workman R , Brooker A G and Kynoch J E (2007). *Measurement and interpretation of underwater noise during construction and operation of offshore windfarms in UK waters*. Subacoustech Report No. 544R0738 to COWRIE Ltd. ISBN: 978-0-9554279-5-4.

Nedwell J R, Turnpenny A W H, Lovell J, Parvin S J, Workman R, Spinks J A L, Howell D (2007). *A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise.* Subacoustech Report Reference: 534R1231, Published by Department for Business, Enterprise and Regulatory Reform.

Nicholls, P.; Hewitt, J.; Halliday, J. (2003). *Effects of suspended sediment concentrations on suspension and deposit feeding marine macrofauna.* NIWA Client Report HAM2003-077 prepared for Auckland Regional Council. August (NIWA Project ARC03267).

Normandeau, Exponent, T. Tricas, and A. Gill. (2011). *Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species.* U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09.

Ohman, M.C., P. Sigray, and H. Westerberg. (2007). *Offshore Windmills and the Effects of Electromagnetic Fields on Fish.* Ambio 36(8):630-633.

OSPAR (2010). *Background Document for Spotted ray Raja montagui.* Available from: http://qsr2010.ospar.org/media/assessments/Species/P00478_spotted_ray.pdf (accessed 10/9/12)

Parvin, S.J., J.R Nedwell, and E.Harland (2007*). Lethal and physical injury of marine mammals, and requirements for Passive Acoustic Monitoring.* Subacoustech Report No. 565R0212

Pawson, M.G.(1995). *Biogeographical identification of English Channel fish and shellfish stocks.* Fisheries Research Technical Repor*t,* Directorate of Fisheries Research, Lowestoft, 99:1–72.

Pierce G. L, Hastie L., Pita, C., Viana, M., Smith, J., and S.Wangvoralak, (2009). *Squid fishing in UK Waters.* Report to the Seafish Industry Authority, May 2009.

Poloczanska, E. S., and A.D Ansell (1999). *Imposex in the whelks Buccinum undatum and Neptunea antiqua from the west coast of Scotland.* Marine Environmental Research, Vol. 47 Issues 2. 203-212.

Popper, A.N., and Fay R.R., (1993). *Sound detection and processing by fish: critical review and major research questions.* Brain Behav. Evol 41, 14-38

Rogers S, Stocks R (2001). *North Sea fish and fisheries. Department of Trade and Industry. Strategic Environmental Assessment—SEA2 Technical Report 003*—Fish and Fisheries CEFAS.

Sabatini, M. and J. Hill (2008). *Nephrops norvegicus. Norway lobster. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line].* Plymouth: Marine Biological Association of the United Kingdom. [cited 26/07/2012]. Available from: <http://www.marlin.ac.uk/speciesfullreview.php?speciesID=3892> (accessed 10/9/12)

Scottish Government (2011). *Herring TAC and Advice*: *North Sea.* Available at http://www.scotland.gov.uk/Topics/marine/marine-environment/species/fish/TAC/herring (accessed 10/9/12)

Scottish Government (undated a). *King scallop web page* available at: http://www.scotland.gov.uk/Topics/marine/marine-environment/species/fish/shellfish/scallop (accessed 10/9/12)

Scottish Government (undated b*). Nephrops web page.* Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=2390 (accessed 10/9/12)

Scottish Government (undated c). *Brown crab web page.* Available http://www.scotland.gov.uk/Topics/marine/marine-environment/species/fish/shellfish/BrownCrab (accessed 10/9/12)

Scottish Government (undated d). *Lobster web page.* Available at: http://www.scotland.gov.uk/Topics/marine/marine-environment/species/fish/shellfish/EuropeanLobsterBiology (accessed 10/9/12)

Scottish Government (undated e). *Velvet crab web page.* Available at: http://www.scotland.gov.uk/Topics/marine/marine-environment/species/fish/shellfish/VelvetCrab (accessed 10/9/12)

Scottish Government (undated f). *Sandeel web page.* Available at: http://www.scotland.gov.uk/Topics/marine/marine-environment/species/fish/sandeels (accessed 10/9/12)

Scottish Government (undated g). *Freshwater Fish web page.* Available at http://www.scotland.gov.uk/Topics/marine/marine-environment/species/fish/freshwater (accessed 10/9/12)

Shumway S. and Parsons GJ (2006). *Scallops: biology, ecology and aquaculture.* Elsevier, Amsterdam

Skaret, G., Axelsen, B. E., Nittestad, L., Ferno, A., and Johannessen, A. (2005). *The behaviour of spawning herring in relation to a survey vessel.* ICES Journal of Marine Science, 62: 1061–1064

Slotte, A., Hansen, K., Dalen, J., and One, E. (2004). *Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast.* Fish. Res. 67: 143-150.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R. Kastak, D., Ketten, D. R., Miller, J. H., Nachtigall, P. E., Richardson, W. J. Thomas, J. A., Tyack, P. L, (2007). *Marine Mammal Noise Exposure Criteria Aquatic Mammals*, Vol 33 (4).

Subacoustech (2011). *Galloper Offshore Wind Farm Project: Underwater Noise Impacts Assessment*. Subacoustech Environmental Report E218R0119.

Taylor, D., B.G. Maddock, G. Mance (1985). *The acute toxicity of nine 'grey list' metals (arsenic, boron, chromium, copper, lead, nickel, tin, vanadium and zinc) to two marine fish species: Dab (Limanda limanda) and grey mullet (Chelon labrosus).* Aquatic Toxicology, Volume 7, Issue 3, November 1985, Pages 135–144

Thomsen, F., Lüdemann, K., Kafemann, R. and Piper, W. (2006). *Effects of offshore wind farm noise on marine mammals and fish.* Biola, Hamburg, Germany on behalf of COWRIE Ltd. www.offshorewind.co.uk

Tollefson R, and Marriage L D. (1949). *Observations on the effects of the intertidal blasting on clams, oysters and other shore inhabitants.* Oregon Fish Comm. Res. Briefs 2(1): 19-23

Tyler-Walters, H. (2007). *Modiolus modiolus. Horse mussel. Marine Life Information Network: Biology and* Sensitivity *Key Information Sub-programme [on-line].* Plymouth: Marine Biological Association of the United Kingdom. [cited 02/06/2012]. Available from: <http://www.marlin.ac.uk/speciessensitivity.php?speciesID=3817>

U.S. Department of the Interior Bureau of Ocean Energy Management, Regulation and Enforcement (2011). *Effects of EMF from undersea power cables on elasmobranchs and other marine species.*

Van der Kooij J, Scott BE, Mackinson S (2008). *The effects of environmental factors on daytime sandeel distribution and abundance on the Dogger Bank.* Journal of Sea Research 60: 201-209.

van Deurs, M., van Hal, R., Tomczak, M. T., Jónasdóttir S. H. and P Dolmer (2009). *Recruitment of lesser sandeel Ammodytes marinus in relation to density dependence and zooplankton composition*. Mar Ecol Prog Ser. Vol. 381: 249–258, 2009

Westerberg, H. and Langenfelt, I. (2008). *Sub-sea power cables and the migration behaviour of the European eel*. Fisheries Management and Ecology, 15, 369-375.

Wheeler, A. (1978). *Key to the fishes of northern Europe*. London, Frederick Warne, 380.

Wilhelmsson, D., Malm, T., and Ohman, M. C. (2006). *The influence of offshore windpower on demersal fish*. ICES Journal of Marine Science, 63: 775e784.

Wilson. E (2006). *Loligo forbesi. Long finned squid. Marine Life Information Network: Biology and* Sensitivity *Key Information Sub-programme [on-line]*. Plymouth: Marine Biological Association of the United Kingdom. [cited 15/ 10/ 2011]. Available from: <http:/ / www.marlin.ac.uk/ speciesinformation.php?speciesID=3717>

Wilson. E (2006). *Necora puber. Velvet swimming crab. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme*. Plymouth: Marine Biological Association of the United Kingdom. [Cited 23/ 07/ 2012]. Available from: <http:/ / www.marlin.ac.uk/ speciesinformation.php?speciesID=3858>

Wright P.J, Bailey MC (1993). *Biology of sandeels in the vicinity of seabird colonies at Shetland*. Marine Laboratory, Aberdeen Scottish Office Agriculture and Fisheries Department, Aberdeen

Wright PJ, H. Jensen and I. Tuck (2000). *The influence of sediment type on the distribution of the lesser sandeel, Ammodytes marinus*. J Sea Res 44: 243−256

Yelverton, J. T., Richmond, D. R., Hicks, W., Saunders, K. and Fletcher, E. R. (1975). *The Relationship Between Fish Size and Their Response to Underwater Blast*. Report DNA 3677T, Director, Defence Nuclear Agency, Washington, DC

Young I.A.G., Pierce G.J., Stowasser. G., Santos. M.B., Wanga.J, Boyle P.R, OW Shawb, Bailey. N, Tuckc I. and Collins. M.A (2006). *Moray Firth directed squid fishery*.

Youngson. A.F, Maclean. A.C and Fryer.R.J (2002). *Rod catch trends for early-running MSW salmon in Scottish rivers (1952–1997): divergence among stock components*. ICES Journal of Marine Science, 59 836–849. 2002 doi:10.1006/ jmsc.2002.1195, available online at http:/ / www.idealibrary.com

Zijlstra J.J (1969). *On the "Racial" Structure of North Sea Autumn-Spawning Herring*. ICES Journal of Marine Science 33 (1): 67-80.