11 WIND FARM FISH AND SHELLFISH ECOLOGY

11.1 INTRODUCTION

1. This Section of the ES evaluates the likely significant effects of the Wind Farm on fish and shellfish ecology. The assessment has been undertaken by Brown and May Marine Ltd and includes an assessment of cumulative effects.

2. This section of the ES is supported by the following documents:

- Annex 11A – Fish and Shellfish Ecology Technical Report;
- Annex 11B – Ontogenic Development of Auditory Sensitivity in Fish;
- Annex 16A - Commercial Fisheries Baseline;
- Annex 16B - Salmon and Sea Trout Ecology and Fisheries Technical Report;
- Annex 10A – Benthic Survey 2010 Technical Report;
- Annex 9A – Physical Processes Baseline Assessment; and
- Annex 7A – Underwater Noise Modelling Technical Report.

3. This Section includes the following elements:

- Assessment Methodology and Significance Criteria;
- Baseline Conditions;
- Assessment of Potential Effects;
- Mitigation Measures and Residual Effects;
- Summary of Effects;
- Assessment of Cumulative Effects;
- Statement of Significance;
- Habitats Regulations Appraisal; and
- References.

11.1.1 POLICY AND PLANS

4. The assessment takes into account the following guidelines.

- SEA of Draft Plan for Offshore Wind Energy in Scottish Territorial Waters: Volume 1. Environmental Report (Marine Scotland, 2010);
- Guidelines for Ecological Impact Assessment in Britain and Ireland. Marine and Coastal (IEEM, 2010);
- Habitats Regulations Appraisal of Draft Plan for Offshore Wind Energy in Scottish Territorial Waters. Appropriate Assessment information Review (Marine Scotland, 2011); and
- Centre for Environment Fisheries and Aquaculture (CEFAS) Guidance Note for Environmental Impact Assessment in Respect of the FEPA and CPA Requirements (CEFAS, 2004).

11.2 ASSESSMENT METHODOLOGY AND SIGNIFICANCE CRITERIA

11.2.1 CONSULTATION

5. Consultation was undertaken with the organisations and individuals listed below and inputs were included in the baseline where appropriate.

- Marine Scotland Science (MSS);
- SNH;
- JNCC;
- MSS sandeel specialists: Dr. Simon Greenstreet and Dr. Peter Wright; and
- MSS herring specialist: Emma Hatfield.

6. In the case of salmon and sea trout, additional consultation was undertaken with the following DSFBs, stakeholders and their representatives. The full consultation list is provided in Annex 16B: Salmon and Sea Trout Ecology and Fisheries Technical Report.

- Findhorn, Nairn and Lossie Fisheries Trust;
- Cromarty Firth DSFB, Brora DSFB and Cromarty Netsmen;
- Moray Firth Sea Trout Project (MFSTP);
- Ness and Beauly Fisheries Trust, Ness DSFB and Beauly DSFB;
- Kyle of Sutherland and Helmsdale DSFB;
- Spey DSFB;
- Deveron DSFB; and
- Moray and Pentland Firths Salmon Protection Group (MPFSPG).

7. Further to the consultation above, scoping responses were taken into account for the undertaking of the assessment. These are summarised in Table 11.1 below.

Table 11.1 Summary of Consultation Undertaken

Consultee	Summary of Consultation Response	Project Response
Marine Scotland	For some species there may be more recent and or/site specific information available on spawning and nursery grounds than that provided in the Fishery Sensitivity Maps (Coull *et al*., 1998).	Where available, alternative publications and the findings or recent research were used to inform the baseline and impact assessment.
	Diadromous fish of freshwater fisheries interest: In order that Marine Scotland is able to assess the potential impacts of marine renewable devices on diadromous fish and meet legislative requirements the developer should consider the site location (including proximity to sensitive areas), type of device, and the design of any array plus installation methodology.	Production of a Salmon and Sea trout Ecology and Fisheries Technical report. Other diadromous migratory species were included in the Fish and Shellfish Ecology Technical Report. Potential effects on diadromous migratory species are addressed within the fish and shellfish ecology impact assessment.

Consultee	Summary of Consultation Response	Project Response
SNH and JNCC	SAC Fish Species to include in EIA and HRA: • Atlantic salmon (adults and juveniles) • Freshwater pearl mussel • Sea lamprey SAC populations of the above species requiring assessment (as updated in the Scoping response for the Offshore Transmission Works): • Berriedale and Langdale Waters SAC • River Evelix SAC • River Moriston SAC • River Oykel SAC • River Spey SAC • River Thurso SAC Other fish species of conservation importance that should be included for assessment: European eel.	Fish and shellfish species of conservation interests in the relevant SACs have been included for assessment. The assessment has taken account of European eel.
Moray Firth Inshore Fisheries Group	Concern on the effect of widespread disturbance of the seabed on the king scallop and sediment loading and noise associated with construction and sub-sea cabling systems on squid. Concern on the effect of EMFs on commercially exploited species (including crustaceans)	The effect of increased suspended sediment concentrations, sediment re-deposition, loss of habitat and construction noise has been assessed. The potential effect of EMFs was assessed for various species groups, including, elasmobranchs, diadromous migratory species, other fish species and invertebrates.
RSPB	The area lies within a nursery area for sandeel and herring and a spawning area for sandeel and sprat, making it an important fishing area for seabirds	The principal species of concern (herring, sandeel and sprat) have been included for assessment of potential effects. In the particular case of herring and sandeels, consultation meetings were undertaken with MS specialists, as detailed above.

8. Consultation with the various stakeholders above will continue throughout the planning stage and through the development of the Wind Farm if consented.

11.2.2 SCOPE OF ASSESSMENT

9. For the purposes of the assessment, the following four main aspects have been taken into account:

- Commercial importance of fish and shellfish species;
- Presence of spawning and nursery grounds;

- Key prey species for sea birds, marine mammals and fish; and
- Presence of species of conservation importance, including migratory species.

10. It should be noted that certain species are relevant within more than one of the aspects given above and as a result, some overlap is to be expected.

11. In addition to providing an assessment of the potential effects on a species/species group basis, an assessment of effects on fish and shellfish species that are qualifying interests in the SACs, identified by SNH in the scoping response as requiring consideration (Table 11.1 consultation table), has been undertaken for each potential effect. The effects have also been summarised in terms of their Likely Significant Effect on features of the European designated sites in order to highlight those effects that will be carried forward for further assessment under the Habitats Regulations (to be presented in a Report to Inform an Appropriate Assessment).

11.2.2.1 Geographical Scope

12. The study areas used for the assessment of the natural fish and shellfish resources are shown in Figure 11.1. The local study area has been defined as ICES rectangle[1] 45E7, the rectangle within which the Wind Farm is located. The regional study area comprises rectangle 45E7 and adjacent rectangles.

13. The geographical scope above has been defined taking into account fisheries statistics, which are collated by ICES rectangle. In some instances (i.e. species with spawning and nursery grounds) a wider area is considered for assessment.

14. In the case of diadromous[2] migratory species, given the uncertainties in relation to migratory pathways, the geographical scope of assessment has been based on the proximity of the Wind Farm Site to rivers, taking particular account of those which are designated SAC. In addition, a national context has also been provided (see Annex 11A: Fish and Shellfish Ecology Technical Report and Annex 16B: Salmon and Sea Trout Ecology and Fisheries Technical Report). Rivers designated as SACs in the Moray Firth and the wider area are also shown in Figure 11.1.

11.2.3 BASELINE COLLECTION METHODOLOGY

15. The principal sources of information used for the collation of the fish and shellfish ecology baseline were as follows.

- MSS publications;
- ICES publications;
- MMO landings data;
- SNH publications;
- JNCC publications;
- CEFAS publications; and

[1] ICES (International Council for the Explorations of the Sea) rectangles are the smallest spatial unit used for the collation of fisheries statistics by the European Commission (EC) and Member States.
[2] Species which migrate between freshwater and salt water (e.g. Atlantic salmon, European eel)

- Other relevant research publications.

11.2.4 ASSESSMENT METHODOLOGY

16. The following Section describes the assessment methodology used for evaluation of effects on fish and shellfish species. The effects requiring assessment are as follows:

11.2.4.1 Direct Effects

- Increased suspended sediment concentrations and sediment re-deposition;
- Underwater noise and vibration (construction and operation);
- Loss of habitat; and
- Electromagnetic Fields (EMFs).

11.2.4.2 Indirect Effects

- Introduction of new habitat; and
- Changes to fishing activity.

17. The above potential effects will be separately assessed for the construction/decommissioning phases and the operational phase in terms of site specific effects. For the purposes of this assessment and in the absence of detailed information on decommissioning schedules and methodologies, it is assumed that any effects derived from the decommissioning phase will, at worst, be of no greater significance than those derived from the construction phase.

18. A full decommissioning plan will be prepared prior to any decommissioning being undertaken at the site.

11.2.4.3 Worst Case

19. The worst case scenario for the effects of the Wind Farm upon fish and shellfish ecology has identified the Wind Farm design parameters which will have the most detrimental effect upon fish and shellfish ecology.

20. In general terms, it is considered that the installation of the maximum number of turbines (277) will constitute the worst case scenario for all receptors, as this would result in the greatest total footprint and number of construction related operations.

21. Further identification of the worst case based on more detailed parameters of the Wind Farm design is complicated as worst cases vary depending on the potential effect being considered.

- For assessment of noise during construction, the use of tubular jackets and pin piles will be considered worst case, as installation of these foundations will result in the highest associated noise levels and will be the most frequent activity (i.e. in comparison to installation of meteorological masts);
- For assessment of loss of habitat and introduction of new habitat, the worst case assumes the use of gravity bases, , as this will result in the greatest footprint and largest introduction of hard substrate. In addition, the maximum length of cabling and the assumption that up to 50% of the cable could be protected by means of rock dumping/matressing has been made;

- For assessment of increased sediment concentrations and sediment re-deposition, both drilling to facilitate pin pile installation and dredging for gravity base foundations will be assessed. In addition, the use of energetic methods, such as jetting and ploughing, will also be assessed for inter-array cable installation; and
- For assessment of EMFs, the use of the maximum length of cabling (350 km) and that inter-array cables will, where feasible, be buried to a minimum depth of 0.6 m or protected by means or rock dumping/matressing will be considered.

22. The limitations of the realistic worst case scenarios described above should be recognised. Worst case engineering options have been considered by potential effect. The overall assessment of the effect on a given receptor will not be realistic when considering all the potential effects, as it is not possible that some of the design options defining worst cases given above will coexist (e.g. worst case loss of area derived from gravity bases and worst case construction noise due to piling of 2.4 m diameter pin piles).

23. The worst case scenarios used for the assessment are summarised in Table 11.2 and further described in the relevant assessment sections below.

Table 11.2 Worst Case Scenario Design Parameters for Assessment of Effects on Fish and Shellfish Ecology

Potential Effect	**Wind Farm Design Parameters**	**Worst Case**
Construction/Decommissioning		
Increase in suspended sediment concentrations and sediment re-deposition	Turbine type Foundation type Max no of turbines Max length of inter-array cable buried	3.6 MW Gravity bases 277 325 km
Noise	Turbine type Max no of turbines Max no of simultaneous piling events Max pile diameter	3.6 MW 277 2 Piling of 2.4 m diameter pin piles (4 piles per foundation)
Operation		
Loss of habitat and introduction of new habitat	Turbine type Foundation type Max no of turbines Length of inter-array cabling	3.6 MW Gravity bases 277 50% of inter-array cable length is protected by matressing/rock dumping
Operational Noise *	Max no of turbines	277
EMFs	Max length of inter-array cabling Cable post installation status	350 km Buried/protected where feasible
Changes to Fishing Activity*	Max number of turbines	277

* Limited information available for detailed worst case definition. The maximum number of turbines is assumed to constitute worst case.

11.2.4.4 Assessment Limitations

24. The assessment provided below is subject to a number of limitations as a result of the lack of current knowledge on the sensitivity of particular species to certain potential effects. In some instances other species/species groups assumed to have similar sensitivities (surrogates) and for whom more detailed information is available have therefore been considered. In addition, as a result of uncertainties in relation to the distribution of some species and the use that they may make of the area of the Wind Farm, particularly in the case of migratory species, a number of conservative assumptions have had to be made. Where applied these are detailed in the following sections.

11.2.4.5 Significance Criteria

25. The significance of an effect is determined taking account of the magnitude of the effect and the sensitivity of the receptor. The parameters used to define these take account of the IEEM (2010) impact assessment guidelines and are described below.

Magnitude of Effect

26. The magnitude of the effect refers to the size of amount of an effect. Magnitude values have been assigned based on the following considerations.

- Extent of effect, referring to the full area over which the effect occurs (e.g. noise impact range);
- Duration of effect, referring to the duration over which the effect is expected to last;
- Frequency of the effect; and
- Reversibility: Irreversible effects are those from which recovery is not possible within a reasonable timescale. Reversible (temporary) are effects from which spontaneous recovery is possible or, for which effective mitigation is both possible and an enforceable commitment has been made.

Sensitivity

27. The sensitivity of the receptor has been assigned taking account of its degree of adaptability, tolerance and recoverability to the potential effect. In addition the following parameters have been considered:

- Timing of the effect, referring to whether effects are caused during critical life-stages or season (e.g. spawning season, migration); and
- Ecological value, referring to the conservation status of the receptor and importance in the area (e.g. key prey species, species commercially important).

Significance

28. The significance of an effect is determined following the matrix below (Table 11.3) as “negligible”, “minor”, “moderate” or “major”. Whether the predicted effect is considered to be “positive” or “negative” is also described. As set out in Section 4: EIA Process and Methodology, effects which are of moderate and major significance are considered to be significant in relation to the EIA Regulations, and those of minor and negligible significance are considered to be not significant.

Table 11.3 Assessment Significance Criteria Matrix

Sensitivity or Value of Resources or Receptor	Magnitude of Effect			
	Negligible	**Small**	**Medium**	**Large**
Low	Negligible	Negligible	Minor	Moderate
Medium	Negligible	Minor	Moderate	Major
High	Negligible	Moderate	Major	Major

29. It should be noted, that for certain effects the limited information available to date does not allow for the assessment to follow the standard methodology described above, as defining magnitude of effect and identification of receptors and their sensitivity is difficult. In those instances the assessment has been based on a literature review of the current knowledge of the particular effect and the receptors under consideration and on indirect evidence from monitoring studies carried out in operational wind farms.

30. Taking the limitations of the assessment described above and the uncertainties in relation to the relative importance of the area of the Wind Farm to some species, the probability for each predicted effect to occur has been assessed as “certain”, “probable”, “unlikely” and “extremely unlikely”. The definition of the probability categories used in this assessment is given below as provided in the IEEM (2010) guidelines:

- Certain/near certain: probability estimated at 95% or higher;
- Probable: probability estimated above 50% but below 95%;
- Unlikely: probability estimated above 5% but less than 50%; and
- Extremely unlikely: Probability estimated at less than 5%.

11.3 BASELINE CONDITIONS

31. The following section presents a summary of the baseline conditions present within the study area. This is described in further detail in Annex 11A: Fish and Shellfish Ecology Technical Report and Annex 16B: Salmon and Sea Trout Ecology and Fisheries Technical Report.

11.3.1 COMMERCIAL SPECIES

32. The Moray Firth supports a number of commercial fish and shellfish species. An indication of the relative importance of these in the regional study area is given in Figure 11.2, based on annual average (2000 to 2009) landings weights (tonnes) by species and ICES rectangle (MMO, 2010).

33. The annual average landings weights (2000 to 2009) by species in the local study area are shown in Table 11.4 and Table 11.5 for shellfish and fish species respectively.

Table 11.4 Annual Average Landings Weights (2000 to 2009) of Principal Commercial Shellfish Species in the Local Study Area (ICES Rectangle 45E7)

Common Name	Latin Name	Average (2000-2009) Landings Weight (t)	Total Shellfish Landings Weight (%)	Total Landings Weight (all fish and shellfish species combined) (%)
King Scallop	*Pecten maximus*	539.0	78.1	48.0
Nephrops	*Nephrops norvegicus*	106.7	15.5	9.5
Squid	*Loligo forbesi*	40.2	5.8	3.6
Edible Crab	*Cancer pagurus*	2.5	0.4	0.2
Queen Scallop	*Aequipecten opercularis*	1.2	0.2	0.1
Velvet Crab	*Necora puber*	0.3	<0.1	<0.1
Octopus	-	0.1	<0.1	<0.1
Whelk	*Buccinum undatum*	< 0.1	<0.1	<0.1
Green Crab	*Carcinus maenas*	< 0.1	<0.1	<0.1
Lobster	*Homarus gammarus*	< 0.1	<0.1	<0.01
Mixed Crabs	-	< 0.1	<0.01	<0.01
Periwinkle	*Littorina littorea*	< 0.1	<0.01	<0.01
Pink Shrimp	*Pandalus montagui*	< 0.01	<0.01	<0.01

Source: MMO 2010

Table 11.5 Annual Average Landings Weights (2000 to 2009) of Principal Commercial Fish Species in the Local Study Area (ICES Rectangle 45E7)

Common Name	Latin Name	Average (2000-2009) Landings Weight (t)	Total Fish Landings Weight (%)	Total Landings Weight (all fish and shellfish species combined) (%)
Haddock	*Melanogrammus aeglefinus*	280.6	65.2	25.0
Monkfish or Anglers	*Lophius piscatorius/L. budegassa*	43.1	10.0	3.8
Herring	*Clupea harengus*	39.1	9.1	3.5
Whiting	*Merlangius merlangus*	16.4	3.8	1.5
Cod	*Gadus morhua*	12.4	2.9	1.1
Horse Mackerel	*Trachurus trachurus*	8.2	1.9	0.7
Megrim	*Lepidorhombus whiffiagonis*	7.3	1.7	0.6
Plaice	*Pleuronectes platessa*	6.7	1.6	0.6
Witch	*Glyptocephalus cynoglossus*	2.8	0.7	0.3
Spurdog	*Squalus acanthias*	2.3	0.5	0.2
Hake	*Merluccius merluccius*	2.0	0.5	0.2
Skates and Rays	-	1.8	0.4	0.2
Ling	*Molva molva*	1.8	0.4	0.2
Lemon Sole	*Microstomus kitt*	1.6	0.4	0.1
Saithe	*Pollachius virens*	1.4	0.3	0.1
Other	-	3.2	0.8	0.3

Source: MMO 2010

34. The principal shellfish species caught in the local study area are king scallop, nephrops, edible crab and squid. Haddock, herring, monkfish and whiting account for the majority of the fish landings.

35. Within the regional study area, the relative importance of different species to the total landings weights varies depending on the ICES rectangle under consideration. Nephrops for example, are of greatest importance in the southern (44E6, 44E7 and 44E8) and eastern (46E8 and 45E8) rectangles. Haddock accounts for a relatively high percentage of the total landings in the majority of rectangles, although the highest landings by weight for this species are recorded in the eastern rectangles of the regional study area. In the case of scallops, landings values by weight are particularly high in the local study area (45E7) and in adjacent rectangles 46E7, 45E6 and 44E6.

36. Elasmobranch species (sharks and rays) constitute a small percentage of the landings weights, both in the local and regional study area, being included under the category 'other' in Figure 11.2 and in Table 11.5.

37. A description of the ecology and behaviour of the principal commercial fish and shellfish species is given in Annex 16A: Commercial Fisheries Baseline.

11.3.2 SPECIES WITH SPAWNING AND NURSERY GROUNDS

38. Spawning and nursery grounds have been defined for a number of species within and in the immediate vicinity of the Wind Farm. These are shown in Table 11.6 together with spawning times and intensity of spawning/nursery areas. Spawning times are given as provided in Coull *et al* (1998) and spawning/nursery grounds intensity as described in Ellis *et al* (2010).

Table 11.6 Species with Spawning and Nursery Areas Within and in Close Proximity to the Wind Farm and Spawning Times and Intensity

Species	Seasonality of Spawning (Intensity and Peak Spawning *)												Nursery (Intensity)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Cod		*	*										
Herring													
Lemon Sole													
Nephrops				*	*	*							
Plaice	*	*											
Sandeel													
Sprat					*	*							
Whiting													
Anglerfish	n/a												
Blue Whiting	n/a												
Haddock	n/a												
Hake	n/a												
Ling	n/a												
Mackerel	n/a												
Saithe	n/a												
Spotted Ray	n/a												
Spurdog	n/a												
Thornback Ray	n/a												

Sources: Coull *et al* (1998), Ellis *et al* (2010)
Note: Colour Key: (red) = high Intensity Spawning/Nursery Ground, (yellow) = low Intensity Spawning/Nursery Ground, (green) = unknown Intensity, (*) = Peak Spawning

39. The distribution of spawning and nursery grounds in the Moray Firth and the wider area is illustrated in Annex 11A: Fish and Shellfish Ecology Technical Report, together with information on the ecology and spawning behaviour of the species.

11.3.3 KEY PREY SPECIES

40. Sandeels, herring and sprat are present in the area of the Wind Farm and play a key role in the North Sea's food-web, being situated in a mid-trophic position. They are major predators of zooplankton and the principal prey of many top predators such as birds, marine mammals and piscivorous fish.

41. Sandeels are most commonly preyed upon when they are in transit to, or feeding in the water column. They are an important component of the diet of many birds (kittiwakes, razorbills, puffins, common terns, etc), piscean predators such as herring, salmon, sea trout, cod and haddock and marine mammals such as grey seals, harbour porpoises and minke whales.

42. A number of fish species (e.g. salmon, sea trout, whiting, cod) seabirds and a number of marine mammals such as harbour porpoises, bottlenose dolphins, grey seals and common seals feed on herring.

43. Sprat is also fed upon by a number of fish species, sea birds and marine mammals.

11.3.4 SPECIES OF CONSERVATION IMPORTANCE

44. A number of species of conservation importance are found in the Moray Firth and may therefore transit the Wind Farm and/or its vicinity. These include diadromous migratory species, elasmobranchs and commercial fish species.

45. Diadromous migratory species potentially using areas relevant to the Wind Farm and their conservation status are given in Table 11.7 below.

Table 11.7 Diadromous Migratory Species of Conservation Importance

Common Name	**Scientific Name**	**Conservation Status**								
		OSPAR[3]	**IUCN**[4] **Red List**	**Bern Convention**	**Habitats Directive**	**The Wildlife & Countryside Act 1981**	**The Conservation (Natural Habitats, &c.) Regulations 1994**	**UK BAP**[5] **species**	**Draft Scottish Priority Marine Feature (PMF) (SNH, 2011)**	**The Nature Conservation (Scotland) Act 2004**
European eel	*Anguilla anguilla*	✓	Critically endangered	-	-	-	-	✓	✓	-
Allis shad	*Alosa alosa*	✓	Least concern	✓	✓	✓	✓	✓	-	-
Twaite shad	*Alosa fallax*	-	Least concern	✓	✓	✓	✓	✓	-	-
Sea Lamprey	*Petromyzon marinus*	✓	Least concern	✓	✓	-	-	✓	✓	-
River Lamprey	*Lampetra fluviatilis*	-	Least concern	✓	✓	-	✓	✓	✓	-
Smelt	*Osmerus eperlanus*	-	Least concern	-	-	-	-	✓	✓*	-
Salmon	*Salmo salar*	✓	Lower Risk/ least concern	✓	✓	-	✓	✓	✓	-
Sea Trout	*Salmo trutta*	-	Least concern	-	-	-	-	✓	✓	-

* = Smelt is due to be added to the SNH PMF list (MS communication, 20/10/2011)

[3] OSPAR: Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic.
[4] IUCN: The International Union for Conservation of Nature.
[5] BAP: Biodiversity Action Plan.

46. It should be noted that of the diadromous fish species listed above, salmon and sea lamprey, are of conservation interest in a number of SAC rivers in the Moray Firth area.

47. In addition to these, the freshwater pearl mussel is also of conservation interest in a number of river SACs. Given the location of the Wind Farm relative to the habitat of this species (restricted to freshwater), freshwater pearl mussel populations will not be directly affected by the construction/decommissioning and operation of the Wind Farm. They could, however, be indirectly affected if significant effects on their host species (e.g. salmon and sea trout) occur.

48. The qualifying status of the fish and shellfish species of conservation interest in the River SACs identified by SNH as requiring assessment is given in Table 11.8.

Table 11.8 Qualifying Status of Species of Conservation Importance in SAC Rivers

SAC Rivers	Primary reason for SAC site selection	Qualifying feature for SAC site selection
Berriedale and Langwell Waters	Atlantic salmon	n/a
River Evelix	Freshwater pearl mussel	n/a
River Moriston	Freshwater pearl mussel	Atlantic salmon
River Oykel	Freshwater pearl mussel	Atlantic salmon
River Spey	Freshwater pearl mussel, sea lamprey, Atlantic salmon	n/a
River Thurso	Atlantic salmon	n/a

Source: JNCC (2011)

49. A description of the ecology and distribution of diadromous species of conservation importance is provided in Annex 11A: Fish and Shellfish Ecology Technical Report, with the exception of salmon and sea trout. The ecology of the latter is described separately in Annex 16B: Salmon and Sea Trout Ecology and Fisheries Technical Report.

50. Elasmobranchs (sharks and rays) have slow growth rates and low reproductive output compared to other species groups. This results in slow rates of stock increase and low resilience to fishing mortality (Holden, 1974). Directed fisheries have caused stock collapse for a number of species, although at present mortality in mixed-species and by-catch fisheries seems to be a greater threat (Bonfil, 1994). The distribution and ecology of elasmobranch species in the Moray Firth is described in Annex 11A: Fish and Shellfish Ecology Technical Report.

51. The principal elasmobranch species with conservation status and/or declining stocks, potentially using areas relevant to the Wind Farm are given in Table 11.9.

Table 11.9 Principal Elasmobranch Species of Conservation Importance

Common Name	Latin Name	MMO Landings Data	Recorded in the Moray Firth (Ellis *et al* 2005)	Conservation Status						
				OSPAR	IUCN Red List	The Wildlife & Countryside Act 1981	The Conservation (Natural Habitats, &c.) Regulations 1994	UK BAP species	Draft Scottish Priority Marine Feature (PMF) (SNH, 2011)	The Nature Conservation (Scotland) Act 2004
Sharks										
Basking shark	*Cetorhinus maximus*	-	-	✓	Vulnerable	✓	-	✓	✓	✓
Blue shark	*Prionace glauca*	-	-	-	Near threatened	-	-	✓	-	-
Gulper shark	*Centrophorus granulosus*	✓	-	✓	Vulnerable	-	-	✓	-	-
Leafscale gulper shark	*Centrophorus squamosus*	✓	-	✓	Vulnerable	-	-	✓	-	-
Porbeagle	*Lamna nasus*	-	-	✓	Vulnerable	-	-	✓	-	-
Portuguese dogfish	*Centroscymnus coelolepis*	✓	-	✓	Near threatened	-	-	✓	-	-
Sailfin Roughshark	*Oxynotus paradoxus*	✓	-	-	Data deficient	-	-	-	-	-
Spurdog	*Squalus acanthias*	✓	✓	✓	Vulnerable	-	-	✓	✓	-
Tope	*Galeorhinus galeus*	✓	-	-	Vulnerable	-	-	✓	-	-
Skates and Rays										
Common skate	*Dipturus batis*	✓	✓	✓	Critically endangered	-	-	✓	✓	-
Long-nosed skate	*Dipturus oxyrinchus*	✓	-	-	Near threatened	-	-	-	-	-
Sandy ray	*Leucoraja circularis*	-	-	-	Vulnerable	-	-	✓	-	-
Spotted ray	*Raja montagui*	-	✓	✓	Least concern	-	-	-	-	-
Thornback ray	*Raja clavata*	✓	✓	✓	Near Threatened	-	-	-	-	-
White skate	*Rostroraja alba*	✓	-	✓	Endangered	-	-	✓	-	-

52. In addition to the diadromous migratory species and elasmobranchs mentioned above, there are a number of other fish species with conservation status. The majority of these are commercially exploited in the Moray Firth having been recorded in landings data (MMO, 2010) within the regional study area. These are given in Table 11.10.

Table 11.10 Other Fish Species of Conservation Importance

Common Name	Latin Name	Draft Scottish Priority Marine Feature (PMF)	UK BAP Species	OSPAR	IUCN Red List
Angler fish	*Lophius piscatorius*	✓ (juveniles)	✓	-	-
Atlantic halibut	*Hippoglossus hippoglossus*	-	✓	-	Endangered
Atlantic mackerel	*Scomber scombrus*	✓	✓	-	-
Black scabbardfish	*Aphanopus carbo*	-	✓	-	-
Blue ling	*Molva dypterygia*	-	✓	-	-
Cod	*Gadus morhua*	✓	✓	✓	Vulnerable
Greenland halibut	*Reinhardtius hippoglossoides*	-	✓	-	-
Hake	*Merluccius merluccius*	-	✓	-	-
Herring	*Clupea harengus*	✓ (juveniles and spawning adults)	✓	-	Least concern
Horse mackerel	*Trachurus trachurus*	-	✓	-	-
Ling	*Molva molva*	✓	✓	-	-
Norway Pout	*Trisopterus esmarkii*	✓	-	-	-
Plaice	*Peluronectes platessa*	-	✓	-	Least concern
Roundnoise Grenadier	*Coryphaenoides rupestris*	-	✓	-	-
Saithe	*Pollachius virens*	✓ (juveniles)	-	-	-
Sandeels	*Ammodytes marinus*	✓	✓	-	-
	Ammodytes tobianus	✓	-	-	-
Whiting	*Merlangius merlangus*	✓ (juveniles)	✓	-	-

11.4 ASSESSMENT OF POTENTIAL EFFECTS

53. The following sections detail the predicted effects from the construction/ decommissioning and operational phases of the Wind Farm on fish and shellfish ecology. Effects are expected to vary, depending on species specific sensitivities, life stage under consideration (eggs, larvae, juveniles and adults), use that the particular species make of the area and seasonal variations (e.g. spawning or nursery grounds, feeding grounds, migration routes).

11.4.1 CONSTRUCTION/DECOMMISSIONING

54. The following potential effects are assessed for the construction/decommissioning phase of the Wind Farm.

- Increased suspended sediment concentrations and sediment re-deposition; and
- Noise.

11.4.1.1 Increased Suspended Sediment Concentrations and Sediment Re-deposition

55. Construction activities will result in re-suspension and dispersion of sediment into the water column and subsequent re-deposition of sediment. These processes are described in detail in Section 9: Wind Farm Physical Processes and Geomorphology and include the following activities.

- Dredging as part of bed preparation for installation of gravity base foundations;
- Drilling to install jacket pin piles; and
- Cable trenching by energetic means (e.g. ploughing and jetting).

56. The maximum localised increase in SSC expected in the immediate vicinity of construction vessels (50 to 100 m) is 21 mgl^{-1} for dredging as part of seabed preparation for gravity bases and 25 mgl^{-1} for drilling for the installation of pin piles, lowering down to 10 mgl^{-1} or less in the main plume. These effects are expected to only occur during and up to one hour after dredging/drilling, after which time SSC are reduced to less than 4 mgl^{-1} due to dispersion and deposition on the seabed. In general terms, the effects of dredging and drilling are consistent with the natural range of variability in the area. Local effects around construction vessels may be potentially in excess of this however very localised and temporary. Cable installation will have a relatively higher magnitude effect on suspended sediment, however the effect will be short term (order of seconds to minutes) and will be largely localised to the cable installation location (main effect within 10s of metres). The effect of the expected increases in SSC is therefore considered to be of small magnitude (see Section 9: Wind Farm Physical Processes and Geomorphology).

57. In addition to increased SSCs, accumulation of fine material (silts and clays) is expected to occur approximately 5 to 25 km outside of the Wind Farm Site, near to or within the south-western end of the Moray Firth Round 3 Zone WDA. In the unlikely scenario that all fine material from all 277 foundations is released on a very short time scale and is very poorly sorted the maximum local accumulation thickness could be of 0.5 to 0.6 mm but more typically 0.01 to 0.10 mm for dredging and 0.7 to 0.9mm but more typically 0.01 to 0.15 mm for drilling. In the case of

drilling associated to the installation of jacket pin piles, a localised accumulation of sandy material in the near vicinity of each foundation (within 50 to 100 m) is also expected. The thickness of the sand deposits has been conservatively predicted to be up to 5 m (see Section 9: Wind Farm Physical Processes and Geomorphology). It should be noted, however, that drilling will only be employed in certain areas that are resistant to piling and therefore many areas within the Wind Farm will remain unaffected. Sediment re-deposition is therefore considered to result in an effect of small magnitude.

58. The principal shellfish species present in areas relevant to the Wind Farm are, with the exception of squid, of limited mobility (e.g. scallops, crabs, lobster, nephrops, whelks) compared to most fish species. It is likely that these will remain in areas disturbed by increased SSC whilst construction works are taking place. In addition, some of them could be affected by smothering as a result of sediment re-deposition. Increases in SSC, in the case of filter feeders such as scallops, could also potentially affect their ability to feed. Experiments carried out in New Zealand with the scallop *Pecten novaezelandiae* found that for periods of time less than a week, this species coped with suspended sediment concentrations more than 250 mgl^{-1}, whilst for periods greater than a week suspended sediment concentrations over 50 mgl^{-1} may lead to decreased growth (Nicholls *et al*, 2003).

59. Examples of the sensitivity to smothering, increased SSC and displacement for a number of shellfish species found within the site and in the wider Moray Firth are given in Table 11.11 as defined in the Marine Life Information Network (MarLIN, 2011).

Table 11.11 Sensitivity of Shellfish Species to Smothering, Increased SSC and Displacement

Species	Smothering	Increased SSC	Displacement
Edible Crab	Very low	Low	Not sensitive
King Scallop	Low	Low	Not sensitive
Nephrops	Not sensitive	Not sensitive	Very low

60. Based on the above shellfish species are considered receptors of low sensitivity. The effect of increased SSC and sediment re-deposition is therefore assessed to be negligible and probable.

61. Life stages such as eggs and larvae may not be able to avoid disturbed areas, as they may passively drift through (if pelagic) or remain (if demersal) in areas where construction works are being undertaken.

62. Eggs and larvae are generally considered to be more sensitive to suspended sediment effects than later life stages, although sensitivities vary between species. Rönnbäck and Westerberg (1996) found that at concentrations above 100 mgl^{-1} the mortality of cod eggs increased. Studies carried out on eggs of freshwater and estuarine fish found that hatching success began to be reduced at concentrations of

500 to 1000 mgl^{-1} (Auld and Schubel, 1978). Messieh *et al* (1981) were unable to detect any deleterious effect on herring eggs hatching at suspended sediment concentrations as high as 7000 mgl^{-1}, whilst Griffin *et al* (2009) suggest that the attachment of sediment particles on herring eggs leads to retarded development and reduced larval survival rates at sediment concentrations as low as 250 mgl^{-1}. In the case of larvae, as the water becomes more turbid their vision is impeded, in addition fine silt may adhere to the gills and cause suffocation (de Groot, 1980). Eggs and larvae are considered receptors of medium sensitivity and the effect of increased SSC assessed to be negative, minor and probable.

63. In addition to increased SSC, fish eggs could be affected by re-deposition of suspended sediment. This is of particular importance to species which deposit eggs on the seabed, such as sandeels and herring. Messieh *et al* (1981) reported that burial of Atlantic herring eggs under thin veneer of sediment caused substantial mortality. Sediment re-deposition could also result in a temporary loss of spawning grounds to these species, in the event that the characteristics of the substrate changed significantly and made the grounds unsuitable for spawning as a result. De Groot (1980) suggests that altering the structure of the spawning grounds of herring may affect stocks because herring in spawning condition may be unable to locate their normal spawning grounds and as a result shed their eggs on less optimal sites. Sandeels and herring are however considered receptors of medium sensitivity given the small degree of overlap potentially occurring between their spawning grounds and the localised areas where significant sediment re-deposition is expected to occur. The effect of sediment re-deposition on sandeels and herring is therefore assessed to be negative, minor and probable.

64. Mobile fish species are able to avoid localised areas disturbed by increased SSC. If displaced, juveniles and adults would be able to move to adjacent undisturbed areas within their normal distribution range. In the case of migratory species, assuming fish are migrating through the site, increased SSC would result in localised disturbance to migration. An indication of the risk to fish and their habitat at different levels of increased SSC above background conditions is given in Table 11.12.

Table 11.12 Summary of Risk to Fish and their Habitat Derived from Increased Sediment Concentrations

Sediment Increase (mgl^{-1})	**Risk to fish and their habitat**
0	No risk
< 25	Very low risk
25-100	Low risk
100-200	Moderate risk
200-400	High risk
> 400	Unacceptable risk

Source: Birtwell (1999)

65. In light of the above, juvenile and adult fish and diadromous migratory species are considered receptors of low sensitivity. The effect of increased SSC is assessed to be negligible and probable.

66. Based on the assessment above, it is considered that the effect of increased SSCs and sediment re-deposition will result in a negligible and probable effect on the SAC populations of Atlantic salmon, sea lamprey and freshwater pearl mussel requiring assessment (Table 11.8).

11.4.1.2 Noise

67. There are a number of wind farm construction related activities which generate underwater noise. These include suction dredging, drilling, impact piling and rock placement. Noise generated by different construction activities is described Annex 7A: Underwater Noise Modelling Technical Report. Impact piling is considered the activity with highest potential to result in a significant effect on fish and shellfish. As a result, the noise assessment and noise modelling exercise has been primarily focused on this noise source.

68. A summary of the criteria used to assess noise effects on fish is given in Table 11.13, as described in Annex 7A: Underwater Noise Modelling Technical Report.

Table 11.13 Criteria Used to Assess Behavioural Effects as a Result of Piling Noise

Level dB_{ht} (Species)	Effect
90 and above	Strong avoidance reaction by virtually all individuals
Above 110	Tolerance limit of sound; unbearably loud
Above 130	Possibility of traumatic hearing damage from single event

69. A lower level of 75 dB_{ht} (*Species*) representing "significant avoidance"[6] has also been modelled and used in the noise assessment (Annex 7A: Underwater Noise Modelling Technical Report). The assessment of behavioural effects, will however be primarily based upon the 90 dB_{ht} *(Species)* modelling outputs as this is the level at which strong avoidance reactions are expected.

70. Levels above 110 and 130 dB_{ht} *(Species)* would only occur in the immediate vicinity of where piling operations take place, having very small effect ranges (order of tens to few hundred metres at the 130 dB_{ht} *(Species)* level, depending on species specific sensitivities). It should be noted that soft start piling will be used with the aim of triggering avoidance reactions in mobile species in the immediate vicinity of piling locations in advance of the highest noise levels being reached.

71. Concerns were noted during consultation regarding the sensitivities of juvenile fish, and in particular salmon and sea trout smolts. To address this issue a report on

[6] 75dB_{ht} (Species) is a level which represents significant avoidance. It assumes that 85% of individuals will react to the noise, although the effect will probably be transient and limited by habituation.

ontogenic[7] development of auditory sensitivity in fish was commissioned (Annex 11B: Ontogenic Development of Auditory Sensitivity in Fish). This concluded that the experimental evidence suggests that the juveniles of marine species of fish are no more sensitive to sound than the adults of the species. Furthermore, in some cases it appears that there is a degree of insensitivity to sound of juveniles when compared with adults, implying some protection from the adverse effects of noise. In light of this, juvenile fish are assessed using the same criteria as that used for evaluation of the effect of impact piling on adults.

72. The noise modelling undertaken to support this assessment is focused on dab, salmon, cod and herring, species for which there is detailed information on their hearing ability and that represent different ranges of hearing capabilities and sensitivity to noise. The assessment of construction noise on other fish species has been inferred from the outputs of the noise modelling undertaken for dab, salmon, cod and herring. The effect of construction noise on larvae, other life stages of species of limited mobility (e.g. glass eels) and shellfish species is addressed separately at the end of this section.

73. The level of hearing specialisation in fish is assumed to be associated to whether they possess a swim bladder and whether this is connected to the ear. Fish with specialist structures are considered of highest sensitivity, non specialist with a swim bladder of medium sensitivity and non-specialist with no swim bladder of lowest sensitivity (Nedwell *et al*, 2004).

74. A summary of the hearing ability of the species selected for modelling is given below, based on information provided in Thomsen *et al* (2006).

- Dab does not possess a swim bladder. Sound travels directly to the otolith organ via tissue conduction. As a result, dab is only sensitive to particle motion. The species is relatively insensitive to sound and hears over a very restricted range of frequencies. Dab hears in a frequency range between 30 and 250 Hz. Dab is chosen in order to represent other fish species of very low sensitivity to sound, especially flatfishes without a swim bladder. For the purposes of this assessment, dab has been used as a surrogate for plaice (see Annex 7A: Underwater Noise Modelling Technical Report);
- Atlantic salmon possess a swim bladder that is not always completely filled. In addition, it is disconnected from the skull. Hawkins and Johnstone (1978) concluded that the swim bladder plays no part in hearing of the species. Salmon have been found to respond only to low frequency tones (below 380 Hz) with best hearing (threshold 95 dB re 1 μPa) at 160 Hz. As a consequence of the hearing mechanism, particle motion, rather than sound pressure, proved to be the relevant stimulus. The hearing of salmonids (salmon and sea trout) is poor with narrow frequency span, poor power to discriminate signals from noise, and low overall sensitivity. Salmon has been used as a surrogate for sea trout (see Section 7A: Underwater Noise Modelling Technical Report);

[7] Ontogenic: referring to the origin and development of an individual organism from embryo to adult.

- Cod has a gas-filled swim bladder. Though there is no direct connection between the swim bladder and ear, the anterior of the swim bladder is in close proximity to the inner ear. Therefore, this species is more sensitive to sound than both dab and Atlantic salmon. Cod has been used as a surrogate for whiting (see Annex 7A: Underwater Noise Modelling Technical Report); and
- Herring, like all members of the order Clupeiformes, has a swim bladder and inner ear structures which explain their special hearing capabilities. Structural specialisations include an extension of the swim bladder that terminates within the inner ear. Herring hears in an extended range of frequencies between 30 Hz and 4 kHz, with a hearing threshold of 75 dB re 1 µPa at 100 Hz.

75. A comparative indication of the expected 90 dB_{ht} (*Species*) noise effect ranges for the four species modelled is given in Figure 11.3 for a single piling operation. As it can be seen dab (*Limanda limanda*) and salmon (*Salmo salar*) are expected to exhibit strong avoidance reactions only in close proximity of the foundations, whilst cod (*Gadus morhua*) and herring (*Clupea harengus*) are expected to avoid wider areas.

Modelled Species and Surrogates

76. Given below is the assessment of the effect of construction noise on the species modelled and their surrogates. The noise modelling scenarios used for assessment are described in Table 11.14 below and illustrated in Figure 11.4 to Figure 11.7. In all cases these take account of simultaneous piling of two 2.4 m diameter piles at blow forces of 2300 kJ in two locations within the Wind Farm.

77. A number of other noise scenarios were modelled in addition to those listed below. These are detailed and illustrated in Annex 7A: Underwater Noise Modelling Technical Report, and include the outputs for different pile sizes, including 5 m diameter piles (worst case scenario for the meteorological masts) and piling at different blow forces.

Table 11.14 Noise Modelling Scenarios considered in the Assessment

Species	**Locations**	**dB_{ht} (*Species*) Level**
Dab (surrogate for plaice)	A and B	90 dB_{ht} and 75 dB_{ht}
Salmon (surrogate for sea trout)	A and B	90 dB_{ht} and 75 dB_{ht}
Cod (surrogate for whiting)	A and E	90 dB_{ht} and 75 dB_{ht}
Herring	C and D	90 dB_{ht} and 75 dB_{ht}

78. In order to help the assessment and provide an indication of the ecological significance of the predicted effect, in addition to the noise effect ranges, the location of spawning grounds is also shown for herring, cod and plaice and, in the case of salmon, the location of SAC rivers (Figure 11.4 to Figure 11.7).

79. Taking account of the predicted effect ranges, the magnitude of effect of construction noise has been defined as follows.

- Based on the noise modelling outputs for dab (surrogate for plaice) the magnitude of the effect is considered to be small;

- Based on the noise modelling outputs for salmon (surrogate for sea trout), the magnitude of effect is considered to be small; and
- Based on the noise modelling outputs for cod (surrogate for whiting) and herring, the magnitude of the effect is considered to be medium.

80. The sensitivity of the receptors, based on their ecological importance and the use that they make of the Wind Farm Site, and the significance of the predicted effect have been assessed as follows:

- Plaice have defined spawning and nursery grounds in areas relevant to the Wind Farm, there are however relatively large and considered of low intensity (Ellis *et al*, 2010). Plaice is considered a receptor of low sensitivity. The effect of noise on plaice is assessed to be negligible and probable;
- In the absence of detailed information on the migratory routes of salmon and sea trout it is assumed that they transit the Wind Farm as part of their normal migration. In addition, they are assumed to transit the site as part of their foraging activity (particularly sea trout). Taking the small potential degree of overlap between noise contours at the 90dBht (*Salmo salar*) level and fish during migration/feeding, and the potential for habituation to occur in areas affected at the 75dBht (*Salmo salar*) level, salmon and sea trout are considered of medium sensitivity and the effect is assessed to be negative, minor and probable;
- The cod population of the Moray Firth is genetically distinct from other North Sea cod populations and spawning activity has been low in recent years. In addition they are known to use the Moray Firth as a nursery ground (Annex 11A: Fish and Shellfish Ecology Technical Report). Noise contours at the 90dBht (Species) level may overlap with a significant area of their spawning and nursery grounds (Figure 11.6). It should be noted that the precise location, spatial extent and relative importance of the areas currently used by cod for spawning and as nursery grounds in the Moray Firth is not well defined. These areas are however likely to be currently smaller than those defined in Coull *et al*, (1998) and Ellis *et al*. (2010) (see Annex 11A: Fish and Shellfish Ecology Technical Report). In addition, cod are pelagic spawners not needing the presence of a specific substrate on which to lay their eggs and hence spawning is not as spatially restricted as for other species (e.g. herring). Cod has been considered a receptor of medium sensitivity and the effect of construction noise is assessed to be negative, moderate and unlikely. For an effect of moderate significance to occur the distribution of currently active cod spawning and nursery grounds would have to be limited to the Wind Farm Site and its immediate vicinity;
- Whiting (for which cod has been used as a surrogate) have defined spawning and nursery grounds in areas relevant to the Wind Farm, these are however comparatively large. Whiting is considered a receptor of low sensitivity and the effect is assessed to be negative, minor and probable; and
- Herring are known to spawn in the Moray Firth and use the area as a nursery ground. They are important as prey species for a number of other marine organisms. In addition they are substrate specific spawners needing the presence of an adequate coarse substrate on which to lay their eggs. It should be

noted, however, that the highest intensity of herring spawning tends to take place in the area between the Orkney and the Shetlands in most years, and that gravelly substrate is available to the Orkney/Shetland stock in various areas unaffected at the 90dBht (*Clupea harengus*) level (Figure 11.7, Annex 11A: Fish and Shellfish Ecology Technical Report). It is recognised, however, that there is substantial annual variability in the areas used and intensity of spawning in the Moray Firth Area, with spawning activity off the Caithness coast also being of relative importance in some years. Taking the uncertainties in relation to exact spawning location and intensity during the construction phase of the Wind Farm, herring are considered receptors of medium sensitivity and the effect is assessed to be negative, moderate and unlikely. As previously described for cod, a moderate effect could occur if spawning during the years of construction is primarily concentrated in the area of the Wind Farm and its vicinity.

Other Fish Species

81. As previously mentioned the level of hearing specialisation in fish is assumed to be associated to whether they possess a swim bladder and whether this is connected to the ear. Based on the classification of hearing specialisation given above (Nedwell *et al*., 2004), potential magnitudes of effect have been assigned to a number of species known to be present in the Moray Firth for which noise modelling has not been undertaken and direct surrogates have not been defined as follows:

- For flatfish species and other species which lack a swim bladder, namely sandeels, elasmobranchs, anglerfish, river lamprey and sea lamprey the magnitude of effect assigned to the noise contours for dab (small) has been applied;
- For species with a swim bladder but not connected to the ear, namely haddock and European eel, the magnitude of effect assigned to the noise contours for cod (medium) has been applied; and
- For species which possess a connection between the swim bladder and the ear such as sprat, the magnitude of effect assigned to the noise contours for herring (medium) has been applied.

82. It should be noted that data on hearing ability exist for a limited number of species and extrapolation of hearing capabilities between species, and especially those that are taxonomically distant, should be done with the greatest caution (Hasting and Popper, 2005). In the case of European eel, for instance, the assessment has been based on the noise contours modelled for cod. Both are considered hearing generalists, however they are taxonomically distant. In addition, the swim bladder in cod is in close proximity to the ear whilst in European eel there is an extremely long distance in between these (Jerkø *et al,* 1989). It is therefore probable that the noise contours modelled for cod overestimate the ranges at which behavioural effects may occur in European eel. The limitations and the qualitative nature of the noise assessment for the species which have not been modelled and for which direct surrogates have not been defined should therefore be recognised and the extrapolated magnitudes of effect taken as an indicative, and likely conservative, worst case.

83. The assessment for the species not modelled and without defined surrogates is summarised in Table 11.15. Given the limitations and qualitative nature of the assessment, a probability has not been assigned to the significance of the effect.

Table 11.15 Qualitative Assessment for Species not Modelled and without defined surrogates based on Extrapolated Magnitudes of Effect

Species	Potential Magnitude of Effect	Receptor Sensitivity		Significance of Effect
Sandeels	Small	Important prey species and PMF	Medium	Minor
		Unknown distribution and density within the site		
		Substrate specific		
Elasmobranchs	Small	Most species are of conservation importance	Low	Negligible
		Generally more prevalent in the North and West coast of Scotland		
		The nursery areas of some of them fall within the site (thornback ray, spurdog, spotted ray). These are however comparatively large and considered of low intensity		
River and sea lamprey	Small	Both species are of conservation importance	Medium	Minor
		Potentially transiting the site during migration (lack of detailed information on migration)		
Anglerfish	Small	Species of conservation importance (PMF)	Low	Negligible
		The Wind Farm falls within a high intensity nursery area. This is however comparatively large		
Haddock	Medium	Commercially important	Low	Negligible

Species	Potential Magnitude of Effect	Receptor Sensitivity		Significance of Effect
		Nursery grounds within the site and spawning grounds in the vicinity of the site. Both spawning and nursery grounds are however comparatively large		
European eel	Medium	Species of conservation importance	Medium	Moderate
		Potentially transiting the site during migration and recorded in the majority of rivers in the Moray Firth area (lack of detailed information on the migration route)		
Sprat	Medium	Important prey species	Low	Minor
		Spawning and nursery grounds in the area, however these are comparatively large		

Life Stages of limited mobility

84. Life stages of limited mobility such as larvae, and in the case of European eel their juvenile form (glass eels), will not be able to avoid areas where the highest noise levels are reached, assuming they drift with the currents through the Wind Farm site. Although there is limited information on the effect of piling noise to date on early life stages of fish, research recently carried out by the Institute for Marine Resources and Ecosystems Studies, Ijmuiden IMARES (Bolle *et al*, 2011) suggested that the assumption of 100% of larvae mortality within a radius of 1000 m around a piling site (used in the Appropriate Assessment of Dutch offshore wind farms) was too conservative. Bolle *et al* (2011) found no significant effects in the larval stages analysed at the highest exposure level (Cumulative Sound Exposure Level "SEL"= 206 dB re 1 μPa2s) which represented 100 pulses at a distance of 100 m from a piling site. It is recognised that the results, based on sole (*Solea solea*) larvae, should not be extrapolated to fish larvae in general, as inter-specific differences in vulnerability to sound exposure may exist. The findings, however, do suggest that larval mortality would only be expected within a few hundred metres from where piling is taking place. On this basis the magnitude of the effect is considered small. The limited seasonality of the larval drift for a given species in conjunction with the construction schedule should be noted. In the particular case of glass eels these would most likely transit areas relevant to the Wind Farm during the winter

months. The sensitivity of larvae and glass eels is considered medium and the effect is assessed to be negative, minor and probable.

Shellfish Species

85. The majority of shellfish species present in areas relevant to the site (e.g. scallops, nephrops, edible crabs, lobster, whelks) have limited mobility in comparison to most fish species and hence they may not be able to avoid areas in close proximity to piling operations. The hearing mechanisms of invertebrates are currently not well understood. They are generally assumed to be less sensitive to noise than fish due the lack of swim bladder. Recent studies, however, have found that species such as the shrimp (*Palaemus serratus*) and the longfin squid (*Loligo pealeii*) are sensitive to acoustic stimuli and it has been suggested that these species may be able to detect sound similarly to most fish, via their statocysts (Lovell *et al*, 2005; Mooney *et al*, 2010).

86. Scallops are the principal commercial shellfish species present in areas relevant to the Wind Farm Site, with squid, nephrops, crabs, lobster and whelks being more prevalent in other areas within the Moray Firth (Annex 11A: Fish and Shellfish Ecology Technical Report). Whilst detailed information on the hearing ability of scallops is currently lacking, they are not considered to be sensitive to noise (MarLIN, 2011). No species specific information on the sensitivity to noise of nephrops, crabs, lobsters and whelks, is currently available, however, they are expected to be present in relative low numbers within the site being more prevalent in other areas within the region. Squid are seasonally present in the Moray Firth to spawn and as previously mentioned, may potentially be affected by noise in a similar way as fish. They are however mobile and principally occur in coastal areas in the southern Moray Firth.

87. In light of the above the magnitude of the effect is considered small and the sensitivity of shellfish species low. The effect is therefore assessed to be negative of minor significance and probable. The effect of noise on invertebrates is further discussed in Section 10: Wind Farm Benthic Ecology.

88. Based on the assessment for salmon, the effect of construction noise on SAC populations of Atlantic salmon and freshwater pearl mussel requiring assessment is considered to be negative, minor and probable. In the particular case of the River Spey SAC population of sea lamprey, given the distance from the Wind Farm to the SAC, and taking the assumed small magnitude of effect and medium sensitivity of the receptor (Table 11.15), the effect is considered to be negative, minor and unlikely. The limitations in relation to the assessment of noise on species for which noise modelling has not been undertaken and direct surrogates have not been defined should however be recognised.

11.4.2 OPERATION

89. The following effects on fish and shellfish ecology are assessed below for the operational phase of the Wind Farm.

- Loss of habitat;

- Introduction of new habitat;
- EMFs;
- Operational noise; and
- Changes to fishing activity.

11.4.2.1 Loss of Habitat

90. The installation of the Wind Farm will result in a loss of habitat proportional to the total footprint of the development.

91. The worst case scenario for habitat loss, as described in Section 10: Wind Farm Benthic Ecology assumes that 277 turbines, each with a gravity base, two AC OSPs and one DC OSP. As previously mentioned, inter-array cables will be buried or protected where feasible. For the purposes of this assessment, the assumption that up to 50% of the inter-array cable may be protected has been made. Taking this into consideration and based on engineering information the total loss of habitat would be of approximately 3.8 km^2. This accounts for just under 2.9% of the total seabed within the site (Table 11.16).

Table 11.16 Loss of Habitat based on Worst Case Design Parameters

Worst Case Design Options	**Loss of Habitat (m^2)**
277 Turbines (Gravity bases)	3,238,130
2 x AC OSP	24,230
1 x DC Converter	45,100
Maximum area of cable protected	487,500
Total loss of habitat	**3,794,960**

92. In light of the small area of seabed predicted to be lost in the worst case scenario, the magnitude of the effect is considered to be negligible.

93. In addition to direct loss of habitat, the introduction of structures could result in changes in the distribution of seabed sediment in the Wind Farm during the operational phase. As detailed in the physical processes section (Section 9: Wind Farm Physical Processes and Geomorphology), changes to the tidal, wave and sediment transport regime due to the presence of the Wind Farm foundations are not considered to be significant. The potential for changes in sediment type and sediment distribution within the site and the wider area to have an effect on fish and shellfish species during the operational phase is therefore not considered further.

94. The majority of fish and shellfish species present in the area of the Wind Farm have relatively wide distribution ranges. These vary depending on the species under consideration but are consistently large relative to the predicted loss of seabed area of 3.8 km^2. In general terms, fish and shellfish species are considered receptors of low sensitivity to habitat loss. The effect of loss of habitat is assessed to be negligible and probable. An exception to this are spawning herring and sandeels,

which given their dependence on the existence of suitable substrate types are assessed separately below.

95. Herring requires the presence of a coarse substrate for spawning. They are demersal spawners and, assuming eggs are laid within the site, there is potential for the introduction of the Wind Farm infrastructure to result in a direct loss of spawning grounds.

96. The Wind farm is located outside defined herring spawning grounds (as per Coull *et al*, 1998). Some degree of spawning may however take place within the site as suggested by IHLS data, the presence of adequate coarse sediment being recorded in some grab samples during the benthic survey within the Wind Farm Site and the location of the spawning grounds as defined in other publications (e.g. Payne, 2010). An indication of the distribution of gravel and gravelly sands (considered preferred herring spawning substrates) in the Moray Firth is given in Figure 11.8, based on BGS data together with the wider spawning grounds defined in Coull *et al* (1998). As it is apparent from the figure the predicted worst case loss of habitat is very small in comparison to the total gravelly areas available to the Orkney/Shetland stock. Herring are therefore considered of medium sensitivity and the effect is assessed to be negligible and probable.

97. In the case of sandeels, loss of habitat would occur if Wind Farm infrastructure is placed in areas where sandeels are located. Sandeels are substrate specific and inhabit discreet patches of seabed. Sandeel populations are known to exist in the Smith Bank and there is evidence from the results of the benthic survey that they are present within the site. There is, however, a lack of current data on the distribution of the sandeels within the site and the wider area to the spatial scale required for this assessment. The assessment has therefore been carried out taking into account the following considerations:

- The potential for other areas in the Smith Bank and the wider Moray Firth to constitute important sandeel habitats;
- The uncertainties regarding the location of potential discrete high density sandeel patches within the Wind Farm and;
- The uncertainties relative to the importance of the site as a sandeel habitat in the context of the wider Moray Firth.

98. Taking the above into account, in addition to their importance as prey species and conservation status (PMF), sandeels are considered of high sensitivity. The effect of habitat loss is assessed to be negligible and probable.

99. Based on the information in paragraph 95 for fish and shellfish species it is considered that habitat loss will result in a negligible and probable effect on the Atlantic salmon, sea lamprey and freshwater pearl mussel SAC populations requiring assessment (Table 11.8).

11.4.2.2 Introduction of New Habitat

100. The sub-surface sections of the turbine towers, foundations, scour protection and concrete mattressing or rock used for cable protection will result in the introduction

of hard substrate which will be colonised by a number organisms. Localised, long-term positive changes on the overall diversity and productivity of the seabed communities are expected to occur as a result. The introduction of the structures will replace areas of existing predominantly sandy or slightly gravelly biotopes with communities typical of harder substrates. Potential changes and effects on the benthic community are described in detail in Section 10: Wind Farm Benthic Ecology.

101. The impact assessment methodology described above is not considered practicable for the assessment of the effects derived from the introduction of new habitat, given the difficulty of assigning both sensitivities to potential receptors and effect magnitudes. Furthermore, receptors may change through the operational phase as changes in benthic communities take place. The assessment of this effect is therefore based on a review of current knowledge on the subject and on indirect evidence from the results of monitoring programmes undertaken in operational wind farms and other offshore infrastructures.

102. The increase in diversity and productivity of seabed communities expected as a result of the introduction of hard substrate may have an effect on fish either through attraction or increased productivity (Hoffman *et al*, 2000). The potential for marine structures, whether manmade or natural, to attract and concentrate fish is well documented (Sayer *et al*, 2005; Bohnsack, 1989; Bohnsack and Sutherland, 1985; Jorgensen *et al*, 2002), however, whether these structures act only to attract and aggregate fish or actually increase biomass is unclear.

103. Studies carried out in Sweden (Wilhelmsson *et al,* 2006) in operational wind farms suggest that the structures may function as combined artificial reefs and fish aggregations devices (FADs) for demersal and semi pelagic fish. This was concluded on the basis of the greater abundance of fish found on and near monopiles. Wilhelmsson *et al* (2006) pointed out that that added structures on the monopiles may attract species that would not have been there otherwise and suggested that the changes in abundance of some species could result in positive local effects on commercial species, provided local increases on the species that they prey upon also occur.

104. A review on the short term ecological effects of the offshore wind farm Egmond aan Zee (OWEZ) in the Netherlands, based on two years' post-construction monitoring (Lindeboom *et al,* 2011), found only minor effects upon fish assemblages, especially near the monopiles, and it was suggested that species such as cod may find shelter within the Wind Farm. Data collected by the pelagic and demersal surveys indicated a highly dynamic fish community with large differences between the catches before the Wind Farm was built and the catches in the operational phase. A switch in the dominance of pelagic species from herring to sandeels and an increase in the species richness of demersal species in the first year after construction was recorded. Those changes were, however, also observed in reference areas and it was concluded that it was unlikely to be caused by the presence of the Wind Farm. At OWEZ an exclusive significant increase inside the Wind Farm was found for sole, whiting and striped red mullet (*Mullus surmuletus*)

during the summer, whereas a significant decrease was found for lesser weever (*Echiinchthys vipera*), both in summer and in winter. No clear explanation was however found for the change in abundance of these species (Lindeboom *et al*, 2011).

105. During post construction monitoring work at the operational wind farm of Horns Rev in Denmark, it was estimated that the loss of infauna habitat derived from the introduction of hard bottom habitats provided 60 times increased food availability for fish and other organisms in the wind farm area compared to the native infauna biomass (Leonhard and Pedersen, 2005). A succession in the number of fish species was observed when comparing the results of surveys undertaken in March and in September and it was suggested that it could be a result of seasonal migrations of fish species to the turbine site for foraging. Bib *(Trisopterus luscus)* were observed presumably partly feeding on crustaceans on the scour protection, together with schools of cod. Other species such as rock gunnel (*Pholis gunnellus*) and dragonet (*Callionymus lyra*) were commonly found inhabiting caves and crevices between the stones. In addition, pelagic and semi pelagic fish such as sprat, mackerel and lesser sandeel (*Ammodytes tobianus*) seemed to be more frequently recorded than previously (Leonhard and Pedersen, 2005).

106. Research carried out at Lysekil, a test wave power park off the Swedish west coast, found significantly higher abundance of fish and crabs on the foundations compared to the surrounding soft bottoms. Fish numbers were however not found to be influenced by increased habitat complexity (Langhamer and Wihelmsson, 2009).

107. The results of fish monitoring programmes carried out in the operational wind farms in the UK do not suggest that major changes in species composition, abundance or distribution of fish have occurred. At North Hoyle a change in the diversity of organisms or the species composition of the benthic and demersal community was not found. The annual post-construction beam trawl survey indicated that most of the fish species considered were broadly comparable to previous years and within the long-term range, with some species showing recent increases and decreases, but broadly mirroring regional trends (CEFAS, 2009).

108. At Barrow pre and post construction otter trawl survey results from the wind farm area showed similar patterns of abundance, with the most frequently caught fish being dab, plaice, whiting and lesser spotted dogfish (*Scyliorhinus canicula*). Results from control locations show a similar pattern, and found no significant differences between the catches of the two most abundant species (dab and plaice) before and after installation of the wind farm, or between the numbers caught at control locations and within the wind farm area after the wind farm was constructed (CEFAS, 2009).

109. It has been suggested (Linley *et al,* 2007) that the introduction of wind farm related structures could extend the distribution of some mobile species such as crabs, lobsters and fin fish, as a result of increased habitat opportunities. At Horns Rev for example, it was found during post construction monitoring that the wind farm

site was being used as a nursery area by juvenile edible crabs (Leonhard and Pedersen, 2005).

110. Colonisation of structures by commercial shellfish species has also been reported at the artificial reef constructed in Poole Bay in 1989, where attraction and loyalty was demonstrated for lobster and edible crab within three weeks of deposition (Collins *et al*, 1992; Jensen *et al*, 1994). In addition, evidence of reproductive activity for a number of shellfish species such as spider crabs, velvet crabs, and whelks and presence of berried females of lobster was also found (Jensen *et al*, 1992). Based on the experience at Horns Rev and Poole Bay, Linley *et al* (2007) suggest that the edible crab may be among the early colonisers of wind farm structures.

111. In the Wind Farm Site, scallop dredging constitutes one of the main fishing activities. Whilst of limited importance in the Wind Farm Site, crab and lobster fisheries take place in coastal areas in the proximity of the site. The introduction of new habitat could therefore result in the distribution of these species being extended through increased habitat availability. In addition, there may be potential for the area to be used as nursery and spawning area for some of these species as suggested by the findings of monitoring studies at Horns Rev and Poole Bay.

112. Based on the results of monitoring programmes described above, the effect of introduction of new habitat on fish and shellfish species is assessed to be minor and probable. The effect may be positive or negative depending on the species under consideration (e.g. positive to species for which feeding opportunities are increased and protection is found in the array, and negative for other species if subject to increased predation within the site). In the particular case of edible crab, and potentially other commercial shellfish species, it is considered that a positive minor and probable effect will occur.

113. It should be noted that further to the introduction of new habitat other factors such as the potential effects of EMFs, operational noise and changes in fishing activity within and in the vicinity of the site could further result in changes to the distribution of sensitive fish and shellfish species. These potential effects are separately addressed in the following sections.

11.4.2.3 Electromagnetic Fields

114. The inter-array cables used in the Wind Farm will be three core 33 kV or 66 kV AC cables. During the operational phase these will generate an electric field (E) and a magnetic field (B). The total E field cancels itself out to a large extent and the remaining E field is shielded by the metallic sheath and the cable armour. The varying magnetic field (B), however, produces an associated induced electric field (Ei), therefore both B and Ei fields will be generated by inter-array cables during the operational phase of the Wind Farm.

115. The strength of the magnetic field decreases rapidly horizontally and vertical with distance from source. An indication of this is given in Table 11.17. This shows averaged predicted magnetic fields at intervals above and horizontally along the seabed for a number of AC projects, as provided in Normandeau *et al* (2011).

Table 11.17 Averaged magnetic field strength values from AC cables above and horizontally along the seabed assuming 1m burial

Distance (m) above seabed	**Magnetic Field Strength (μT)**		
	Horizontal Distance (m) from Cable		
	0	4	10
0	7.85	1.47	0.22
5	0.35	0.29	0.14
10	0.13	0.12	0.08

Source: Normandeau *et al* (2011)

116. Since the strength of the magnetic field decreases with distance from the source, the potential effects of EMFs on fish and shellfish will likely be influenced by the position of particular species in the water column and on water depth. In the Wind Farm Site, surveyed water depths range from approximately 38 m to 68 m.

117. It should be noted that cable burial does not effectively mitigate B or Ei fields, however, it reduces exposure of electromagnetically sensitive species to the strongest EMFs that exist at the 'skin' of the cable owing to the physical barrier of the substratum (OSPAR, 2008). For the purposes of this assessment, it is assumed that inter-array cables will be buried to a minimum depth of 0.6 m or protected where feasible, and that 277 turbines will be installed resulting in the maximum length of cabling.

118. Given the relatively small area where any effects may occur, limited to the area of the Wind Farm and in the proximity of the cables, the magnitude of the effect of EMFs is considered to be small.

119. Information on the sensitivity and use that marine species make of EMFs is limited to date, there is however evidence of a response to EMFs in a number of species in UK waters. Species for which there is evidence of a response to E fields and B fields are given in Table 11.18 and Table 11.19 respectively as provided in Gill *et al* (2005).

Table 11.18 Species found in UK waters for which there is evidence of a response to E Fields

Species/Species Group	**Latin Name**
Elasmobranchs	
Lesser Spotted Dogfish	*Scyliorhinus canicula*
Blue shark	*Prionace glauca*
Thornback ray	*Raja clavata*
Round ray	*Rajella fyllae*
Agnatha	
River lamprey	*Lampetra fluviatilis*

Species/Species Group	Latin Name
Sea lamprey	*Petromyzon marinus*
Teleosts	
European eel	*Anguilla anguilla*
Cod	*Gadus morhua*
Plaice	*Pleuronectes platessa*
Atlantic salmon	*Salmo salar*

Source: Gill *et al* (2005)

Table 11.19 Species found in UK waters for which there is evidence of Response to B fields

Species	
Elasmobranchs	
All Elasmobranchs possess the ability to detect magnetic fields	
Agnatha	
River lamprey	*Lampetra fluviatilis*
Sea lamprey	*Petromyzon marinus*
Teleosts	
European eel	*Anguilla anguilla*
Plaice	*Pleuronectes platessa*
Atlantic salmon	*Salmo salar*
Sea trout	*Salmo trutta*
Yellowfin tuna	*Thunnus albacares*
Crustacea	
Lobster, crabs, shrimps and prawns	Specific cases non-UK Decapoda: *Crangon crangon* (ICES, 2003) Isopoda: *Idotea baltica* (Ugolini & Pezzani, 1995) Amphipoda: *Talorchestia martensii* (Ugolini. 1993), *Talitrus saltator* (Ugolini & Macchi, 1988)
Molluscs	
Snails, bivalves and squid	Specific case non-UK Nudibranch: *Tritonia diomedea* (Willows, 1999)

Source: Gill *et al* (2005)

Elasmobranchs

120. Elasmobranchs are the major group of organisms known to be electrosensitive. They possess specialised electroreceptors called Ampullae of Lorenzini. These species naturally detect bioelectric emissions from prey, conspecifics[8] and potential

[8] Organisms belonging to the same species

predators/competitors (Gill *et al*, 2005). The E-sense is primarily used in close proximity to the E fields in the detectable range. In addition they are known to either detect magnetic fields using their electronsensory systems or through a yet-to-be described magnetite receptor system (Normendaeu *et al,* 2011). Magnetic field detection is thought to be used as a means of orientation in elasmobranches, however, evidence for magnetic orientation by behaving sharks and rays is limited to date (Meyer *et al,* 2005) and there is currently debate on the actual mechanisms used (Johnsen and Lohmann 2005).

121. Both attraction and repulsion reactions have been observed associated to E-fields in elasmobranch species. Gill and Taylor (2001) found limited laboratory based evidence that the lesser spotted dogfish (*Scyliorhinus canicula*) avoids DC E-fields at emission intensities similar to those predicted from offshore wind farm AC cables. The same fish were attracted to DC emissions at levels predicted to emanate from their prey. Marra (1989) found evidence of a communication cable being damaged by elasmobranchs (*Carcharhinid* species and *Pseudocarcharias Kamoharai*). Further research on EMFs and elasmobranchs (Gill *et al*, 2009) found that two benthic species, lesser spotted dogfish and thornback ray, were able to respond to the EMFs of the type and intensity associated with sub-sea cables. The responses found were however not predictable and did not always occur; when there was a response this was species dependant and individual specific, meaning that some species and their individuals are more likely to respond by moving more or less within the zone of EMF (Gill *et al*, 2009).

122. Information gathered as part of the monitoring programme undertaken at Burbo Bank suggest that certain elasmobranch species (sharks, skates and rays) do feed inside the wind farm and demonstrated that they are not excluded during periods of low power generation (CEFAS, 2009). Monitoring at Kentish Flats found an increase in thornback rays, smooth hound and other elasmobranchs during post construction surveys in comparison to surveys before construction. It appeared, however, not to be any discernible difference between the data for the wind farm site and reference areas, including population structure changes, and it was concluded that the population increase observed was unlikely to be related to the operation of the wind farm (CEFAS, 2009).

123. As described in Annex 11A: Fish and Shellfish Ecology Technical Report, the majority of elasmobranch species potentially present in the area of the Wind Farm are in most cases more frequently found in the north and west coast of Scotland. The Wind Farm, however, falls within defined nursery grounds for a number of these, namely spurdog, thornback ray and spotted ray. Given the conservation status of most elasmobranch species, the potential for the Wind Farm to be used as a nursery ground for some of them, and the evidence of their ability to detect E fields they are considered of medium sensitivity. The effect of EMFs on elasmobranchs is therefore assessed to be negative, minor and probable.

River and Sea Lamprey (Agnatha)

124. Lampreys possess specialised ampullary electroreceptors that are sensitive to weak, low-frequency electric fields (Bodznick and Northcutt 1981; Bodznick and Preston,

1983). Whilst responses to E fields have been reported on these species, information on the use that they make of the electric sense is limited. It is likely however that they use it in a similar way as elasmobranches to detect prey, predators or conspecifics and potentially for orientation or navigation (Normadeau *et al* 2011). Chung-Davidson *et al* (2008) found, based on experiments carried out on sea lamprey that weak electric fields may play a role in their reproduction and it was suggested that electrical stimuli mediate different behaviours in feeding-stage and spawning-stage sea lampreys.

125. Both river and sea lamprey are species of importance from a conservation point of view with sea lamprey being a primary reason of selection of the River Spey SAC, in the Moray Firth. Whilst the behaviour and distribution of both species in the marine environment is poorly understood there is potential for both to transit the Wind Farm during migration. EMFs generated by the inter-array cables may result in behavioural effects on these species and limited disturbance during migration, assuming they use the electric sense for navigation. Lampreys are therefore considered of medium sensitivity and the effect of EMFs on them to be negative, minor and unlikely.

European Eel

126. European eel are known to possess magnetic material of biogenic origin of a size suitable for magnetoreception (Hanson *et al* 1984; Hanson and Walker, 1987; Moore and Riley, 2009) and are thought to use the geomagnetic field for orientation (Karlsson, 1985). In addition, their lateral line has been found to be slightly sensitive to electric current (Vriens and Bretschneider, 1979; Berge 1979).

127. A number of studies have been carried out in relation to the migration of eels and the potential effect of EMFs derived from offshore wind farm cables. Experiments undertaken at the operational wind farm of Nysted detected barrier effects, however correlation analysis between catch data and data on power production showed no indication that the observed effects were attributable to EMFs. Furthermore, mark and recapture experiments showed that eels did cross the export cable (Hvidt *et al* 2006). Similarly research by Westerberg (1999) on HVDC cables and eel migration found some effects associated to the magnetic disturbance were likely to occur on eel migration although the consequences appeared to be small. In addition, no indication was found that the cable constituted a permanent obstacle to migration, neither for adult eels nor for elvers.

128. Further research, where 60 migrating silver eels were tagged with ultrasonic tags and released north of a 130 kV AC cable, found swimming speeds were significantly lower around the cable than in areas to the north and south (Westerberg and Lagenfelt, 2008). It was noted that no details on the behaviour during passage over the cable were recorded and possible physiological mechanisms explaining the phenomenon were unknown. Based on the results of Westerberg and Lagenfelt (2008) before publication, Öhman *et al* (2007) suggested that even if an effect on migration was demonstrated the effect was small and pointed out that on average the delay caused by the passage was about 30 minutes.

129. Based on the above European eel is considered of medium sensitivity and the effect of EMFs to be negative, minor and probable.

Salmon and Sea trout

130. Research carried out on salmon and sea trout indicates these species are able to respond to magnetic fields (Formicki *et al,* 2004; Formicki and Winnicki, 2009; Tanski *et al*, 2005; Sadowski *et al*, 2007). In addition, the presence of magnetic material of a size suitable for magnetoreception has been reported in Atlantic salmon (Moore *et al,* 1990) and the ability to respond to electric fields (Rommel and McLeave, 1973). Most of the limited research undertaken on the subject on these species, has however, been focused on physiology based laboratory studies. Research under these conditions has found that EMFs can elicit localised physiological responses on the two species (McCleave and Richardson, 1976; Vriens and Bretshneider, 1979; Hanson *et al* 1984, Formicki *et al* 1997; 2004). It is however recognised that laboratory based responses to a stimulus do not necessarily imply that the same behavioural response will be triggered at sea. Öhman *et al* (2007) point out that detection of stimuli may not necessarily lead to behavioural responses in fish and that senses that detect magnetic fields are not the only means of spatial orientation, as vision, hearing and olfaction as well as hydrographic and geoelectric information could all be used for spatial orientation.

131. The strength of EMFs decreases quickly with distance to the source. The magnitude and intensity of the potential movement and behavioural effects on salmonids, likewise in other pelagic species, would be closely linked to the proximity of the fish to the source of EMF. Gill and Barlett (2010) suggest that if there is going to be any effect on the migration of salmon and sea trout, this will be most likely dependent on the depth of water and the proximity of the rivers to the development site. Salmon and sea trout transiting the area of the Wind Farm will for the most not be exposed to the strongest EMFs as they normally swim in the upper metres of the water column during migration (water depths in the Wind Farm range from 38 to 68 m).

132. Based on the information provided above, and given the conservation importance of both salmon and sea trout, the potential for these species to transit the Wind Farm during migration and as part of their foraging activity (particularly in the case of sea trout), they have been assigned medium sensitivity . The effect of EMFs on salmon and sea trout is therefore considered to be negative, minor and probable.

Other Fish Species

133. As indicated inSource: Gill *et al* (2005)

134. Table 11.19Table 11.19 (Source: Gill *et al* (2005)) further to the species described above, there is some evidence of a response to EMFs in other teleost species such as cod and plaice. The results of monitoring programmes carried out in operational wind farms do not, however, suggest that EMFs have resulted in a detrimental effect on these species. Lindeboom *et al* (2011) suggest that the presence of the foundations and scour protection and potential changes in the fisheries related to

offshore wind farm development, are expected to have the greatest effect upon fish species and that noise from the turbines and EMFs from cabling do not seem to have a major effect on fish and other mobile organisms attracted to the hard bottom substrates for foraging, shelter and protection (Leonhard and Pedersen, 2006). In line with this, research carried out at the Nysted offshore wind farm (Denmark), focused on detecting and assessing possible effects of EMFs on fish during power transmission (Hvidt *et al*, 2006), found no differences in the fish community composition after the wind farm was operational. Whilst effects on the distribution and migration of four species were observed (European eel, flounder, cod and Baltic herring), it was recognised that the results were likely to be valid on a very local scale and only on the individual level and that an effect on a population or community level was likely to be very limited.

135. It is considered that fish species/species groups other than those previously assessed are receptors of low sensitivity. The effect on these species is assessed to be negligible and probable.

Shellfish Species

136. Limited research has been carried out to date on the ability of marine invertebrates to detect EMFs. Whilst there is to date no direct evidence of effects to invertebrates from undersea cable EMFs (Normandeau *et al*, 2011) the ability to detect magnetic fields has been studied for some species and there is evidence of a response to magnetic fields in some of them, including molluscs and crustaceans (Source: Gill *et al* (2005)

137.

138. Table 11.19Table 11.19). Research undertaken by Bochert and Zettler (2004) , where a number of species, including crustaceans such as the brown shrimp (*Crangon crangon*) and molluscs such as mussels (*Mytilus edulis*) both found in UK waters, were exposed to a static magnetic field of 3.7 mT for several weeks, found no differences in survival between experimental and control animals. The functional role of the magnetic sense in invertebrates is hypothesized to be for orientation, navigation and homing using geomagnetic cues (Cain *et al*, 2005; Lohmann *et al*, 2007). Concern has therefore been raised on the potential for shellfish species which undertake migrations to be affected by EMFs. The edible crab (*Cancer pagurus*) and lobster (*Homarus gammarus*) are both species commercially important in the Moray Firth and undertake inshore/offshore seasonal migrations. As suggested by fisheries data, these species are principally found along the Caithness coast, in coastal areas off Fraserburgh and, to a lesser extent, in coastal areas in the southern Moray Firth. Whilst there is not detailed information on the extent and preferred migration routes used by these species in the Moray Firth, there may be potential for these species to transit the Wind Farm during migration. Research undertaken on the Caribbean spiny lobster (*Panulirus argus*) (Boles and Lohmann, 2003) suggest that this species derive positional information from the Earth's magnetic field. Limited research undertaken with the European lobster (*Homarus gammarus*), however, found no neurological response to magnetic field strengths considerably

higher than those expected directly over an average buried power cable (Normandeau *et al* 2011, Ueno *et al,* 1986).

139. Indirect evidence from monitoring programmes undertaken in operational wind farms do not suggest that the distribution of potentially magnetically sensitive species of crustaceans or molluscs have been affected by the presence of submarine power cables and associated magnetic fields. In this context, however, the lack of shellfish specific EMFs monitoring programmes should be recognised.

140. Based on the above, shellfish species are considered receptors of low sensitivity. The effect on shellfish species is assessed to be negligible and probable.

SAC Fish and Shellfish Populations

141. Taking the assessment for salmon and sea lamprey above, it is considered that EMFs may result in a negative minor effect on the SAC populations of Atlantic salmon, sea lamprey and freshwater pearl mussel requiring assessment (Table 11.8). This is considered likely in the case of salmon (and subsequently freshwater pearl mussel) and unlikely for sea lamprey.

11.4.2.4 Operational Noise

142. During the operational phase of a wind farm, noise is principally generated by the turbine's gear boxes and transferred into the water and sediment through the towers and foundations (Lindell, 2003). Sound emissions during this period are expected especially in the low-frequency range (Westerberg, 1994; Degn, 2000; Lindell, 2003). Detailed information on the potential effects of operational noise on fish and shellfish is limited to date, it is however generally accepted that the effects of operational noise are restricted to masking of communication and orientation signals, rather than causing damage or consistent avoidance reactions (Wahlberg and Westerberg, 2005). The implication of this will depend on the ecology and use that particular species make of the area of the Wind Farm and its vicinity and on the hearing ability of different species.

143. For assessment of operational noise it has been assumed that the maximum number of turbines constitute the worst case scenario. It should be noted, however, that there is a lack of species/species group specific knowledge on the effects of operational noise to allow for sensitivities and receptors being described. The assessment has therefore been based on a literature review of current knowledge on the subject and on indirect evidence derived from the results of monitoring programmes carried out in operational wind farms.

144. Measurements of operational noise at a series of UK wind farm sites (Nedwell *et al.,* 2007) indicated that in general, the level of noise was very low. The study calculated the operational noise levels that would be encountered by various species using dB_{ht} units. When the results were averaged across all of the fish species considered, the noise levels within the wind farms were found to be just over $2dB_{ht}$ higher than background noise levels in waters surrounding the wind farm sites. The level of variation is well within the spatial and temporal variations that are typically encountered in background noise, and hence it was concluded that, whilst there

might be a small net contribution to noise in the immediate vicinity of the wind farm, this is no more than is routinely encountered by marine animals during their normal activity.

145. Walhberg and Westerberg (2005) studied the responses of three species representing various hearing capabilities (e.g. cod, Atlantic salmon) to operational wind farm noise and found that noise was detected at a distance between 0.4 km and 25 km at wind speeds of 8 to 13 ms^{-1}. Operational noise was found not to have any destructive effects upon the hearing ability of fish, even within distances of a few metres and it was estimated that fish would only be consistently scared away from wind turbines at ranges shorter than about 4 m, and only at high wind speeds (higher than 13 ms^{-1}).

146. Vella *et al* (2001) based on operational noise data measurements at the Svante wind farm in Sweden (estimated to peak at 120dB at 16Hz) concluded that noise levels appear to be outside the behavioural reaction sensitivities of most species for which data was available, however noted that some effect could be apparent in species such as cod. Cod and other gadoids, such as haddock are known to be able to produce low frequency sounds during spawning (Hawkins and Chapman, 1966; Hawkins and Rasmussen, 1978; Nordeiede and Kjellsby, 1999; Fudge and Rose, 2009). Hawkins and Amorim (2000) suggest that the sound produced by haddock serves to bring male and female fish together and that the sound also plays a role in synchronising the reproductive behaviour of the male and the female. Similarly, Brawn (1961) suggests that sounds produced by cod are used to attract females during spawning. Studies undertaken by Westerberg (1994) found the catchability of cod (*Gadus morhua*) and roach (*Rutilus rutilus*) increased by a factor of two within 100 m of a wind turbines when the rotor was stopped under otherwise similar conditions and did not find significant changes in the swimming behaviour of European eel when passing at a distance of 0.5 km from a small (200 kW single-unit) offshore wind turbine.

147. Post construction monitoring of hard bottom communities at Horns Rev (Leonhard and Pedersen, 2005) found based on comparisons with fish fauna on shipwrecks in other parts of the North Sea that there was great similarity in the species observed including benthic species and pointed out that there was no indication that noise or vibrations from the turbines generators had any effects on the fish community. In line with this, as previously described in Section 11.4.2.2 above, post construction monitoring undertaken in operational wind farms do not suggest that major changes in the distribution and abundance of fish and shellfish species have occurred, hence if operational noise is having any effect this is expected to be very limited.

148. Based on the above it is considered that operational noise will result in a negative, minor and unlikely effect on fish and shellfish species in general. In the case of spawning cod and haddock, assuming operational noise interferes with mating calls during the spawning period, given the location of spawning grounds relative to the Wind Farm and the localised effect of the potential effect of operational noise

(limited to the Wind Farm and its vicinity), the effect is considered to be negative, minor and unlikely.

149. Taking the assessment above, it is considered that operational noise will result in a negative minor and unlikely effect on the SAC populations of Atlantic salmon, sea lamprey and freshwater pearl mussel requiring assessment (see Table 11.8).

11.4.2.5 Changes to Fishing Activity

150. Changes to fishing activity as a result of the installation of the Wind Farm could potentially affect fish and shellfish species. Primarily this would be species commercially targeted and/or caught as by-catch, although a wider range of organisms may also be affected due to changes in seabed communities associated to seabed disturbance. Scallop dredging is the principal fishing method used in the Wind Farm. Physical disturbance to habitat arising from the passage of fishing gear over the seabed occurs in a number of ways (Kaiser *et al*, 2003).

- Disturbance to upper layers of the sea bed causing short-term re-suspension of sediment, re-mineralisation of nutrients and contaminants, and re-sorting of sediment particles;
- Direct removal, damage, displacement or death of a proportion of the animals and plants living in or on the seabed;
- A short term attraction of carrion consumers into the path of the fishing gear; and
- The alteration of habitat structure.

151. A reduction in fishing activity in the Wind Farm may have some benefits to seabed communities although the potential displacement of fishing into other areas should be noted. This could in turn benefit fish and shellfish species, provided the productivity of the area increased. In addition, target and by-catch species would be positively affected through a direct decrease in fishing mortality on a site specific basis.

152. The area of the Wind Farm is considered of relatively low importance as a fishing ground in comparison to other areas in the Moray Firth and the wider area. The commercial fisheries assessment (see Section 16: Wind Farm Commercial Fisheries) concluded that the complete loss or restricted access to traditional fishing grounds associated to the operational phase of the Wind Farm will be of minor significance, as fishing is likely to be able to continue in the Wind Farm during the operational phase, although it may be reduced to some extent. Given the relatively lower importance and degree of exploitation of the fisheries within the Wind Farm, the effect of a reduction in fishing activity is considered of negligible magnitude. Scallops, being the species primarily targeted in the site are considered receptors of high sensitivity, whilst other fish and shellfish species occurring in the area are considered receptors of low/medium sensitivity. The effect of changes to fishing activity on fish and shellfish species (including scallops) is therefore assessed to be negligible and probable.

153. Taking the above into consideration, the effect on relevant SAC populations of Atlantic salmon, sea lamprey and freshwater pearl mussel derived from changes to

fishing activity during operation, is expected to be negligible and probable (Table 11.8).

11.5 MITIGATION MEASURES AND RESIDUAL EFFECTS

11.5.1 CONSTRUCTION/DECOMMISSIONING

154. There are currently no mitigation measures proposed to reduce effects associated to the construction/decommissioning phase of the Wind Farm on fish and shellfish ecology.

11.5.2 OPERATION

155. No mitigation measures other than inter-array cable burial/protection, where feasible, are proposed to reduce the effects associated to the operational phase of the Wind Farm on fish and shellfish ecology.

11.5.3 RESIDUAL EFFECTS

11.5.3.1 Construction/Decommissioning

156. Residual effects are as described in Section 11.4.1.

11.5.3.2 Operation

157. Residual effects are as described in the predicted effects Section 11.4.2.

11.6 MONITORING AND ENHANCEMENT

158. BOWL will work with key stakeholders and Marine Scotland to identify any future monitoring programmes considered necessary.

11.7 SUMMARY OF EFFECTS

159. The effects on the fish and shellfish ecology, expected as a result of the construction/decommissioning and operational phases of the Wind Farm are summarised in Table 11.20.

Table 11.20 Summary of Effects on Fish and Shellfish Ecology

Effect	Receptor	Sensitivity of Receptor	Magnitude of Effect	Nature	Assessment of Effect	Probability	Significant Effect (Y/N)
Increased SSC and sediment re-deposition	Shellfish	Low	Small	-	Negligible	Probable	N
	Eggs and larvae	Medium	Small	Negative	Minor	Probable	N
	Herring and sandeels	Medium	Small	Negative	Minor	Probable	N
	Adult and juvenile fish (including diadromous migratory species)	Low	Small	-	Negligible	Probable	N
Construction Noise[9]	Plaice	Low	Small	-	Negligible	Probable	N
	Salmon and sea trout	Medium	Small	Negative	Minor	Probable	N
	Cod	Low/Medium	Medium	Negative	Moderate	Unlikely	Y
	Whiting	Low	Medium	Negative	Minor	Probable	N
	Herring	Low/Medium	Medium	Negative	Moderate	Unlikely	Y
	Larvae and life stages of limited mobility (e g glass eels)	Medium	Small	Negative	Minor	Probable	N
	Shellfish	Low	Small	-	Negligible	Probable	N
Loss of habitat	General (Fish and Shellfish)	Low	Negligible	-	Negligible	Probable	N
	Herring	Medium	Negligible	-	Negligible	Probable	N
	Sandeels	High	Negligible	Negative	Negligible	Probable	N
Introduction of new habitat	General (Fish and Shellfish)	-	-	Negative/Positive	Minor	Probable	N
	Edible crab	-	-	Positive	Minor	Probable	N
EMFs	Elasmobranchs	Medium	Small	Negative	Minor	Probable	N

[9] In addition to the species, species groups and life stages listed, the potential effect of construction noise was assessed for a number of fish species not modelled and without defined surrogates, including sandeels, elasmobranchs, river and sea lamprey, anglerfish, haddock, European eel and sprat. The effect of construction noise on these was assessed to be negligible or negative minor, depending on the species under consideration. An exception to this was the European eel, for which a negative moderate effect was predicted (Table 11.15). Given the limitations and qualitative nature of the noise assessment carried out for these species, probabilities were not assigned to the predicted significance of the effect, and they are not included in the table.

Effect	Receptor	Sensitivity of Receptor	Magnitude of Effect	Nature	Assessment of Effect	Probability	Significant Effect (Y/N)
	River and sea lamprey	Medium	Small	Negative	Minor	Unlikely	N
	European eel	Medium	Small	Negative	Minor	Probable	N
	Salmon and sea trout	Medium	Small	Negative	Minor	Probable	N
	Other fish species	Low	Small	-	Negligible	Probable	N
	Shellfish species	Low	Small	Negative	Negligible	Probable	N
Operational Noise	General	-	-	Negative	Minor	Unlikely	N
	Cod, haddock (spawning)	-	-	Negative	Minor	Unlikely	N
Changes to Fishing Activity	General (Fish and Shellfish)	Low/Medium	Negligible	-	Negligible	Probable	N
	Scallops	High	Negligible	-	Negligible	Probable	N

11.8 ASSESSMENT OF CUMULATIVE EFFECTS

11.8.1 INTRODUCTION

160. Given below is the assessment of cumulative effects upon fish and shellfish ecology arising from the Wind Farm in conjunction with other existing or foreseeable planned marine project/development activities.

161. CIADD (MFOWDG, 2011) was produced sets out the developments to be considered and the assessment method for each technical assessment and is the basis of this assessment. The CIADD is presented in Annex 5B.

11.8.2 SCOPE OF ASSESSMENT

162. The scope and method of this assessment was previously described in the CIADD (MFOWDG, 2011). This remains unchanged from the method presented in the CIADD (Annex 5B).

163. The assessment of cumulative effects has been made against the existing baseline conditions as presented in Section 11.3 for the Wind Farm and in Annex 11A: Fish and Shellfish Ecology Technical Report and Annex 16B: Salmon and Sea Trout Ecology and Fisheries Technical Report.

164. It should be noted, that for the purposes of this assessment given the numerous uncertainties in relation to final engineering design and construction schedules of the developments included for assessment, the probability for cumulative effects to occur has not been described. Cumulative effects have been defined based on their nature (negative or positive) and its potential significance (negligible, minor, moderate or major). The significance assigned to the potential cumulative effects in this assessment therefore provides an indication of likely significant effects, although does not attempt to quantify effects.

11.8.3 GEOGRAPHICAL SCOPE

165. As presented in the CIADD the geographical scope of the study area for the cumulative assessment is focused in the Moray Firth area. It is however recognised that some mobile species may spend varying periods of time outside the Moray Firth and, as a result, there is potential for these to be affected by other activities/developments further afield. This is most obvious in the case of diadromous migratory species, particularly salmon (and to a lesser extent sea trout). The developments/activities considered for assessment are detailed below.

11.8.4 DEVELOPMENTS CONSIDERED IN ASSESSMENT

166. The following developments have been considered for assessment of cumulative effects on fish and shellfish ecology.

- OfTW;
- Moray Firth Round 3 Zone: Eastern Development area and Western Development area;
- Moray Firth Round 3 Zone OfTW cable;
- Proposed SHETL cable and offshore hub;
- Any relevant port and harbour developments in the Moray Firth;

- Relevant oil and gas activities;
- Dredging and sea disposal in the Moray Firth;
- Commercial fisheries;
- Marine energy development in the Pentland Firth and Orkney waters; and
- Relevant military activities

167. For the purposes of the assessment of cumulative effects on salmon and sea trout, in addition to the above, the following proposed offshore wind farms in the East coast of Scotland have also been considered:

- Neart Na Gaoithe (Scottish Territorial Waters);
- Inch Cape (STW);
- Aberdeen Bay Offshore Wind Farm; and
- Firth of Forth R3 Zone.

168. It should be noted that there are not currently any aggregate dredging areas in the Moray Firth. Similarly, there are no port and harbour developments planned to be undertaken in coastal areas in the vicinity of the Wind Farm. Cumulative effects in relation to dredging and disposal and port and harbour development in the Moray Firth are not considered further in the cumulative assessment.

169. The assessment is primarily focused on the Wind Farm, in conjunction with the proposed Moray Firth Round 3 Zone as a result of their proximity. A summary of the worst case parameters of wind farm design for the Moray Firth Round 3 Zone in terms of fish and shellfish ecology is given below. The worst case parameters for the Wind Farm are as provided above.

170. It should be noted, that although it is assumed that the entire Wind Farm Site will be developed (131.5 km^2), it is at this stage uncertain what percentage of the Moray Firth Round 3 Zone will be developed.

171. The worst cases for the Moray Firth Round 3 Development Zone based on available engineering parameters as provided in the Rochdale Envelope are given below.

- In general terms the installation of the maximum number of turbines (420) is considered to constitute the worst case;
- For construction noise the use of 3 m diameter pin piles is taken as worst case as this would result in the highest associated noise levels and the use of up to six construction vessels simultaneously;
- In terms of loss of habitat the worst case scenario takes account of the combination that results in the maximum area of seabed permanently lost based on the following: 145 x 3.6 MW machines (seabed footprint including scour protection of 11,690 m^2 each) and 275 x 5 MW machines (seabed footprint including scour protection of 16,286 m^2 each) across the eastern and western areas. This equates to around 1.18% of the proposed Moray Firth Round 3 Zone development area. In addition, for cable installation it is assumed that 50% of the inter-array cable (maximum total length 482 km) is buried and that 50% requires mattresses or rock dumping that is 3 m wide, taking the total anticipated worst case losses from foundations and inter-array cable protection

to approximately 6.6 km² (1.3% of the proposed Moray Firth Round 3 Development Zone); and

- For assessment of EMFs the use of the maximum length of inter-array cable (482 km) has been assumed worst case.

Table 11.21 Summary of Worst Case Scenario for the Moray Firth Round 3 Zone

Potential Effect	Wind Farm Design Parameters	Worst Case
Construction/Decommissioning		
Increase in suspended sediment concentrations and sediment re-deposition	Foundation type Max no of turbines Max length of inter-array cable buried	Gravity bases 420 482 km
Noise	Max no of turbines Max no of simultaneous piling events Max pile diameter	420 6 Piling of 3 m diameter pin piles (4 piles per foundation)
Operation		
Loss of habitat and introduction of new habitat	Foundation type Max no of turbines Length of inter-array cabling	Gravity bases 420 (145 x 3.6 MW and 275 x 5 MW) 50% of inter-array cable length is protected by matressing/rock dumping
Operational Noise	Max no of turbines	420
EMFs	Max length of inter-array cabling Cable post installation status	482 km Buried/protected where feasible
Changes to Fishing Activity	Max number of turbines	420

11.8.5 PREDICTED EFFECTS

11.8.5.1 Increased SSCs and sediment re-deposition

172. The release of sediment into the water column as a result of construction works being carried out simultaneously in adjacent areas may cumulatively affect fish and shellfish species. The potential cumulative effect of multiple and simultaneous sources of sediment release is detailed in Section 9: Wind Farm Physical Processes and Geomorphology. This takes account of the following:

- BOWL and Moray Firth Round 3 Zone foundation installation (drilling for pin piles or bed preparation for gravity foundations);
- BOWL and Moray Firth Round 3 Zone inter-array cable burial;
- BOWL and Moray Firth Round 3 Zone OfTW cable burial; and
- SHETL cable burial.

173. The cumulative result of interaction between sediment plumes is and additive increase in SSC. As indicated in Section 9: Wind Farm Physical Processes and Geomorphology, the cumulative effects of plume interaction from a variety of sources are of a magnitude consistent with the natural range of variability. Local effects around cable burial machines may be potentially in excess of the natural

range of variability but will also be only localised and temporary. Taking this into account, and the potential for fish and shellfish species to be disturbed consecutively at different locations in the Moray Firth area, the cumulative effect derived from increased suspended sediment concentrations and sediment re-deposition on fish and shellfish species is assessed to be negative and minor, including the SAC populations of Atlantic salmon, sea lamprey and freshwater pearl mussel requiring assessment.

11.8.5.2 Construction Noise

174. As indicated above in the assessment of construction noise for the Wind Farm itself, impact piling for installation of foundations is considered the construction related activity with greatest potential to result in a detrimental effect on fish and shellfish species. As assessed in Section 23 for the OfTW, the noise levels associated to cable installation related activities are considered comparatively low and therefore the contribution of the OfTW to a potential cumulative effect very small. In line with this, the contribution of the installation of the Moray Firth Round 3 Zone inter-array and export cables and the SHETL cable to a potential cumulative effect is considered to be comparatively very small.

175. This assessment is therefore focused on the effect of piling activity taking place in the Wind Farm and in Moray Firth Round 3 Zone simultaneously. It is recognised, however, that there is also potential for fish and shellfish species to be exposed to noise resulting from the installation of oil and gas infrastructure (e.g. foundation installation, etc), installation of the SHETL cable offshore hub, and the undertaking of military activities in the Moray Firth. The contribution of these activities to the potential cumulative effect is however expected to be comparatively small, taking the likely shorter duration of construction periods/noise disturbance, associated to these developments/activities.

176. In order to help this assessment, worst case noise effect ranges for cumulative scenarios at the Wind Farm and the Moray Firth Round 3 Zone were modelled for herring, cod, salmon and dab. The outputs of this are provided in the Annex 7A: Underwater Noise Modelling Technical Report where noise contours at the $90d_{Bht}$ and $75d_{Bht}$ *(Species)* are shown for each species. As a result of the different number of simultaneous piling operations proposed for the two developments (two at the Wind Farm and six in the MORL Round 3 Zone), the contribution of the Wind Farm in terms of the overall area affected by noise is expected to be comparatively small.

177. The assessment of cumulative effects is focused on the species for which effects above minor in relation to construction noise were identified in the Wind Farm Site specific assessment (herring, cod and European eel). In addition, given the wider areas affected by piling noise in cumulative terms and the uncertainties in relation to the migratory routes and the use that salmon and sea trout make of the Moray Firth area, the potential cumulative effects of noise on these species has also been considered for assessment.

Herring

178. Simultaneous piling in the Wind Farm and in the Moray Firth Round 3 Zone will result in a wide area being affected by piling noise. The resultant cumulative effect is however not considered to exceed that previously assessed for the Wind Farm itself (negative and moderate), given the location and distribution of herring spawning grounds relative to the location of the Wind Farm and the Moray Firth Round 3 Zone and the outputs of the cumulative noise modelling for herring.

Cod

179. Taking the location of defined spawning grounds of cod relative to the Moray Firth Round 3 Zone and the outputs of the cumulative noise modelling for this species, it is assessed that noise derived from simultaneous piling in the Moray Firth Round 3 Zone and in the Wind Farm will result in a negative and moderate to major effect on cod. As indicated by the noise modelling, the majority of the spawning grounds of cod (i.e. as defined in Coull *et al*, 1998) would be affected at the $90dB_{ht}$ (*Gadus morhua*) level. As mentioned in the Wind Farm Site specific assessment, however, this is based on incomplete knowledge of the current relative importance of the area of the developments as a spawning ground. For a moderate/major effect on cod to occur the distribution of currently active spawning grounds would have to be limited to the Wind Farm Site and the Moray Firth Round 3 Zone and their proximity.

European Eel

180. Taking the cumulative noise modelling carried out for cod, it is considered that the effect of noise will not exceed that previously assessed for European eel during construction of the Wind Farm itself (negative and moderate). The limitations and likely conservative nature of the approach taken for assessment of the effects of noise on European eel (as indicated in assessment of construction noise for the Wind Farm itself) (Section 11.4.1.2, paragraphs 81-83) should however be recognised.

Salmon and Sea Trout

181. Taking the location of the developments, the outputs of the cumulative noise modelling for salmon and the uncertainties in relation to the migratory routes and the use that salmon and sea trout make of coastal areas around Scotland, noise has been assessed to result in a negative and moderate cumulative effect on salmon and sea trout. This takes account of the outputs of the noise modelling undertaken and the potential for salmon and sea trout to also be affected by construction noise generated in other wind farm developments in the Firth of Forth and in the Aberdeen Bay area at a later or earlier stage during migration.

182. Based on the above, it is considered that there is potential for a negative moderate cumulative effect related to construction noise to occur on the SAC populations of Atlantic salmon, and freshwater pearl mussel (indirectly associated to the effects on salmon and sea trout) requiring assessment. This is however based on incomplete knowledge of the migratory routes taken by salmon originating in these SACs and

of construction schedules and engineering design parameters to be used in other offshore wind farms considered in this assessment, particularly those located in the Firth of Forth area.

11.8.5.3 Loss of Habitat

183. The assessment of the cumulative effect of loss of habitat has been focused on the Wind Farm and the Moray Firth Round 3 Zone. Whilst it is recognised that other marine developments in the Moray Firth (e.g. Oil and gas, SHETL cable and offshore hub), could further contribute to habitat loss, this would be very small from a cumulative point of view.

184. The permanent loss of habitat resulting from the worst case defined for the Moray Firth Round 3 Zone (approx. 6.6 km^2 including both the EDA and WDA) would account for approximately 1.3% of the total area of the Moray Firth Round 3 Zone. Given the comparatively wide distribution range of fish and shellfish species and the small expected loss of habitat, the significance of the potential cumulative effect is not considered to exceed that previously assessed for the Wind Farm itself (negligible).

185. In the particular case of sandeels, however, the introduction of foundations and cable protection material in the MORL Round 3 Zone, may significantly add to the loss of habitat incurred by the Wind Farm itself. The significance of this effect will depend on the location of high density sandeel patches and the degree of overlap between these and wind farm infrastructure. Taking the uncertainties in relation to the distribution of sandeels in both the Wind Farm and MORL Round 3 Area, it is considered that a negative moderate cumulative effect on sandeels could occur if infrastructure is located consistently on areas of high density sandeel patches.

186. Based on the assessment above, the cumulative effect of loss of habitat on the SAC populations of Atlantic salmon, sea lamprey and freshwater pearl mussel requiring assessment (Table 11.8) is considered to be negligible.

11.8.5.4 Introduction of New Habitat, EMFs and Operational Noise

187. The adjacent location of the MORL Round 3 Zone and the Wind Farm will result in an increase in the spatial range of the effects derived from the introduction of new habitat, EMFs and operational noise. Given the comparatively small area of the Wind Farm, however, it is expected that its contribution to a cumulative effect will be comparatively small.

188. The results of post-construction monitoring undertaken in operational wind farms do not suggest that introduction of new habitat, EMFs and operational noise have had a significant detrimental effect on fish and shellfish species.

189. EMFs associated to the SHETL cable during operation, may cumulatively add to the effects incurred by the inter-array cables of the Wind Farm, the OfTW, inter- array cables in the Moray Firth Round 3 Zone and the Moray Firth Round 3 Zone OfTW, on sensitive species.

190. It is not considered that the effect of introduction of new habitat, EMFs and operational noise will exceed that previously assessed for the Wind Farm itself

(negative and minor). The combined larger sea area affected by these potential effects, taking into account the combined size of the Wind Farm and the Moray Firth Round 3 Zone, in relation to the developments in which monitoring programmes have been undertaken to date (see Section 11.4.2.2, 11.4.2.3 and 11.4.2.4) should however be noted.

191. Taking the above assessment into account, it is not considered that the cumulative effect associated to the introduction of new habitat, EMFs and operational noise on the SAC populations of Atlantic salmon, sea lamprey and freshwater pearl mussel requiring assessment (Table 11.8) will exceed that assessed for the Wind Farm itself (negative and minor).

11.8.5.5 Changes to Fishing Activity

192. As indicated in Section 16: Wind Farm Commercial Fisheries, commercial fishing could potentially be reduced in the Wind Farm and the Moray Firth Round 3 Zone during the operational phase.

193. The potential for changes to fishing activity to result in a cumulative effect on fish and shellfish species will depend on the level of fishing activity sustained in the area during the operational phase of the wind farms. A decrease in fishing effort or a change in the fishing methods or practices used within the sites may result in changes to the seabed community which may in turn have an effect on fish and shellfish species. In addition, species commercially targeted in the area and those caught as by-catch may benefit from a decrease in direct fishing mortality if fishing activity is reduced.

194. The potential for fishing effort to be displaced into other areas within the Moray Firth or further afield, should however be noted. In the particular case of scallop dredging, the Moray Firth Round 3 Zone, is of relative importance at the regional level, whilst the area of the Wind Farm sustains lower levels of scallop dredging activity.

195. Based on the above, it is considered that, the cumulative effect of changes to fishing activity on fish and shellfish ecology, although may result in a beneficial effect on a site specific basis, will not exceed that previously assessed for the Wind Farm itself (negligible).

196. In light of the above, the cumulative effect on SAC populations of Atlantic salmon, sea lamprey and freshwater pearl mussel requiring assessment (Table 11.8) is not considered to exceed that previously assessed for the Wind Farm itself (negligible).

11.8.6 SUMMARY OF CUMULATIVE EFFECTS

197. A summary of the assessment of cumulative effects is provided in Table 11.22 below.

Table 11.22 Summary of the Assessment of Cumulative Effects

Effect	Receptor	Nature	Assessment of Cumulative Effect	Significant Effect (Y/N)
Increased SSC and sediment re-deposition	All (General)	Negative	Minor	N
Construction Noise	Herring	Negative	Moderate	Y
	Cod	Negative	Moderate/Major	Y
	European eel	Negative	Moderate	Y
	Salmon and sea trout	Negative	Moderate	Y
Loss of habitat	All (General)	-	Negligible	N
	Sandeels	Negative	Moderate	Y
Introduction of new habitat	General (All)	Negative/Positive	Minor	N
EMFs	All (General)	Negative	Minor	N
Operational Noise	General	Negative	Minor	N
Changes to Fishing Activity	All (General)	-	Negligible	N

11.9 HABITATS REGULATIONS APPRAISAL

198. As outlined in section 11.2.2, in addition to the assessment of sensitive receptors to the proposed Wind Farm in relation to the requirements for EIA, a Habitats Regulations Appraisal (HRA) has also been conducted. A Report to Inform an Appropriate Assessment has been prepared in relation to the designated sites set out in Table 11.8.

199. The requirements of the HRA are focussed on the qualifying features of European designated sites of conservation importance (often referred to as Natura 2000 sites). Where a proposed development could affect an SAC, there is a requirement for the Competent Authority to determine whether the proposal will have a Likely Significant Effect (LSE) on the conservation objectives, and if so, to make an Appropriate Assessment of the implications of the proposal on these. It should be noted that this is distinct from the determination of significant effects under the EIA Regulations.

200. The Likely Significant Effects on features of the European designated sites are summarised in Table 11.23. This table highlights those effects that will be carried forward for further assessment under the Habitat Regulations (to be presented in a Report to Inform and Appropriate Assessment).

Table 11.23 Screening matrix for the Report to Inform the Appropriate Assessment

<table>
<tr><th>Designated Site and Qualifying Feature</th><th>Conservation Objectives</th><th>Potential Impacts and Effects</th><th>Proposed Generic Mitigation Measures</th><th>Likely Significant Effects Alone</th><th>Likely Significant Effects in Combination</th></tr>
<tr><td>Berriedale and Langwell Waters SAC
Atlantic salmon</td><td rowspan="6">To avoid deterioration of the habitats of the qualifying species or significant disturbance to the qualifying species, thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to achieving favourable conservation status for each of the qualifying features; and
To ensure for the qualifying species that the following are maintained in the long term:
-Population of the species, including range of genetic types for salmon, as a viable component of the site
- Distribution of the species within site
- Distribution and extent of habitats supporting the species
- Structure, function and supporting processes of habitats supporting the species
- No significant disturbance of the species
- Distribution and viability of freshwater pearl mussel host species
-Structure, function and supporting processes of habitats supporting freshwater pearl mussel host species</td><td rowspan="6">Disturbance associated to increased SSC
Disturbance associated to noise during construction
Loss of habitat and introduction of new habitat
Disturbance associated to EMFs
Disturbance associated to Operational Noise
Indirect effects associated to changes to fishing activity</td><td rowspan="6">Use of soft start piling to avoid exposure to the highest noise levels
Cables will be buried/protected where feasible</td><td rowspan="6">No likely significant effect</td><td rowspan="6">Likely significant effect</td></tr>
<tr><td>River Evelix SAC
Freshwater pearl mussel</td></tr>
<tr><td>River Moriston SAC
Freshwater pearl mussel
Atlantic salmon</td></tr>
<tr><td>River Oykel SAC
Freshwater pearl mussel
Atlantic salmon</td></tr>
<tr><td>River Spey SAC
Freshwater pearl mussel
Atlantic salmon
Sea lamprey</td></tr>
<tr><td>River Thurso SAC
Atlantic salmon</td></tr>
</table>

11.10 STATEMENT OF SIGNIFICANCE

201. The construction/decommissioning and operational phase of the Wind Farm will in general terms not result in significant effects in relation to EIA regulations.

202. An exception to this is the effect of construction noise on cod, herring, and European eel, for which the assessment has concluded that a moderate and therefore significant effect may occur. It should be noted, however, that in the case of herring and cod the probability of a moderate effect to occur has been considered to be unlikely. In the case of European eel, the limitations and likely conservative nature of the noise assessment, which has been based on the outputs of the noise modelling for cod, should be recognised.

203. Similarly, the predicted cumulative effects of the Wind Farm with other marine installations/activities are in general terms considered not significant in relation to EIA regulations. However, as indicated for the Wind Farm project itself, a number of exceptions apply. As indicated in Table 11.22, cumulative effects in relation to construction noise which are significant in terms of the EIA Regulations, have been assessed for cod, herring, European eel, salmon and sea trout. This takes account of the worst case scenario for the Wind Farm and MORL Round 3 Area, which assumes that eight piling operations are taking place simultaneously. In addition, in the case of salmon and sea trout, it has been assumed that there is potential for the fish to be affected by piling operations taking place in the Aberdeen Bay and the Firth of Forth.

204. Further to the above, a potential moderate cumulative effect on sandeels associated to loss of habitat, has been identified. This has taken a conservative approach based on the lack of site specific information on the distribution and relative importance of the Wind Farm and the MORL Round 3 Zone as a sandeel habitat, in the context of the wider Moray Firth.

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