Chapter 15 Fish and Shellfish Ecology

15.1 Introduction

1 This chapter describes the fish and shellfish ecology within and around the vicinity of the proposed Neart na Gaoithe offshore wind farm site. To quantify spatial and temporal variation, fish populations are described both at the local level and at the wider regional (North Sea) level in order to provide context to the baseline.

2 Key stages in the life cycle of both commercial and non-commercial species, such as spawning and the juvenile nursery stages, are given particular prominence. By characterising the existing environment the potential ecological impacts arising from the development can be identified and assessed. Where potential impacts are considered to interact with species of conservation concern, these impacts are discussed with regard to Habitats Regulation Appraisal (HRA) and information is presented to inform an Appropriate Assessment (AA) (for more detail refer to Chapter 11: Nature Conservation).

3 Species of commercial and conservation importance are also discussed in Chapter 16: Commercial Fisheries and Chapter 11: Nature Conservation respectively.

15.2 Guidance and Legislation

4 The relevant legislative frameworks pertaining to fish and shellfish species are common to high level policies concerning ecology and nature conservation and are discussed in Chapter 11: Nature Conservation.

5 The following publications provided specific guidance in the preparation of this chapter:

- Developing guidance on fisheries cumulative impact assessment for wind farm developers (Blythe-Skyrme, 2010);
- European Union (EU) guidance on wind energy development in accordance with the EU nature legislation (EU, 2010);
- OSPAR guidance on environmental considerations for offshore wind farm development (OSPAR, 2008);
- Nature Conservation guidance on the implications of HRA to offshore windfarm development (Defra, 2005);
- Best practice guidelines for the Irish Wind Energy Industry (IWEA) (IWEA, 2008);
- International Union for Conservation of Nature (IUCN) report on offshore development and the risks to biodiversity (Wilhelmsson *et al*., 2010);
- Scottish Natural Heritage (SNH) guidance on HRA (Tyldesley and Associates, 2010);
- Institute for Ecology and Environmental Management (IEEM) ecological impact assessment guidelines (IEEM, 2010); and
- Firth and Tay Offshore Wind Developers Group (FTOWDG) discussion documents (see Appendix 6.2: Scottish Territorial Waters Offshore Wind Farms – East Coast – Discussion Document – Cumulative Effects and Appendix 6.3: Scottish Offshore Wind Farms – East Coast – Discussion Document – Approach to Cumulative Effects Assessment).

15.3 Literature and Data Sources

15.3.1 Literature Search and Data Review

6 A detailed review was undertaken of the currently available literature and used to give an overview of the general ecology of fish and shellfish species known to occur within the wider North Sea region of the Neart na Gaoithe development. The major data sources reviewed are summarised in Table 15.1.

Source	Area of research
Centre for Environmental, Fisheries and Aquaculture Science (Cefas)	Fish and shellfish nursery and spawning grounds; Fish migration; and Fish and shellfish ecology and biology.
The Joint Nature Conservation Committee (JNCC)	Overview of Region 4 Southeast Scotland: Montrose to Eyemouth.
Collaborative Offshore Wind Research Into the Environment (COWRIE)	Environmental impacts of noise and electromagnetic fields and mitigation measures.
Marine Scotland	Site specific data on sandeel, cod and scallops.
IUCN	Biodiversity risks and opportunities of offshore renewable energy; and Migratory fish ecology and biology.
Environment Agency (EA)	Fish biology and ecology.
OSPAR	Impact guidance and legislation; and Fish biology and ecology.
Department of Business, Enterprise and Regulatory Reform (BERR) (now Department for Business, Innovation and Skills (BIS))	Artificial reef effects and mitigations; and Cable installation techniques, impacts and mitigation.
Other	Journals, PhD theses, white papers, research articles.

Table 15.1: Summary of major data sources reviewed

7 Data on species abundance and biology, and on sites of conservation interest relevant to fish species, were also obtained from the websites of the following organisations:

- JNCC;
- SNH;
- Cefas;
- UK Biodiversity Action Plan (UKBAP);
- Scottish Environmental Protection Agency (SEPA);
- UK Marine Life Information Network (MarLIN);
- International Council for the Exploration of the Sea (ICES); and
- National Lobster Hatchery (NLH).

8 In addition, data on specific species distributions were supplied by Marine Scotland (Marine Scotland, 2011a, *pers. comm.*) and also obtained from Cefas (Ellis *et al.*, 2012) and Coull *et al.* (1998).

15.3.2 Site Specific Surveys

9 In 2009, a benthic survey was carried out over the offshore site and export cable route. The periphery of the proposed development area was considered within the predicted maximum tidal excursion over a single spring tide occasion (based on Admiralty tidal diamond data Chart 1407). Fish and shellfish resources were sampled using a scientific beam trawl to provide a primary description of the site specific communities, within and peripheral to the offshore works area (refer to Appendix 14.1: Benthic Ecology Characterisation Survey for further information). Figure 15.1 illustrates the locations of the beam trawls.

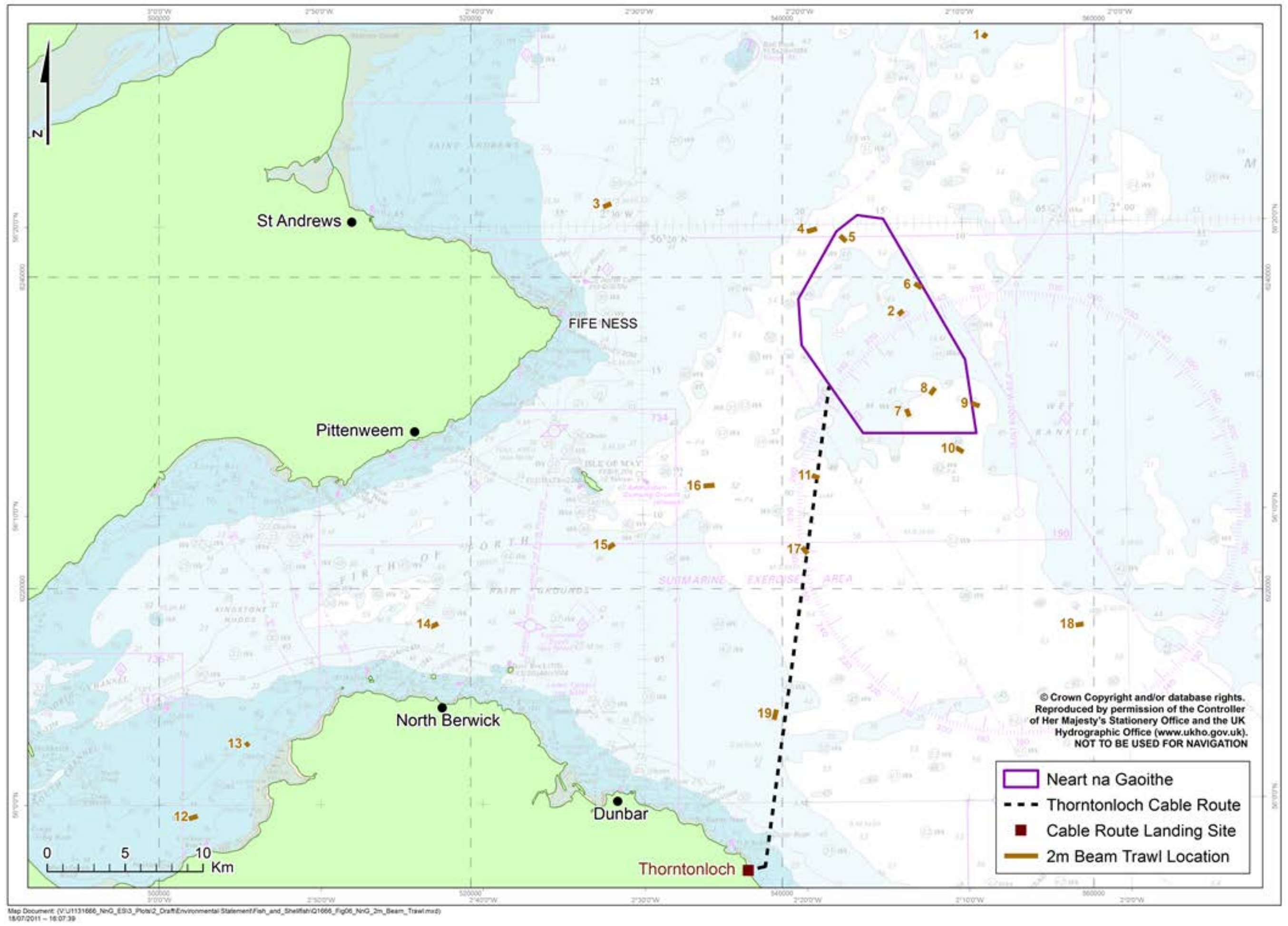


Figure 15.1: Survey locations for scientific beam trawl (see Appendix 14.1: Benthic Ecology Characterisation Survey for further information)

15.4 Engagement and Commitments

15.4.1 Strategic and Site Level Requirements

10 A series of commitments has been made on behalf of the developer. These commitments are both at the strategic and site specific levels and are outlined in Table 15.2, including details of where they are considered within this chapter.

15.4.2 Consultation

11 In addition to requirements outlined above, specific consultation has been undertaken with regulators and wider stakeholders. Consultation with SNH and commercial fishing representatives identified specific species to be assessed within this chapter.

12 The Scottish Government collated advice and recommendations on issues considered essential to be assessed in the Environmental Impact Assessment (EIA) process. Consultees responding to this consultation included:

- Marine Scotland;
- Association of Salmon Fisheries Board (ASFB);
- Fisheries Research Services (FRS);
- Inshore Fisheries Management Groups;
- Scottish Fisherman's Federation (SFF); and
- Scottish Natural Heritage (SNH).

13 Details on this consultation can be seen in Chapter 16: Commercial Fisheries, and Chapter 11: Nature Conservation.

Source	Comment	Relevance/reference
Blue Seas - Green Energy: A Sectoral Marine Plan for Offshore Wind Energy in Scottish Territorial Waters. Part A: The Plan (Marine Scotland, 2011b)	Specific impacts on species and habitats (including fisheries) should be reduced through appropriate design, and selection and use of appropriate construction and operation methods.	See Section 15.7: Impact Assessment
	Any mitigation measures identified as part of future studies on migratory fish should be taken into account.	See Section 15.8: Mitigation Measures
Scoping Opinion (SNH advice)	Assessment of structures and foundations and scour required with reference to fish species assemblages and indirect impacts such as changing the species composition away from important prey species for seabirds.	Section 15.7.2.1: Offshore Site
	Indirect impacts of the reef effects caused by structures, scour etc need assessing, with relationship to species assemblages and prey for birds.	Section 15.7.2.1: Offshore Site
	Suggest squid fishery could be in area. Assessment of this and potential interactions with marine mammals suggested.	Section 15.6.5.1: Key Shellfish Species Found on Site
	Suggest *Nephrops norvegicus*, scallops and bivalves and associated fisheries may be present.	Section 15.6.5: Shellfish Species in the Region
	Commercial survey techniques should be agreed with Marine Scotland Science to ensure they are appropriate.	Noted
	Spawning and nursery grounds are not geographically or temporally fixed. Consult Marine Scotland Science to check data and survey techniques are appropriate.	See Section 15.6: Baseline Description
	If impacts identified to spawning events/nursery grounds in the vicinity of the development site, mitigation should be used to minimise impacts (e.g., Timing of works).	See Section 15.7: Impact Assessment
	Suggest NNG site has minimal impact on spawning/nursery areas provided appropriate steps are taken to minimise impacts. Recommend cumulative and in-combination effects be assessed in region.	See Section 15.9: Cumulative and In-Combination Impact
	Impacts arising through electro-magnetic fields (EMF) need identifying (particularly for elasmobranchs and demersal/pelagic fish with swim bladders).	See Section 15.7.2.2: Export Cable
	Require use of best practise to minimise negative impacts from EMF; burying of cables to minimise negative effects where possible.	See Section 15.9: Cumulative and In-Combination Impact
	Benthos recovery will vary (e.g., depending on turbine layout and hydrodynamics). Suggest excluding mobile fishing gear and combined impact could aid recovery. Suggest exclusion could result in higher commercial stocks in area (including unexploited) and overspill to adjacent areas.	Section 15.8: Mitigation and Residual Impacts
Scoping Opinion (Marine Scotland advice)	Require consideration of prevention and clean-up measures for construction, operation and decommissioning, to address impacts such as increased sediment loading, point source pollution, migration disturbance, spawning disturbance, drainage and water quality issues and contamination. Suggest consultation with the Inshore Fisheries Group (IFG).	Consultation with IFG undertaken; see Section 15.4.2: Consultation
Scoping Opinion (Royal Society for the Protection of Birds (RSPB) comments)	Welcome assessment of hydrodynamic regime and sediment changes with relation to impacts on bird prey (e.g., sandeel, sprat).	Noted
Scoping Opinion (ASFB comments)	Consultation with local District Salmon Fishery Boards (Tay and Forth) required for any impacts on salmon or sea trout.	See Section 15.4.2: Consultation
	Impacts on migratory fish should include assessment of direct effects of noise and vibration, water quality, and EMF and indirect effects of habitat changes and water quality changes.	See Section 15.7.2: Impact Assessment – Operation and Maintenance
Scoping Opinion (FRS comments, now Marine Scotland Science)	Consideration needs to be made of migratory fishes including salmon and sea trout (Rivers Tay and Forth are important rivers for salmon and sea trout; the River Tay is a SAC for salmon, and a migratory route for salmon is potentially in the site). Need to consider EMF, noise and exclusion impacts. Suggest referring to Robin Rigg for information, if any doubt over potential impacts a monitoring programme should be implemented, and consultation with Marine Scotland Science on catch data.	See Section 15.6.2: Pelagic Fish Species, Section 15.6.3: Demersal Species, and Section 15.6.5: Shellfish Species in the Region
Advice to Forth and Tay Offshore Wind Developer Group (SNH)	There is a need to clarify with Marine Scotland whether there are survey requirements to determine cumulative impacts on fish and shellfish, including migratory and freshwater species.	Noted; review on migratory fish route (Malcolm *et al.*, 2010) referred to.
	Consequences of displaced fishing effort on fish and shellfish resources inside and outside the development site should be considered. Assessment ought to consider where fishing effort is likely to be displaced to.	See Section 15.7.2.1: Offshore Site. More details in Chapter 16: Commercial Fisheries
	Cumulative studies should examine potential positive effects of refuge areas for fish and shellfish activity.	See Section 15.7.2.1: Offshore Site
	'Migratory fish' should be defined as it does not just refer to salmonids and eels, as numerous other fish and shellfish species exhibit movements over a variety of ranges.	See Section 15.6: Baseline Description (migration is considered with respect to each species)
	Guidance available: Review of migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: implications for development of marine renewables (Malcolm *et al.*, 2010) – Scottish Government website; literature review on potential effects of EMF and subsea noise on salmon, sea trout and eel (SNH) - SNH website; Fisheries Bioacoustics Manual.	Noted
Comment to Forth and Tay Offshore Wind Developer Group (RSPB)	Impacts on bird prey species including sprat should be considered.	See Section 15.7: Impact Assessment

Table 15.2: Strategic and site level commitments and requirements

15.5 Impact Assessment Methodology

14 The overarching approach to EIA for this Environmental Statement (ES) is described in Chapter 6: The Approach to Environmental Impact Assessment. To support this, the following is a summary of the criteria considered for the ecological impact assessment of fish and shellfish communities.

15.5.1 The Rochdale Envelope

15 As discussed in Chapter 6: The Approach to Environmental Impact Assessment, the worst (realistic) case scenario used in the assessment varies depending on the receptor in question and the projected effect. For example, gravity base foundations are anticipated to result in greater seabed disturbance and increased suspended sediments, due to the increased seabed preparation required compared with jacket foundations. Conversely, the need to use pile driving during the installation of jacket foundations is anticipated to result in a greater level of noise than the installation of gravity bases.

16 The Rochdale Envelope attributes utilised in this chapter take into account the outputs from the coastal process and noise modelling undertaken for this ES. Inputs to the coastal processes modelling are discussed in Chapter 9: Physical Processes, and the noise model is included in Appendix 13.1: Noise Model Technical Report.

17 As described in Chapter 9: Physical Processes, the metocean model assessment was progressed prior to the design criteria of the development being finalised. The modelled parameters are described in more detail in Chapter 9: Coastal Processes and are considered sufficiently conservative to provide a robust assessment of all proposed scenarios (i.e., parameters within the Rochdale Envelope).

18 In light of this, two evaluation scenarios were used in the assessment: one using the project parameters as described in Chapter 5: Project Description; and the second using the metocean model as necessary. It is not the intention of this chapter to further discuss the rationale of the model parameters but rather to explain how the outputs have been applied. The worst (realistic) case scenarios applied in the assessment of benthic impact vary with both the receptor and the perceived effect.

19 The elements of the Rochdale Envelope that would constitute the worst (realistic) case scenarios for fish and shellfish receptors have been identified as follows and are detailed in Table 15.3. It should be noted that since the Rochdale Envelope was defined for assessment, the engineering parameters for scour protection and volume of excavated material has been refined. Consequently, the assessment of these impacts can be considered to be conservative.

- Disruption of habitat in the construction process from the installation of jacket foundations (and associated structures) and inter-array cables;
- Seabed disturbance and suspended sediments arising from the installation of 126 x 6 MW turbines on gravity base foundations (refer to Chapter 9: Physical Processes);
- Increase in underwater noise: modelling study based on the installation of 75 x 6 MW turbines installed on jacket foundations (four piles per turbine) (refer to Appendix 13.1: Noise Model Technical Report);
- Loss of habitat and introduction of artificial substrate during the operational phase arising from the presence of 75 x 6 MW turbines installed on gravity base foundations; and
- Change in electromagnetic fields and water temperature arising from 33 km of export cables and 140 km of inter-array cables.

20 Parameters are based on those illustrated in Chapter 5: Project Description. Where parameters are not defined, values have been taken from published guidance on best practice sizes for anchors and cable barge deployments such as BERR (2008).

Potential effect	Rochdale Envelope parameter	Value		Scenario for fish and shellfish ecology receptors
Construction				
Direct habitat disturbance	**Wind turbine foundations**	Number	125	Direct habitat disturbance from: ● Wind turbine foundation and installation = 0.52 km^2; ● Substation foundation and installation = 0.01 km^2; ● Inter-array cable plough = 1.4 km^2; ● Inter-array cable anchoring = 0.18 km^2; ● Export cables plough = 0.66 km^2; and ● Export cables anchoring = 0.09 km^2.
		Overall type	Jackets	
		Footprint of foundation	250 m^2 including scour protection	
		Method of installation	Jack-up vessels	
		Footprint of jack-up vessel	Eight spud cans of 106 m^2 each	
		Jack-up vessel anchors	Eight anchors	
		Footprint of jack-up vessel anchors	Assumed to be 16.38 m^2 (from BERR, 2008)	
		Placements of jack-up vessel	Five locations per turbine	
	Substation foundations	Number	Two	
		Type	Jackets	
		Installation method	Assumed to be equal to that required per turbine with equal parameters for jack-up vessels	
	Inter-array cables	Length	140 km	
		Installation method	Cable laying vessel and plough	
		Cable laying vessel anchors	Eight (BERR, 2008)	
		Footprint of cable laying vessel anchors	Assumed to be 16.38 m^2 (from BERR, 2008)	
		Cable laying vessel deployments	One per every 100 m (BERR, 2008)	
		Cable laying plough total width on seabed footprint	10 m	
	Export cable	Number	Two	
		Length	33 km each	
		Installation method	Assumed to be equal to that required for the inter-array cables	
Increased suspended sediments concentration sediment deposition and scour	**Wind turbine foundations**	Number	126	Modelled release of up to 5,000 m^3 of sediment from 50 m^3 area around each foundation.
		Overall type	Gravity base	
		Diameter	35 m	
		Seabed preparation dredging depth	2 m	
	Inter-array cables	Length	140 km	
	Export cables	Length	33 km	
	Inter-array and export cables	Trench parameters if buried	1 m wide x 2 m deep	Modelled sediment release of 800 m^3 per hour.

Table 15.3: Rochdale Envelope worst (realistic) case parameters for the fish and shellfish ecology receptors

Potential effect	Rochdale Envelope parameter	Value		Scenario for fish and shellfish ecology receptors
Construction				
Noise and vibration from construction	**Wind turbine foundation piling**	Up to 3 hours and 36 minutes of repeated noise per pile with nine hours noise break between piles. Maximum blow energy of 1,635 kJ for a 3.5 m diameter pile for installation of up to 16 piles (6 MW 4x4 piles) with one strike every two seconds. Soft start procedures are built in as an assumed control prior to drilling and driving. Impact ranges to include zone of injury (130 dB_{ht}), zone of strong avoidance (90 dB_{ht}) and zone of significant avoidance behaviour (75 dB_{ht}) for the following fish species: • Herring *Clupea harengus*; • Salmon *Salmo salar*; • Sea trout *Salmo trutta*; and • Dab *Limanda limanda*.		
Operation and Maintenance				
Direct loss of habitat	**Wind turbine foundations**	Number	75	Direct habitat loss from: • Wind turbine foundations = 0.17 km^2; • Substation foundations = 0.001 km^2; • Inter-array cable scour protection = 0.14 km^2; and • Export cables scour protection = 0.05 km^2.
		Overall type	Gravity base	
		Footprint of foundation	1600 m^2 plus 8 m additional beyond diameter for scour protection	
	Substation foundations	Number	Two	
		Overall type	Jackets	
		Footprint of foundation	Four x 3.5 m diameter piles	
	Inter-array cables	Length	140 km	
		Post-installation status	Protected for 20% length, otherwise buried	
		Width of scour protection (BERR, 2008)	5 m	
	Export cable	Number	Two	
		Length	33 km each	
		Post-installation status	Protected for 15% length, otherwise buried	
Change in hydrodynamics	**Wind turbines**	Number	126	Current speeds are predicted to increase by up to 0.02 m/s on the mean spring peak ebb tide and decrease by up to 0.04 m/s on the mean spring peak flood tide. This is against the background current speed of up to 0.6 m/s on both the flooding and ebbing spring tides and up to about 0.4 m/s on both the flooding and ebbing neap tides.
		Overall type	Jacket foundations	
Noise from operation of wind farm	**Wind turbines**	Qualitative assessment based on the operation of 125 turbines.		

Table 15.3: Rochdale Envelope worst (realistic) case parameters for the fish and shellfish ecology receptors (continued)

Potential effect	Rochdale Envelope parameter	Value		Scenario for fish and shellfish ecology receptors
Operation and Maintenance				
Introduction of New Substrate	**Wind turbine foundations**	Number	128	New substrate from: • Gravity base, including turbine tower, gravity base cone and extended scour protection = 0.23 km^2; • Substation foundations = unknown; • Inter-array cable scour protection = 0.14 km^2; and • Export cables scour protection = 0.05 km^2.
		Type	Gravity base	
		Diameter of gravity base	30 m	
		Height of gravity base cone (see Chapter 9: Physical Processes)	34 m	
		Assumed turbine tower distance from top of cone to sea surface	20 m	
		Width of turbine tower	8 m	
		Width of scour protection surrounding gravity base	8 m	
	Substation foundations	Number	Two	
		Type	Jackets	
	Inter-array cables	Length	140 km	
		Post-installation status	Protected for 20% length, otherwise buried	
		Width of scour protection (BERR, 2008)	5 m	
	Export cable	Number	Two	
		Length	33 km each	
		Post installation status	Protected for 15% length, otherwise buried	
EMF	**Inter-array cables**	Length	140 km	Qualitative assessment based on these parameters.
		Post-installation status	Buried in sediment to up depths of up to 1-3 m	
	Export cable	Number	Two	
		Length	33 km each	
		Post installation status	Buried in sediment to depths of up to 2 m	
Temporary direct habitat loss from operation and maintenance vessels	**Wind turbines and foundations**	Number	125 (in a possible 128 locations)	Total temporary direct habitat disturbance is 0.05 km^2 over 25 years.
		Overall type	Jackets	
		Method of maintenance	Jack-up vessels	
		Footprint of jack-up vessel	Eight spud cans of 106 m^2 each	
		Jack-up vessel anchors	Eight anchors	
		Size of jack-up vessel anchors	16.38 m^2 (BERR, 2008)	
		Operational time	25 years	
		Visits and placements of jack-up vessel	Two uses of jack-up vessel per year	

Table 15.3: Rochdale Envelope worst (realistic) case parameters for the fish and shellfish ecology receptors (continued)

21 Impacts in the decommissioning phase are likely to include temporary habitat disturbance and associated species displacement from the removal of the cable and decommissioning vessel footprints e.g., Jack-up barges and increases in suspended sediment concentration (SSC) and sediment deposition from the cutting and dredging works. The impacts of these activities on subtidal habitats and benthic communities are estimated to be similar to, or less (for example, if cables are left *in situ*), than those occurring as a result of construction, as a result the impacts of decommissioning are not considered further here.

15.5.2 The Approach to Impact Assessment

22 For each fish and shellfish receptor, the potential effects are identified. The potential impact of each effect on fish and shellfish receptors is assessed relative to baseline conditions and natural background variation.

23 Impacts are assessed relative to the phase of development, i.e., those arising in the construction, operation or decommissioning phases and are discussed individually.

24 Impacts are considered to be direct i.e., those arising as a result of an action related in some way to the development and those effects considered to be indirect where a causal link can be established to the consequences of the direct impact (refer to Chapter 6: The Approach to Impact Assessment).

15.5.2.1 Magnitude of Effect

25 The characterisation of the effect magnitude is based on the following four criteria:

- Spatial extent (S): The geographic area of influence where the effect is noticeable against background variability;
- Duration (D): The temporal extent that the effect is noticeable against background variability;
- Frequency (f): How often the effect occurs (important in terms of habitats/species' ability to recover between impacts; and
- Severity (v): The degree of change – toxicity, mass, volume, concentration.

26 The characteristic criteria for magnitude of effect for physical changes in relation to fish and shellfish receptors have been defined using guidelines described in Wilhemsson *et al.* (2010) (refer to Table 15.4).

Characteristic	Categories	Definition/description
Spatial extent (S)	Negligible	Detectable within 10 m from source.
	Low	Detectable within 10-100 m from source.
	Medium	Detectable within 100-1,000 m from source.
	High	Apparent >1,000 m from source.
Duration (D)	Negligible	Intermittent through construction or operation phase.
	Low	Through construction phase.
	Medium	Through operational phase.
	High	Effects persist beyond the operational and decommissioning phases.
Frequency (f)	Negligible	Intermittent through construction or operation phase.
	Low	Through construction phase.
	Medium	Through operational phase.
	High	Effects persist beyond the operational and decommissioning phases.
Severity (v)	Negligible	Should not influence or have very small impacts on size or structure of assemblage.
	Low	Potential to have small impacts on size or structure of assemblage.
	Medium	Impacts could moderately influence species assemblages, generally or for particular species.
	High	Impacts could significantly influence size or structure of species assemblages, generally or for particular species.

Table 15.4: Magnitude of effect parameters in relation to fish and shellfish ecology (modified from Wilhelmsson *et al.*, 2010 to incorporate additional characteristics)

15.5.2.2 Vulnerability of Receptor

27 As defined in Chapter 6: The Approach to Environmental Impact Assessment, the vulnerability is based on the adaptability, tolerance, recoverability and value of the receptor.

28 Criteria to define the overall vulnerability of fish and shellfish receptors are based on guidelines outlined in MarLIN (2011) and illustrated in Table 15.5 below.

Characteristic	Categories	Definition/description
Adaptability (A)	Negligible	The species is very adversely affected by the impact and is not expected to recover. The species population as whole may recover in the long term or not at all.
	Low	The species is adversely affected by the impact and many individuals may die but the population as whole is expected to recover between 10 and 25 years.
	Medium	Some individuals within a population may be adversely affected by the impact and die but the population as whole will not be severely affected and is expected to recover between one and five years.
	High	The species is not likely to be affected by an impact or may be able to develop defensive mechanisms to adapt to the change.
Tolerance (T)	Negligible	The species population is likely to be killed by the impact under consideration.
	Low	Some individuals of the species may be killed by the impact under consideration and the viability of the species population may be reduced.
	Medium	The species population will not be killed by the impact under consideration but the viability of the species may be reduced.
	High	The impact under consideration does not have a detectable effect on the survival or viability of a species individually and as a population.
Recoverability (R)	Negligible	Partial recovery is only likely to occur after 25 years and may not recover fully.
	Low	Only partial recovery is likely within 10 years and full recovery is likely to take up to 25 years.
	Medium	Only partial recovery is likely in five years and full recovery may take up to 10 years.
	High	Full recovery will occur within five years, but it may also occur within months or even days.
Value (V)	Negligible	The species hold no conservation importance, are widespread and play no key role in the ecosystem.
	Low	The species hold regional conservation importance, are widespread and play a key role within the ecosystem.
	Medium	The species hold national conservation value.
	High	The species hold international conservation status.

Table 15.5: Vulnerability of receptor parameters for fish and shellfish ecology (modified from MarLIN, 2011 to incorporate additional characteristics)

15.5.3 Cumulative and In-Combination Impact Assessment Approach

15.5.3.1 In-Combination Impacts

29 In-combination effects are considered to be those arising from interactions with other (non-wind farm) developments or activities. In the case of fish and shellfish ecology, an in-combination impact may occur when a fish or shellfish species may be under pressure from an existing activity such as commercial fishing or port development, in addition to impacts as a result of development of offshore wind farms (refer to Appendix 6.2: Scottish Territorial Waters Offshore Wind Farms – East Coast Discussion Document – Cumulative Effects).

30 Potential cumulative effects may arise from the development of other offshore wind farms in the vicinity of Neart na Gaoithe. Cumulative effects may be:

- Additive through frequency, amount (quantity) or threshold (resilience);
- Secondary; or
- Synergistic (Howell and Holt, 2011).

31 An assessment of in-combination effects has been undertaken by considering and cross referencing relevant aspects between chapters within the ES. This approach allowed a realistic assessment of in-combination effects.

32 In terms of fish and shellfish ecology, the following activities were considered to potentially have an in-combination effect:

- Commercial Fishing (refer to Chapter 16: Commercial Fisheries for more detail); and
- Water Quality (refer to Chapter 8: Geology and Water Quality for more detail).

33 Other potential in-combination impacts, such as aggregate activities or oil and gas installations, have been screened out of the assessment as there are none active in the study area or region. Chapter 22: Other Users provides information on other activities in the region.

15.5.3.2 Schemes Considered

34 Currently there are plans for the development of two further offshore wind farms in the vicinity of Neart na Gaoithe (see Chapter 5: Project Description for further information on these projects), which could result in cumulative impacts on fish and shellfish receptors.

35 Through collaborative work with the FTOWDG, information on other project parameters and site characterisation has been shared and a cumulative Rochdale Envelope derived (see Chapter 5: Project Description for more information).

36 This sharing of information and development parameters has allowed an assessment of a worst (realistic) case scenario on a cumulative basis. The potential cumulative effects arising from the developments of both the Inch Cape and Firth of Forth Round 3 Zone 2 developments include those listed as potential at a site level.

37 The Rochdale Envelope for the Inch Cape and Round 3 Zone 2 (Phases 1, 2 and 3) is detailed in Table 15.6 and describes the effects assessed for potential cumulative impacts. It is important to note that since the assessment was completed the values for the Inch Cape offshore wind farm Rochdale Envelope were refined. As the calculations, particularly for habitat disturbance and habitat loss were derived using the original values it was decided to keep the higher values but also show where the numbers have reduced. As a result, the cumulative impact assessment can be considered to be more conservative than necessary

38 There are further wind farms planned for development around the coast of the UK and further afield. For the purposes of this ES, these are not considered to have a cumulative impact on fish and shellfish species.

<table>
<tr><th>Potential effect</th><th colspan="2">Rochdale Envelope parameter</th><th>Value for Inch Cape</th><th>Value for the Firth of Forth Round 3 Zone 2 Development</th><th>Resulting assessment parameter</th><th>Notes</th></tr>
<tr><td colspan="7">Construction</td></tr>
<tr><td rowspan="13">Direct Habitat Disturbance</td><td rowspan="2">Wind turbine foundations</td><td>Number</td><td>286
(revised down to 213)</td><td>616</td><td rowspan="13">• Turbine foundation disturbance = 8.82 km^2;
• Substation foundation disturbance = 0.32 km^2;
• Met mast foundation disturbance = 0.12 km^2;
• Inter-array cable installation disturbance = 4.2 km^2;
• Export cables installation disturbance = 0. 59 km^2; and
• Total habitat disturbance from construction is therefore 14.04 km^2.</td><td rowspan="13">This calculation is made with the following assumptions:
• Gravity bases are assumed the worst (realistic) case for turbine foundations, using the maximum number of turbines and maximum footprint including scour protection for the Inch Cape offshore wind farm, and using the most likely number of turbines and maximum footprint for the Firth of Forth Round 3 Zone 2 development;
• Met masts and offshore substations are assumed to have the same foundations and numbers as the assumptions for turbines; and
• Inter-array and export cables are assumed to disturb a 3 m corridor. Inter-array cable lengths are assumed to be proportional to those in Neart na Gaoithe (0.31 km/MW site capacity).</td></tr>
<tr><td>Footprint of foundation</td><td>7,300 m^2</td><td>10,923 m^2</td></tr>
<tr><td rowspan="2">Substation foundations</td><td>Number</td><td>5</td><td>2</td></tr>
<tr><td>Footprint of foundation</td><td>45,000 m^2</td><td>45,100 m^2</td></tr>
<tr><td rowspan="2">Met mast foundations</td><td>Number</td><td>3 (revised to 1)</td><td>9</td></tr>
<tr><td>Footprint of foundation</td><td>7,300 m^2</td><td>10,923 m^2</td></tr>
<tr><td rowspan="3">Inter-array cables</td><td>Length</td><td>311,111 m</td><td>1,088,889 m</td></tr>
<tr><td>Installation method</td><td>trench</td><td>trench</td></tr>
<tr><td>Width of trench (disturbance corridor)</td><td>3 m</td><td>3 m</td></tr>
<tr><td rowspan="3">Export cables and interconnectors</td><td>Length</td><td>75 km</td><td>120 km</td></tr>
<tr><td>Installation method</td><td>trench</td><td>trench</td></tr>
<tr><td>Width of trench (disturbance corridor)</td><td>3 m</td><td>3 m</td></tr>
<tr></tr>
<tr><td>Change to SSC, sediment settlement and smothering</td><td colspan="5">• Increase in SSC arising from the installation of 1454 gravity base foundations and up to 939 km of export cables and 2,291 km of inter-array cables (estimates based on the Neart na Gaoithe cable length);
• 126 6 MW gravity base turbine foundations for Neart na Gaoithe (based on complete coverage of the site);
• 328 7- 10 MW gravity base foundation for Inch Cape (based on complete coverage of site);
• 1000 6 MW gravity base foundations for Firth of Forth (based on consented capacity of site);
• Release of up to 5,000 m^3 of sediment per each gravity base foundation (details in Chapter 9: Physical Processes); and
• Release of up to a maximum of 800 m^3 of sediment per hour for cable installation, assuming a typical rate for trenching of 400 m per hour, a trench of 2 m depth and 1 m width and 100% sediment liberation during trenching.</td><td>For assumptions see Chapter 9: Physical Processes</td></tr>
<tr><td>Changes to Underwater Noise</td><td colspan="5">Repeated noise deriving from the concurrent pile driving at the following:
• Neart na Gaoithe = Max blow energy of 1200 kj for 2500 mm diameter pile for installation of 300 piles, each piling event taking 3 hours and 20 minutes to complete and 26.5 hours noise break between piling events;
• Inch Cape = Max blow energy of 1200 kj for 2438 mm diameter pile for installation of 812 piles, each piling event taking 3 hours to complete; and
• Firth of Forth = Max blow energy of 1800 kj for 2400 mm diameter pile for installation of 1000 piles, each piling event taking 2 hours to complete and 3 hours noise break between piling events.
• Soft start and ramp up procedures are built in as an assumed control prior to drilling and driving.
• Impact ranges to include zone of injury defined as decibel hearing threshold (dB_{ht}) (130 dB_{ht}), zone of strong avoidance (90 dB_{ht}) and zone of significant avoidance behaviour (75 dB_{ht}) for the following fish species:
▪ Herring C. harengus;
▪ Salmon S. salar;
▪ Sea trout S. trutta; and
▪ Dab L. limanda.</td><td>For assumptions see Appendix 13.1: Noise Model Technical Report.</td></tr>
</table>

Table 15.6: Cumulative (other developments) Rochdale Envelope worst (realistic) case parameters for fish and shellfish ecology receptors

Potential Effect	Rochdale Envelope parameter		Value for Inch Cape	Value for the Firth of Forth Round 3 Zone 2 development	Resulting assessment parameter	Notes
Operation and Maintenance						
Habitat loss	**Wind turbine Foundations**	Number	286	616	• Turbine foundation loss = 8.82 km^2; • Substation foundation loss = 0.312 km^2; • Met mast foundation loss = 0.12 km^2; and Total habitat loss through foundation footprints is therefore 9.25 km^2.	• Assumptions on parameters used are the same as those used for construction for turbine, met mast and substation parameters; and • There is not assumed to be any habitat loss from cables, they are assumed to be buried in all places (no other information available).
		Footprint of foundation	7,300	10,923		
	Substation foundations	Number	5	2		
		Footprint of foundation	45,000	45,100		
	Met mast foundations	Number	3	9		
		Footprint of foundation	7,300	10,923		
Introduction of new substrate	Assumed to be equal to the amount of habitat loss (no assumption included for vertical new substrate for other developments).				As calculations for habitat loss.	
EMF and heating impacts from operational cables	Qualitative assessment					
Operational noise	Qualitative assessment.					

Table 15.6: Cumulative (other developments) Rochdale Envelope worst (realistic) case parameters for fish and shellfish ecology receptors (continued)

15.6 Baseline Description

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

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

41 The southeast Scotland region hosts important inshore populations of shellfish, the distribution of which is highly influenced by the substratum type, as these highly sedentary organisms have habitat specific requirements. Shellfish (as with fish species) are of considerable ecological value as prey species for a number of marine mammals and birds (Chapter 12: Ornithology and Chapter 13: Marine Mammals). In addition they represent an important source of revenue (refer to Chapter 16: Commercial Fisheries).

15.6.1 Study Area

42 The study area contains the offshore site and export cable route as highlighted in Section 15.6.4 and Figure 15.1. To put the fish and shellfish populations found on site into context, it is necessary to describe the population structure characteristics of the wider North Sea.

15.6.2 Pelagic Fish Species

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

44 These species are commercially exploited in the wider region (see Chapter 16: Commercial Fisheries for details) and sprat and herring play an important ecological role as principal prey items for several larger fish species, marine birds and mammals (see Chapter 12: Ornithology and Chapter 13: Marine Mammals for information on predators of fish and shellfish resources).

15.6.2.1 Pelagic Species Spawning Areas

45 Data from Ellis *et al.* (2012) and Coull *et al.* (1998) indicate that sprat and herring spawn in the southeast Scotland region (Figures 15.2 and 15.3). Neither the offshore site nor export cable route coincide with sprat spawning areas, while herring spawning areas only coincide with the inshore region of the export cable. The offshore works area does not coincide with spawning areas for mackerel.

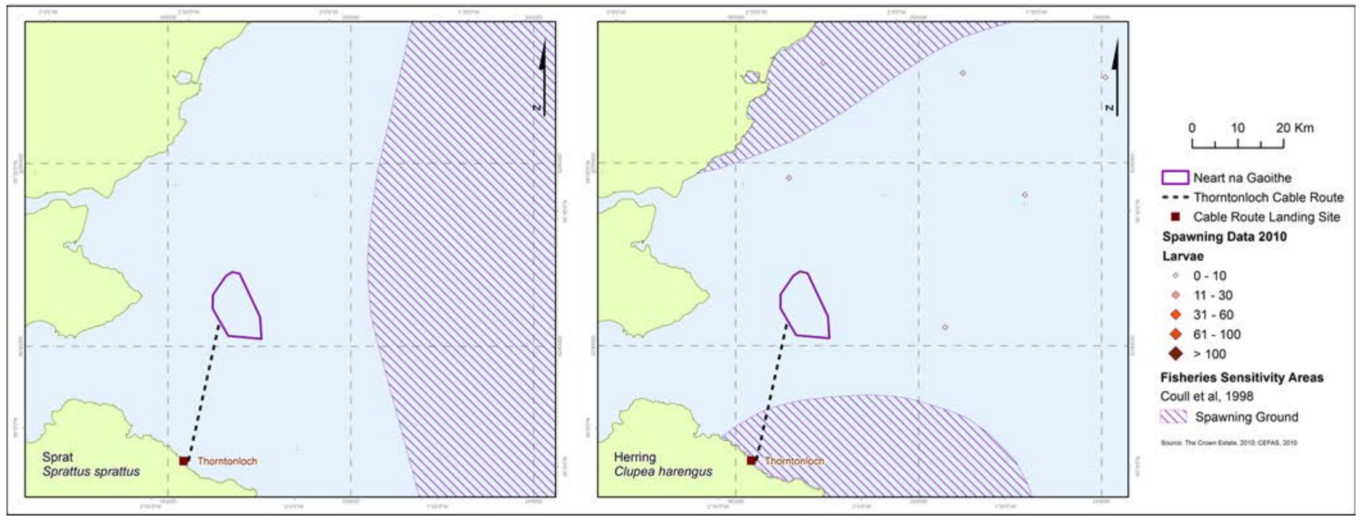


Figure 15.2: Distribution of spawning areas for pelagic species within the study area in the regional context (data from Ellis *et al.,* 2012; Coull *et al*., 1998)

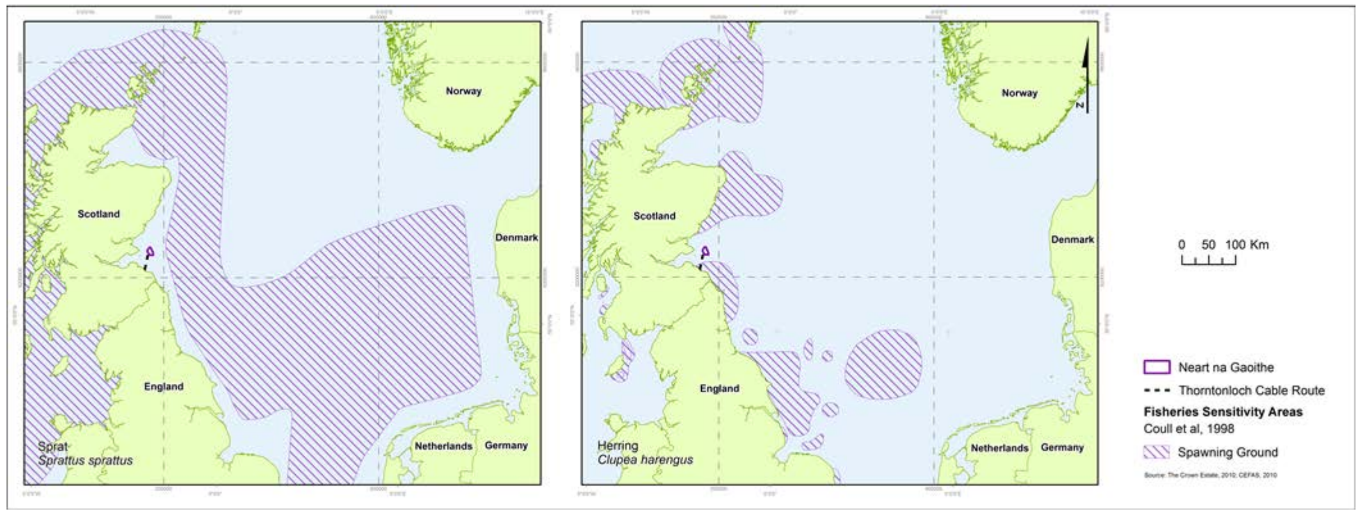


Figure 15.3: Distribution of spawning areas for pelagic species within the study area in the national context (data from Ellis *et al.*, 2012; Coull *et al.*, 1998)

15.6.2.2 Pelagic Species Nursery Areas

46 Data from Ellis *et al.* (2012) and Coull *et al.* (1998) further indicate that herring, sprat and mackerel nursery areas are found in the offshore works area as shown in Figure 15.4 below, and in a national context as illustrated in Figure 15.5. Coull *et al.* (1998) found sprat to be ubiquitous across the region during nursery periods; however, data for specific nursery periods are not readily available as "*nursery grounds for most fish species are dynamic features of life history*" (Cefas, 2001).

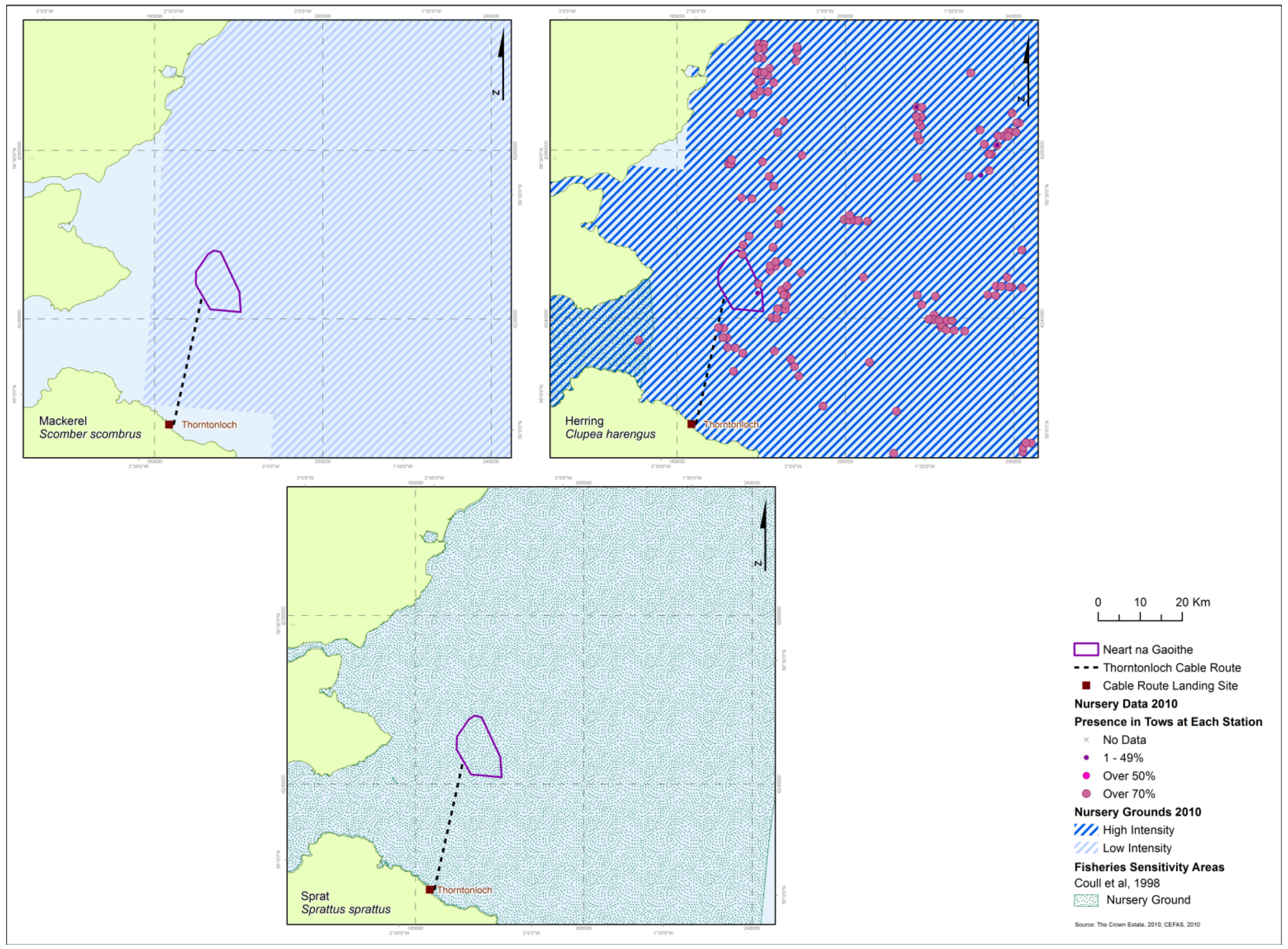


Figure 15.4: Distribution of nursery areas for pelagic species within the study area in a regional context (data from Ellis *et al.*, 2012; Coull *et al.*, 1998)

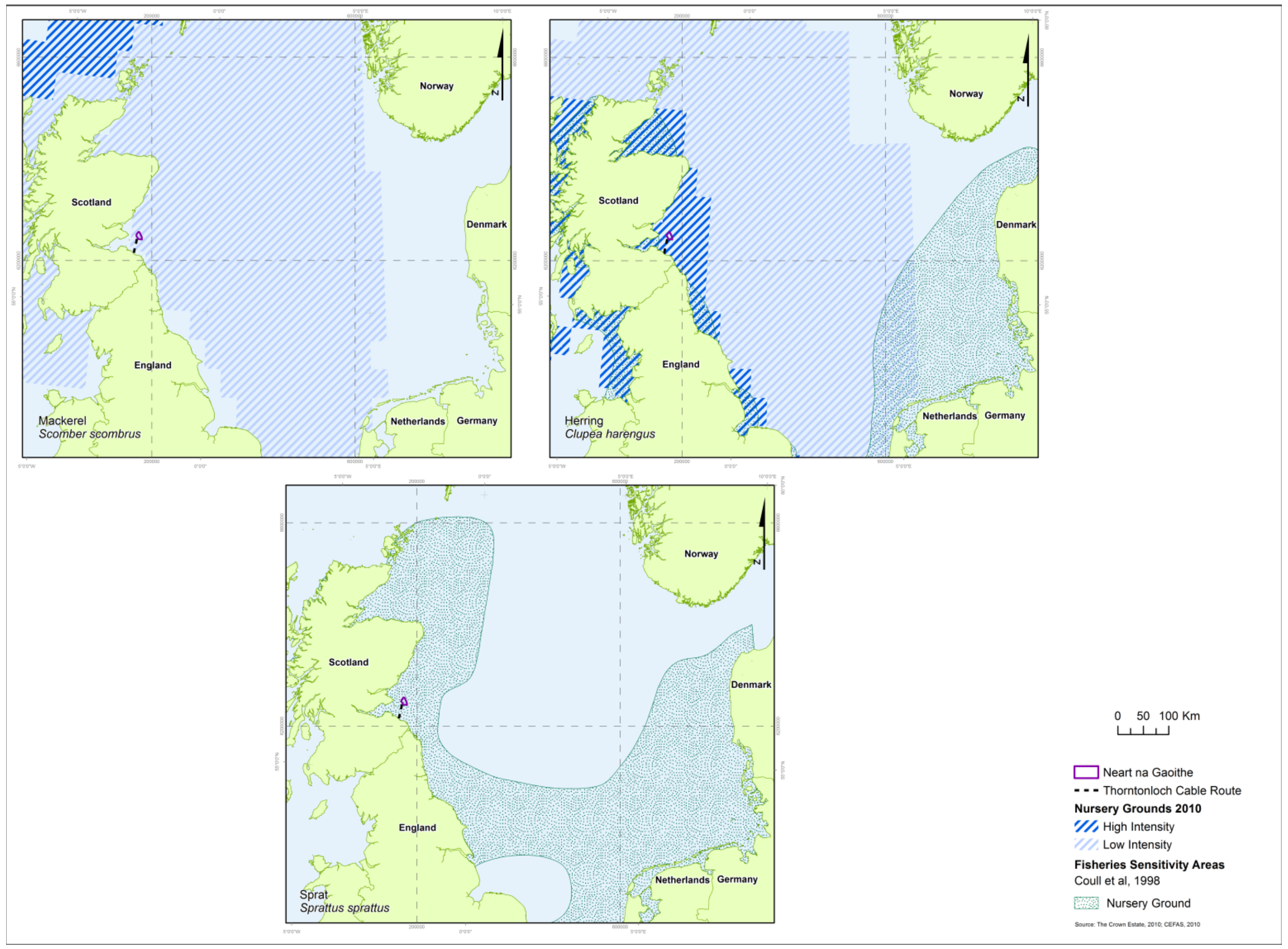


Figure 15.5: Distribution of nursery areas for pelagic species within the study area in a national context (data from Ellis *et al.*, 2012; Coull *et al.*, 1998)

15.6.2.3 Vulnerabilities and Seasonal Sensitivities of Key Pelagic Species

47 Sensitivity data for the specific pelagic species considered here are relatively sparse. However, research shows that the main issues for pelagic fish species are noise and SSC levels. The relative mobility of pelagic fish may allow localised avoidance of some of the above aspects, such as suspended sediments (Birkuland and Wijsman, 2005). However, effects such as noise may be unavoidable as they can be detected at relatively long distances.

48 Herring, unlike most other fish, have specialised adaptations connecting the swim bladder and oesophagus to the inner ear. These morphological adaptations make them one of the most sensitive fish species to noise (ICES, 2006a). Herring may also be disturbed by, and avoid, raised suspended sediment levels (Birkuland and Wijsman, 2005). Salmonid species are not sensitive to sound pressure but react to the particle motion element of noise and thus may detect sound influences over some distance (Mueller-Blenkle *et al.,* 2010). For other pelagic species, such as mackerel or herring, raised sediment levels may also cause avoidance behaviour. In addition, shad species are noted to be highly intolerant to pollution, which is one of the main factors in the species' decline and resulted in their heighted conservation status (Freyhof and Kottelat, 2008; Doherty *et al*., 2004).

49 Table 15.7 details the key pelagic species, their conservation status and seasonality of spawning activity. A brief summary of herring biology with regard to the North Sea population is presented below, with a view to identifying species key life stages likely to be particularly sensitive to noise from construction and operation of the wind farm. Additional information on the commercial importance of each species can be found in Chapter 16: Commercial Fisheries.

Herring

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

51 Most authors distinguish four major spawning groups within the North Sea defined by distinct spawning times and sites (Payne, 2010). Those that spawn off the east of Scotland are known as the Orkney/Shetland and Buchan components. The Orkney-Shetland component spawns in August/September between the Islands that give it its name; the Buchan component to the east of Scotland in September/October. Some authors consider Buchan/Shetland as one component (Ellis *et al.*, 2012; Cefas, 2001), spawning between August and September (Cefas, 2001). In the context of the current study, the spawning period has been considered to extend from August to October with peak activity in September (refer to Table 15.7). Natural variability in the timing of spawning is to be expected (Payne, 2010), owing to year to year changes of environmental conditions at the time of egg development and larval hatch, as well as changes in the timing of emergence of eggs and larvae or a combination of both (Wieland *et al.*, 2000).

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

= Peak spawning   = Spawning

Table 15.7: Seasonal sensitivities and conservation importance for key pelagic species

15.6.3 Demersal Species

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

53 The following demersal species are present in the area according to Ellis *et al.* (2012), Greenwood and Hill (2003), Greenwood *et al.* (2002) and Coull *et al.* (1998).

- Cod *Gadus morhua*;
- Sole *Solea solea*;
- Whiting *Merlangius merlangus*;
- Turbot *Psetta maxima*;
- Blue whiting *Micromesistius poutassou*;
- Brill *Scophthalmus rhombus*;
- Hake *Merluccius merluccius*;
- Lemon sole *Microstomus kitt*;
- Haddock *Melanogrammus aeglefinus*;
- Flounder *Platichthys flesus*;
- Norway pout *Trisopterus esmarkii*;
- Monkfish (or anglerfish) *Lophius piscatorius;*
- Pollack *Pollachius pollachius*;
- Long rough dab *Hippoglossoides platessoides;*
- Saithe *Pollachius virens*;
- Pogge *Agonus cataphractus*;
- Ling *Molva molva*;
- Fatherlasher *Myoxocephalus scorpius*;
- Plaice *Pleuronectes platessa*;
- Eelpout *Zoarces viviparous*;
- Dab *L. limanda*;
- Gobies *Gobiidae*
- Sandeel *Ammodytidae*;
- Spurdog *Squalus acanthias*;
- Lesser spotted dogfish *Scyliorhinus canicula;*
- Thornback ray *Raya clavata*;
- Cuckoo ray *Raya naevus*;
- Basking shark *Cetorhinus maximus*; and
- Tope *Galeorhinus galeus*.

15.6.3.1 Key Demersal Species Spawning Areas

54 Data from Ellis *et al.* (2012) and Coull *et al.* (1998) indicate that several demersal species spawn in the region surrounding the offshore works area. Figure 15.6 shows spawning grounds for whiting, lemon sole, cod and plaice, all of which spawn in the region. The distribution of spawning grounds of these species relative to the wider national context is illustrated in Figure 15.7.

55 Many demersal species, such as whiting *M. merlangus* and plaice *P. platessa*, have buoyant eggs that are released into the water column where they remain for several weeks until the pelagic larvae emerges (van Damme *et al.*, 2011). Some data (Ellis *et al.*, 2012; Coull *et al.*, 1998) suggests that whiting spawning grounds may occur within the offshore works area for Neart na Gaoithe (see Figure 15.6 below).

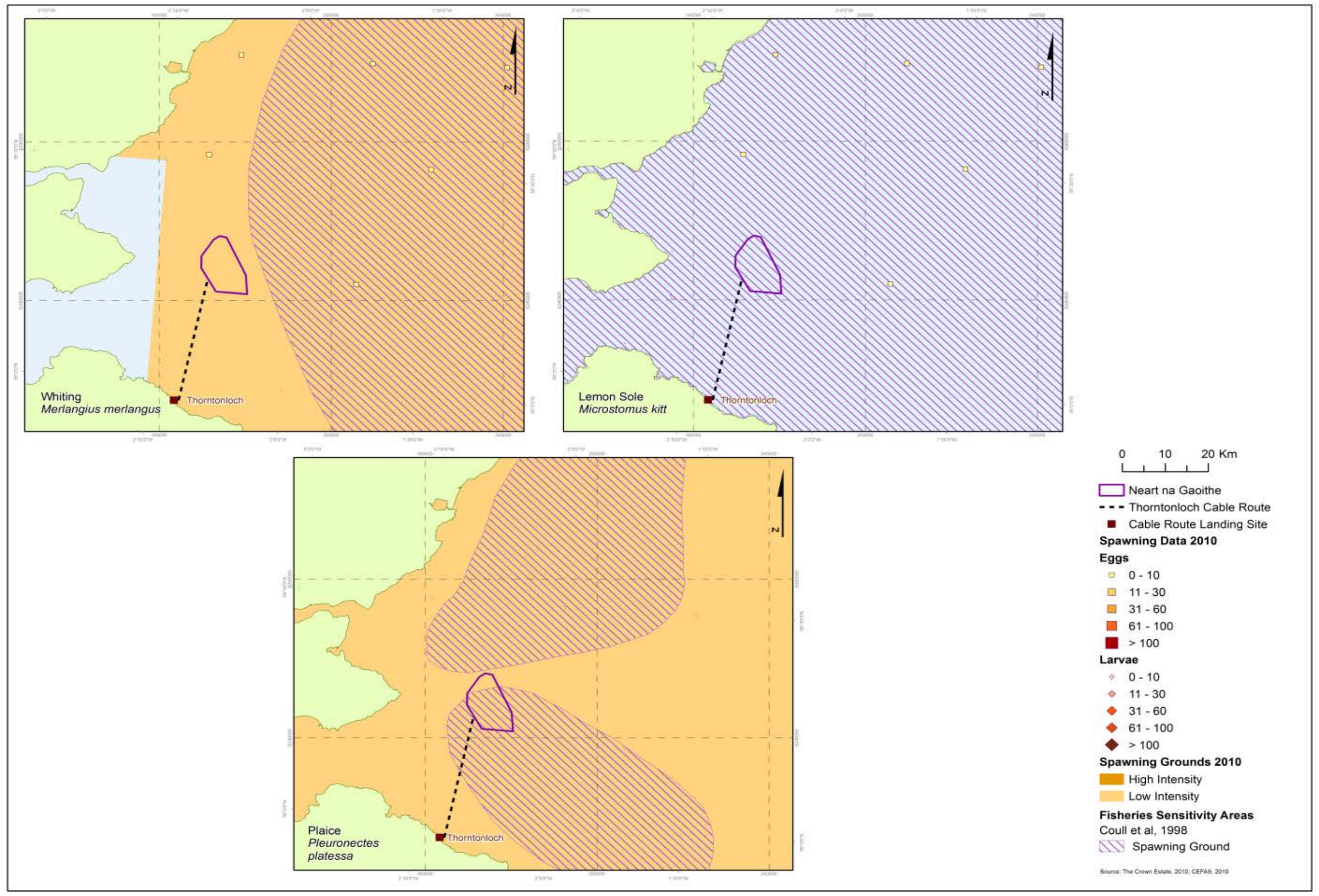


Figure 15.6: Distribution of spawning areas for demersal species within the study area in a regional context (data from Ellis *et al*., 2012; Coull *et al*., 1998)

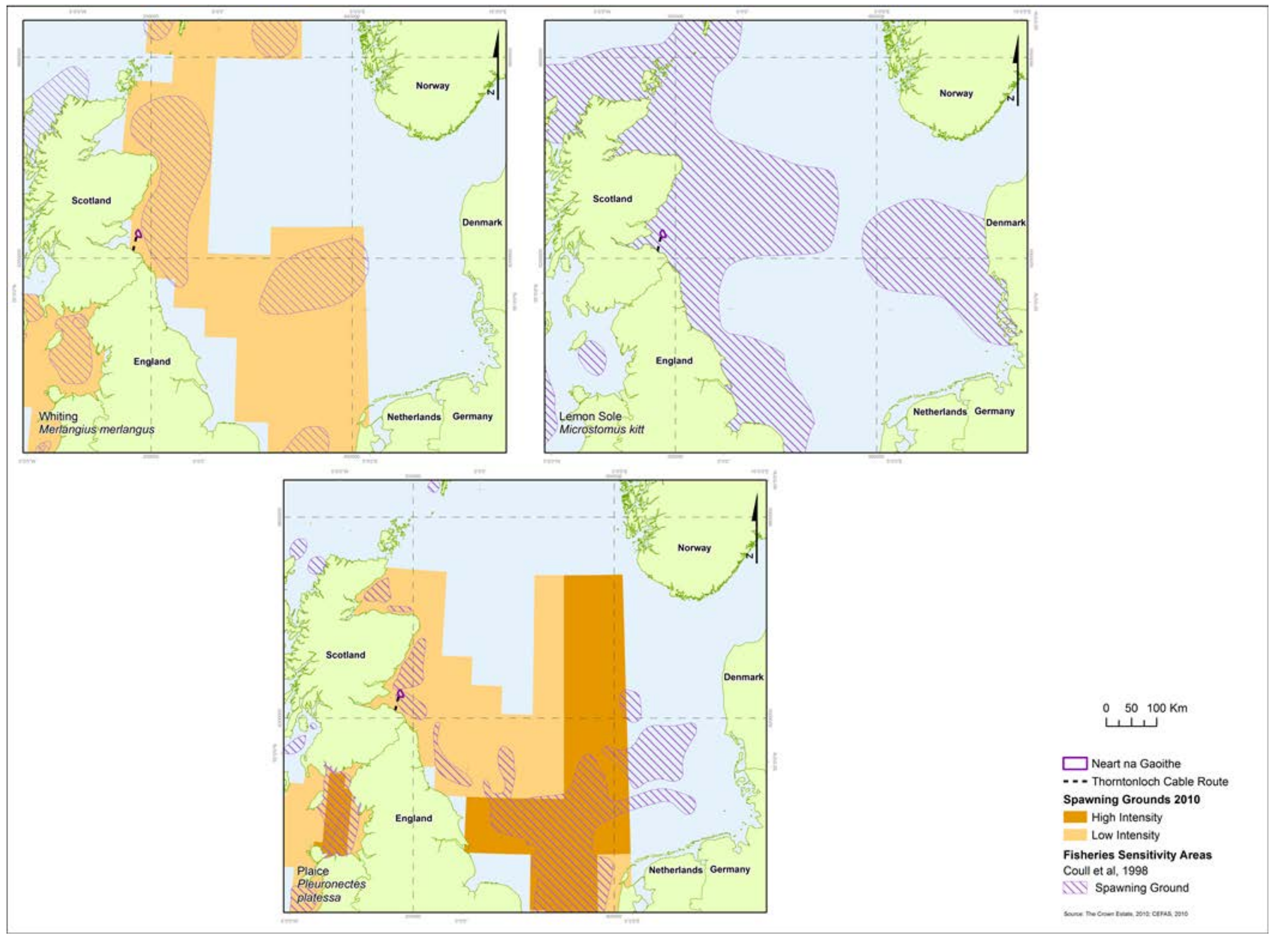


Figure 15.7: Distribution of spawning areas for demersal species within the study area in a national context (data from Ellis *et al*., 2012; Coull *et al*., 1998)

15.6.3.3 Demersal Species Nursery Grounds

56 Data indicate that high intensity nursery areas for cod and whiting nursery grounds, and low intensity areas for lemon sole, blue whiting, plaice, ling and hake nursery grounds overlap with the offshore works area (see Figures 15.8 to 15.11). In addition, nursery areas for pollock have been reported to coincide with the northern-most boundary of the offshore site (Figure 15.10).

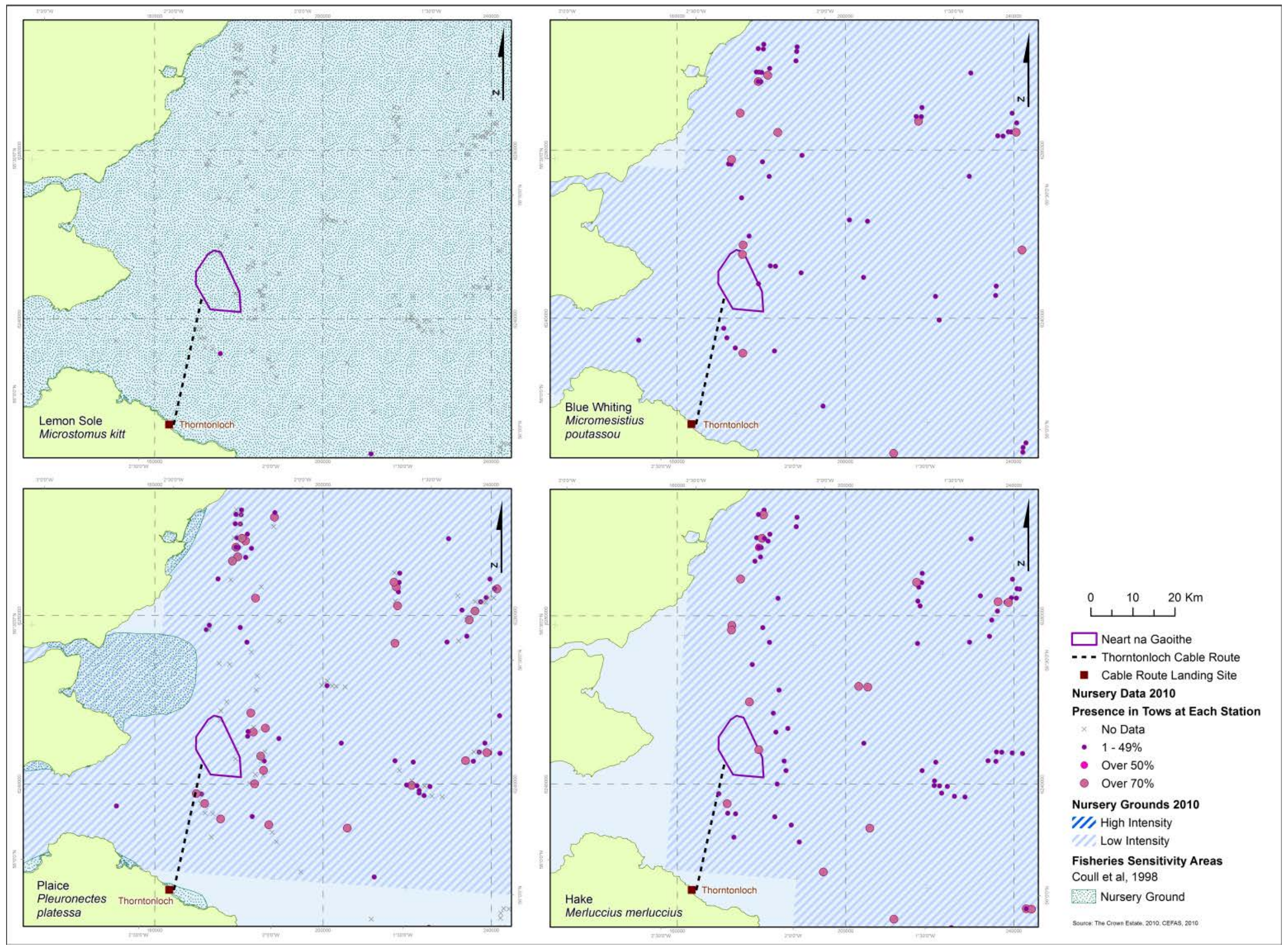


Figure 15.8: Distribution of nursery areas for demersal species in the study area in a regional context (data from Ellis *et al*., 2012; Coull *et al*., 1998)

Figure 15.9: Distribution of nursery areas for demersal species in the study area in a national context (data from Ellis *et al.*, 2012; Coull *et al*., 1998)

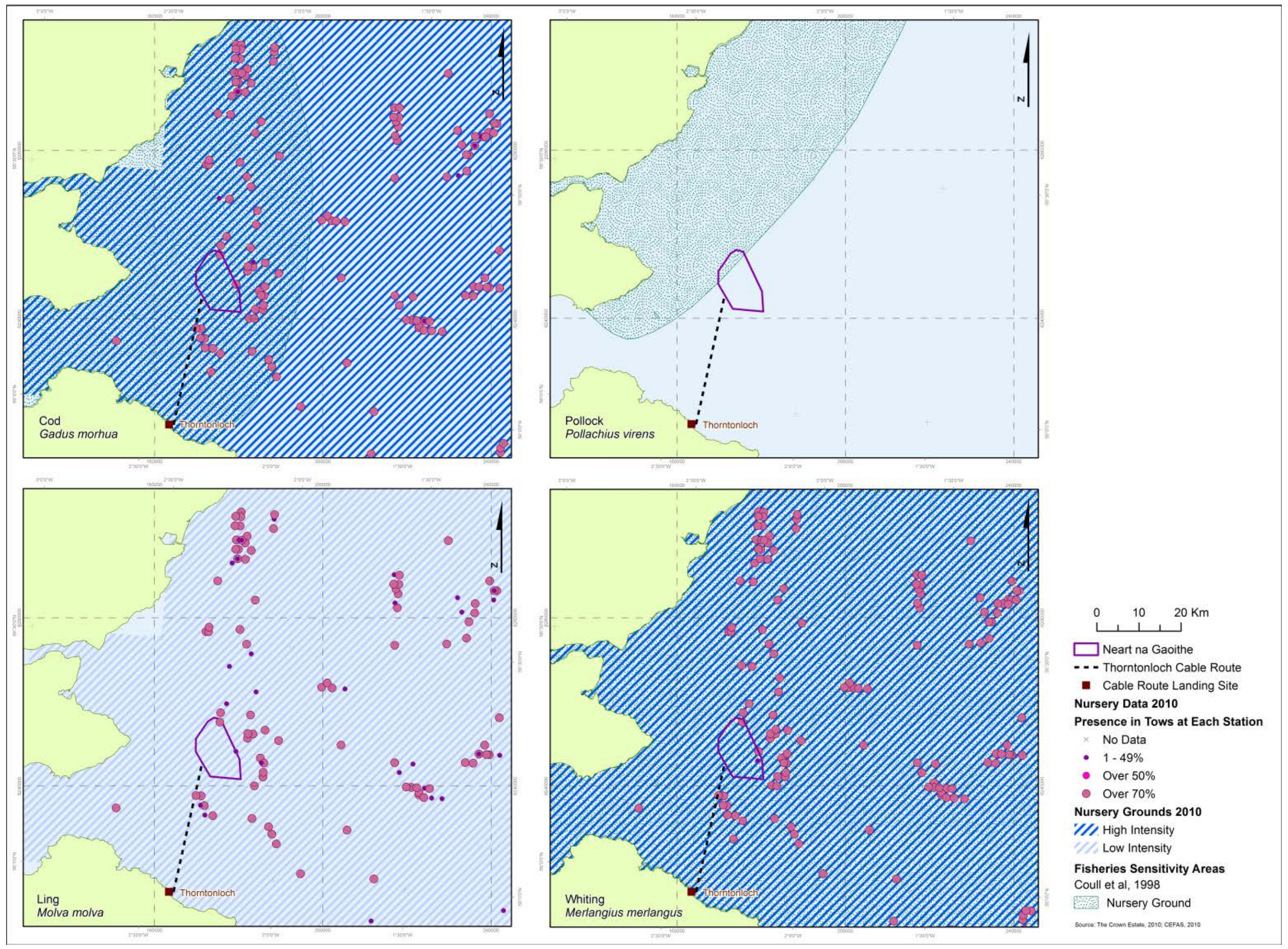


Figure 15.10: Distribution of nursery areas for demersal species in the study area in a regional context (data from Ellis *et al.,* 2012; Coull *et al*., 1998)

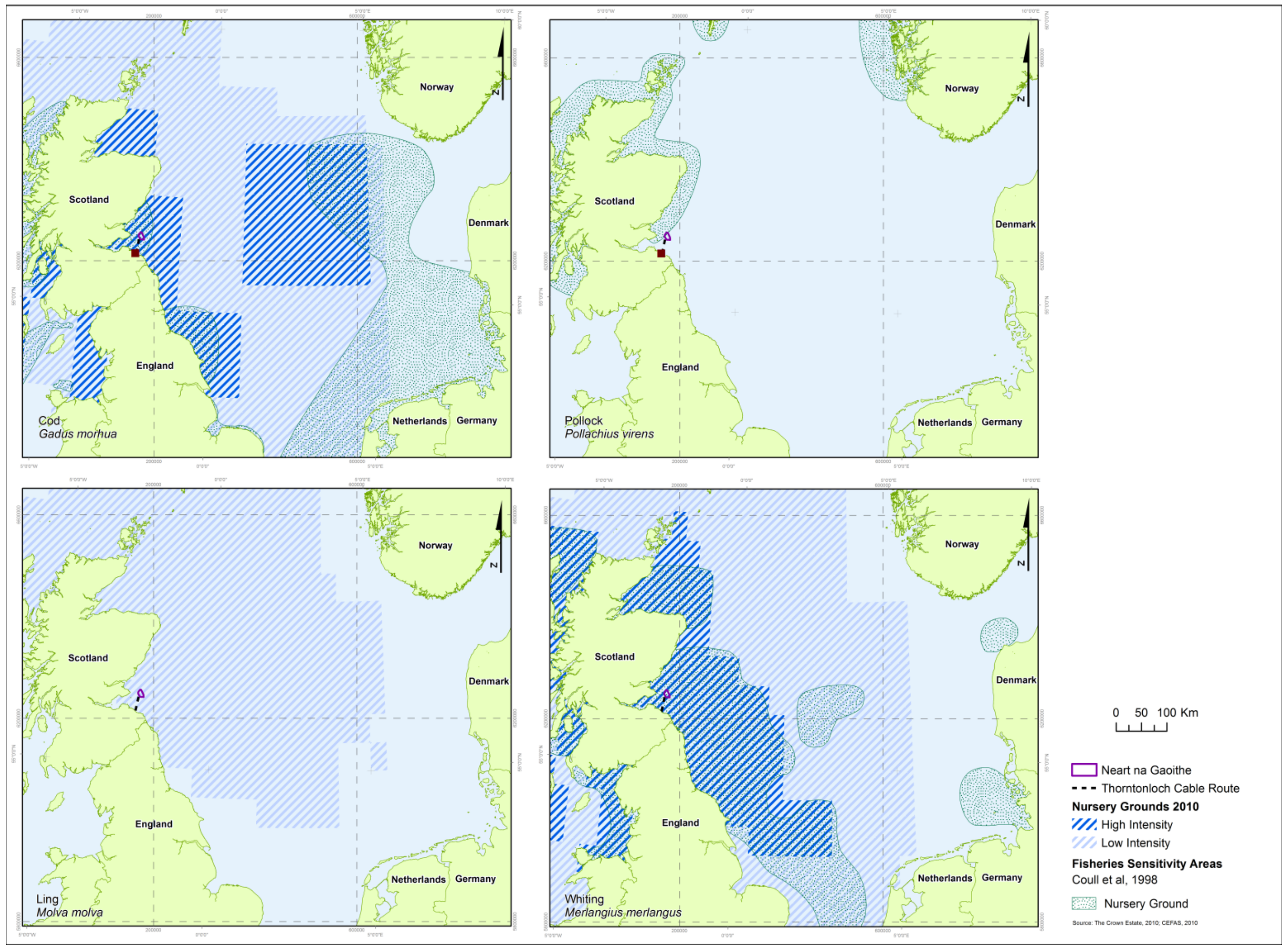


Figure 15.11: Distribution of nursery areas for demersal species in the study area in a national context (data from Ellis *et al.,* 2012; Coull *et al.,* 1998)

15.6.3.4 Sandeel

57 There are five species of sandeel in the North Sea, though the majority of commercial landings are of *Ammodytes marinus* (Cefas, 2001). Sandeel occur in the southeast Scotland region and are abundant on the series of sandbanks that lie at about 30-50 km offshore, including the Berwick Bank, Scalp Bank, Montrose Bank and Wee Bankie (Robson, 1997). The sandeel populations around these banks are of particular importance as they are within the feeding range of many seabirds breeding at colonies in and around the Firth of Forth (Wanless *et al.*, 1998). As major predators of zooplankton, sandeel play a key role in the North Sea food-web (see Chapter 14: Benthic Ecology) and are the principal prey of many top predators including marine mammals (see Chapter 13: Marine Mammals) and birds (see Chapter 12: Ornithology). In addition, sandeel are the target of a large-scale industrial fishery in the North Sea (see Chapter 16: Commercial Fisheries). The occurrence of sandeel within the southeast Scotland region, and specifically in relation to the Neart na Gaoithe development, is presented in Figure 15.12 which illustrates all demersal gear catches in 2011 (Marine Scotland, 2011a).

58 Sandeel inhabit shallow turbulent sandy areas with a high percentage of medium to coarse grained sand (particle size 0.25-2 mm) (Greenstreet *et al.,* 2010). Sandeel have highly specific habitat requirements as these organisms do not maintain permanent burrow opening and, therefore, have to ventilate their gills with interstitial water; thus fine sediment particles could clog their gills inhibiting respiration (Holland *et al.*, 2005). Sandeel also require well flushed tidally active areas (Wright *et al.*, 2000) with current flows greater than 0.6 ms^{-1} (Jensen *et al.*, 2011).

59 Sandeel are also known to prefer depths of 30 to 70 m, although they may occur between depths of 15 and 120 m (Holland *et al.,* 2005). The highly specific habitat requirements of sandeel also means that the distribution of post-settled sandeel is very patchy. This was demonstrated in a recent study by Jensen *et al.* (2011) that aimed to produce a map of the foraging habitat of sandeel across the North Sea examine the extent of sandeel population mixing between foraging areas (defined by the authors as areas supporting potentially large densities of non-buried sandeel, as they bury when not feeding). The study used the whole North Sea map of lesser sandeel distribution to evaluate dynamics over a complex mosaic of grounds, differing widely in size and proximity to each other. Detailed data were collected between 1999 and 2008 and used to map fishery grounds that were then assumed to correspond to the foraging habitats of the species (Jensen *et al.*, 2011). Length distribution data from individual hauls were used to assess differences in the distribution as a function of distance between samples. Results showed that sandeel foraging habitat covers about 5% of the total area of the North Sea. The study showed a lack of mixing between grounds and foraging is likely restricted to a preferred habitat type, which may result in large differences in sandeel abundance between adjacent grounds (Jensen *et al.*, 2011).

60 Sandeel are most active in late spring/early summer, during which time they move freely, on a diurnal basis, between the seabed and the water column. During autumn and winter, sandeel lie dormant in the sediment except for a brief midwinter emergence to spawn (Greenstreet *et al.*, 2010). Post settled sandeel are very rarely found at depths greater than 15 m from known habitats and the maximum distance travelled by tagged fish displaced from grounds was 64 km (Jensen *et al.*, 2011).

61 Results of the site specific survey and analysis using recommendations outlined in Greenstreet *et al.* (2010) indicate that due to the relatively high mud content, habitats within the Neart na Gaoithe offshore works area are unlikely to be suitable for sandeel populations (see Figure 15.13). Results of the faunal analyses showed that the total number of sandeel recorded was very low (five individuals were captured across the entire survey area), with Sites 38 and 60 accounting for three and one individual, respectively, the other individual recorded at Site 50. Catch records (Appendix 14.1: Benthic Ecology Survey Report; Greenstreet *et al.*, 2010) indicate no sandeel are caught within the offshore site but a small number have been recorded as being caught on or along the export cables route (refer to Figure 15.12).

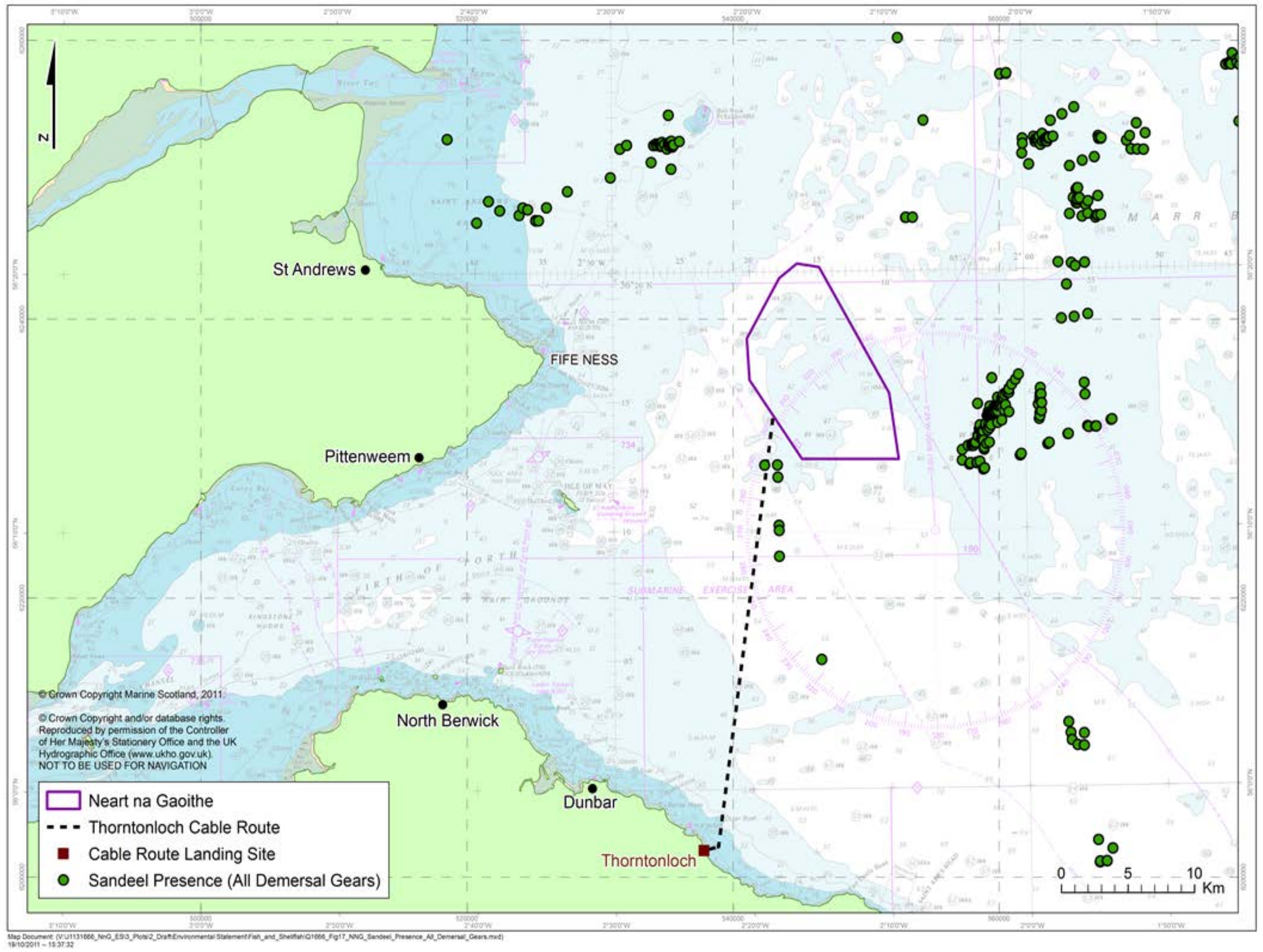


Figure 15.12: Sandeel catch records (Marine Scotland, 2011a, pers. comm.)

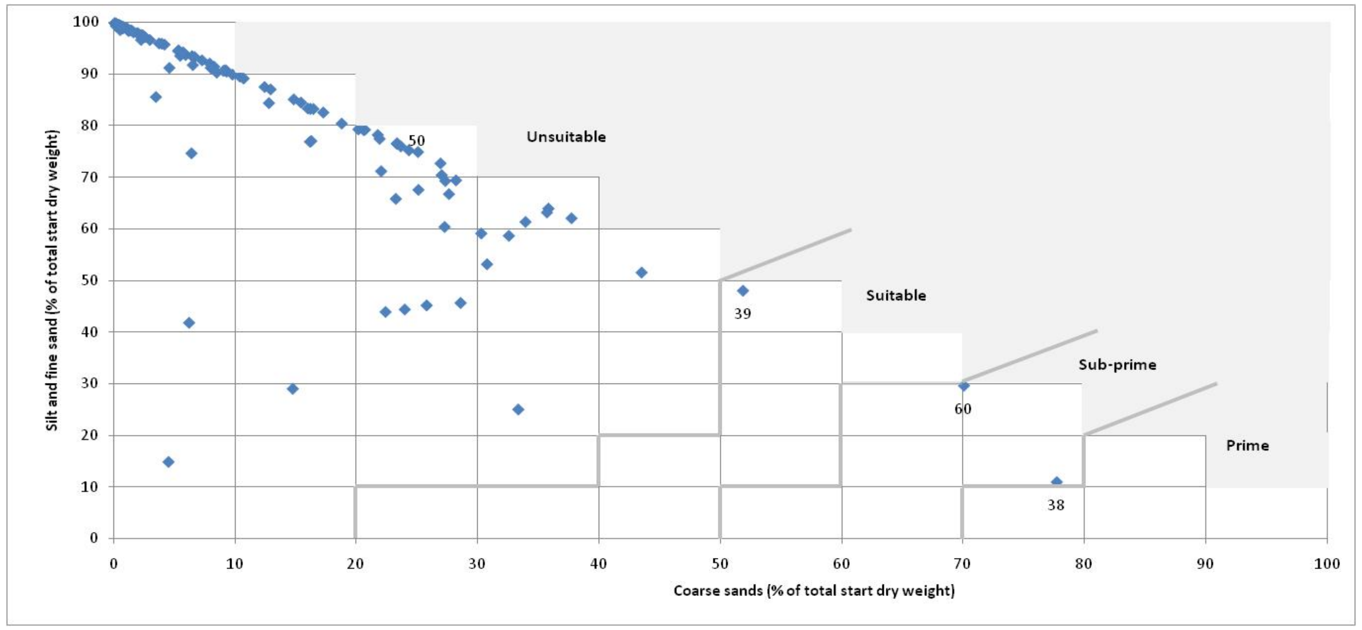


Figure 15.13: Suitability of sediment within the offshore works area for sandeel, as described in Greenstreet *et al.* (2010) (see Appendix 14.1: Benthic Ecology Survey Report)

15.6.3.5 Demersal Species Vulnerabilities and Sensitivities

62 Several demersal fish species may be sensitive and/or vulnerable to effects arising from construction, operation and maintenance of the project, including noise, suspended sediment levels, electromagnetic fields and heating from operating subsea cables.

63 Increases in SSC may affect movement and shoaling behaviour causing avoidance of the area by certain species (for example cod and plaice). Increase in sediment load may also affect fish species with pelagic eggs, causing them to sink before hatching, potentially having an influence on survivability (Birklund and Wijsman, 2005).

64 The vulnerability of organisms to sedimentation is species specific, arising as a result of differences in tolerance, recoverability and adaptability of different species. Species that require particular sediment types for spawning and or burying, such as herring or sandeel, may be affected by any sedimentation change.

65 Herring, although recognised as a pelagic species, require demersal habitats of coarse substrate such as gravel and stones for spawning purposes. The survival and development of herring eggs have been reported to be insensitive to even high concentrations of suspended sediment, but studies have concluded that smothering is likely to be detrimental unless the material is removed rapidly by the current (Birklund and Wijsam, 2005).

66 Due to the highly specific habitat requirements of sandeel, some effects, particularly an increase in SSC and subsequent sedimentation, may have an impact. In addition, sandeels may be vulnerable to other effects in the same way as other demersal species.

67 Vulnerability of demersal fish to noise is dependent on two independent but related sensory systems, these are the inner ear (or otolith) and to a lesser extent, the lateral line. The ear bones or otoliths are denser than both the rest of the body of the fish and the water in which it swims. The otoliths move more slowly in response to noise than the rest of the fish; this difference in reaction bends sensory cells in the inner ear which is interpreted as noise. The sensitivity to noise differs among species and is affected by the proximity of the inner ear to the swim bladder.

68 Fish whose swim bladders are connected to the inner ear, such as the clupeids, herring, sprat and shad are considered to be hearing specialists. In contrast, species that lack a swim bladder including flatfish, e.g., plaice, and elasmobranchs such as thornback rays, as well as species whose swim bladder is well removed from the inner ear such as salmon, tend to have low sensitivity to noise.

69 The lateral line detects vibration or particle motion through the water. It is used for prey detection and predator avoidance in the near-field (up to a few body lengths) as well as aiding the fish to form a three dimensional image of their local environment. Studies indicate a limited role of the lateral line organ in far-field detection (Andersson, 2011). Impacts from increased noise on demersal fish are similar to those for pelagic fish and range from behavioural changes (e.g., changes in swimming speed and direction) (Mueller-Blenkle *et al.*, 2010), to lethal effects at very close range (e.g., haemorrhage of internal organs) (Halvorsen *et al.*, 2011).

70 The detection of magnetic and electric fields in species such as sea lamprey *Petromyzon marinus* and European eel *Anguilla anguilla* has been closely related to navigation during long distance migration and spawning ground location (Gill and Bartlett., 2010). It is, therefore, important to pay particular attention to such species when considering the effects of the subsea power export cables. Adult stocks of demersal fish are considered to be less vulnerable than juveniles to some of the effects associated with wind farm development, such as habitat loss, due to their adaptability and tolerance by way of their mobile nature and generalist feeding behaviour. However, adult stocks are reliant upon successful spawning, nursery and migratory phases; therefore, loss of habitats for spawning and nursery grounds will be reflected in future adult fish populations.

71 Table 15.8 details the sensitive periods and conservation status of the key demersal species likely to be present in the area. Additional information on the commercial or conservation importance of each species can be found in Chapter 16: Commercial Fisheries and Chapter 11: Nature Conservation respectively.

Name	Seasonal spawning activity												Notes on conservation and commercial importance
	J	F	M	A	M	J	J	A	S	O	N	D	
Cod *G. morhua*	Spawning	Peak	Peak	Spawning									Scottish Nature Conservation Marine Protected Area (MPA) search feature; Listed on Scottish Biodiversity List; Scottish Priority Marine Feature (PMF); UK Biodiversity Action Plan (BAP) species; Listed as vulnerable on the IUCN Red List; OSPAR species; and Widespread commercial species, however not targeted in the region.
Whiting *M. merlangus*	Spawning	Spawning	Spawning	Peak	Peak	Spawning	Spawning	Spawning					Scottish Nature Conservation Marine Protected Area (MPA) search feature (juvenile); Scottish Biodiversity List; PMF (juveniles); and UK BAP species.
Saithe *P. virens*	Spawning	Spawning	Spawning	Spawning									PMF.
Ling *M. molva*			Spawning	Spawning	Spawning	Spawning							UK BAP species; Scottish Biodiversity List species; and PMF.
Plaice *P. platessa*	Spawning	Peak	Spawning									Spawning	UK BAP species.
Dab *L. limanda*	Spawning	Spawning	Spawning	Spawning	Spawning	Spawning							Species of commercial importance.
Sole *S. solea*					Spawning	Spawning	Spawning	Spawning					UK BAP species; and Scottish Biodiversity List species.
Lemon sole *M. kitt*				Spawning	Spawning	Spawning	Spawning	Spawning	Spawning				Species of commercial importance (however not noted in region).
Long rough dab *Hipoglossoides platessoides*	Spawning	Spawning	Spawning	Spawning	Spawning	Spawning							Species of commercial importance (however not noted in region).
Blue whiting *Micromesistius potassou*		Spawning	Spawning	Spawning									UK BAP species; and Species of commercial importance (however not noted in region).
Sandeel *Ammodytes* spp.	Spawning	Spawning									Spawning	Spawning	Scottish Nature Conservation Marine Protected Area search feature; PMF; and Species of commercial importance.

(Peak) = Peak spawning; (Spawning) = Spawning

Table 15.8: Seasonal sensitivities and conservation importance for key demersal species

15.6.3.6 Elasmobranchs

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

Elasmobranch Breeding Patterns

73 The distribution of elasmobranch breeding grounds, in relation to the Neart na Gaoithe offshore works area is presented in Figure 15.14.

74 It can be seen that the breeding grounds of both spotted ray and skate occur outside the proposed Neart na Gaoithe offshore site and export cables route. With respect to the spurdog and the tope, both species' breeding grounds coincide with the offshore site and the export cables route.

75 In the northeast Atlantic, female spurdog are likely to be mature when they reach 74-83 cm, whereas males mature at a length of 55-64 cm, and fecundity generally increases with size (ICES, 2006b). Mating takes place in the winter months and gestation lasts 22 to 24 months (the longest of any vertebrate) before females give birth to live young measuring between 19 cm and 30 cm. Off the coast of Plymouth females are reported to give birth from August to December in soft sediment bays and estuaries (ICES, 2006b). No data directly available for the Firth of Forth region were found during the literature review.

76 Tope are live-bearing shark. Each female gives birth to a litter of 20 to 40 young each measuring 40 cm in length (Dipper, 2001). The number of young at birth increases with the size of the mother (Maitland and Herdson, 2009). The gestation period is about 10 months and the females move inshore to give birth in late summer (Dipper, 2001). Males reach sexual maturity at eight years old when they are between 120 cm and 170 cm long, and females at 11 years old when they are between 130 cm to 185 cm long. It is estimated that this species can reach an age of at least 55 years. Males and females live apart except during mating season (Dipper, 2001).

77 Lesser spotted dogfish become sexually mature at a length of about 50 cm (Maitland and Herdson, 2009). Females deposit egg-cases protected by a horny capsule on macroalgae in shallow coastal waters or on sessile erect invertebrates if further away from the shore. Spawning occurs all year around with a gap between August and October (Ellis and Shackley, 1997). Incubation lasts for 5 to 11 months after which the young hatch, measuring about 10 cm.

78 Thornback rays deposit their eggs on the sea floor in shallow water, one at a time with each containing one embryo (ICES, 2006c). North Sea populations are mature when they reach 77 cm (female) and 68 cm (males). Spawning season spans from February to September (Pawson, 1995). Embryonic development lasts about 4-6 months depending on water temperature and the young are 1-13 cm long when they hatch (Pawson, 1995). Nursery grounds are likely to coincide broadly with spawning grounds (Ellis *et al.*, 2012).

79 Cuckoo ray lay their egg capsules (mermaid's purses) all year around though mostly in December to May and each female can lay up to 100 eggs per year (Hughes and Nickell, 2009). The capsules are small (6 cm long and 3.5 cm wide) (Dipper, 2001). The incubation period in the wild is not known (Dipper, 2001), but in the aquarium is just over eight months, with the young fish reaching about 12 cm before hatching (Hughes and Nickell, 2009; Dipper, 2001).

80 Basking sharks are characterised by slow growth, large size, late sexual maturity (16-20 years) and a long gestation period (1-3 years), after which females give birth to up to six live pups each measuring about 1.5 m in length. Mating is thought to occur in early summer and birth in late summer (Fowler, 2005).

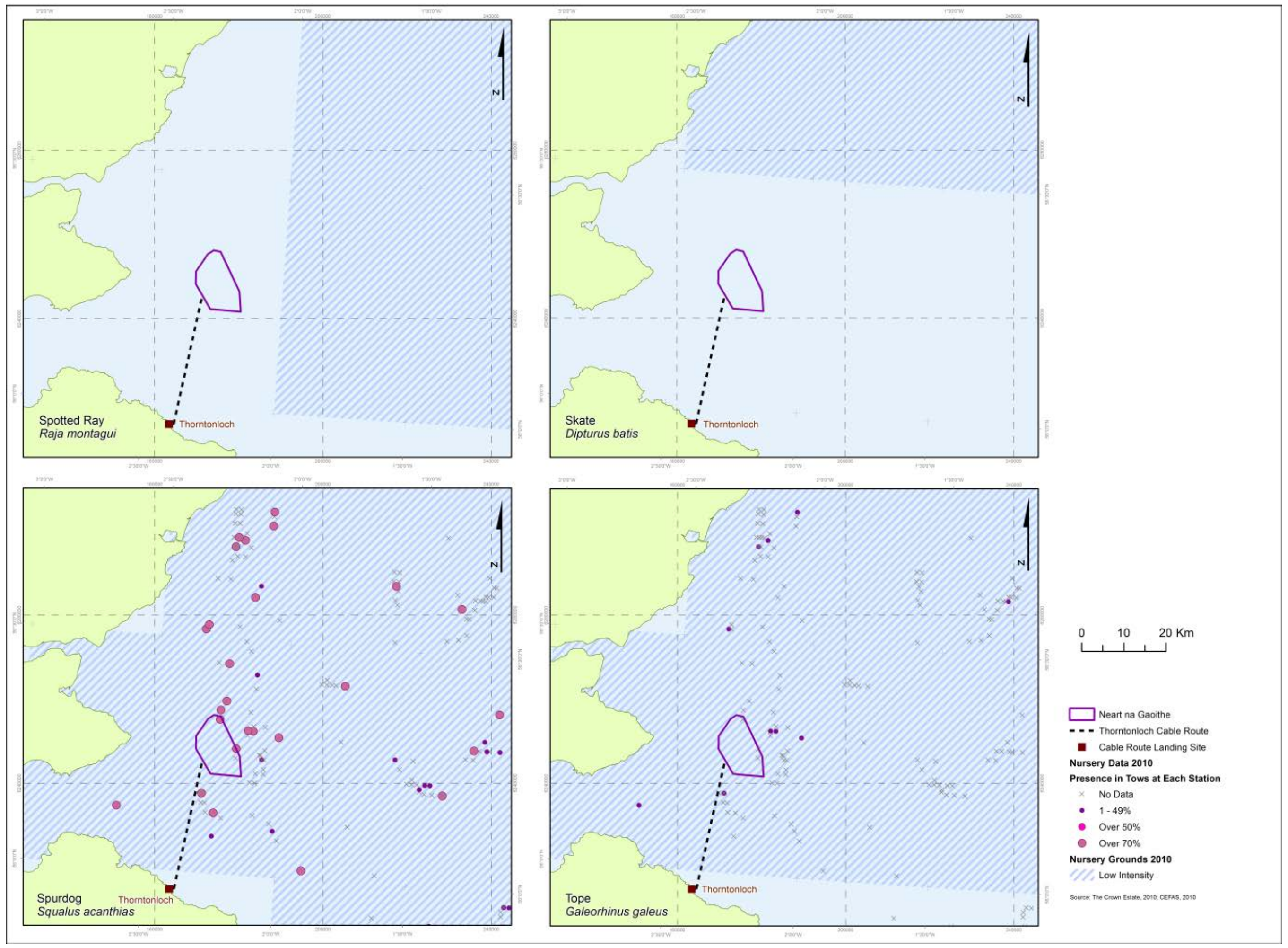


Figure 15.14: Distribution of breeding areas for elasmobranchs species in the study region (data from Coull *et al.*, 1998; Ellis *et al.*, 2010)

Elasmobranches Vulnerabilities and Sensitivities

81 Elasmobranch species may be sensitive and/or vulnerable to several effects associated with the Neart na Gaoithe development, such as sediment disturbance, noise from construction and operation, and electromagnetic fields generated by subsea cables.

82 Experimental studies have provided evidence that some elasmobranch species (i.e., the lesser spotted dogfish and the thornback ray) can respond to the presence of electromagnetic fields that are of the type and intensity associated with the sub-sea cables anticipated (Gill *et al.*, 2009). The reaction of the fish was unpredictable and did not always occur. When a reaction occurred it appeared to be species specific and, in some cases, individual specific, behavioural activity associated with foraging (Gill *et al.*, 2009). Thornback rays were reported to be more likely to move around within the electromagnetic field generated by an operating cable, whereas the lesser spotted dogfish were reported to have more restricted movements within the electromagnetic field generated by an operating cable (Gill *et al.,* 2009).

83 Table 15.9 details the sensitive periods and conservation status of the key elasmobranch species likely to be present in the area. Additional information on the commercial or conservation importance of each species can be found in Chapter 16: Commercial Fisheries and Chapter 11: Nature Conservation respectively.

Name	Breeding season												Notes on conservation and commercial importance (see Chapter 11: Nature Conservation and Chapter 16: Commercial Fisheries for further information)
	J	F	M	A	M	J	J	A	S	O	N	D	
Spurdog or Spiny dogfish ***S. acanthias***								Spawning	Spawning	Spawning	Spawning	Spawning	• Scottish Nature Conservation Marine Protected Area (MPA) search feature; • OSPAR species – Stock depleted and in danger of collapse; and • North Sea stock considered to be critically endangered according to IUCN red list.
Basking shark ***C. maximus***								Spawning	Spawning				• Listed under several international conventions as of conservation importance, including: • EC Habitats Directive Annex V (and transposing regulations) species (known as a European Protected Species); • Listed as vulnerable on the IUCN Red List; • Barcelona Convention listed species (Annex II); • Bern Convention listed species (Appendix IIB); and • Convention on Migratory Species/Bonn Convention list species (Appendix I and IID).
Tope ***G. galeus***								Spawning	Spawning				• Listed as vulnerable on the IUCN Red List; and • UK BAP species.

(dark orange)	Peak Spawning	(light orange)	Spawning

Table 15.9: Seasonal sensitivities and conservation importance for key elasmobranch species

15.6.3.7 Diadromous Fish

84 Diadromous species are migratory fish moving between sea and freshwater (or vice versa) for breeding/spawning purposes. They will have a significant period of their life stages within both freshwater and seawater habitats. Anadromous fish are those that spend the majority of their lives at sea, but specifically move upstream to freshwater to breed and spawn e.g., salmon *S. salar*. Conversely catadromous fish are those that move from freshwater to the sea to spawn e.g., the European eel.

85 Although no diadromous species have nursery or breeding areas directly within the Firth of Forth they are known to travel through the area. Anadromous species may spawn or have nursery areas in the lower estuary (e.g., shad) or in fully freshwater rivers (e.g., salmon and sea trout), whereas catadromous species (e.g., eel) will pass through the Firth of Forth on their way to spawning grounds in the sea.

86 Information available shows that some diadromous species are taken in inshore surveys (e.g., smelt *Osmerus eperlanus* (Ellis *et al.*, 2012b)) and may be assumed to be present around the export cables route area rather than the offshore development. However, overall migratory route and distribution data in the Firth of Forth (and elsewhere) are currently limited, for example shad behaviour is acknowledged as poorly researched (Doherty *et al.*, 2004). Additional information on the commercial importance of each species can be found in Chapter 16: Commercial Fisheries and Chapter 11: Nature Conservation

87 The following diadromous species are known to be present in the Firth of Forth region, although in small numbers (Greenwood *et al.*, 2002) and transient in the Neart na Gaoithe export cable route and offshore sites areas:

- Atlantic salmon *S. salar;*
- Sea trout *S. trutta;*
- River lamprey Lampetra fluviatilis;
- Sea lamprey *P. marinus;*
- Eel A. anguilla;
- Allis shad *Alosa alosa*; and
- Twaite shad *Alosa fallax*;
- Smelt O. eperlanus.

Diadromous Fish Vulnerabilities and Sensitivities

88 The migratory behaviour of diadromous species means that they are likely to be sensitive to certain effects associated with the Neart na Gaoithe development, specifically noise generated during construction and operation and EMF generated by subsea cables. Noise generated by pile driving is reported to be lethal for those species with swim bladders, which include several salmonid species. It is recognised that mortality is only likely to occur at close range to the source of the noise (Gill and Bartlett, 2010).

89 Some species (salmonids and anguillid eels) are likely to utilise electromagnetic fields for navigation purposes during long distances migrations, which occur at specific life stages of their life cycle (Gill et al., 2005). These aspects are discussed in more detail in Section 15.7: Impact Assessment. In addition diadromous species are known to be sensitive to pollution. Raised sediment levels may cause population fragmentation through individual avoidance behaviour (Thorstad et al., 2005; Wilber and Clarke, 2001). Table 15.10 details the sensitive periods and conservation status of the key diadromous species likely to be present in the area.

Freshwater Pearl Mussel

90 The freshwater pearl mussel *Margaritifera margaritifera* colonises and disperses through temporary parasitisation of diadromous salmon and sea trout (SNH, 2010). Freshwater pearl mussel lives in clean fast-flowing streams and rivers. They tend to live completely or partially buried between 0.5-2 m in the fine gravel and coarse sand. A healthy population of salmonids is essential to the life cycle of freshwater pearl mussel (Skinner *et al.*, 2003). Their complex lifestyle and vulnerability to river pollution has led to significant decline resulting in them achieving full conservation status and protection. Because of their association with salmon and trout, they require consideration in conjunction with these species.

15.6.4 Site Specific Survey

91 The site specific benthic survey carried out in 2009 recorded ten fish species within the study area. Additional information on the survey and analysis techniques can be found in Appendix 14.1: Benthic Ecology Characterisation Survey. Of the ten species identified, four were of commercial importance and included:

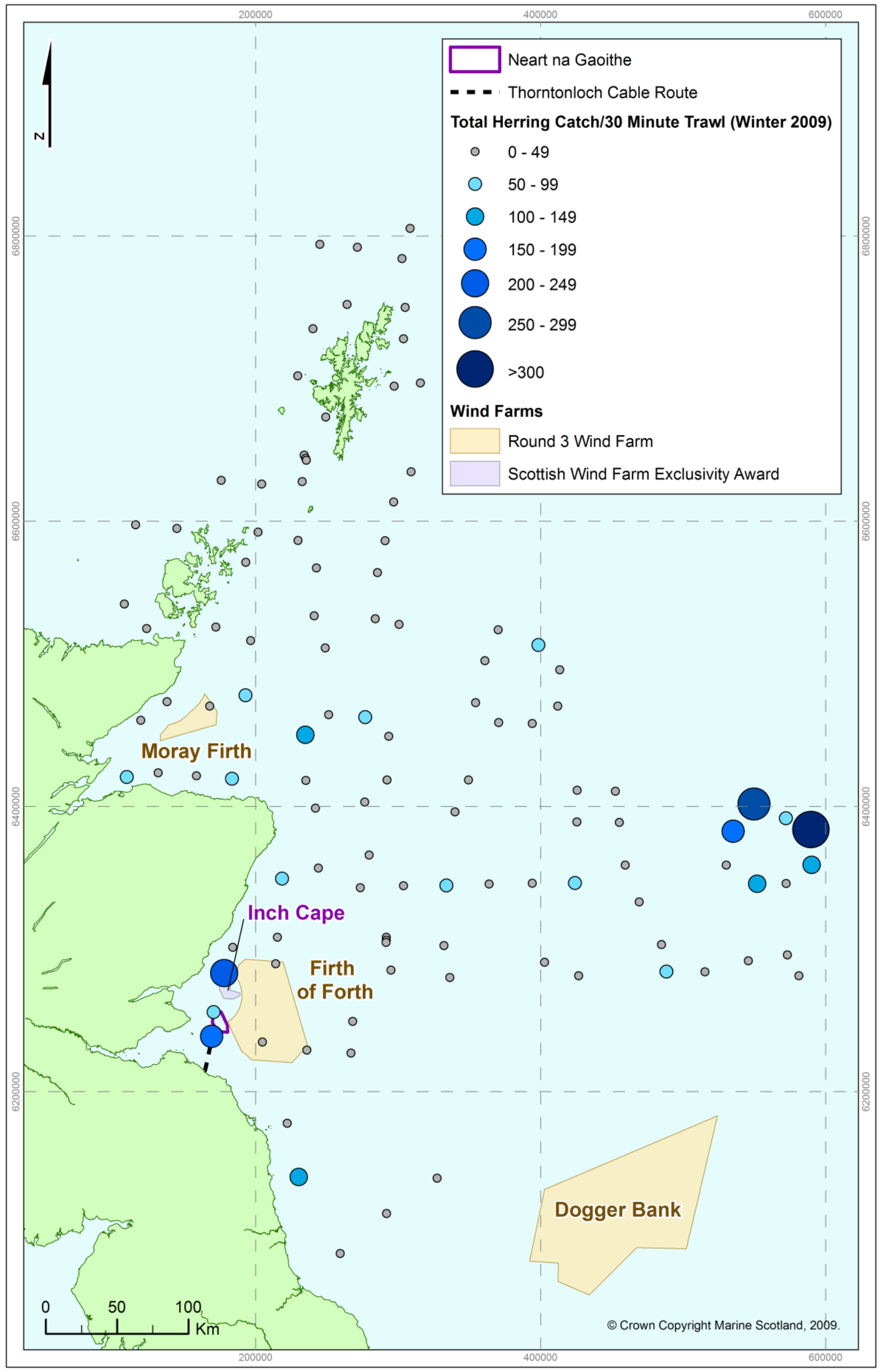
- Cod;
- Long rough dab;
- Dab; and
- Plaice.

92 Long rough dab was the most abundant species found within the Neart na Gaoithe survey area. Although found across the survey area, long rough dab tended to cluster within a discrete area within the mouth of the Forth Estuary and outside the southwest boundary of the proposed turbine array. In addition to long rough dab, gobies and the shrimps *Crangon allmanni* and *Pandalus montagui* were also found. In contrast, dab was distributed further offshore and occurred in samples collected from the east and north of the study area. Distribution patterns of other mobile epibenthos were less apparent due to the lower number of individuals recorded. Marine Scotland (2011, pers. comm.) data indicate that adults and juvenile herring species occur within and peripheral to the offshore works area (see Figures 15.15 to 15.19). Cod (see Figure 15.20) occur outside the offshore works area, in agreement with the results of the site specific survey that recorded this species at a single location outside the development area (see Figure 15.21), although they are also likely to occur within the offshore site and export cables route.

Species	Time of migration to and from natal rivers												Notes on conservation and commercial importance (see Chapter 11: Nature Conservation and Chapter 16: Commercial Fisheries for further information)
	J	F	M	A	M	J	J	A	S	O	N	D	
Atlantic salmon *S. salar*													EC Habitat Directive Annex II and V (and transposed regulations) species; Qualifying feature of the River South Esk, River Tay and River Teith Special Areas of Conservation (SACs) with varying conservation objectives and statuses as part of these sites (see SNH, 2012); Scottish Nature Conservation MPA search feature (marine life stages); Priority Marine Feature Scottish Waters (Marine part of life cycle).UK BAP species; Bern Convention Appendix 3; OSPAR species; Scottish Biodiversity List; and Commercially targeted species in region (within rivers and at coastal netting stations).
Sea trout *S. trutta*													Scottish Nature Conservation MPA search feature (marine life stages); and UK BAP species.
European eel *Anguilla anguilla*													IUCN Red List critically endangered; OSPAR species; and PMF (marine part of life cycle).
Smelt/sparling *O. eperlanus*													UK BAP species; Scottish Biodiversity List species; and PMF (marine part of life cycle).
River lamprey *Lampetra fluviatilis*													EC Habitat Directive Annex II and V (and transposed regulations) species; Qualifying feature for River Tay SAC Bern Convention, Appendix 3; Habitat Regulations, Schedule 3; Scottish Biodiversity List species; and PMF (marine part of life cycle).
Sea lamprey *Petromyzon marinus*													EC Habitat Directive Annex II and V (and transposed regulations) species; Qualifying feature of River Tay SAC; UK BAP species; OSPAR species; Scottish Biodiversity List species; and PMF (marine part of life cycle).
Allis shad *Alosa alosa*													EC Habitat Directive Annex II and V (and transposed regulations) species; Qualifying feature of a number of Special Areas of Conservation (SACs) in the region; UK BAP species; Bern Convention, Appendix 3; Habitat Regulations, Schedule 3; and Scottish Biodiversity List species.
Twaite/Twait shad *Alosa fallax*													Conservation information as per Allis shad.

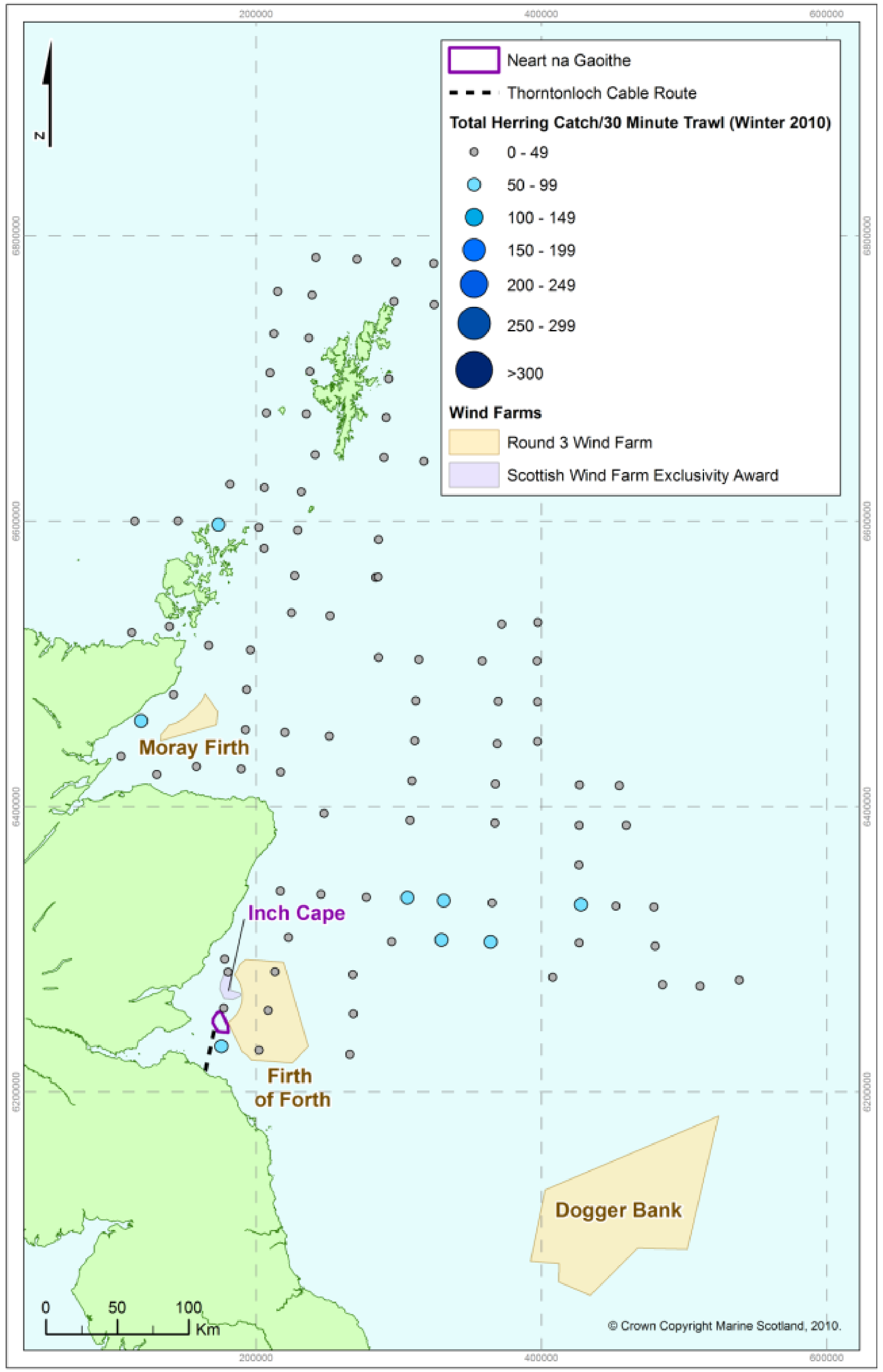
Spawning

Table 15.10: Seasonal sensitivities and conservation importance for key diadromous species



Map Document: (V:\J1131666_NnG_ES\3_Plots\2_Draft\Environmental Statement\Fish_and_Shellfish\Q1666_Fig08_NnG_Herring_Catches_Winter_2009.mxd)
28/09/2011 -- 10:45:48

Figure 15.15: Total herring catch per 30 minutes trawl (winter 2009)



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28/09/2011 -- 10:58:37

Figure 15.16: Total herring catch per 30 minutes trawl (winter 2010)

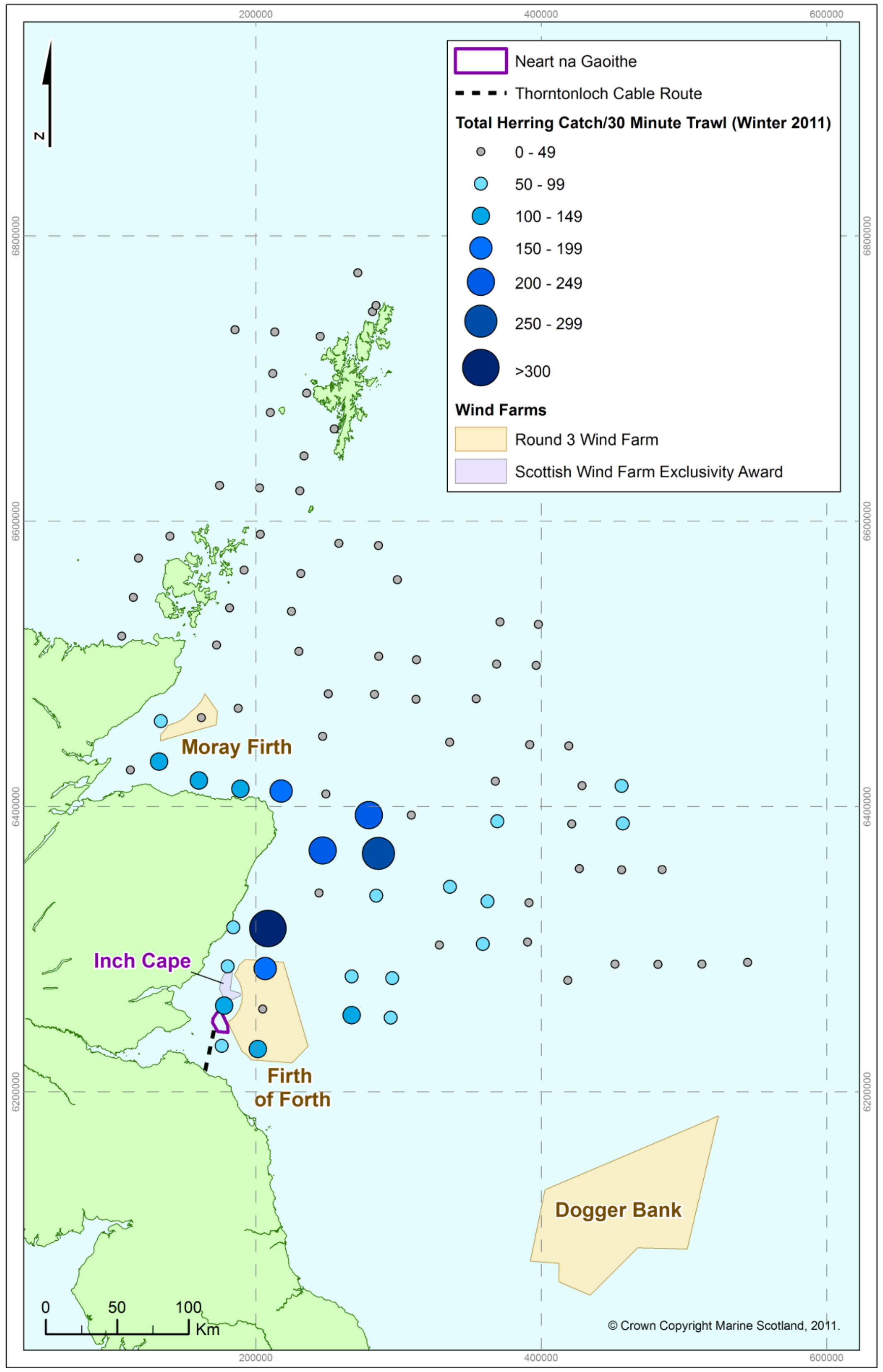

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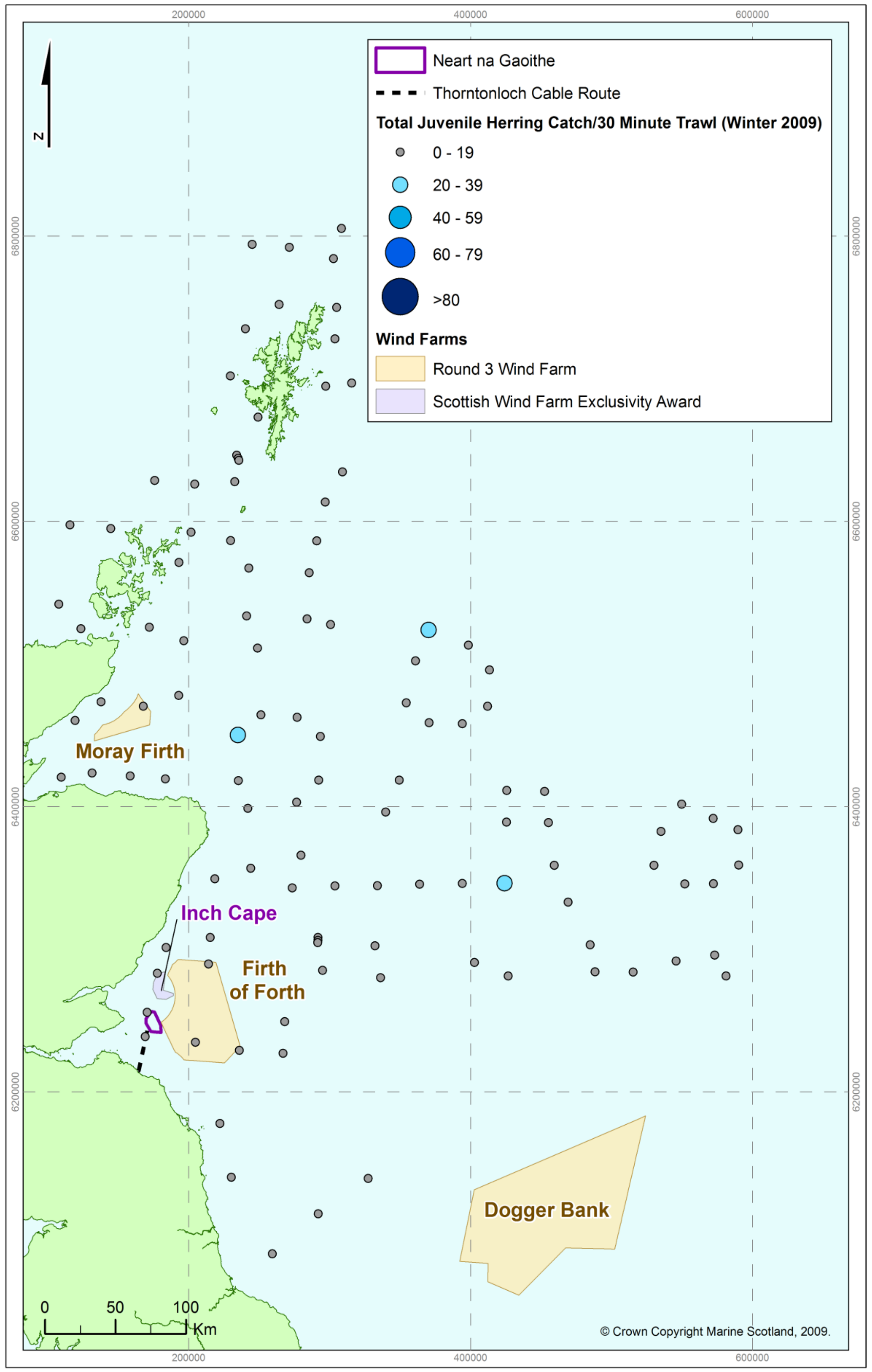
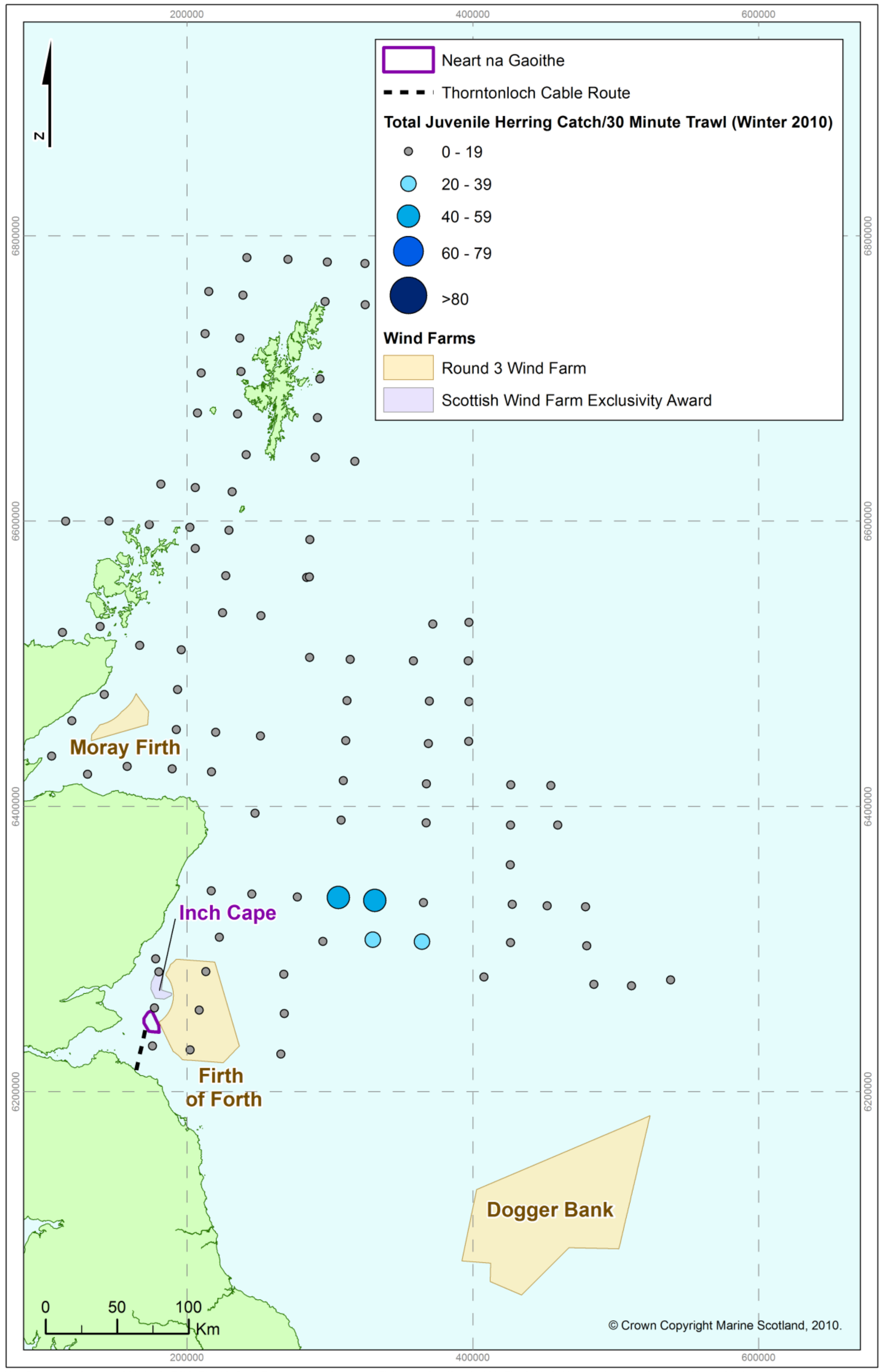
Figure 15.17: Total herring catch per 30 minutes trawl (winter 2011)



Map Document: (V:\J1131666_NnG_ES\3_Plots\2_Draft\Environmental Statement\Fish_and_Shellfish\Q1666_Fig11_NnG_Herring_Juvenile_Catches_Winter_2009.mxd)
29/09/2011 -- 11:33:52

Figure 15.18: Total juvenile herring catches per 30 minute trawl (winter 2010)



Map Document: (V:\J131666_NnG_ES\3_Plots\2_Draft\Environmental Statement\Fish_and_Shellfish\Q1666_Fig12_NnG_Herring_Juvenile_Catches_Winter_2010.mxd) 29/09/2011 -- 11:35:58

Figure 15.19: Total juvenile herring catches per 30 minute trawl (winter 2011)

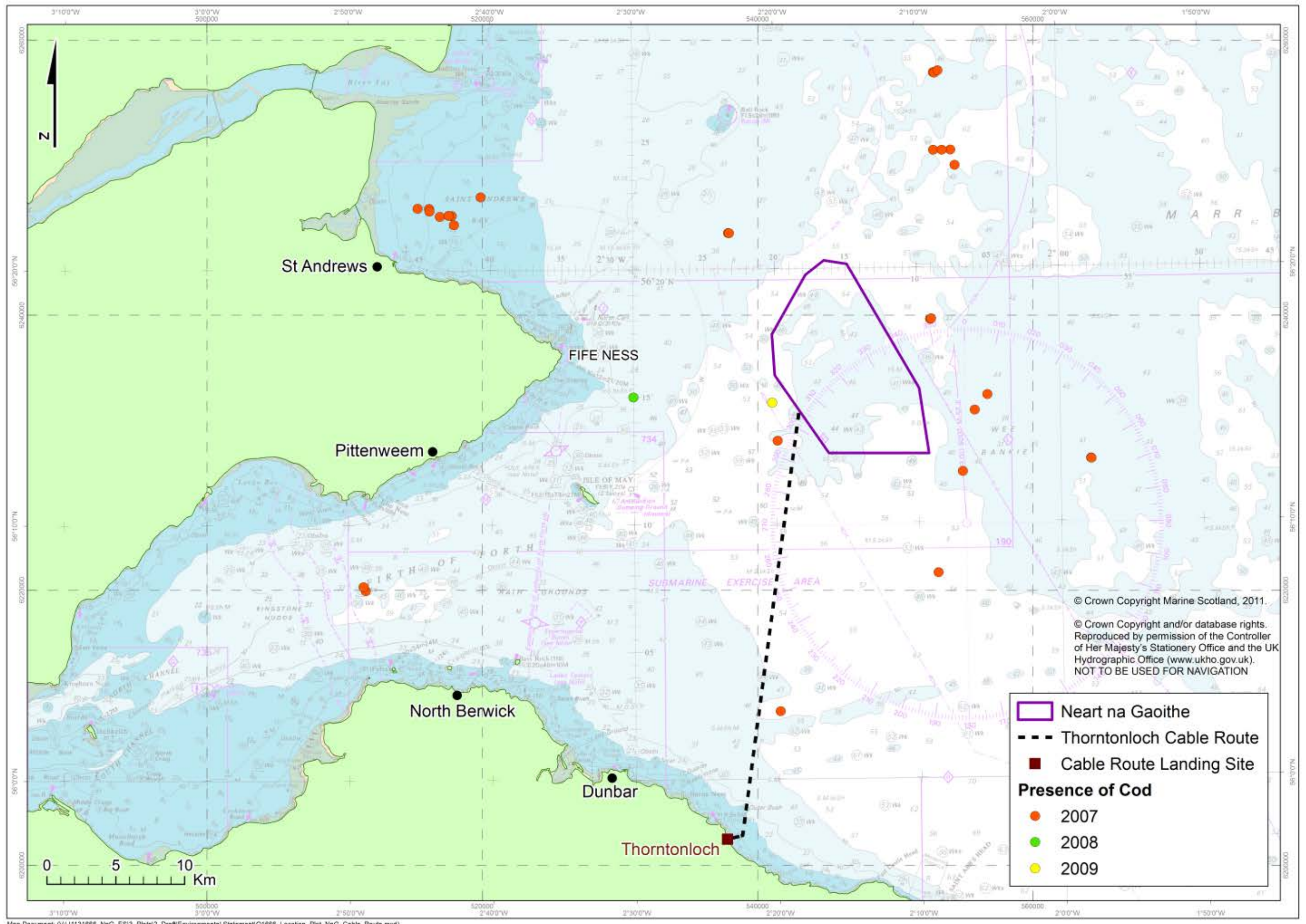


Figure 15.20: Presence of cod within the study area (Marine Scotland 2007, 2008 and 2009 data (Marine Scotland, 2011a, *pers. comm.*))

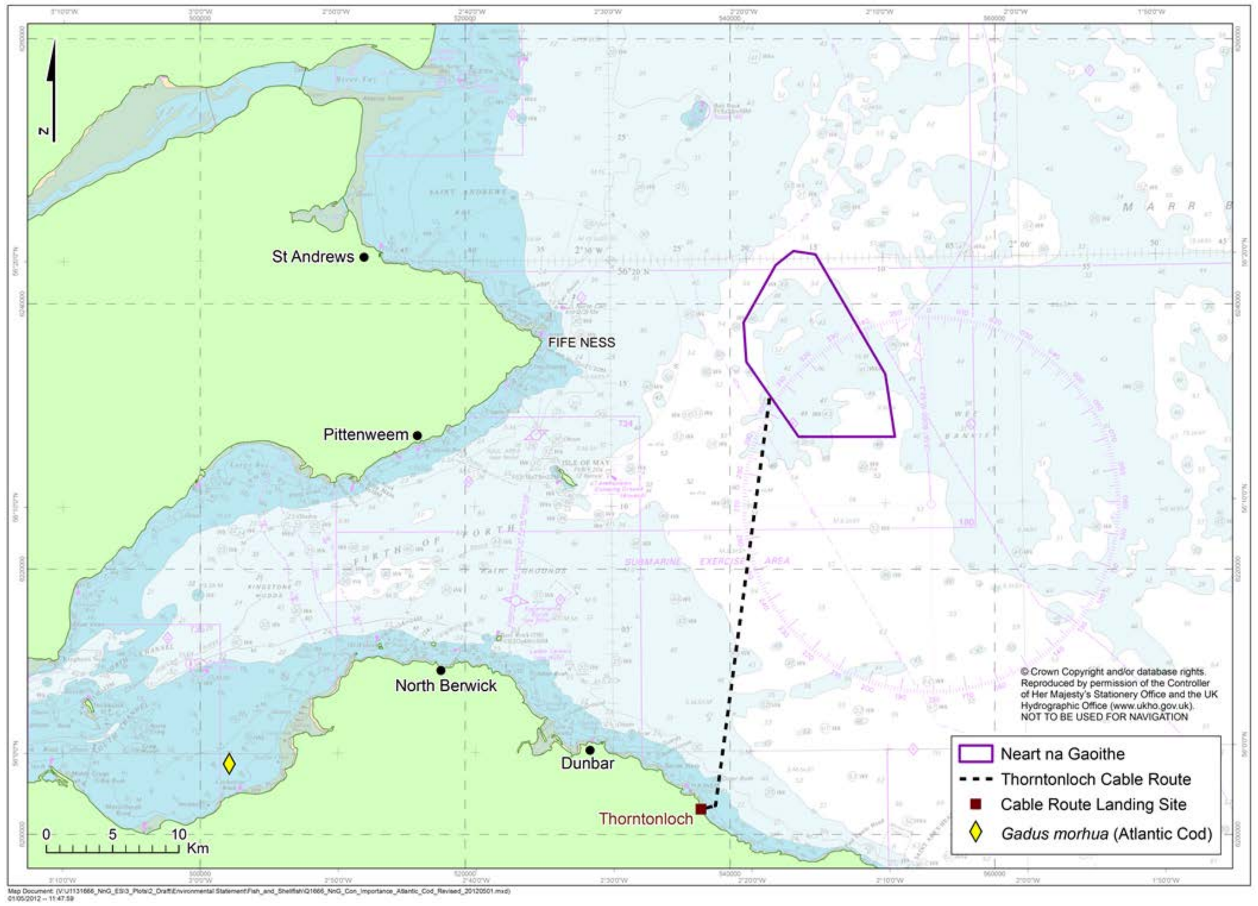


Figure 15.21: Presence of cod during the site specific survey

15.6.5 Shellfish Species in the Region

93 The range of shellfish species found in the region is shown in Table 15.11, which provides an overview of information on habitats, prey species and species of commercial and conservation importance.

94 Concentrations of squid *Loligo forbesi* occur seasonally along the southeast coast of Scotland, particularly within the kelp aggregations around the Isle of May, which also offer shelter to fish and crabs. Squid reach sexual maturity at about one year of age. They mainly reproduce only once during their limited lifespan of one to two years although they occasionally live up to three years. Breeding occurs yearly from autumn through to spring. At night females lay up to 100,000 eggs in colourless capsules attached to the seafloor (Taylor, 2002). Winter breeding cohorts spawn in inshore waters and some evidence suggests that spawning grounds of the summer breeders may also be inshore (Viana *et al.*, 2009). The embryonic development stage lasts approximately 30 days after which the young squid hatch. The young maintain a vertical body structure for a period of time, floating and drifting passively. Growth occurs rapidly during the summer and the species reaches sexual maturity between June and October (Taylor, 2002).

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

96 Two resident shrimp species, brown shrimp *Crangon crangon* and pink shrimp *P. montagui*, and a migrant species, *C. allmani*, have been identified as the main three species of shrimp in the Firth of Forth (Jayamanne, 1995), whereas crawfish *Palinurus elehas* are reported as being uncommon (Robson, 1997). *C. crangon* has been recorded throughout the estuary, while the pink shrimp occurred in the lower reaches of the estuary (Jayamanne, 1995).

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

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

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

100 Nephrops do not travel far from their burrows and as a result, the distribution of spawning and nursery grounds coincide with the adult population. Females mature at about three years old and from then on carry eggs each year from September to April or May. After hatching, the larval stage lasts 6 to 8 weeks, before settlement to the seabed (Cefas, 2001). The distribution of Nephrops spawning grounds in relation to the Neart na Gaoithe development and the North Sea is shown in Figures 15.22 to 15.25.

101 Scallops are sedentary for most of their life cycle; hence their spawning areas correspond with the areas of adult distribution (Pawson, 1995). There is considerable regional variation in the time of spawning; in Scottish waters spawning occurs in the spring and in the autumn (Cefas, 2001). It is speculated that a minimum density of spawning adults may be necessary to ensure good recruitment of juvenile scallops; consequently, productive spawning areas may be more restricted than the overall distribution of the species (Pawson, 1995).

102 Following fertilisation the egg develops rapidly into a shelled veliger larvae that is planktonic for four to five weeks, depending on water temperature, before descending to the seabed where metamorphosis occurs. During the planktonic period, hydrodynamic processes determine whether larvae disperse to new areas or return to their bed of origin (Pawson, 1995).

103 Inshore bedrock and rocky habitats also support velvet swimming crab *Necora puber*. Mating of the velvet swimming crab takes place while the female is in a soft shelled condition, with moulting (ecdysis) occurring after the main breeding season. Data on the biology of this species from Scotland, Wales and England indicate that there is much variation in the timing of reproductive events between localities (Bakir and Healy, 1995). In general, for crabs two years old and older two broods per season is considered usual in British populations. In northwest Scotland the main spawning period is reported to start in March with all berried females recorded in June carrying eggs at the hatching stage. No berried females are reported to occur between July and January (Bakir and Healy, 1995).

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

105 Ocean quahog *Arctica islandica*, the bivalve mollusc *Devonia perrieri* and the gastropod *Simnia patula* are also known to occur in the North Sea within Scottish waters (SNH, 2011) (see Chapter 14: Benthic Ecology).

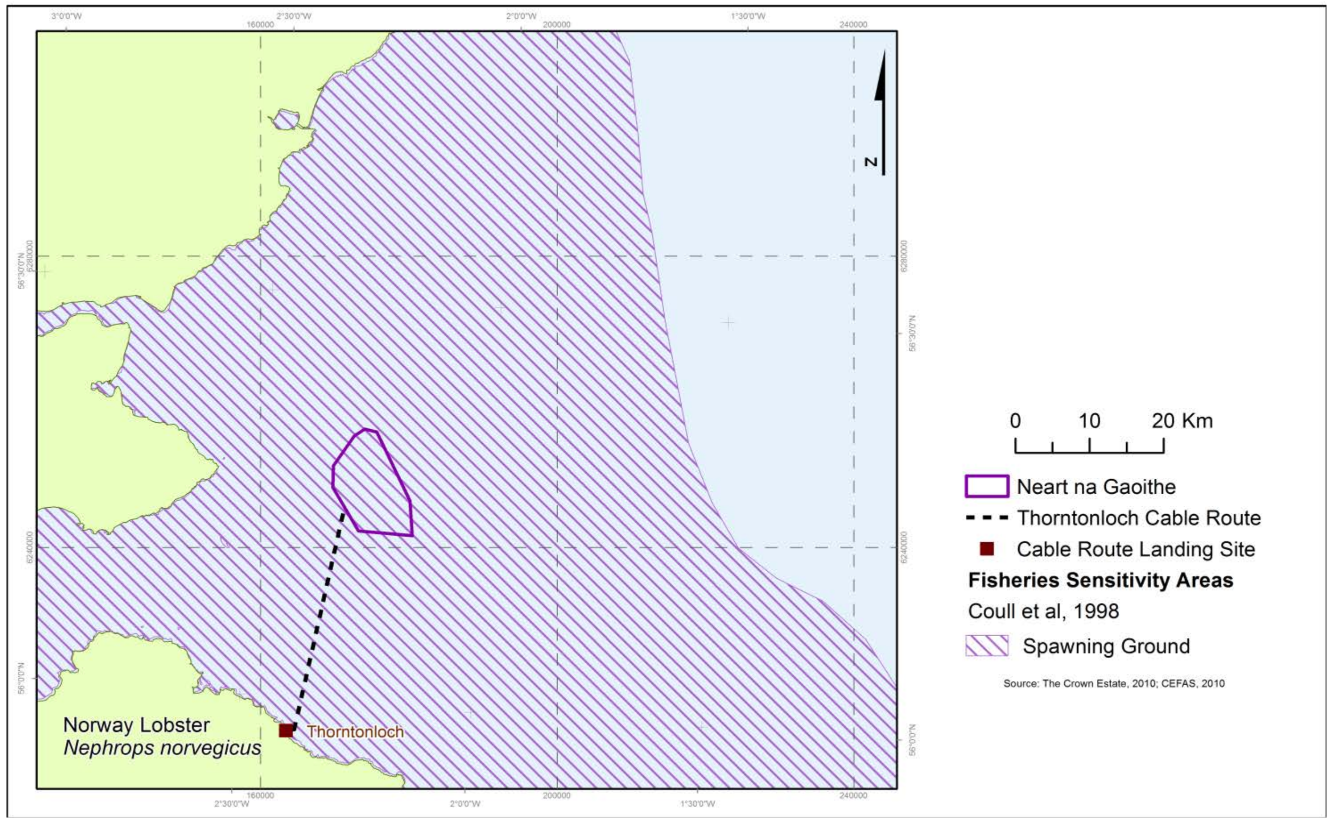


Figure 15.22 Distribution of Nephrops spawning grounds within the South coast of Scotland (Coull *et al.*, 1998)

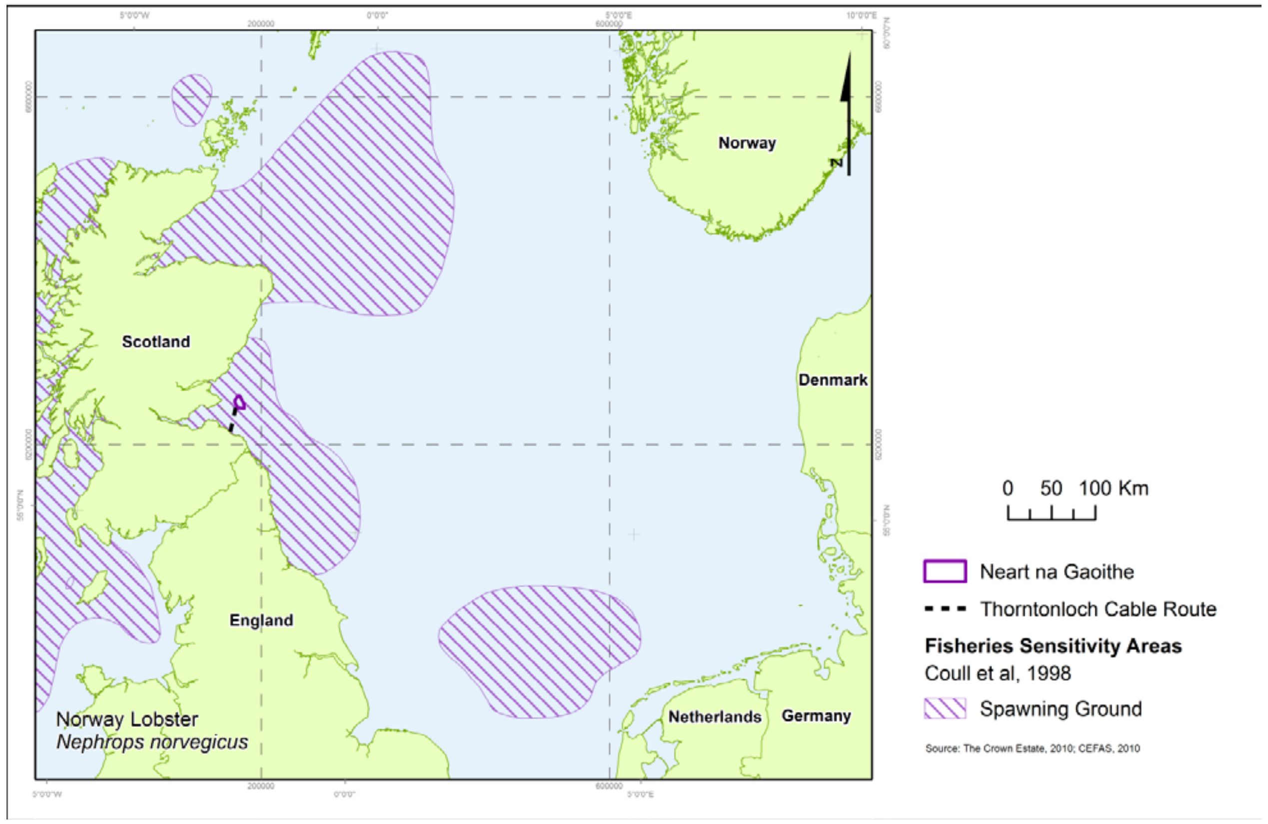


Figure 15.23 Distribution of Nephrops spawning grounds within the North Sea (Coull *et al.*, 1998)

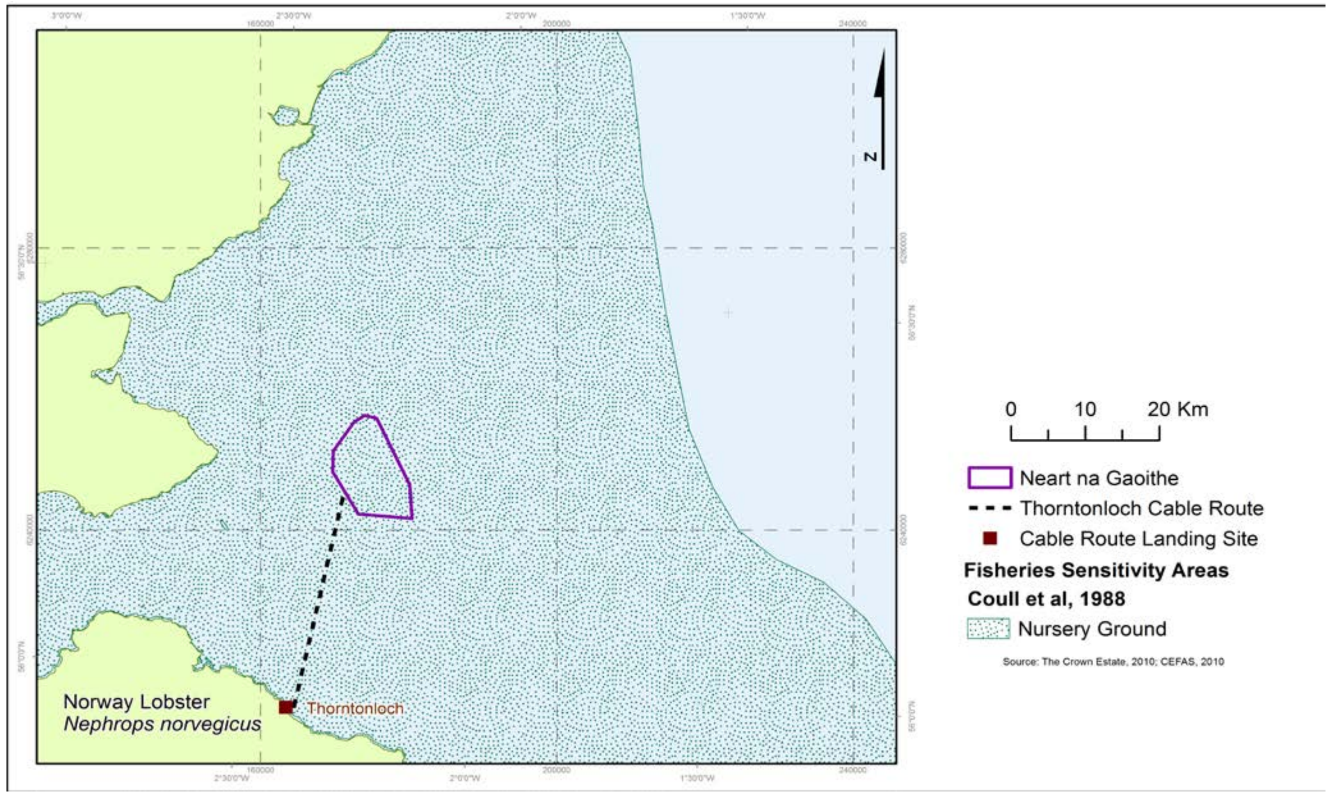


Figure 15.24 Distribution of Nephrops nursery grounds within the South coast of Scotland (Coull *et al.*, 1998)

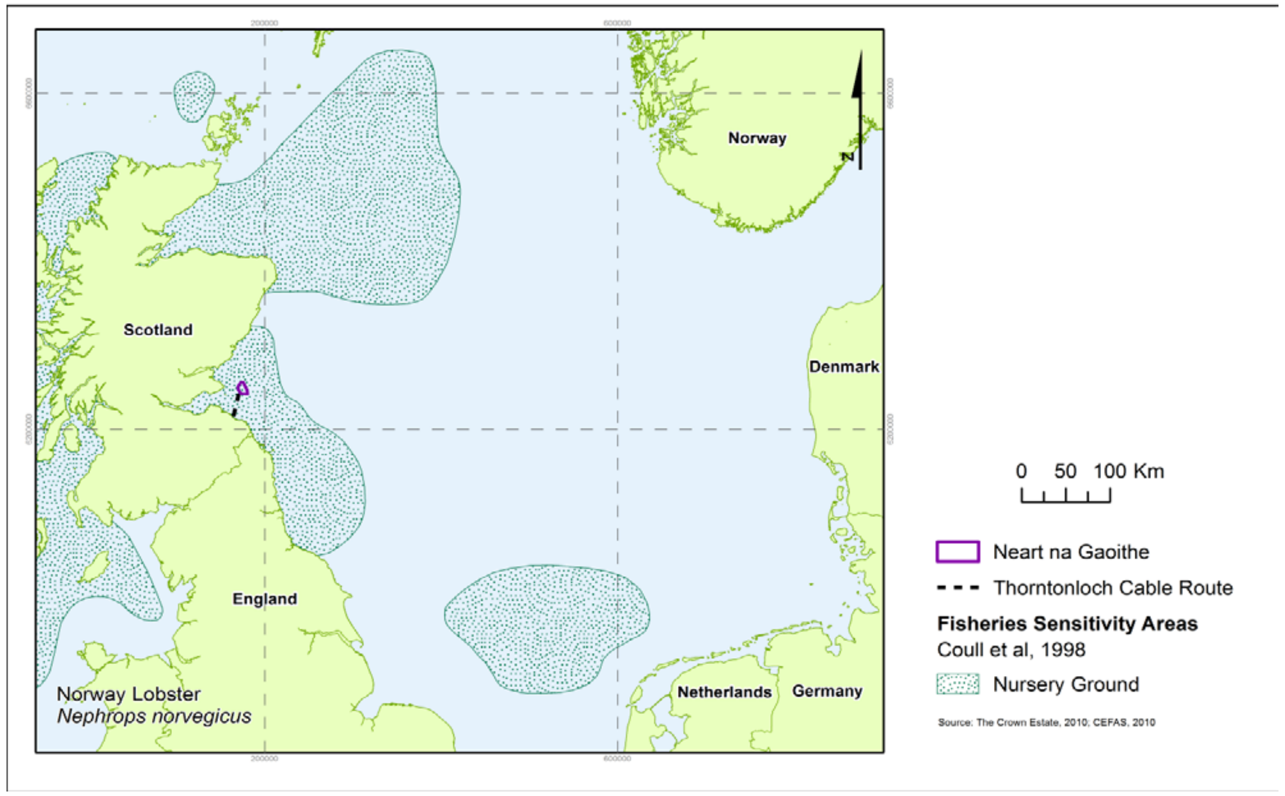


Figure 15.25 Distribution of Nephrops nursery grounds within the North Sea (Coull *et al.*, 1998)

15.6.5.1 Key Shellfish Species Found on Site

106 Forty species of shellfish were also recorded in the 2 m beam trawl samples of which five are commercially targeted in the region (shrimps *C. crangon* and *C. allmanni*, Norway lobster *N. norvegicus*, whelk *Buccinum undatum* and Queen scallop *A. opercularis*). The benthic survey allowed characterisation of much of the offshore site as the biotope SS.SMu.CfiMu.SpnMeg, Seapens and burrowing megafauna in circalittoral fine mud. This biotope is characterised by shellfish species such as Nephrops, *N. norvegicus.* Although very few individuals of Nephrops were found in the beam trawls, additional survey methods for the site characterisation, including underwater video transects and photography, indicated that there were a number of burrows in the sediment, suggesting that Nephrops may be supported in the area. In the absence of ground truthed grab samples the distribution of the megafauna burrows are assumed to be Nephrops, as shown in Figure 15.26.

107 Data from Marine Scotland indicate the Neart na Gaoithe study area does not support scallop populations. A summary of the key shellfish species is detailed in Table 15.11 (refer to Chapter 11: Nature Conservation and Chapter 16: Commercial Fisheries for further information).

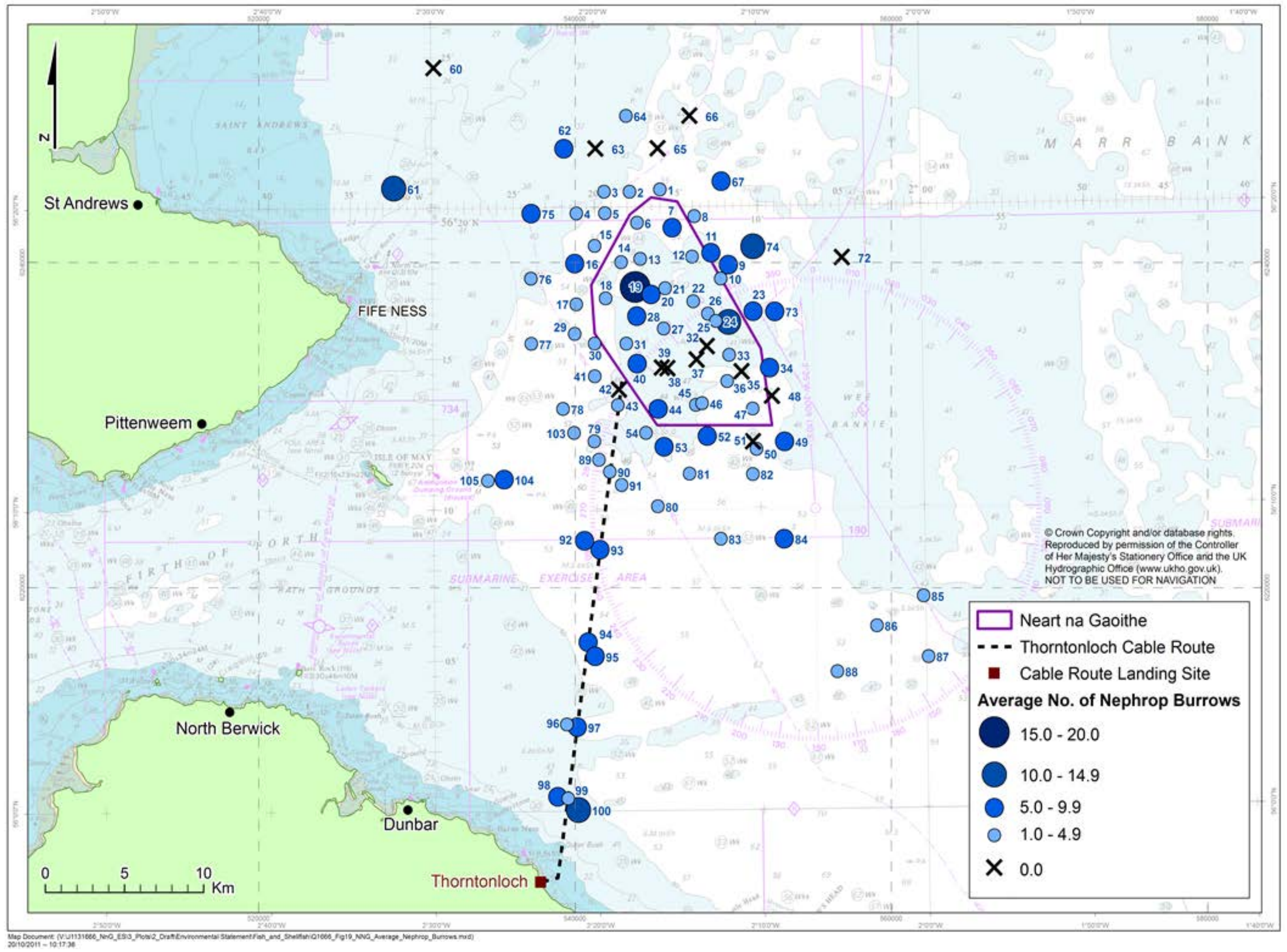


Figure 15.26: Megafauna burrows (presumably Nephrops) distribution recorded within the Neart na Gaoithe study area during the site specific survey (EMU, 2009)

Common name	Seasonal spawning activity												Habitat and feeding	Migration	Notes
	J	F	M	A	M	J	J	A	S	O	N	D			
European lobster ***Hommarus gammarus***									■	■	■	■	Demersal, on hard substrate (rock and crevices). Larvae feed on zooplankton; adults feed on crabs, molluscs, sea urchins, starfish and polychaete worms.	No regular migrations but small random movements which could be prompted by local competition for food.	Commercially targeted species
Edible/brown crab ***Cancer pagurus***					■	■							Demersal, on mixed coarse sediment habitats. Feed on a variety of crustaceans and molluscs.	Edible crabs can travel 2–3 km per day and may undertake migrations of up to 200 nautical miles.	Commercially targeted species
Velvet swimming crab *N. puber*			■	■	■	■							Demersal, on rocky and stony seabeds. Versatile feeders on fish, prawns, worms and molluscs.	No information.	Commercially targeted species
King scallop ***P. maximus***				■	■				■	■			Demersal, sedentary. Filter feeders.	The species does not migrate.	Commercially targeted species
Norway lobster ***N. norvegicus***	■	■	■	■					■	■	■	■	Demersal, in semi-permanent burrows in muddy sediments. Scavengers feeding.	The species does not migrate.	Component species of PMF and MPA search features 'burrowed mud' Commercially targeted species
Squid *L. forbesi*	■	■	■	■	■					■	■	■	Demersal. Feed on gadoid fish (mainly *M. merlangus* and *Trispopterus* sp.), sandeel and herring.	Inshore-offshore migrations, with juveniles moving from shallow inshore waters spawning grounds to feeding grounds near the shelf edge until sexual maturity when they migrate back to inshore waters to spawn.	Commercially targeted species

■ = Spawning

Table 15.11: Summary of ecological aspects of fish and shellfish species of the southeast Scotland region

15.6.6 Summary of Species Taken Forward to Impact Assessment

108 Individual species are not directly taken forward to the impact assessment, rather all potential effects are considered at each of the development phases and the corresponding impact on fish and shellfish species as a whole. The impact assessment in this case considers all fish and shellfish species but will highlight those with particular vulnerabilities to a specific impact.

15.6.7 Summary of Effects Scoped Out of Impact Assessment

109 Benthic survey results (see Appendix 14.1: Benthic Ecology Characterisation Survey) indicated that offshore sediment contaminants at the construction site were below Cefas sediment action levels and Canadian Interim Sediment Quality Guidelines. As a result, the effect of potential contaminant release from sediment disturbance is not considered to pose a threat to marine benthic invertebrate communities and has been scoped out of the impact assessment.

15.7 Impact Assessment

110 The impact assessment considers the potential effects and associated impacts arising at each stage of the development. The assessment also considers the offshore site and cable route as two distinct aspects.

111 The direct impacts identified within the Neart na Gaoithe wind farm site caused by physical changes include:

- Physical habitat disturbance during the construction phase resulting in e.g., displacement of adult stocks; disturbance to and/or loss of feeding, spawning and nursery grounds;
- Increase in SSC and turbidity during the construction phase (e.g., effects on fish respiration due to clogging of gills; impairment and change of predator-prey relationships because of visual disturbance);
- Underwater noise and vibration during the construction phase (e.g., potential injury and/or death or behavioural response; alteration of hearing thresholds leading to impairment in predator-prey interactions and/or mating behaviour);
- Habitat loss due to the presence of underwater foundation structure footprints during the operational phase;
- Habitat disturbance due to maintenance vessels and equipment during the operational phase; and
- Electromagnetic fields in the operational phase (e.g., potential behavioural reaction and disruption to migration routes and/or orientation in finding feeding/spawning grounds).

112 Indirect impacts occur as a consequence of a direct impact and may be experienced spatially and temporally from the source. These impacts acknowledge the wider ecosystem and trophic interactions between associated habitats and may include:

- Changes in hydrodynamics and nutrient transport (e.g., passive species movement and localised community interaction to higher fish species, change in localised trophic levels because nutrient cycles diverted);
- Changes in trophic links (e.g., displacement/loss of key fish/shellfish prey for higher predators, e.g., birds and marine mammals); and
- Reef effects due to the introduction of artificial substrate

113 Inter-relationship impacts are changes that occur on a single receptor from multiple sources and pathways (e.g., displacement of species due to habitat disturbance or loss and smothering by increased SSCs).

114 Cumulative impacts result from the potential interaction of effects from the Neart na Gaoithe project with other offshore and onshore wind farm projects. These are considered in the context of background variability.

115 A key component to the assessment has been the application of peer-reviewed literature with regard to species sensitivity and response to the potential effects of offshore wind farm development (e.g., noise and vibration, electromagnetic fields).

15.7.1 Impact Assessment – Construction Phase

15.7.1.1 Offshore Site

116 Effects arising from the wind farm construction have the potential to impact directly on fish and shellfish species and their related habitats. This is particularly so if a species has specific requirements or if the habitat is vital for population survival (e.g., feeding, spawning and nursery grounds and migration routes).

117 The environmental effects arising from the construction period are likely to be temporary, lasting through development activities and a period after their completion. They encompass effects associated with the turbine foundation installation and the inter-array cable installation. They are likely to include:

- Physical habitat disturbance (displacement, physical disturbance and abrasion);
- Increase in SSC and turbidity;
- Increased sediment settlement (smothering); and
- Change to noise and vibration levels from construction operations.

Physical Habitat Disturbance

118 Physical habitat disturbance is a form of direct disturbance. This may interrupt spawning or feeding behaviours and deter species from following migration routes or from using overwintering grounds.

119 Direct habitat disturbance will result in potential impact on fish populations, particularly if it encompasses spawning and nursery areas. This assessment takes into account the low magnitude of the effect due to temporal (during construction) and spatial (local to the source) limitation, together with medium severity, as sediment disturbance, across the whole site, is estimated to encompass 2.11 km^2 of the Neart na Gaoithe offshore site. This represents the worst (realistic) case scenario. This scenario assumes, amongst other parameters, use of jack-up vessels with a maximum size of spud can to install the maximum number of turbines and offshore substations, and disturbance of a 10 m wide corridor for the inter-array cables, whereas in practice trench widths usually range from 0.3 to 0.7 m (refer to Chapter 9: Physical Processes) and are up to 1.5 m deep (refer to Chapter 5: Project Description).

120 The vulnerability of juvenile fish within spawning and nursery areas is considered to be low, based on their extensive occurrence within the wider geographic context. Hence any potential disturbance to these areas as a consequence of construction operations is predicted to have a minor significance of impact on future local fish populations. Information on the potential vulnerability of Nephrops habitat is assessed in Chapter 14: Benthic Ecology. Larger, mobile fish species are able to avoid disturbance and survive (EMU, 2004). Shellfish which are, by comparison, much less mobile (some spending most of their time half buried in the sediment), have also been considered to have low vulnerability to physical disturbance based on the fact that even if high numbers of individuals may die as a result of habitat disturbance the whole population is unlikely to be affected (MarLIN, 2011). This is particularly relevant if the shellfish species are widespread within the wider geographical context and can ensure production of offspring to re-populate the area after cessation of operations.

121 Considering the low magnitude and low vulnerability the overall significance of impact is considered to be of ***minor significance***. This assessment carries low uncertainty (refer to Table 15.12).

Source	Pathway	Receptor	Magnitude of effect	Vulnerability of receptor	Significance of impact	Qualification of significance
Installation of turbines, subsea cables and associated structures	Habitat disturbance	Fish and shellfish populations	Low	Low	Minor significance	Probability is high. Uncertainty is low. Mobile species are expected to avoid disturbance and less mobile species are fairly widespread within the region.

Table 15.12: Impact assessment of direct habitat disturbance from construction on fish and shellfish populations in the offshore site

Increased Suspended Sediment Concentration and Turbidity

122 The increase in SSC and turbidity has the potential to have an effect on activities such as filter feeding, migration and movement of fish, survival of pelagic eggs and fish larvae, and forage opportunities of visual predators (Birkuland and Wijsman, 2005). Increases in SSC within the Neart na Gaoithe offshore works area is likely to occur following preparation of the seabed for gravity base foundations, which require levelling of the seabed by dredging. Results of the model analysis (see Chapter 9: Physical Processes) show that the discharge of dredged material during this process will lead to elevated SSC with peaks of up to 300 mg/l (depth averaged) very close to the release location. However, the resulting plumes will not be advected beyond the immediate vicinity of the dredging site and concentrations are predicted to be less than 10 mg/l at a distance of 1 km from the gravity base, which are comparable with natural background levels ranging from 3 to 8 mg/l (see Chapter 9: Physical Processes), which are in themselves very low. The suspended sediment plume (>1 mg/l) is predicted to extend up to 4 km from the release location and will settle out of the water column within one day if released near the surface.

123 Overall the magnitude of the effect is assessed to be low due to its limited spatial and temporal extent and intermittent frequency during the construction operations. Adult fish would normally be able to detect significantly elevated levels of suspended sediment and avoid the affected area (EMU, 2004), although juvenile fish may be more susceptible than adult fish to plumes. Highly sedentary species are less tolerant to increases in SSC, which may result in reduced growth or even death, particularly during spring when spatfall occurs (ABP Research, 1997). Conversely, some filter feeders such as the common mussel are used to large variations in ambient concentrations of suspended matter, and can maintain their normal rate of ingestion and absorption of food at SSC levels of between 0 to 56 mg/l (Birkuland and Wijsman, 2005).

124 Increase in SSC may affect fish species with pelagic eggs, such as cod, plaice and flounder, as silt could adhere to the egg surface increasing their sinking rate. An increase in mortality of pelagic eggs may occur if the eggs sink to the seabed before completion of the pelagic phase. However, the levels of predicted increase of SSC during the construction phase of the proposed development are predicted to be lower than those reported to cause fish egg mortality (Birklund and Wijsman, 2005). In addition, the duration over which the activity will take place will be short and limited to the proximity of the release location (refer to Chapter 9: Physical Processes). Since winter storm events occur within the area, it is likely that many of the fish and shellfish species found in the area will be adapted to temporary increases in SSC. The SSC generated during such a storm will be of greater magnitude than will be produced by the construction works, so sensitivity will be low for most species.

125 The vulnerability of fish and shellfish populations to SSC increases due to construction and operation activities is assessed to be negligible, as SSC will not reach levels significantly higher than natural background levels, except at sites in very close proximity to the source (within 10 m).

126 Considering the low magnitude and negligible vulnerability the overall significance of the impact of increased SSC and turbidity on fish and shellfish is considered to be of ***minor significance***. This assessment carries low uncertainty (refer to Table 15.13).

Source	Pathway	Receptor	Magnitude of effect	Vulnerability of receptor	Significance of impact	Qualification of significance
Installation of turbines, subsea cables and associated structures	Increase in SSC	Fish and shellfish populations	Low	Negligible	Minor significance	Probability is high Uncertainty is low. The increases in SSC predicted to occur during the construction phase (refer to Chapter 9: Physical Processes) are much lower than those reported to impair fish and shellfish

Table 15.13: Impact assessment of increase in SSC from construction on fish and shellfish populations in the offshore site

Increased Sediment Settlement and Smothering

127 Results of the modelling studies indicate that if the dredged material is released at the surface of the water the deposition footprint will be up to 0.1 m thick directly around the indicative turbine locations and up to 0.003 m within the boundary of the offshore site (Chapter 9: Physical Processes). This footprint will be elliptical and aligned with the tidal ellipse, extending up to about 1 km away from the turbine location to a thickness of 1 mm or more. The deposition footprints around each gravity base will overlap neighbouring footprints to form a more or less continuous layer of deposited dredged material of varying thickness across the offshore site.

128 However, if the dredged material were released close to the seabed, the magnitude of the depth averaged concentrations in the resulting plume would be similar, but its extent would be smaller. As with the sea surface release, the sediment deposition footprints will overlap but will not extend as far beyond the site boundary. This assessment assumed that all the dredged material will be released into the water column.

129 Due to the relatively limited spatial and temporal extent and intermittent frequency, the magnitude of the smothering effect of sediment dredging and release for the construction of the gravity base foundations is assessed as being low.

130 The effects of sediment settlement depend on a number of factors, including physical (e.g., rate of sedimentation, sediment type) and biological (e.g., ability of the species to tolerate changes in the bed sediment). In general, sediment deposition in naturally sandy or muddy habitats, like those occurring within the Neart na Gaoithe, is likely to have less impact compared to e.g., gravel habitats hosting sessile and encrusting epibenthic species which are likely to be unaccustomed to fine sediment (Boyd and Rees, 2003). Increased sedimentation and re-suspension caused by dredging in mobile sands are generally thought to be of less concern due to the fact that fauna inhabiting such areas are more adapted to naturally high levels of suspended sediment resulting from wave and tidal current (Sutton and Boyd, 2009). Results of the particle size distribution (PSD) analysis of grab samples collected as part of the site specific survey show that the majority of samples exhibited high fine sediment content; therefore, it is likely that the benthic communities currently present in this area are adapted to high levels of deposited sediment.

131 The overall vulnerability of fish and shellfish species in relation to the development is assessed to be negligible, particularly in view of the occurrence and distribution of sensitive species within the wider geographical context. As the excursion of sediment plumes is predicted to be relatively limited, impacts of smothering are likely to be adjacent to the dredged area and, therefore, of limited impact particularly when compared to direct disturbance/loss of potential spawning/nursery grounds.

132 Considering the low magnitude and negligible vulnerability the overall significance of the impact of increased sediment settlement and smothering is predicted to be of ***minor significance*** and this assessment carries low uncertainty (refer to Table 15.14).

Source	Pathway	Receptor	Magnitude of effect	Vulnerability of receptor	Significance of impact	Qualification of significance
Installation of turbines, subsea cables and associated structures	Increase in sediment settlement/smothering	Fish and shellfish populations	Low	Negligible	Minor significance	Probability is high. Uncertainty is low. Thick depositions of sediment are unlikely to occur on a wide enough area to impair fish and shellfish

Table 15.14: Impact assessment of increased sediment settlement/smothering from construction on fish and shellfish populations in the offshore site

Changes to Noise and Vibration Levels from Construction Operations

133 The potential impact of underwater noise and vibration on fish and shellfish populations within the proposed development areas is associated with pile driving, which could increase the noise level significantly above natural background levels. In UK coastal waters general background levels of sea noise are reported to be approximately 130 dB re 1 μPa (Nedwell *et al.*, 2007; Nedwell *et al.*, 2003).

134 The majority of fish detect sounds from below 50 Hz up to 500-1,500 Hz. A small number of species can detect sounds to over 3 kHz while a very few species can detect sounds to well over 100 kHz. The fish known to have the widest hearing frequency bandwidth are limited to the members of the clupeiform genus *Alosa* (Popper and Hastings, 2009) while the American shad *A. sapidissima* is able to detect sound up to 180 kHz (Andersson, 2011).

135 There is great variety of hearing capabilities among species, with fish generally classified as hearing specialists (those with a connection between the swim bladder and the inner ear) and hearing generalists (those lacking a swim bladder) depending on their ability to detect sound (Thomsen *et al.*, 2006). However, recent studies by Popper and Fay (2010) advise dropping these terms, due to their vague and often different definitions and meaning given in the literature. In addition, there is evidence that most fish species have a sensitivity to both pressure and motion that is frequency dependent, and consequently these species could not be defined as either hearing generalists or specialists (Popper and Fay, 2010).

136 Fish reactions to noise are divided into four zones representing areas where different impacts or injuries could occur. These are briefly summarised below:

- **Zone of hearing loss, injury or discomfort** - When anthropogenic noise in the sea reaches certain levels, fish may sustain lethal or physical injury (Nedwell *et al.*, 2007) or sustain temporal or permanent hearing loss, referred to as *Temporal Threshold Shift* (TTS) and *Permanent Threshold Shift* (PTS) respectively (Thomsen *et al.*, 2006). If the hearing loss is only temporal, the fish will recover within hours or days, depending on the duration and frequency of the noise; however, during the recovery time fish may be more vulnerable to predation or inhibited to perform biologically important activities (Andersson, 2011);
- **Zone of masking** - Fish produce sounds in a "social" context for antagonistic interactions (aggression, defence, territorial) as well as for courtship and mating (Thomsen *et al.,* 2006). Anthropogenic noise raises the ambient level of sound making the detection of sound more difficult as the signal-to-noise ratio decreases leading to a reduction in signal detection distance; this occurs only if there is an overlap in frequencies between the induced noise and the sound of interest (Andersson, 2011);
- **Zone of audibility** - The zone of audibility is linked to the hearing threshold and sensitivity of the individual species (Andersson, 2011). Masking is overcome when the signal-to-noise ratio is high enough for a fish to sense the sound, while even if the natural ambient sounds (e.g., from wind, waves, rain and biological activities) are higher than the induced anthropogenic noise, the fish will not hear it. This is because fish can detect a narrow band signal in a broad band noise, which is the normal acoustic state of the sea (Andersson, 2011); and
- **Zone of responsiveness** - The zone of responsiveness is the region within which fish react behaviourally to a given noise (Thomsen *et al.*, 2006). Behavioural responses can range from startle and avoidance to more subtle reactions such as changes in swimming activity, vertical distribution and schooling behaviour (Andersson, 2011). Fish will most likely respond in different ways to noise, as the tolerance thresholds are linked to age, sex, condition, season and habitat preferences (Andersson, 2011). If fish remain in an area exposed to noise levels above the hearing threshold, but not at a level that triggers behavioural response, other indirect effects may occur such as "physiological stress" (e.g., Increased levels of the stress hormone cortisol which could disrupt growth, maturation and reproductive success) (Thomsen *et al.*, 2006).

137 Field measurements of sound generated during the installation of piles for jacket foundations at an offshore wind farm development indicate a maximum peak level of 195 dB during the pile driving and a maximum sound exposure level (SEL) of 176 dB at 720 m distance from the pile (ITAP, 2008). At a distance of 2300 m the peak level was 180 dB and 164 dB for SEL. The spectral maximum of the pile driving noise was in the frequency range of 80-200 Hz (ITAP, 2008).

Underwater Noise Modelling Approach and Magnitude

138 The potential impact of pile driving operations associated with the construction of the Neart na Gaoithe wind farm was investigated by means of subsea noise modelling using the modelling software package INSPIRE (Appendix 13.1: Noise Model Technical Report). This considered the likely range at which injury and behavioural response might be expected for selected fish species, i.e., dab, trout, salmon, sandeel and herring, the latter known to be particularly sensitive to noise.

139 These species have been selected based upon the availability of a good quality peer reviewed audiogram (e.g., dab), their regional relevance in terms of the proximity of species spawning sites (e.g., herring) and concerns raised during consultation (e.g., salmon, trout and sandeel). The dab is a flatfish species with generalist hearing capability, which provides a precautionary surrogate for sole and flatfish species in general. Salmon and trout are highly mobile species that undertake large seasonal movements and migrations, during which they may be vulnerable to noise associated with construction operations. Sandeel are of particular ecological importance within the study area as they provide a food source for many seabirds and fish; they also have poor hearing capabilities but are likely to be sensitive to particle motion.

140 The dB_{ht}(species) perception unit, corresponding to the sound level above a species' hearing threshold (Nedwell *et al.*, 2007), was used for modelling the assessment, which considers the following impact ranges for the 3.5 m diameter pile (worst (realistic) case scenario) and the 2.5 m (most likely scenario):

- 130 dB_{ht}: traumatic hearing loss;
- 90 dB_{ht}: strong avoidance behaviour; and
- 75 dB_{ht}: significant avoidance behaviour.

141 The criteria assumed for the behavioural responses described above are based on observations carried out in relatively shallow water using fish avoidance systems where it is concluded that at levels of 90 dB_{ht} and above virtually all of a species will avoid the sound. These behavioural responses serve as precautionary estimates and should be used in the absence of more widely agreed and independently evaluated figures.

142 The use of a 130dB_{ht} level provides a suitable criterion for predicting the onset of traumatic hearing damage, taking into account the hearing sensitivity of the species (Nedwell *et al.*, 2007). Based on a large body of measurements of fish avoidance of noise, a level of 90 dB_{ht} was used as the level at which a strong likelihood of disturbance to the majority of individuals of a species would be expected (Nedwell *et al.*, 2007). A lower level of 75 dB_{ht} was used to indicate that a significant behavioural impact in approximately 85% of individuals is likely to occur, although the response from individuals within a species will vary, i.e., one individual may react, whereas another individual may not. In addition, there is some evidence indicating that fish become habituated to lower level noise (Nedwell *et al.*, 2007).

Fish Species Vulnerabilities to Underwater Noise

143 Data from Marine Scotland (2011, pers. comm.) indicate that adult herring, and to a lesser extent juveniles, are present within the site development area (see Section 15.6.2.3). However, the proposed offshore works area does not contain or overlap with any herring spawning grounds. Spawning in the southeast Scotland region takes place during August to October with peak activity in September (Ellis *et al.*, 2012; Payne, 2010; Hughes and Nickell, 2009; Cefas, 2001) with the two main inshore spawning areas located on the northern coast to Orkney and Shetland and off the Aberdeenshire coast (Hughes and Nickell, 2009).

144 Similarly, the data do not record sandeel catches within the proposed offshore site (Marine Scotland, 2011, pers. comm.) and results of the site specific survey indicate that habitats within the Neart na Gaoithe region are likely to be unsuitable for sandeel populations, because of the relatively high mud sediment habitats. This was further investigated adopting the sediment classification outlined in Greenstreet *et al.* (2010), which corroborated the initial assumption (see Section 15.6.3.5).

145 The currently available information on the migratory routes of trout and salmon is scarce, as a result of this uncertainty the precautionary approach has been taken to assume salmon and sea trout are present offshore.

146 The available information indicate that post-smolt salmon migrate rapidly and actively towards open sea from their river sources (Thorstad *et al.*, 2007, Finstad *et al.*, 2005; Lacroix *et al.*, 2005) and do not follow nearby shores except in areas subject to strong coastal currents (Lacroix *et al.,* 2005). Once at sea, migration is northward along the continental shelf, using dominant ocean currents (Malcolm *et al.,* 2010). Spent or spawned salmon, known as kelts, migrate to sea rapidly in shallow waters (Malcolm *et al.*, 2010). Adults return to Scottish waters from areas to the north and west of the British Isles (Malcolm *et al.*, 2010). With regard to sea trout the available information is indicative of relatively wide ranging migrations with local recaptures at less than 40 miles and very few more distant recaptures of up to 270 miles (Malcolm *et al.*, 2010).

147 Research trials on the effects of pile driving carried out with caged farmed *S. trutta* revealed no evidence that the fish reacted to impact piling at a distance of about 400 m nor to vibration piling at close ranges (<50 m) (Gill and Bartlett, 2010). However, the use of farmed fish and relatively low sound pressure levels made the results inconclusive (Gill and Bartlett, 2010).

148 The most recent study on hydro-acoustic impacts on fish from pile driving provides the first critical step at quantifying the effects of pile driving noise on fish, by identifying numerical relationships between the most important variables in pile driving (i.e., cumulative and single strike sound exposure levels and number of strikes) and their effects on fish. However, other quantitative data on variables associated with pile driving (e.g., impulsive sounds) and responses to these by different fish species and fish sizes are necessary to develop a full array of criteria to protect fish (Halvorsen *et al.,* 2011).

149 Much uncertainty still exists with regard to the effect of pile driving operation noise on fish eggs and larvae and the spatial extent at which mortality or injury may occur (Popper and Hastings, 2009). The few studies that are available focus on seismic air guns or mechanical shock, which generate noise very different from that produced by pile driving, and although results of these studies may not be directly comparable (Popper and Hastings, 2009), they provide an indication of sound induced injuries on the fish at different life stages. In general, juveniles and larvae are less mobile and, therefore, presumed more vulnerable than the adults to the effects of subsea noise. Of particular relevance is the study by Kvadsheim and Sevaldsen (2005) which showed that mortality threshold for juvenile herring exposed to sonar signals was 180-190 dB, the former value was only applicable if the transmitted frequency was within the frequency band corresponding to the resonance frequency of the swim bladder, i.e., 1-2 kHz (Kvadsheim and Sevaldsen, 2005). However, a recent IMARES study found no significant effect on North Sea fish larvae to cumulative sound exposure levels up to 206 dB, considerably higher than the US interim criterion for non-auditory tissue damage in fish <two gram at a cumulative SEL of 183 dB (Bolle *et al.,* 2011).

Shellfish Species Vulnerabilities to Underwater Noise

150 Decapod crustaceans including crabs, lobster, Nephrops and shrimps have a variety of physiological adaptations that could act as receptors to sound and vibration. They are also known to produce acoustic signals; however, little is known about their sensitivity to either sound or vibration and the current available literature does not provide robust scientific evidence to draw any conclusions on the potential effects of noise and vibration on marine molluscs and crustaceans. A study reported no apparent impact or catch rate reduction in species such as mussels, brown shrimps and Nephrops, based on noise associated with shooting by air guns or seismic survey (Moriyasu *et al.*, 2004), with the exception of the European squid that was fatally injured when exposed to such noise (Moriyasu *et al.,* 2004). A recent study by André *et al.* (2011) reported acoustic trauma in selected cephalopod species, including the European squid, following exposure to low frequency sound in experimental conditions. However, Fewtrell and McCauley (2012) suggest that such alteration in hearing ability may only be temporary as experimental studies using air guns indicate habituation of the animal to noise at low levels.

151 In a laboratory experiment Nephrops have been shown to elicit distinct postural responses to sound frequencies of 20-180 Hz (Popper *et al.*, 2001). In the field Nephrops responded to particle displacement and not pressure; behavioural thresholds of ~0.9 um over a range of 20-200 Hz were evident (Popper *et al.*, 2001). However no response was observed when the stimulus was further than 0.9 cm from the animal. These sensitivities are substantially poorer than those shown by fishes over the same range of frequencies (Popper *et al.*, 2001, Popper and Fay, 1999, Goodall *et al.*, 1990). Most, if not all, decapods have sensory structures capable of responding to substrate borne vibrational stimuli, however, this area of research has been largely unstudied even for common and commercially important species including lobster and brown crab.

Underwater Noise Modelling Results and Assessment of Impacts: Mortality and Traumatic Hearing Loss

152 Results of the site specific modelling study for pile driving indicate that the range of lethal effect on fish populations is restricted to less than 10 m from the noise source, whereas physical injury will occur within a radius of less than 60 m from the noise source (Subacoustech, 2012). The area of lethality has been calculated to be 78.54 m^2 per pile and the area over which physical injury may occur is 2,827.4 m^2 per pile.

153 Based on the results of the modelling study, the extent of the radius of traumatic hearing loss is anticipated to be localised (<1 km from noise source) from each piling operation and restricted to the duration of pile driving activities. The overall magnitude of the effect is considered to be medium. The vulnerability of the species to mortality or severe traumatic hearing loss is considered high for hearing sensitive species such as herring and cod, moderate for all other fish species and low for crustaceans.

154 It is recognised that most fish species will swim away from the noise source as indicated by experimental studies (Mueller-Blenkle *et al.,* 2010). However, this may not apply to all species as some may have specific habitat requirements from which they are unwilling to move, for example sandy areas occupied by sandeel. In addition, the speed at which the individual fish needs to travel in order to evacuate the area of injury may not be physically possible or sustainable over long distances. To date, interim criteria for the onset of tissue damage due to sound exposure are still being defined. The U.S. Guidance, U.S. Memorandum and the European Commission Marine Strategy Framework Directive Task Group for underwater noise and other forms of energy all recommend using the dual criteria of Carlson *et al.* (2007) that uses single and multiple pulse sound exposure levels. Those originally suggested by Popper *et al.* (2006), 208 dB re 1 µPa peak and 187 dB re 1 μPa^2-s SEL, were based on several conservative assumptions on pile driving and fish behaviour during noise exposure, none of which were validated by field data. Deviation from these assumptions would result in lesser effects on fish (Popper *et al.,* 2006). Subsequent studies used additional data to propose cumulative values of sound exposure levels for onset of tissue damage that depended on fish mass, therefore, as fish get larger, the exposure value increases (Carlson *et al.*, 2007).

155 Site specific measurements of background noise are not available, however, Nedwell *et al.* (2003) report general background noise levels of 130 dB re 1 µPa in UK coastal waters. Increased shipping activity during the construction phase will result in an increase in noise at lower frequencies (≤100 Hz) while also introducing high frequency (kHz) sounds from equipment such as ecosounders (Nedwell *et al.*, 2003). In addition, many fish, (e.g., flatfish species) perceive the sound through particle motion rather than the pressure component of the sound.

Sensitivity to particle motion has particular relevance close to a pile driver where particle motion will be generated in the water column as well as in the sediment; therefore, flatfish may be exposed to much higher particle motion (Muller-Blankle *et al.*, 2010) than the sound pressure estimated. Although experimental research has provided threshold ranges for particle motion effects on sole, these cannot be extrapolated to predict the ranges of behavioural change onsets from real piling operations (Mueller-Blenkle *et al.*, 2010).

156 Based on the results of the modelling study and the information currently available in the literature, the impact of traumatic hearing loss from construction noise on fish and shellfish communities is assessed to be of ***minor significance***. This assessment carries high uncertainty, as many gaps still exist in the literature with regards to, for example, the hearing thresholds/range estimations, since they are based on the assumption that all fish within a species have the same hearing threshold, whereas in reality there are individual differences in sound detection, and in an area with different acoustical properties the detection distance can be either shorter or greater (Andersson, 2011).

Underwater Noise Modelling Results and Assessment of Impacts: Behavioural Responses

157 Aside from mortality and traumatic hearing loss, the effect of noise from pile driving may result in behavioural avoidance. Modelling to determine the potential ranges of behavioural impact (dB_{ht} (Species)) has estimated that for 3.5 m (1635 kJ) and 2.5 m (1200 kJ) piles, the following responses are likely:

- Herring are likely to exhibit a strong behavioural avoidance response out to a maximum of 34 km (3.5 m diameter pile) and 27 km (2.5 m diameter pile). The radius of significant avoidance behaviour is likely to extend up to a maximum of 76 km (3.5 m diameter pile) and 65 km (2.5 m diameter pile);
- Flatfish (using audiogram data for the dab as a surrogate) are estimated to strongly avoid a maximum range of 7 km and 3.8 km for the 3.5 m and 2.5 m pile, respectively. The radius of significant avoidance behaviour is likely to extend up to 30 km (3.5 m diameter pile) and 20 km (2.5 m diameter pile);
- Salmon and trout may strongly avoid an area out to a maximum of 2.6 km and 0.4 km, respectively (3.5 m diameter pile); or for a 2.5 m diameter pile 1.5 km and 0.3 km, respectively; the radius of significant avoidance behaviour is likely to extend up to 14 km for salmon and 2.7 km for trout (3.5 m diameter pile) and 9.2 km for salmon and 1.8 km for trout (2.5 m diameter pile); and
- Sandeel are expected to strongly avoid a maximum area of 0.2 km radius from the pile, for 3.5 m and 2.5 m diameter pile. The radius of significant avoidance behaviour is likely to extend up to 2 km (3.5 m diameter pile) and 1.4 km (2.5 m diameter pile).

158 Behavioural avoidance is likely to encompass a larger radius for all species, particularly the significant avoidance behaviour (75 dB_{ht}), based on the output of the modelling study. The significance of behavioural avoidance is dependent on the behaviour disrupted. For example, avoidance may be significant if it causes a migratory species to be held up or prevented from reaching areas of biological importance, e.g., spawning and feeding areas. In other cases, the movement of species from one area to another may be of no consequence other than a possible increase in energetic expenditure for the fish. The types of behaviour observed in response to noise include alarm response (e.g., startle responses and flash expansions of schools) and changes in schooling patterns, position in the water column and swimming speed.

159 Behavioural avoidance response may be of particular concern with regard to herring as it has the potential to affect to a greater or lesser extent the whole North Sea herring stock. As discussed in Section 15.6.2.3, the North Sea herring stock is made up of four components that mix to a lesser or greater extent outside the spawning season (Payne, 2010); however, the mixing can vary greatly between years, with some years showing steeper latitudinal gradient in the composition of samples than others (Bierman *et al.*, 2010). The temporal variability in the mixing of the North Sea herring components may be due to differences in growth rates between autumn spawners (Shetland/Buchan and Banks) and winter spawners (Downs), as well as to the size-dependent migration pattern of this species, as larger herring migrate further North (Bierman *et al.*, 2010). The Downs component leaves the spawning areas to feed in the central and northern North Sea in summer with the other spawning components. The number of fish from each spawning type in the region will be proportional to its ratio with the other component (Bierman *et al.*, 2010). So, for instance, if in any given year Downs herring do not migrate as far north in large numbers as autumn-spawned herring, almost all the herring present in the North in that particular year will be autumn-spawned (Bierman *et al.*, 2010). The degree of mixing is not predictable, therefore, the degree to which each component is likely to be exposed to the effect of construction noise cannot be predicted.

160 Herring have been reported to show strong behavioural reactions when exposed to sonar signals close to the resonance frequency of the swim bladder (Doksæter *et al.*, 2009), which is mainly determined by the size of the fish and the depth at which the fish reside at the time of the sound exposure (Doksæter *et al.*, 2009). However, Doksæter *et al.* (2009) showed that even when exposed to sonar signals, corresponding to swim bladder resonance, overwintering herring did not react significantly to such signals. Previous studies refer to herring's differential response to noise depending on the season and their physiological state (feeding, spawning, overwintering and migrating). For example, reactions to vessel noise have been reported to be higher during the over-wintering season than during the feeding season (Missund, 1997) and spawning season (Skaret *et al.*, 2005). The different behavioural reaction to the noise may be a biological response of the species engaging in e.g., spawning activity to ensure reproductive success, or feeding to ensure survival, thus overriding a vessel noise avoidance response (Skaret *et al.*, 2005). Doksæter *et al.* (2009) suggest that herring may actually be able to distinguish between sounds of similar frequency, e.g., that from killer whale feeding and that from sonar signals. This would make biological sense in that herring do not feed during overwintering, therefore, energy minimisation is important for survival. Avoidance of predators is also essential for survival, therefore, the ability to distinguish between predator sounds and other similar sound would be of great advantage in maximising energy conservation by limiting reactions to real threats (Doksæter *et al.*, 2009).

161 The radius of herring avoidance behaviour is likely to extend into the Firth of Forth, based on the output of the modelling study. The Firth of Forth provides nursery area for herring which show a well-defined pattern of seasonal estuarine usage, with juvenile peak abundances reported to occur between January and May, although the population as a whole show a large degree of annual variability (Elliot *et al.*, 1998). Figure 15.27 shows the output of the modelling study superimposed onto the herring nursery grounds as reported by Ellis *et al.* (2012) and Coull *et al.* (1998). The radius of strong and significant avoidance behaviour encompass 73 km^2 (8%) and 273 km^2 (30%), respectively, of the more inshore nursery area (Coull *et al.*, 1998). There is, therefore, potential for avoidance behaviour of juvenile herring migrating to sea from the Firth of Forth. However, Slotte *et al.* (2003) reported herring migration through a seismic shooting area during a three to four days shooting break, indicating that migration will proceed as normal after shooting ceases. As reported by Ellis *et al.* (2010), a much larger area of the herring nursery grounds is encompassed within the radius of behavioural avoidance (Figure 15.27 and 15.28); however, when put into the context of the whole North Sea, the herring nursery area encompassed by the radius of behavioural avoidance equates to a maximum of 1%.

162 There are no reports of herring spawning grounds occurring within the development site and results of the site specific survey indicate that the habitat within the Neart na Gaoithe offshore works area are likely to be unfavourable to herring spawning eggs due to the high fine sediment content. However, the radius of behavioural avoidance encompass herring spawning to the north and south of the development, as illustrated in Figure 15.28, which shows the outputs of the modelling study superimposed onto the herring spawning areas as reported by Coull *et al.* (1998) and Ellis *et al.* (2010). The areas of herring spawning grounds encompassed within the radius of strong avoidance behaviour (90 dB_{ht}) and significant avoidance behaviour (75 dB_{ht}) are estimated to be 164 km^2 the former, and 2,554 km^2 the latter, representing 1% and 16%, respectively, of the total herring spawning area within the south coast of Scotland, less when put into the context of the whole North Sea herring spawning grounds.

163 Based on the results of the modelling study, the extent of the radius of herring strong and significant avoidance behaviour is anticipated to cover a relatively large area (medium spatial extent) (refer to Figure 15.27 and Figure 15.28), although the effect will be restricted to the duration of pile driving activities and intermittent during construction operations.

164 The magnitude of the effect on fish species is considered to be medium. Piling operations will be intermittent, with each pile driving event predicted to occur for no longer than three hours and 20 minutes with noise breaks for up to 26.5 hours estimated between piling events (Chapter 5: Project Description).

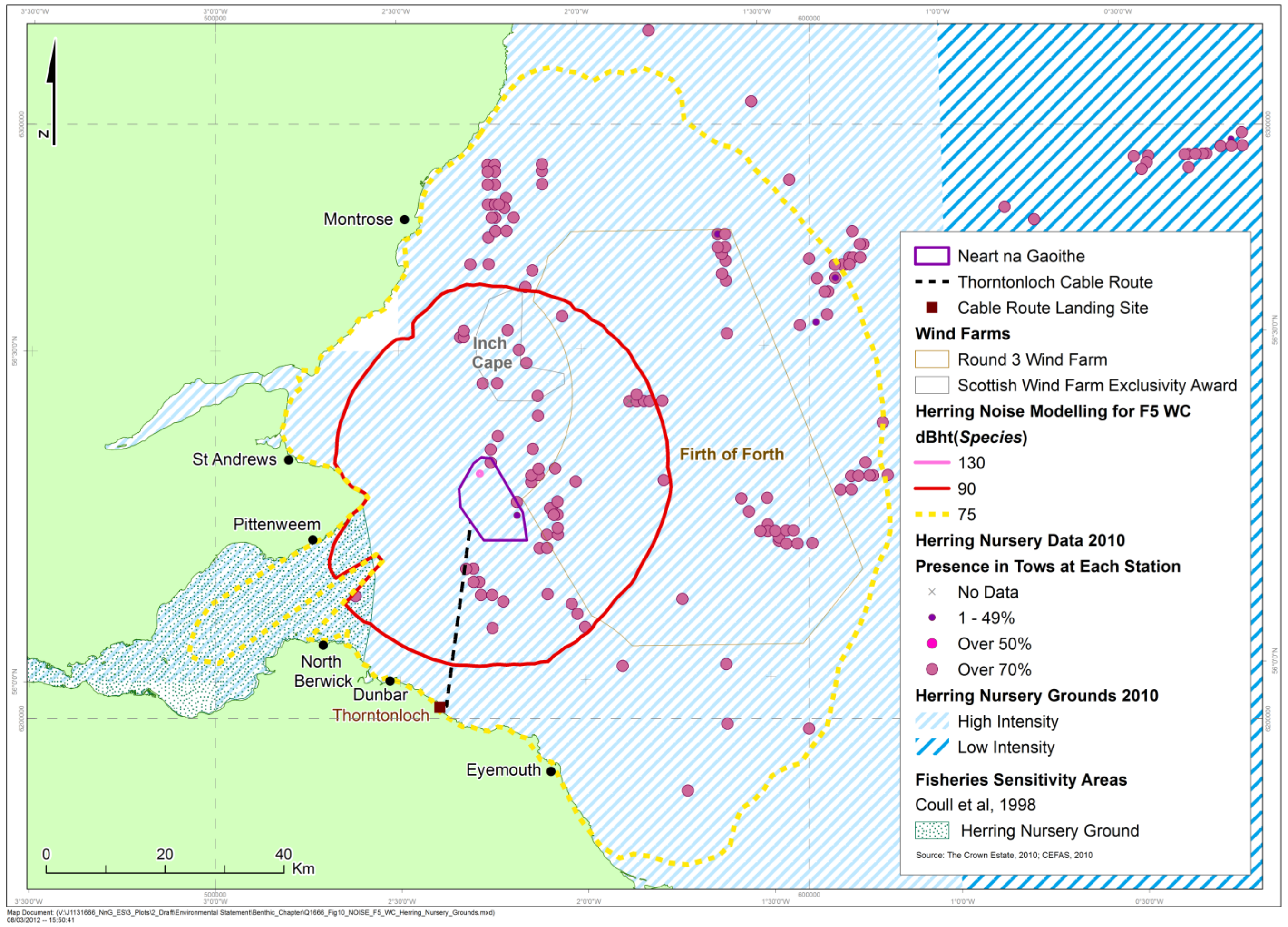


Figure 15.27: Outputs of the noise modelling predictions of herring response to pile driving noise (Subacoustech, 2012) superimposed onto herring nursery grounds (Ellis *et al.*, 2012; Coull *et al.*, 1998).

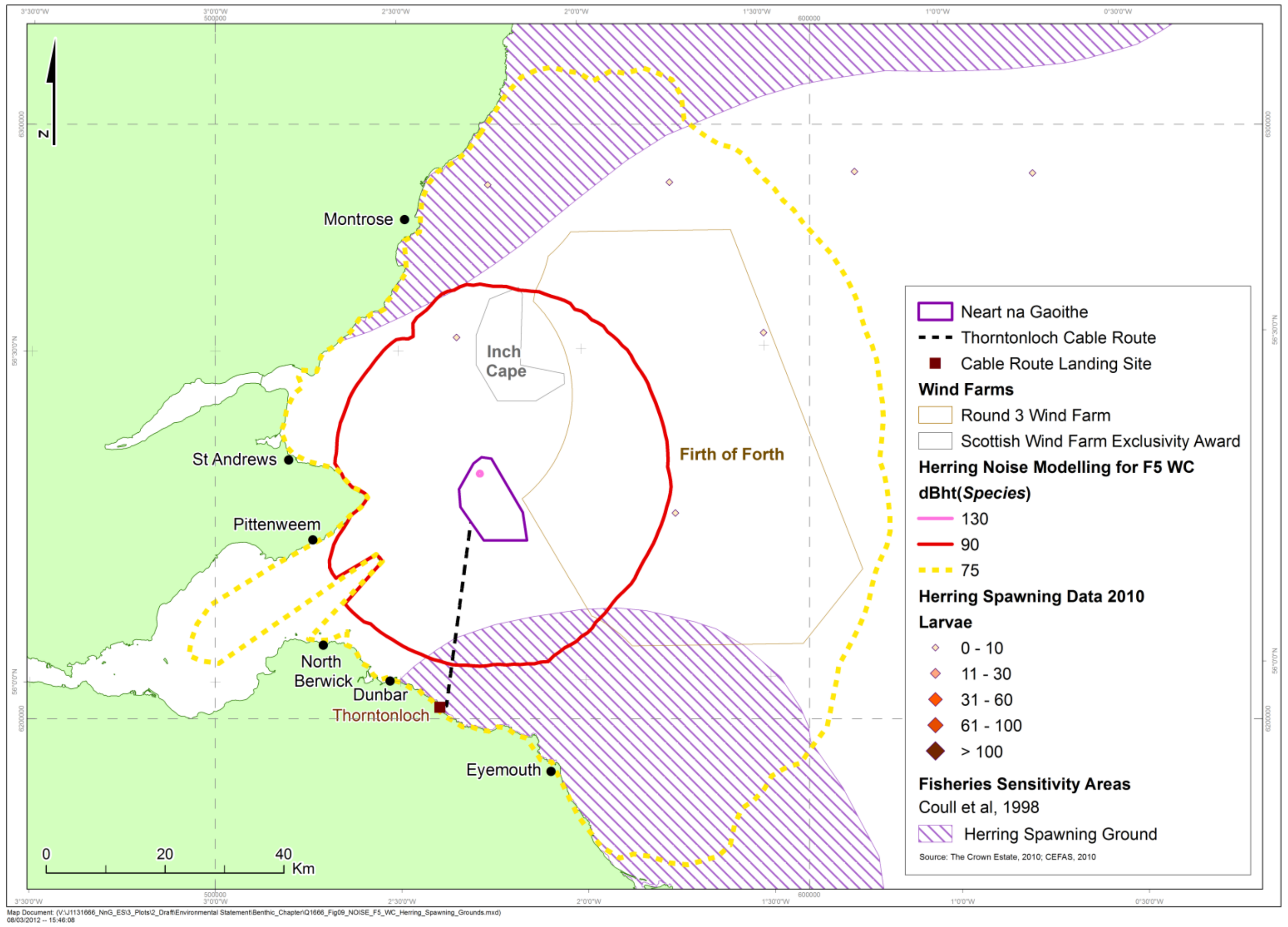


Figure 15.28: Outputs of the noise modelling predictions of herring response to pile driving noise (Subacoustech, 2012) superimposed onto herring spawning grounds (Ellis *et al.*, 2012; Coull *et al.*, 1998).

165 Avoidance behaviour by herring is likely to occur for a short duration, and there is evidence that herring will move through the area once the noise has ceased (Slotte *et al*., 2003). The vulnerability of herring to strong and significant avoidance behaviour is considered to be medium and the overall impact on herring population predicted to be of ***moderate significance***. This assessment carries medium uncertainty as there is currently no certainty on herring response to sound in the field, studies indicating that herring may respond differently to sound depending on their physiological state at the time of exposure; studies also indicate possible habituation to sound exposure (Blaxter and Hoss, 1981) and even ability of the species to distinguish between different noise sources (Doksæter *et al*., 2009) and behave accordingly. In addition, the reported herring spawning grounds are based on the presence of suitable substrate and presence of larvae rather than specific survey that would inform on the contemporary use of some of the potential spawning grounds (Ellis *et al.*, 2012).

166 Studies on the behavioural response of cod and sole exposed to pile driving noise in experimental conditions indicate that both species exhibited significant behavioural reactions to sound levels occurring up to 70 km away from a piling event (Mueller-Blenkle *et al.,* 2010). These data, although indicative of fish response to noise, cannot be used to extrapolate general relationships between the level of exposure and the extent of fish behavioural response as other factors can influence the range of fish audibility (e.g., transmission loss and the ratio between ambient noise and signal) and are highly site specific (Mueller-Blenkle *et al.,* 2010).

167 The behaviour of the cod at onset of the experimental piling noise effect was a significant initial freezing response followed by a period of increased swimming speed during noise exposure (Mueller-Blenkle *et al.*, 2010). The increased swimming speed was enhanced nearer to the sound source, and decreased when the noise was switched off. Sole also showed significant changes in swimming speed and direction though the reactions were more on an individual basis (Mueller-Blenkle *et al.*, 2010). The change in overall swimming speed was less pronounced after the fish was exposed to repeated exposure, suggesting a degree of habituation albeit on an individual basis (Mueller-Blenkle *et al.*, 2010). Habituation following exposure to noise has been reported in several other species of fish (Nedwell *et al.*, 2007) and squid (Fewtrell and McCauley, 2012). Blaxter and Hoss (1981) showed that exposing herring to a noise signal that is ramped so that it takes several cycles for the full amplitude to be reached increased the animal's threshold of a startle response markedly. The authors also found that fish moved away from the source indicating that fish can determine the direction of the sound source from a single cycle. Mueller-Blenkle *et al.* (2010) reached the same conclusion in their experiment with cod and sole.

168 Whiting and cod also use the Firth of Forth as nursery area, the former moving into the estuary as 0+ class from May onwards and remaining into the estuary for a year, before emigrating back to the sea the following summer (Elliot *et al.*, 1998). Cod migrate into the estuary as newly metamorphosed individuals during the summer and emigrate from the estuary as 1+ fish the following summer (Elliot *et al.*, 1998). There is potential for significant avoidance behaviour of these species migrating out of the estuary, based on the output of the modelling study. However, there is evidence that fish will continue migration when the noise stops (Slotte *et al.*, 2003).

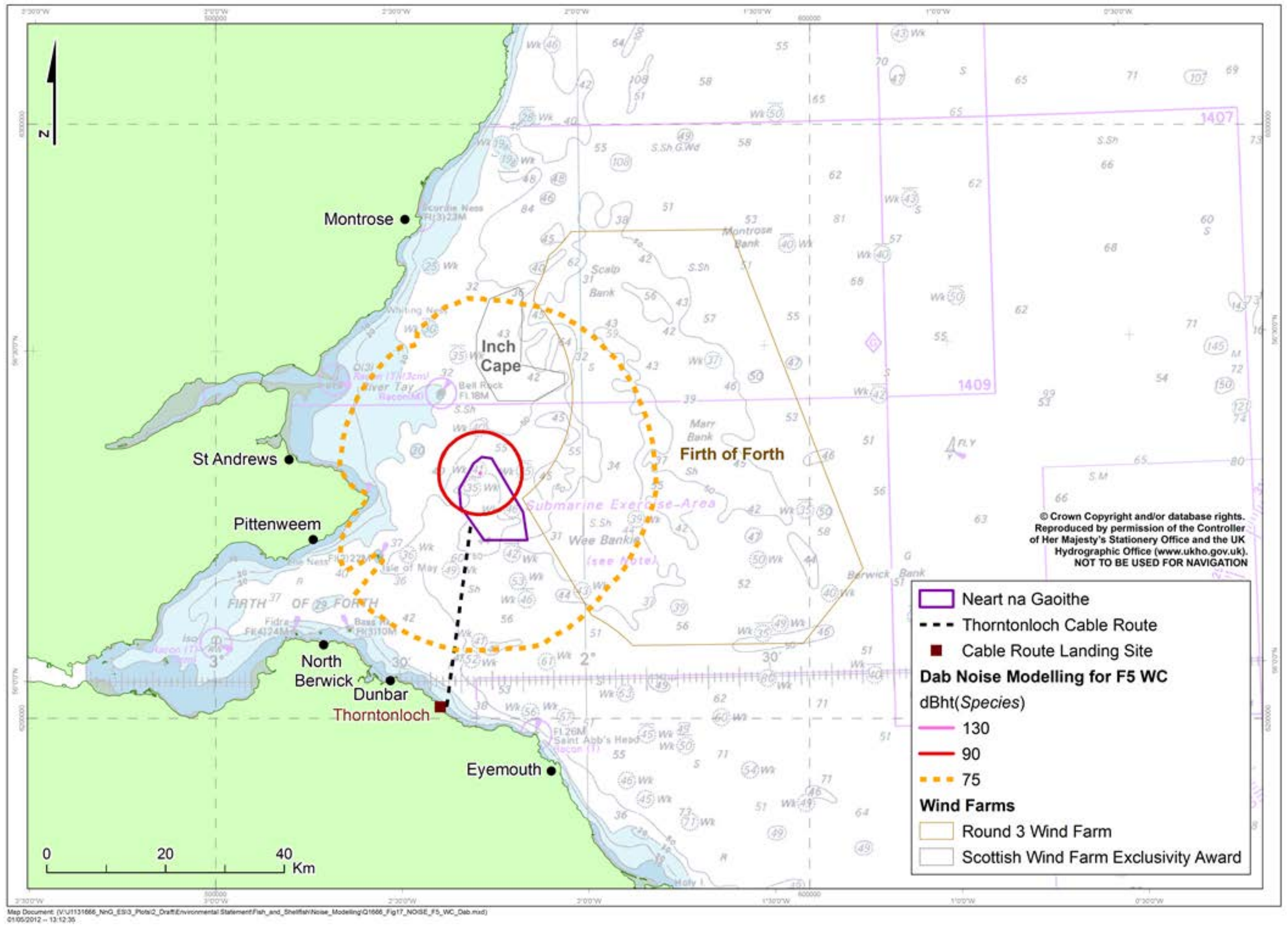


Figure 15.30: Outputs of the noise modelling predictions of dab response to pile driving noise (Subacoustech, 2012)

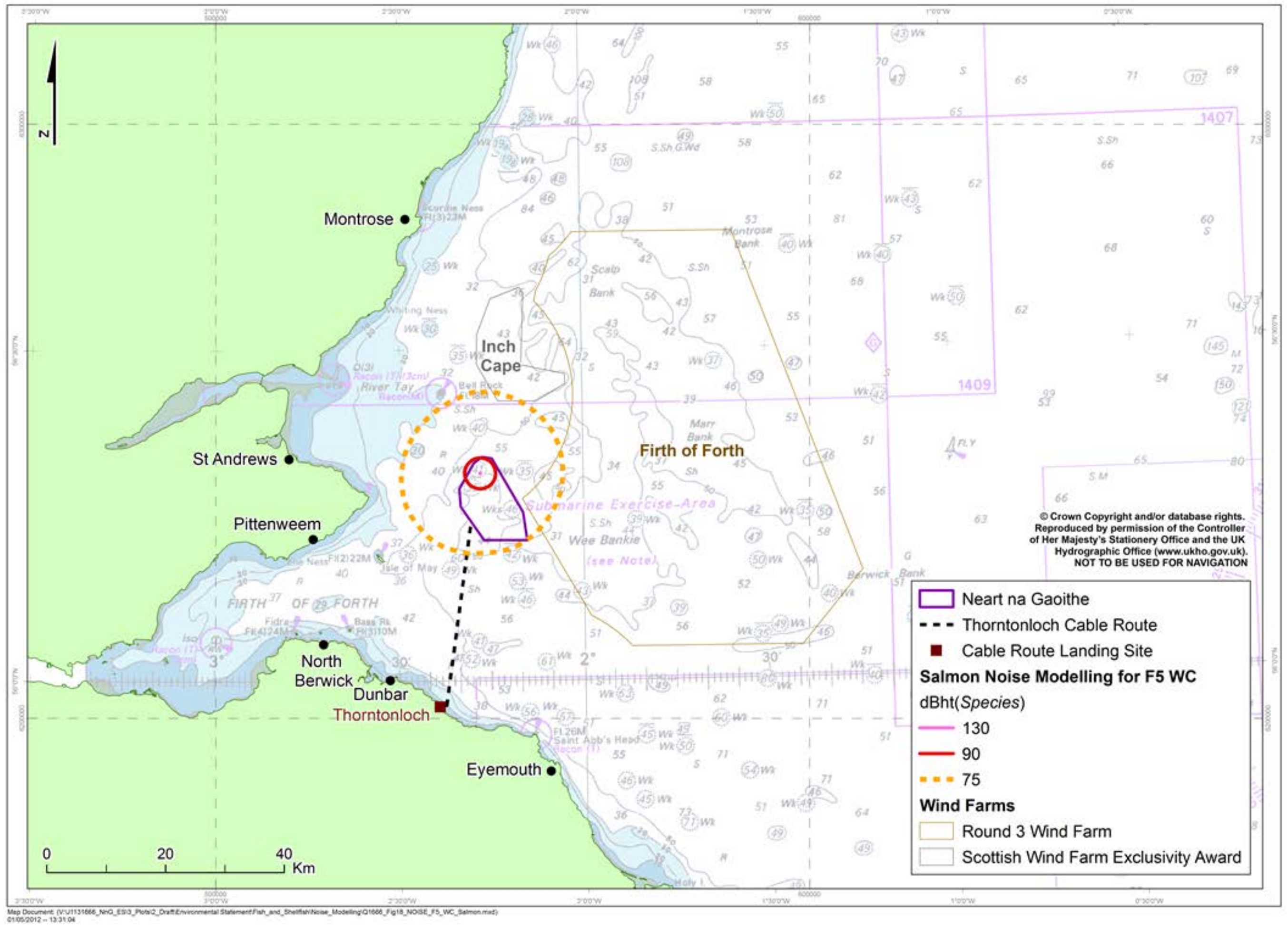


Figure 15.31 Outputs of the noise modelling predictions of salmon response to pile driving noise (Subacoustech, 2012)

169 The vulnerability of cod and whiting is assessed to be medium for both avoidance behaviour types given their hearing sensitivities. The magnitude of the effect is predicted to be medium. This is based on the temporary nature of the effect and intermittency during the construction phase and is a qualitative assessment as cod was not specifically modelling in the noise modelling. The overall impact on cod (and whiting) populations is predicted to be of ***minor*** to ***moderate significance***. This assessment carries high uncertainty.

170 The extent of the radius of behavioural avoidance for flatfish is considerably smaller than that of herring, particularly the strong avoidance behaviour. Dab and plaice use the Firth of Forth as nursery area, the dab showing a well-defined seasonal occurrence, with the 0+ class appearing in September and juveniles (3.7 cm) recorded between October and December (Elliot *et al.*, 1998). The plaice does not show a well-defined pattern of seasonal abundance, the 0+ individuals moving into the estuary in July and back to marine areas the following year as 1+ individuals (Elliot *et al.*, 1998).

171 The magnitude of the effect on dab, plaice and sole is considered to be low for the strong avoidance behaviour and medium for the significant avoidance behaviour. This is based on their spatial extent (refer to Figure 15.30), the temporary nature of the effect and intermittency during the construction phase. The vulnerability of dab and plaice is considered to be low to sound pressure; however, these species are most affected by particle motion.

172 The overall impact on flatfish populations is predicted to be of ***minor*** to ***moderate significance***. This assessment carries medium uncertainty.

173 The behavioural avoidance as a consequence of increased underwater noise on migratory species, e.g., salmon and trout is not fully documented, with the available literature indicating a mild reaction by the salmon at distances of 60 to 80 m (Nedwell, 2003). Salmon and trout are highly mobile species that undergo large seasonal movements and migrations to forage and breed. They are reported to be vulnerable to structures which could act as a barrier, preventing movement to their foraging or nursery grounds. The degree of impact of barrier effects on these species will depend on their ability to move and avoid barrier structures, thus for example, structures placed in a highly confined estuary are likely to be more of an issue than in the open coast.

174 The magnitude of the effect on salmon and trout is considered to be negligible for the strong avoidance behaviour and medium for the significant avoidance behaviour, based on the spatial extent of the radius (refer to Figure 15.31 and 15.32), the temporary nature of the effect and intermittency it will occur during the construction phase.

175 The vulnerability of salmon and trout is considered to be low and the overall impact on salmon and trout populations predicted to be of ***minor significance***. This assessment carries medium uncertainty.

176 The magnitude of the effect on sandeel is considered to be low for the strong and significant avoidance behaviour, based on the spatial extent of the radius (refer to Figure 15.33), the temporary nature of the effect and intermittency it will occur during the construction phase. The vulnerability of sandeel is considered to be low as the site specific survey results and data from Marine Scotland (2011, pers. comm.) indicate that this species is unlikely to occur within the study areas in large number. However, in the absence of results from sandeel specific surveys, a precautionary approach has been taken for the assessment.

177 The overall impact on sandeel populations is predicted to be of ***minor significance***. This assessment carries medium uncertainty.

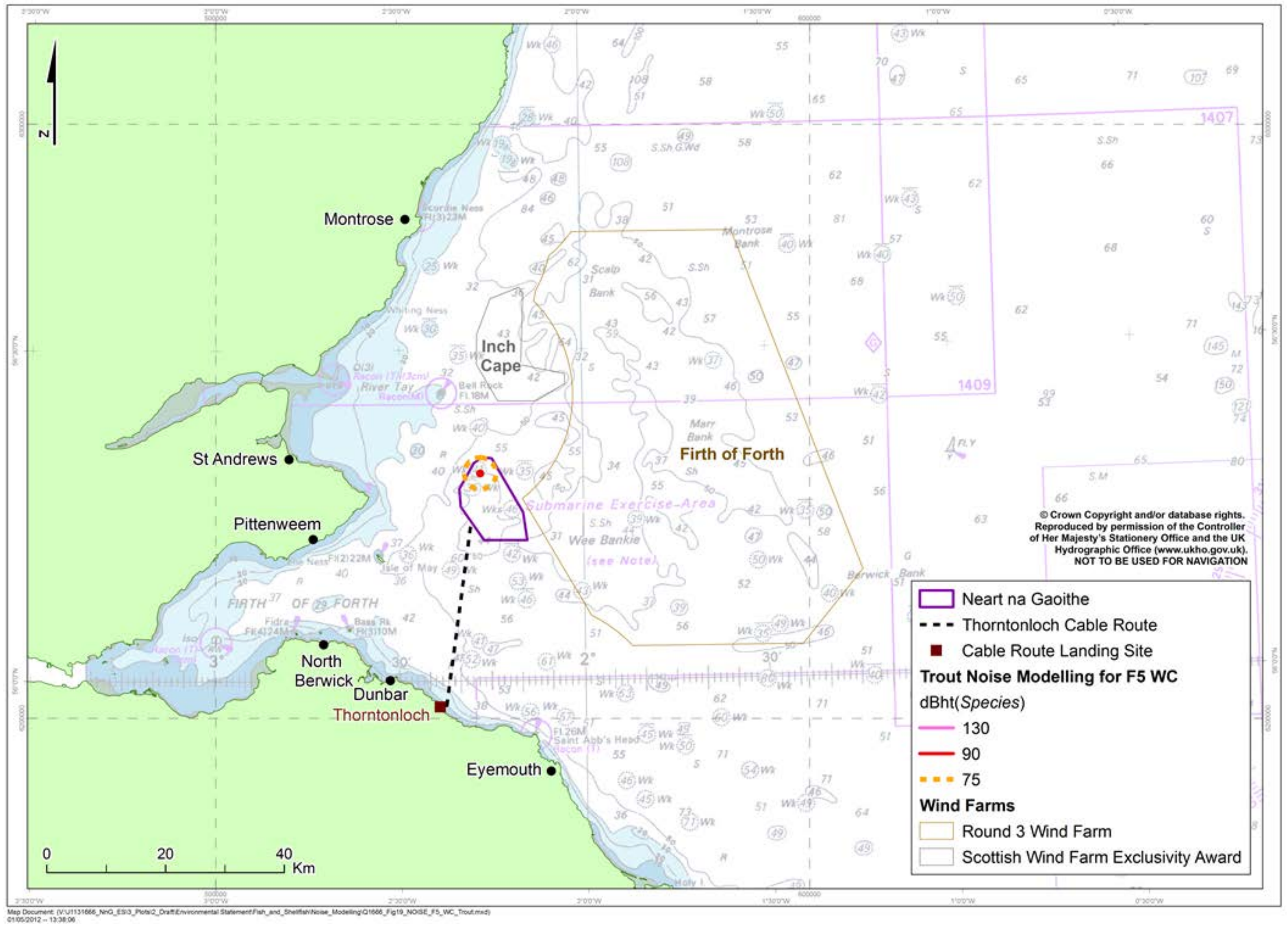


Figure 15.32 Outputs of the noise modelling predictions of trout response to pile driving noise (Subacoustech, 2012)

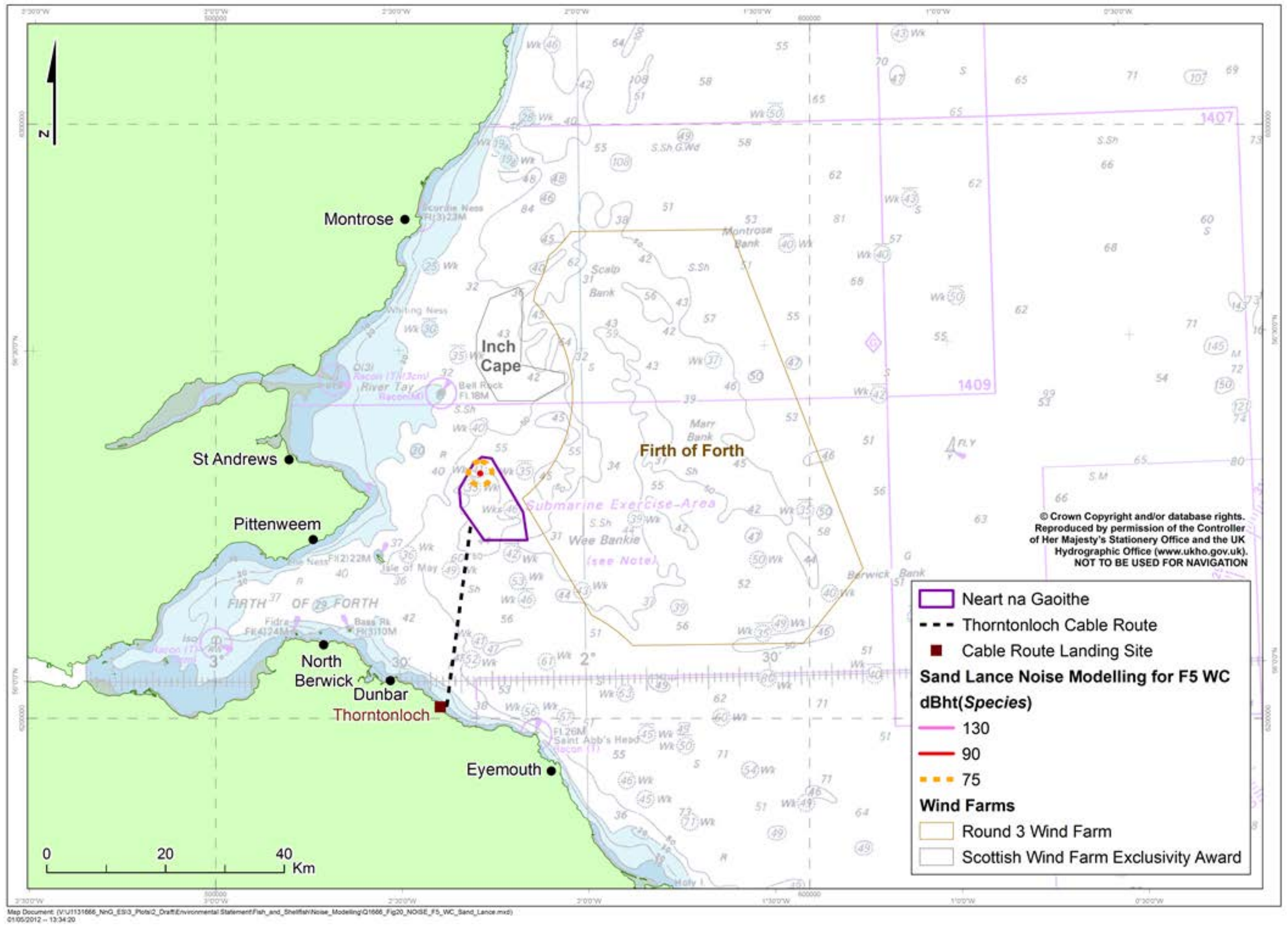


Figure 15.33 Outputs of the noise modelling predictions of sandeel response to pile driving noise (Subacoustech, 2012)

178 Table 15.15 provides a summary of the impacts associated with piling operations.

Source	Pathway	Receptor	Magnitude of effect (derived from the noise modelling, see Appendix 13.1 for detail)	Vulnerability of receptor (overall)	Significance of impact	Qualification of significance
Installation of jacket foundations	Pile driving creating noise and vibration	Fish and shellfish species – traumatic hearing loss	Low	Medium (though Low for some shellfish species and High for herring and cod)	Minor significance	Probability is high. Uncertainty is high. The magnitude of the effect (e.g., radius of traumatic hearing loss is anticipated to be <1 km from source) for each piling activity and restricted in duration. It is recognised that most fish species will swim away from the noise source, though some may have specific habitat requirements or could insufficient swimming speeds. Mortality or traumatic hearing loss unlikely at a large population scale given the species characterising the wider region.
		Herring – behavioural response (avoidance)	Medium (strong and significant avoidance behaviour)	Medium	Moderate significance	Probability is medium. Uncertainty is high. The radius of strong and significant avoidance behaviour is of medium extent and overlaps with herring nursery and spawning grounds. Response, however, is uncertain.
		Cod – behavioural response (avoidance)	Medium (strong and significant avoidance behaviour)	Low to Medium	Minor to moderate significance	Probability is medium. Uncertainty is high. This is a qualitative assessment as the noise modelling did not profile cod. As a hearing specialist cod are sensitive to underwater noise, though not to the same degree as herring but more so than flatfish species.
		Flatfish species - behavioural response (avoidance)	Low (strong avoidance behaviour) to Medium (significant avoidance behaviour)	Low	Minor to moderate significance	Probability is high Uncertainty is medium. Dab and are most affected by particle motion rather than sound pressure.
		Salmon and sea trout - behavioural response (avoidance)	Negligible (strong avoidance behaviour) to Low (significant avoidance behaviour)	Low	Minor significance	Probability is high Uncertainty is medium. Salmon and sea trout are only predicted to be in the offshore area intermittently.
		Sandeel	Low (strong and avoidance behaviour)	Low	Minor Significance	Probability is high Uncertainty is medium. Sandeel are not predicted to occur in the vicinity of the offshore works area, and the radius of avoidance behaviour is of low extent.

Table 15.15 Impact assessment of piling installation of jacket foundations in the offshore site on fish and shellfish populations

15.7.1.2 Export Cables

179 The key impacts relating to cable laying in the marine environment occur mainly during the installation process (BERR, 2008), therefore, are likely to be temporary, lasting through development activities and a period after their completion and include:

- Physical habitat disturbance (displacement, physical disturbance and abrasion);
- Increase in SSC and turbidity; and
- Increased sediment settlement (smothering).

Physical Habitat Disturbance

180 Although the corridor for cable installation activities is relatively long (33 km), sediment disturbance from the installation of the cables is restricted to 5 m either side of the two cables, therefore, the footprint of temporary habitat disturbance is predicted to be minimal (see Chapter 5: Project Description and BERR, 2008).

181 The level to which the seabed is disturbed is primarily related to the nature of the ground and the type of tool selected to bury the cable, the latter likely to have a secondary influence (BERR, 2008). Given the nature of the seabed sediment (i.e., muddy sand) along the cable route, ploughing is the most likely method to be employed for cabling activities. This method ensures that soil disturbance is kept to a minimum. It also allows the sediment to infill rapidly following disturbance, enabling habitat recovery to occur. The cable will be installed using a plough which will travel along the seabed on runners or skis. The transit of the cable plough along the cable route will result in a low severity of disturbance to a 10 m corridor. Within this 10 m corridor, 2 m in the centre will be subject to a high severity of disturbance as the sediments are turned and removed by the plough blade (refer to Chapter 5: Project Description).

182 Quantification of the sediment disturbance will depend upon the specific tool used; however, an estimate of the rate at which the sediment is disturbed can be made based on the size of the slot or trench created by the tool (BERR, 2008). Results of the model study indicate that the maximum volume of sediment displaced is likely to be 800 m^3 per hour, based on a trench width of 1 m, dug to a depth of 2 m, and assuming a typical rate of trenching of 400 m per hour.

183 Herring spawning grounds are reported to occur in coastal areas overlapping the landward extent of the cable corridor at its northernmost boundary (see Figure 15.29). However, due to the temporally and spatially restricted nature of the cable installation activities, the impacts are likely to be highly localised and short term. As a result of this, the magnitude of effect is considered to be low. The vulnerability of the fish and shellfish community to this effect is assessed to be negligible, as mobile species will be able to avoid the disturbance and there are not known shellfish beds occurring along the cable route. The vulnerability of the herring spawning grounds is considered negligible in this respect, particularly in view of its larger extent to the south of the cable corridor, which can compensate for any potential loss of spawning grounds.

184 The overall impact of the installation of the export cables on fish and shellfish is assessed to be of ***minor significance*** and low uncertainty is ascribed to this assessment (refer to Table 15.16).

Source	Pathway	Receptor	Magnitude of effect	Vulnerability of receptor	Significance of impact	Qualification of significance
Installation of export cables	Direct habitat disturbance	Fish and shellfish populations	Low	Negligible	Minor significance	Probability: certain Uncertainty: low There are no records of shellfish beds along the cable route, and percentage of herring spawning grounds likely to be impacted is negligible by comparison to their extent within the region.

Table 15.16: Impact assessment of physical habitat disturbance during construction of the export cables route on fish and shellfish populations

Increased Suspended Sediment Concentration and Turbidity

185 Cable burial by ploughing minimises the amount of sediment likely to be brought into suspension due to the controlled operation by which cable ploughs work, followed by the backfilling of the trench (BERR, 2008). However, the fine sediment (mud) is still likely to mix with water and to be dispersed by tidal currents. Coarser sediments are also likely to be brought into suspension, but are expected to quickly settle back to the seabed and are unlikely to be dispersed over long distances by tidal currents.

186 Results of the modelling studies show that, regardless of the location along the cable route, the elevated SSC are predicted to be between 3 and 10 mg/l with some localised peaks in small areas reaching 30 mg/l. The associated suspended sediment plumes are predicted to be less than 5 km in extent and settle out within a maximum of four hours, with resulting deposition footprints being localised.

187 The magnitude of the effect is assessed to be negligible as limited in time (installation) and space (along the cable route). The fish and shellfish response to increased SSC and turbidity has been considered and presented in the turbine array section and is assessed to be negligible.

188 The overall impact of increased SSC and smothering associated with the installation of the export cables is assessed to be of ***minor significance*** and low uncertainty is ascribed to this assessment (refer to Table 15.14).

Sediment Settlement and Smothering

189 Maximum predicted depositions thickness is 3 mm, and the extent of the deposition footprint, with thickness greater than 0.1 mm is likely to extend up to about 2 km either side of the cable trench. In reality, the amount of sediment that will be re-suspended into the water column is likely to be less, as the modelling study assumed that the entire volume of the trench would be suspended into the water column with no backfilling (see Chapter 9: Physical Processes).

190 The magnitude of the effect is assessed to be negligible as limited in time (installation) and space (along the cable route). The fish and shellfish response to sediment smothering has been dealt with and presented in the turbine array section and is assessed to be negligible.

191 The overall impact of increased SSC and smothering associated with the installation of the export cables is assessed to be ***not significant*** and low uncertainty is ascribed to this assessment (refer to Table 15.17).

Source	Pathway	Receptor	Magnitude of effect	Vulnerability of receptor	Significance of impact	Qualification of significance
Sediment disturbance during burial of export cables	Sediment re-suspension and smothering	Fish and shellfish populations	Negligible	Negligible	Not significant	Probability is high. Uncertainty is low. SSC levels likely to impair fish and shellfish are much higher than those predicted to occur during the construction phase.

Table 15.17: Impact assessment of increased SSC, sediment settlement and smothering during construction of the export cables route on fish and shellfish populations

15.7.2 Impact Assessment – Operation and Maintenance

192 The environmental effects arising from the operation and maintenance of the project are long term, lasting through the operational phase of the wind farm and include:

- Permanent habitat loss directly under turbine foundations, scour protection and substation structures;
- Changes in hydrodynamics including scour and changes in sediment transport;
- Artificial reef effects due to introduction of new substrates from new gravity bases and scour protection/scour protection on cables;
- Changes in EMF due to the inter-array and export cables;
- Changes in ambient noise during operational period (i.e., the noise from wind turbines generated by the gearbox and generator and transferred into the water and sediment through the tower and foundations); and
- Heating effect from cable operation.

193 Some of these effects (e.g., heating and electromagnetic fields generated by subsea cables) are common both to the turbine array and to the export cables route and where this is the case they are discussed under the export cable section.

15.7.2.1 Offshore Site

Permanent Habitat Loss

194 The loss of seabed to turbine foundations and associated scour protection has the potential to impact on fish and shellfish in a number of ways: through changes in the predator-prey dynamics as a result of a potential shift in the species composition of benthic fauna; through removal of key habitats crucial to their survival (e.g., spawning and nursery habitats) and through direct uptake.

195 Changes to prey dynamics have the potential to impact on feeding behaviour of adult stocks and consequently their distribution. Many species are generalist feeders and it is unlikely that species that feed on a range of pelagic prey including other fish and plankton organisms will be impacted by any changes to seabed communities. Fish and shellfish species that target benthic prey have more potential to be impacted. Given that fish and most shellfish are motile to a greater or lesser extent, the scale of any potential impact will be dependent upon the availability of suitable or alternative prey in the wider region and the timescales for impact, together with the predicted rate of seabed recovery (see Chapter 14: Benthic Ecology).

196 Adult stocks of fish are considered to be not vulnerable to habitat loss in terms of their adaptability and tolerance by way of their mobile nature and generalist feeding behaviour. However, adult stocks are reliant on successful spawning, nursery and migratory phases; therefore, impacts on any of these stages will be reflected in future adult fish populations. The proposed development encompasses nursery and spawning grounds of several species; however, these grounds are also widely distributed outside the development and are likely to provide sufficient progeny to ensure the continuation of future fish stocks.

197 Depending on the availability of alternative suitable habitat both within the Neart na Gaoithe site and the wider geographic area the vulnerability of fish and shellfish species to the loss of local habitat will vary. The habitats occurring within the Neart na Gaoithe offshore site are widely distributed within the wider region (see Chapter 14: Benthic Ecology); therefore, the vulnerability of adult stocks to loss of habitat is considered to be negligible.

198 The permanent habitat loss due to turbine installation and scour protection is estimated to be 0.25 km^2 (0.05 %) of the offshore site, based on the presence of 75 x 6 MW gravity base foundations and inter-array cables protected to a degree with scour protection; therefore, the magnitude of the effect is assessed as being low.

199 The overall significance of impact of habitat loss on fish and shellfish communities is considered to be of ***minor significance***. Low uncertainty is ascribed to this assessment (refer to Table 15.18).

Source	Pathway	Receptor	Magnitude of effect	Vulnerability of receptor	Significance of impact	Qualification of significance
Presence of turbine foundations and inter-array cabling with scour protection	Habitat loss	Fish and shellfish populations	Low	Negligible	Minor significance	Probability: certain Uncertainty: low The permanent habitat loss is estimated to be 0.28 km^2 of the Neart na Gaoithe offshore site which is considered low.

Table 15.18: Impact assessment of permanent habitat loss in the offshore site during operation for fish and shellfish populations

Changes in Hydrodynamic Regimes

200 The assessment of the impacts on the metocean environment due to the proposed development has been modelled and is discussed in detail Chapter 9: Physical Processes.

201 The predicted changes to water level due to presence of the wind turbines and their foundations are very small (<0.025% of water depth) and generally localised with the exception of a small change (<0.02%) of spring tidal range in the upper reaches of the Firth of Forth. Changes to the tidal currents are also predicted to be quite small (between 3 and 6% of peak spring tidal velocities) and restricted to the immediate vicinity of the offshore site. Similarly, the predicted changes to the wave climate are considered to be small (<3% of average waves) and restricted to the immediate vicinity of the offshore site. The predicted changes to the sediment transport process are considered to be very small with the frequency of the exceedance of the critical sheer stress changing typically by 1–3% (with a maximum difference of 6%). These changes are also restricted to the immediate vicinity of the offshore site.

202 The physical process modelling also assessed impacts of scour. The results illustrated that under the worst (realistic) case scenario, under the Rochdale envelope, the resulting elevated SSC would be small and localised, with peak concentrations between 100 and 300 mg/l, and concentrations beyond about 250 m of the structures reducing to <10 mg/l. The resulting deposition footprints will be very localised around the turbine base, with a maximum thickness of 0.1 m and the extent of the footprint with a thickness >1 mm reaching up to 500 m. The magnitude of effect from the changes in hydrodynamic regime around the structures is, therefore, considered to be negligible due to the negligible spatial extent and severity, and low frequency and duration, and due to the negligible vulnerability of species to such changes the impact is assessed as ***minor significance*** (refer to Table 15.19)**.**

Source	Pathway	Receptor	Magnitude of effect	Vulnerability of receptor	Significance of impact	Qualification of significance
Presence of turbine foundations and inter-array cabling with scour protection	Tides, current speeds	Fish and shellfish populations	Negligible	Low	Minor Significance	Probability: certain Uncertainty: low. The changes of water level and tidal currents following installation of wind turbines are predicted to be very small based on the output of the modelling study

Table 15.19: Impact assessment of change in hydrodynamic regime in the offshore site during operation for fish and shellfish populations

Introduction of New Substrates

203 Wind farms add new hard substrate to the marine environment; however, these man-made structures cannot be regarded as surrogates for natural substrate since epibenthic assemblages on artificial surfaces have been shown to differ compared to assemblages on natural hard substrate (Wilhelmsson and Malm, 2008).

204 The hard substrate habitat created by the introduction of wind farm foundations, associated scour protection and inter-array cable protection will be colonised within hours or days after the construction by bottom-living (see Chapter 14: Benthic Ecology) and semi-pelagic fish species (Andersson, 2011).

205 The substrate character of the Neart na Gaoithe proposed development encompasses soft and to a lesser extent hard seabed sediment, therefore, the addition of turbines and scour protection is not likely to change the habitat dramatically. The new surface available for colonisation, on 125 x 3.6 MW gravity bases and their associated scour protection (and scour protection on inter-array cables) is estimated at 0.39 km^2, which is considered to be negligible within the proposed development and even more so within the wider geographical context. This is a very broad estimate as habitat enhancement is difficult to quantify due to different surface texture, gaps, and crevices, which are all potentially relevant in providing additional micro habitats (Linley *et al.*, 2007).

206 The longest monitoring program conducted to date, i.e., at the Lillgrund wind farm, in the Öresund Strait in southern Sweden, showed no overall increase in fish numbers, although redistribution towards the foundations within the wind farm area was noticed for some species (i.e., cod, eel and eelpout) (Andersson, 2011). Additionally, more species were recorded after construction than before, which is consistent with the hypothesis that introduced hard bottom on a soft bottom area will increase the biodiversity locally.

207 It is likely that the presence of concrete cable protection may result in a localised increase of biological diversity, as observed for the Torness artificial reef (Irving, 1997). The reef was constructed in 1984, 3.4 km southeast of Torness Point by depositing 210,000 tonnes of limestone rock onto the natural seabed substratum during the construction of the power station (Irving, 1997). Photographic and sampling surveys around this artificial reef indicated that the reef had produced a local enhancement of the cod and European lobster populations. Overall, results of the studies reported in the current literature do not provide robust data (some are just visual observations) that can be generalised to the effects of artificial structures on fish abundance in wind farm areas (Wilhelmsson *et al.*, 2010).

208 Overall, the significance of impact of the introduction of new substrate associated with the Near na Gaoithe development on fish populations is considered to be of ***minor significance***, but this assessment carries *medium uncertainty*, particularly in view of the fact that proving the link between offshore wind farm and changes in fish population requires years of monitoring to distinguish the effects of the wind farm from natural annual variation (refer to Table 15.20).

Source	Pathway	Receptor	Magnitude of effect	Vulnerability of receptor	Significance of impact	Qualification of significance
Presence of turbine foundations and inter-array cabling with scour protection	New substrate materials	Fish and shellfish populations	Low	Low	Minor significance	Probability is high (does not refer to collision risk which is assessed to be extremely unlikely), uncertainty is medium. New substrates are unlikely to change the existing habitat dramatically as hard substrates are already present within the development area

Table 15.20: Impact assessment of new substrates in the offshore site during operation for fish and shellfish populations

Operational Noise

209 The noise from the operation of wind turbines is generated by the gearbox and generator and transferred into the water and sediment through the tower and foundations. Wind farms noise source levels are influenced by size and shape of the foundation, age and model of the turbines and the number of turbines. In addition, transmission loss is site specific, hence any estimate of the amount of noise likely to be generated during the operational phase of a wind farm are highly site specific (Andersson, 2011) with the highest noise levels likely to be recorded in close proximity (1 m) from the foundation during moderate wind speeds (Sigray and Andersson, 2011).

210 Fish species including the cod and haddock, make sounds in a social context and especially during spawning. The sounds from gadoids are low in frequency with most of the energy emitted below 1 kHz and they are low in amplitude. In herring and sprat sounds have been recorded at much higher frequencies, although the behavioural significance of their calls is less certain. Masking of gadoid sounds will take place whenever the level of background noise in the sea is raised by more than a few dB. Masking will occur over those distances where man-made sounds are audible to the fish. Masking by man-made noise can cause problems for the fish at several levels and could potentially:

- Interfere with the detection of a biologically important sounds – the fish no longer hears the sound;
- Prevent fish discriminating between different types of sound; and
- Interfere with communication, so that fish can no longer respond and interpret the sounds that it hears.

211 These different manifestations of masking occur at different noise levels. The overall effect may interfere with the spawning behaviour of these species and render spawning less successful. Spawning takes place in the early part of the year (January to April depending on the area).

212 Even in a noisy area with intense shipping, which increases the background noise significantly (Nedwell *et al.*, 2003), the dominant tonal component of the wind farm noise (i.e., 127 Hz) will run through the ambient noise and make the wind farm detectable by fish at significant distances (Andersson, 2011). Species such as eel and salmon with poor sensitivity to sound pressure are likely to detect a wind farm (e.g., Lillgrund, at wind speed of 14 to 12 m/s) at a distance of less than 1 m (based on a detection threshold of 0 dB). Fish with higher sensitivity to sound pressure, e.g., herring and cod, might detect the wind farm at a distance greater than 16 km (Andersson 2011). At distances greater than this the ambient noise will mask out the wind farm noise (Sigray and Andersson, 2011).

213 Fish sensitive to particle motion will only be able to sense the measured particle acceleration at distance of about 10 m from the foundation (Andersson, 2011). Further away many species are limited by either their hearing threshold or the ambient sound masking the wind farm noise. The detection distance could be greater for species laying in direct contact with the seabed as sound travels at higher speed through the substrate then water (Andersson, 2011).

214 In close vicinity (less than 10 m) to a turbine the received level (about 119 to 136 dB re 1 $\mu Pa_{(RSM)}$ for the 127 Hz component) are most likely sufficient to evoke a behavioural reaction in some species like cod. However, reaction does not necessarily mean avoidance of the area; for example, higher catch areas of cod have been reported in the vicinity (100 m) of a turbine (source $level_{(1m)}$ 102 to 113 dB re 1 µPa) compared to farther away when the turbine was stopped, while tracked eels did not exhibit any effect (Andersson, 2011). In another study using tagged silver eels passing through the Lillgrund wind farm, no effect on swimming speed or direction were observed when eels were encountering the wind farm bases (Andersson *et al.*, 2011).

215 Wahlberg and Westerberg (2005) evaluated the possible effect on fish of underwater noise from wind farms in operation. The study found that Atlantic salmon and cod can detect offshore wind turbines at a maximum distance of about 0.4 to 25 km at wind speeds of 8 and 13 m/s. The research found no evidence that wind farms cause temporal or permanent hearing loss in fish even at a distance of a few metres. The wind turbines produce sound intensities that may cause permanent avoidance by fish within ranges of around 4 m, but only at high wind speeds (13 m/s). In addition, fish have been observed shoaling around the bases of turbines (DECC, 2009).

216 Owing to the restricted knowledge of sound detection in fish and the limitation in sound pressure estimations, it is concluded that fish without a swim bladder or other sound pressure detector, e.g., flatfish, will only perceive offshore wind farm noise close (less than 10 m) to the foundation generated during maximum power production. Fishes with a swim bladder sensitive to sound pressure, although not having any enhanced hearing ability, e.g., salmon and trout, will possibly detect the noise up to 1 km distance. Species with highly specialised hearing, e.g., some gadoids and herring, could detect the wind farm at a distance of several kilometres up to tens of kilometres.

217 Data on background noise within and around the Neart na Gaoithe development and model studies for the predicted source level and transmission loss for the areas are not available, all of which are important in estimating the zone of audibility of different species based on their known audiograms. Assessment is, therefore, qualitative, based on the available literature. The effect of operational noise on fish is considered to be of ***minor significance*** due to the relatively low number of turbines and a predicted (based on known commercial and industrial activities in the areas) high background noise levels. However, this assessment carries medium uncertainty due to lack of site specific data and limited knowledge of fish sound detection (refer to Table 15.21)

Source	Pathway	Receptor	Magnitude of effect	Vulnerability of receptor	Significance of impact	Qualification of significance
Gearbox and generator of wind turbines	Water column, seabed sediment	Fish and shellfish populations	Low	Low	Minor significance	Probability is high. Uncertainty is medium. To date there is no evidence that species capable of perceiving noise from operating wind turbines will be impaired in their biological activities

Table 15.21: Impact assessment of operational noise in the offshore site during operation for fish and shellfish populations

15.7.2.2 Export Cable

Heating Effects

218 The heat dissipation due to transmission losses for Alternative Current (AC) cables may result in a temperature rise of the surrounding sediment (OSPAR, 2009a,b). The literature reports one set of field measurements of seabed temperature near power cables at Nysted offshore wind farm, however, the results are not considered to be robust enough to draw conclusions applicable to other cases (OSPAR, 2009a,b).

219 Published theoretical calculations of the temperature effects of operational buried cables are consistent in their predictions of significant temperature rise of the surrounding sediment (OSPAR, 2009a,b). This may be of importance here as there is evidence that various marine organisms react sensitively to even very small increases in ambient temperature (OSPAR, 2009a,b). Preliminary laboratory experiments showed that species responded differently to seabed temperature increase; however, in the absence of robust field data, the assessment of effects of artificially increased temperature on marine habitats and species remain highly uncertain (OSPAR, 2009a,b).

220 It can be assumed that a permanent increase of the seabed temperature will lead to changes in physiology, reproduction or even mortality of certain benthic species as well as possible alteration of benthic communities due to changes in emigration/immigration patterns. The temperature increase of the upper layer of the seabed depends on the burial depth of the cable, but also factors such as sediment characteristics, grid layout and cable parameters (e.g., the conductor diameter) (OSPAR, 2009a,b).

221 The significance of impacts within the Neart na Gaoithe offshore site from potential heating effects of operational power cables is assessed as being ***not significant*** in view of the low number and small spatial extent of the cables, but this assessment carries high uncertainty due to lack of robust data from field studies (refer to Table 15.22).

Source	Pathway	Receptor	Magnitude of effect	Vulnerability of receptor	Significance of impact	Qualification of significance
Subsea cables (inter-array and export cables)	Seabed sediment heating	Fish and shellfish populations	Negligible	Low	Not significant	Probability is medium. Uncertainty is high. To date there are no robust data sets from field studies that quantify the amount of heating generated by subsea AC cables.

Table 15.22: Impact assessment of heating effects in the export cables route during operation for fish and shellfish populations

Electromagnetic Fields (EMF) generated by subsea cables

222 The term EMF covers both the electric (E) field, measured in volts per metre ($V\ m^{-1}$) and the magnetic field measured in tesla (T). Background measurements of the magnetic (B) field are approximately 50 µT in the North Sea, and the naturally occurring electric field in the North Sea is about 25 $\mu V\ m^{-1}$ (Tasker *et al.,* 2010). Wind farms transmit the energy produced along a network of cables. As energy is transmitted, the cables emit low-energy EMF (Boehlert and Gill, 2010). The E and B fields generated increase proportionally to the amount of electricity transmitted. These fields are known to be in the range of detection of electromagnetic sensitive species (CMACS, 2003).

223 Offshore wind farms typically use a three core AC 33 kV cable for inter-array cables and 115-132 kV for export cables (refer to Chapter 5: Project Description). The flow of electricity in an AC cable changes direction (as per the frequency (Hz) of the AC transmission) and creates a constantly varying E field in the surrounding marine environment (Huang, 2005). Studies to date indicate that the EMF emitted by industry standard AC offshore cables are within the range of detection by the electro-magnetic sensitive fish species (Gill *et al.*, 2005), which include elasmobranches (sharks, rays and skates) and Holocephali (chimaeras or ghost sharks), collectively known as Chondrichthyes (Gill *et al.*, 2005).

224 The main concern with EMF is that it will interfere with the navigation of sensitive migratory species by affecting the speed and/or the course of their migration, causing subsequent potential problems if they do not reach essential feeding, spawning and nursery grounds. Specifically, interaction may occur if the fish migration route coincides with the cables particularly in shallow waters (<20 m) where there is greater probability of encounter the high voltage cables coming to shore. On a more local scale, species like the elasmobranchs that use EMF to detect food may become confused and spend additional time hunting prey as a result of anthropogenic EMF thereby reducing their daily food intake and overall fitness. Likewise, species that use EMF to detect predators or kin may alter their behaviour as a result of anthropogenic EMF. If sufficient numbers of individuals are affected this could have consequences at the population and community scale.

225 The use of conductive sheathing, armouring and burial used in AC cables is totally effective at blocking the E field from entering the marine environment, but is only partially effective at reducing the B field. Current literature

suggests that the magnitude of the fish behaviour due to effects from subsea cable will be closely related to the proximity of the animal to the source of the EMF. The latter are strongly attenuated and decrease as an inverse square distance from the cable (Gill and Bartlett, 2010). These impacts are still relatively unknown making the significance of these effects difficult to quantify.

226 Molluscs, crustaceans, elasmobranch fish, teleost fish and sea turtles are able to detect applied or modified magnetic fields. Field studies at Nysted offshore wind farm provided the first evidence that B fields emitted from export cables alter migration and behaviour of marine fish (Klaustrup, 2006). Elasmobranchs can detect B fields far weaker than the earth's magnetic field and are ten thousand times more electrosensitive than most teleost fish. Spurdog (a critically endangered species likely to occur at Neart na Gaoithe) avoided electrical fields at 10 µV cm^{-1} (Gill and Taylor, 2001). The spiny lobster *Panulirus argus* has been demonstrated to use a magnetic map for navigation (Boles and Lohmann, 2003); however, it is uncertain if other crustaceans including commercially important Nephrops and European lobster are able to respond to magnetic fields in this way.

227 Modelling of the predicted EMF of the inter-array or export cables has not been undertaken so the following assessment is qualitative and based on information gathered from the current literature.

228 The overall effect of EMF is assessed to be of minor significance based on the relatively small footprint of the cables within the Neart na Gaoithe offshore works area (refer to Table 15.23). The vulnerability of the species known to occur within the area is assessed as being negligible, as although most fish and shellfish species are reported to be capable of EMF detection, the current view within the scientific community (e.g., Gill and Bartlett, 2010; Gill *et al*., 2009; Öhman *et al.,* 2007) is that there is no evidence that this capability will translate into any significant effect. However, there is a lack of experimental field studies. Therefore, this assessment carries high uncertainty. This assessment also applies to migratory species (namely *S. salar, S. trutta* and *A. anguilla*), which are particularly important within the context of the Neart na Gaoithe project due to their conservation importance (see Chapter 11: Nature Conservation).

Source	Pathway	Receptor	Magnitude of effect	Vulnerability of receptor	Significance of impact	Qualification of significance
Subsea cables (inter-array and export cables)	Electro-magnetic fields	Fish and shellfish populations	Low	Low	Minor significance	Probability is high. Uncertainty is high. To date there is no sufficient evidence that EMF can be detrimental to species capable of perceiving them.

Table 15.23: Impact assessment of EMF in the export cables route during operation for fish and shellfish populations

15.7.3 Decommissioning

229 The operational life of the Neart na Gaoithe development is estimated to be 50 years with repowering after approximately 25 years (refer to Chapter 5: Project Description). Current decommissioning plans provide for detailed decommissioning techniques to be approved closer to the time of decommissioning to allow for changes in available technologies. At present, there is uncertainty on what decommissioning process will be employed at the end of the lifetime of any development (see Chapter 5: Project Description). To date, little evidence is available on the environmental effects of decommissioning, but where available, it is mostly based on experience from the oil and gas sector (Wilhelmsson *et al.*, 2010). Effects are likely to include temporary habitat disturbance and associated species displacement from the removal of the cable and decommissioning vessel footprints e.g., jack-up barges and increases in SSC and sediment deposition from the cutting and dredging works.

230 The impacts of these activities on subtidal habitats and benthic communities are estimated to be similar to, or less (for example, if cables are left *in situ*), than those occurring as a result of construction. Therefore, the impacts of decommissioning are considered to be analogous to those described for the construction phase but in reverse. Additional information is available in Chapter 14: Benthic Ecology.

15.8 Mitigation and Residual Impacts

15.8.1 Offshore Site

15.8.1.1 Noise from Pile Driving during the Construction Phase

231 Soft start procedure is built into the noise model assessment as an assumed control prior to drilling and driving. Soft start piling involves gradually ramping up the blow force on the hammer. When a soft start procedure is used at the onset of piling the levels of underwater noise from the piling work are lower than during piling at maximum blow force but also above the 90 dB_{ht} strong behavioural avoidance perceived level for many fish species at close range. Any fish species around the piles are, therefore, likely to flee the region around the piling operation.

232 However an impact of moderate significance is predicted on hearing specialists for pile driving during construction. Mitigation measures to minimise and mitigate noise produced during potential piling operations are being actively researched. As previously discussed, the developer is a member of The Crown Estate Underwater Noise Forum and FTOWDG where proposals for further development and testing of mitigation measures are being considered.

233 As part of the site environmental management plan (SEMP) for piling operations, the developer will complete an assessment of the effectiveness for fish of all available mitigation measures for piling noise. Options will include the use of barrier to noise such as large or small bubble curtains or sound-absorbing sleeves. The assessment will be based on technical, H&S requirements, environmental benefit and cost.

15.8.2 Export Cables

15.8.2.1 Sediment Disturbance from Installation of the Export Cables

234 Although no significant impact arising from the installation of the cables is predicted, it is considered good practice to minimise the extent of any unnecessary habitat disturbance. On this basis, material displaced as a result of cable burial activities should be back filled, where possible, in order to promote recovery. This also reduces the potential for re-mobilisation of sediments and enables recovery of benthic organisms to occur within a much quicker time-scale (BERR, 2008).

15.8.2.2 EMF from Export Cables

235 It is commonly recommended that cables should be buried 1 m into the seabed to minimise effects (Wilhelmsson *et al.*, 2010). UK Department of Energy and Climate Change (DECC) (2011) recommends cables to be buried to a depth of at least 1.5 m so as to keep cable below the most active biological layer. Burial of the cable will not dampen the effect because the sediment layer itself has no influence on the magnitude of the EMF (Gill *et al.*, 2009), however, it will increase the distance between the cable and the electro-sensitive species (Gill *et al.*, 2005), and, therefore, reduce the radius of the effect and exposure of electromagnetically sensitive species to the strongest electromagnetic fields that exist at the surface of the cable.

15.8.2.3 Heating Effects from Export Cables

236 Mitigation measures include an appropriate trenching depth to limit the rise in sediment temperature to prevent macrozoobenthic fauna from harm and benthic communities and processes from changes.

15.9 Cumulative and In-Combination Impacts

237 Cumulative impact assessment scenario has taken into account the proposed Inch Cape and the Firth of Forth Round 3 offshore wind farms in conjunction with the Neart na Gaoithe development.

15.9.1 Cumulative Construction Impacts

238 Cumulative impacts are predicted to arise from the development of the two other wind farm areas in the Firth of Forth and Tay Region; Inch Cape offshore wind farm and the Firth of Forth Round 3 Zone 2.

239 The worst (realistic) case for cumulative impacts is that construction operations would occur simultaneously at all three proposed development sites (see Chapter 5: Project Description). Table 15.6 summarises the worst (realistic) case in terms of development options at a cumulative level as assessed for fish and shellfish ecology for Neart na Gaoithe.

240 The potential cumulative impacts relate to the same effects predicted by the development of the Neart na Gaoithe project alone:

- Direct disturbance of habitat due to construction of offshore structures and installation of cables;
- Increases in SSC and corresponding sediment settlement or smothering; and
- Change in ambient underwater noise and vibration due to construction.

15.9.1.1 Cumulative Direct Habitat Disturbance

241 Habitat disturbance associated with the turbine and met masts installation, inter-array, interconnector and export cable laying and supporting infrastructure (e.g., offshore substations) is estimated to be up to 14.41 km^2 across all three sites, based on the worst (realistic) case Rochdale scenario for each development. This represents a low value when considered within the wider geographical context of the developments. The estimated disturbance is predicted to be limited in space (near the source of operations) and time (during the construction phase) and the overall impact is assessed to be of ***minor significance*** with low uncertainty.

15.9.1.2 Cumulative Increase in SSC, Sediment Settlement and Smothering

242 Cumulative changes to the far-field suspended sediment transport pathways due to the three proposed offshore wind farm developments were modelled assuming a continuous discharge of a neutrally-buoyant plume over a spring-neap cycle with an ‘all developments’ scenario hydrodynamic mode (for details see Chapter 9: Physical Processes). Comparison of the results of the predicted cumulative impacts and those generated using the baseline model shows no noticeable differences. This result indicates that the proposed offshore wind farm developments will not cause net changes to the regional sediment transport regime or sediment dynamics along the nearby coastline, even when the three sites are considered cumulatively. In view of these results, in-combination with the vulnerability assessment of fish and shellfish communities (discussed in Section 15.7: Impact Assessment), the potential cumulative impact of increase in SSC is assessed as ***minor significance*** with low uncertainty.

15.9.1.3 Cumulative Construction Noise

243 There is the potential for cumulative underwater noise impacts to affect fish species if two or more projects are undertaking pile driving simultaneously and the noise is of a sufficient level from each source for zones of influence to overlap.

244 The modelling study undertaken to assess the impact of underwater noise at a project level (as discussed above) also modelled potential impacts at a cumulative level, with scenarios covering concurrent piling operations at two or three of the development areas:

- Neart na Gaoithe and Inch Cape offshore wind farms;
- Neart na Gaoithe and the Firth of Forth Round 3 Zone 2 development; and
- Neart na Gaoithe, Inch Cape and the Firth of Forth Round 3 Zone 2 development.

245 The worst case scenario is the third of these, with concurrent piling at all three developments. Each of the scenarios is described below, with further information presented in Appendix 13.1: Noise Model Technical Report.

Neart na Gaoithe and Inch Cape Offshore Wind Farms

246 When considering the cumulative impact of piling at Neart na Gaoithe concurrently with piling at Inch Cape offshore wind farm, the modelling study indicates that for herring there could be a degree of overlap with respect to the strong and significant behavioural avoidance. This indicates that pile driving at these two locations could have a net cumulative impact in terms of the total area in which these fish species may be exposed to adverse levels of underwater noise and time of e.g., increased swimming speed that may result in energetic cost to the animal. When superimposed on to the herring spawning grounds (see Figure 15.34 and 15.35 below), the results of the modelling study show that up to 2710 km^2 of herring spawning grounds fall within the radius of significant avoidance behaviour and 217 km^2 within the strong avoidance behaviour. These represent 17% and 1.4%, respectively, of the total herring spawning area within the southeast of Scotland as reported by Coull *et al.* (1998). When superimposed onto the herring nursery grounds, the cumulative radii of significant and strong avoidance behaviour encompass 1.5% and 0.5%, respectively, of the herring nursery areas across the North Sea as reported by Ellis *et al.*, 2012. With respect to more inshore nursery areas within the Firth of Forth, up to 37% and 1.6% are encompassed within the significant and strong behavioural avoidance, respectively.

247 Given the extent of the potential noise impact and the overlap with herring spawning and nursery grounds, the overall impact of pile driving noise from Neart na Gaoithe and the Inch Cape offshore wind farm on herring is considered to be of ***moderate significance*** with medium uncertainty.

248 Dab, and to a lesser extent salmon, also show a degree of overlap with regard to the significant avoidance behaviour. The significance of the impact of behavioural avoidance on migratory species, e.g., salmon, depends on how easily these species can avoid the area, thus the cumulative effect of the pile driving noise will result in a larger radius that may be energetically costly for the species to avoid. The magnitude of the effect is considered to be low with respect to the strong avoidance behaviour and moderate for the significant avoidance behaviour based on the output of the modelling study. The vulnerability of dab and sole is considered to be low for the strong avoidance behaviour and moderate for the significant avoidance behaviour and the overall impact is assessed to be of ***minor* to *moderate significance*** with medium uncertainty. This assessment is of particular relevance because of the close ecological relationship between salmon and fresh water pearl mussels.

249 Sandeel and trout are assessed to be of low vulnerability to cumulative impact from simultaneous pile driving at Neart na Gaoithe and Inch Cape, based on the output of modelling study as the radii of strong and significant behavioural avoidance are very limited in extent. The magnitude of the effect is negligible and the impact on these species is assessed to be of ***minor significance*** with medium uncertainty.

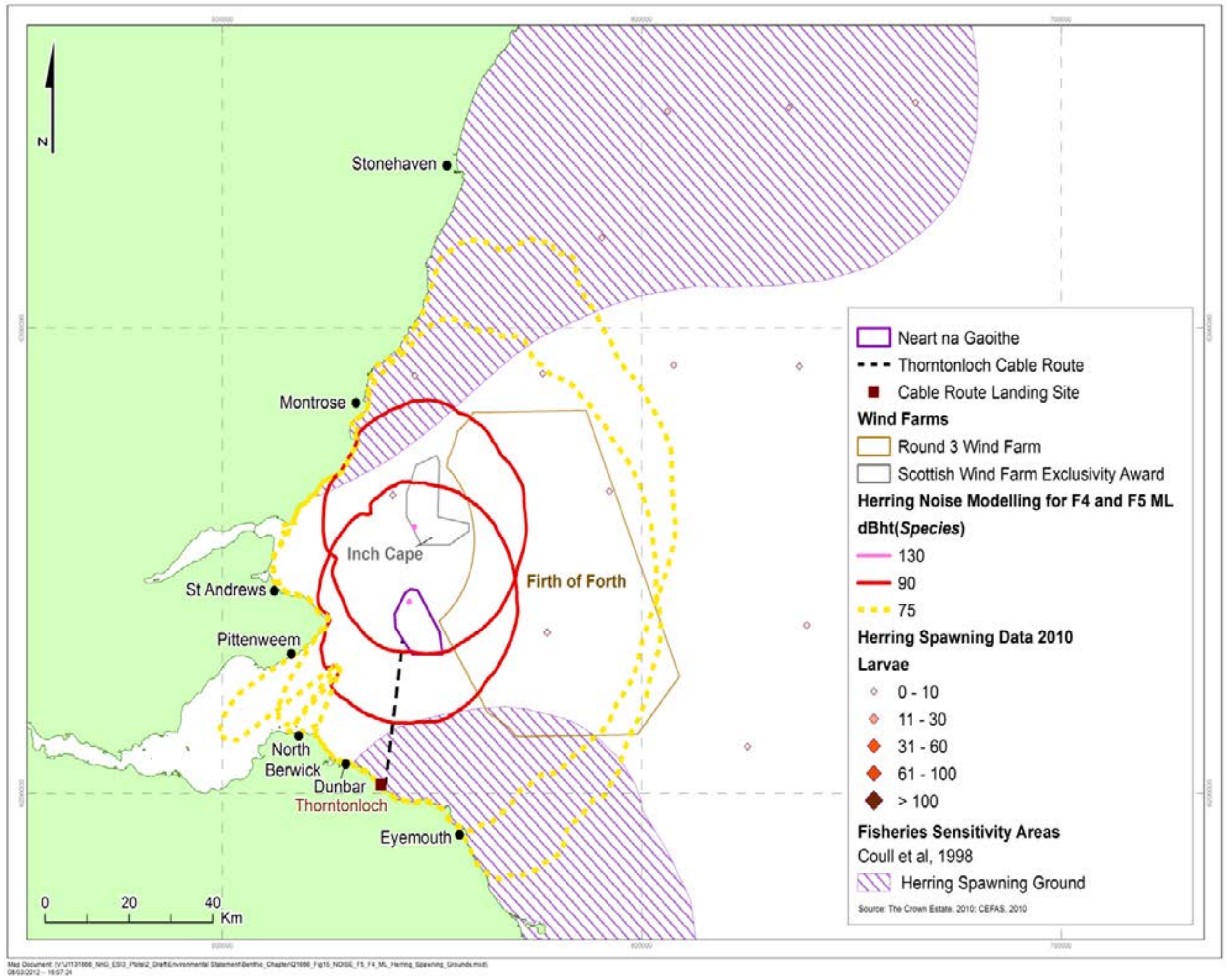


Figure 15.34: Contour plot showing the estimated 130, 90 and 75 dB_{ht} peak to peak impact ranges for herring for the installation of simultaneous piles at Neart na Gaoithe and Inch Cape superimposed onto herring spawning grounds (Coull *et al.*, 1998)

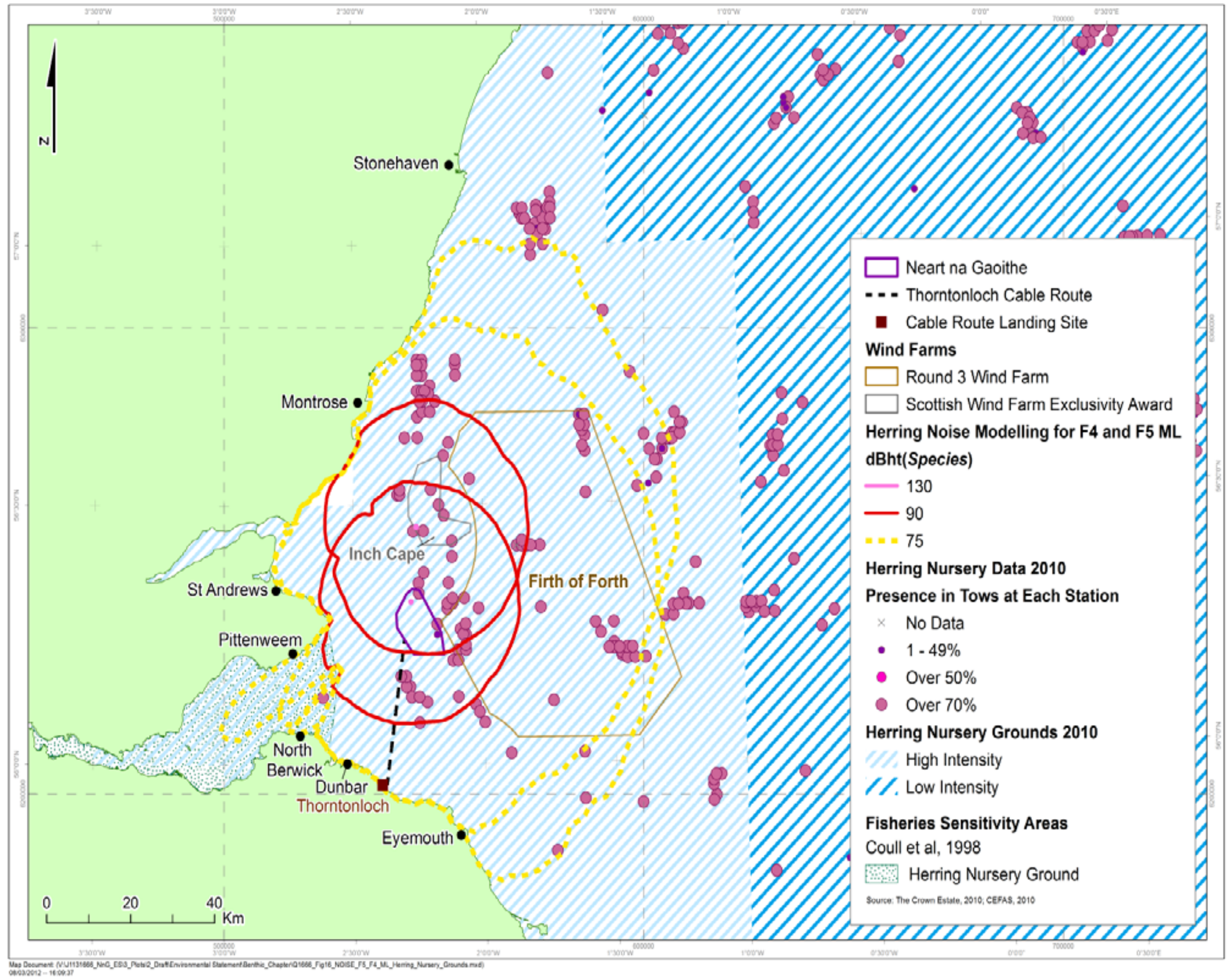


Figure 15.35: Contour plot showing the estimated 130, 90 and 75 dB_{ht} peak to peak impact ranges for herring for the installation of simultaneous piles at Neart na Gaoithe and Inch Cape superimposed onto herring nursery grounds (Ellis *et al.*, 2012; Coull *et al.*, 1998)

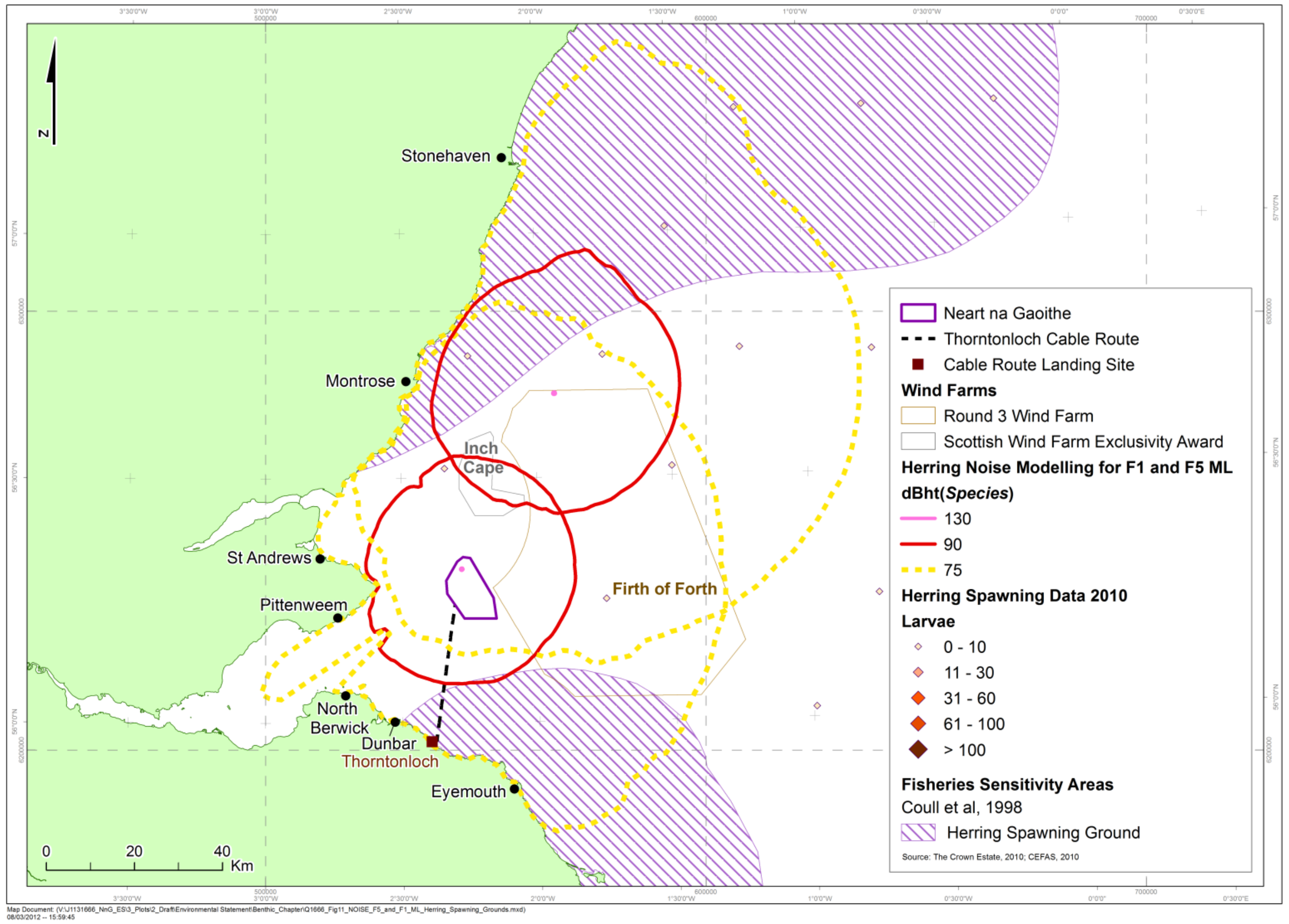


Figure 15.36: Contour plot showing the estimated 130, 90 and 75 dB_{ht} peak to peak impact ranges for herring for the installation of simultaneous piles at Neart na Gaoithe and Firth of Forth superimposed onto herring spawning grounds (Coull *et al.*, 1998)

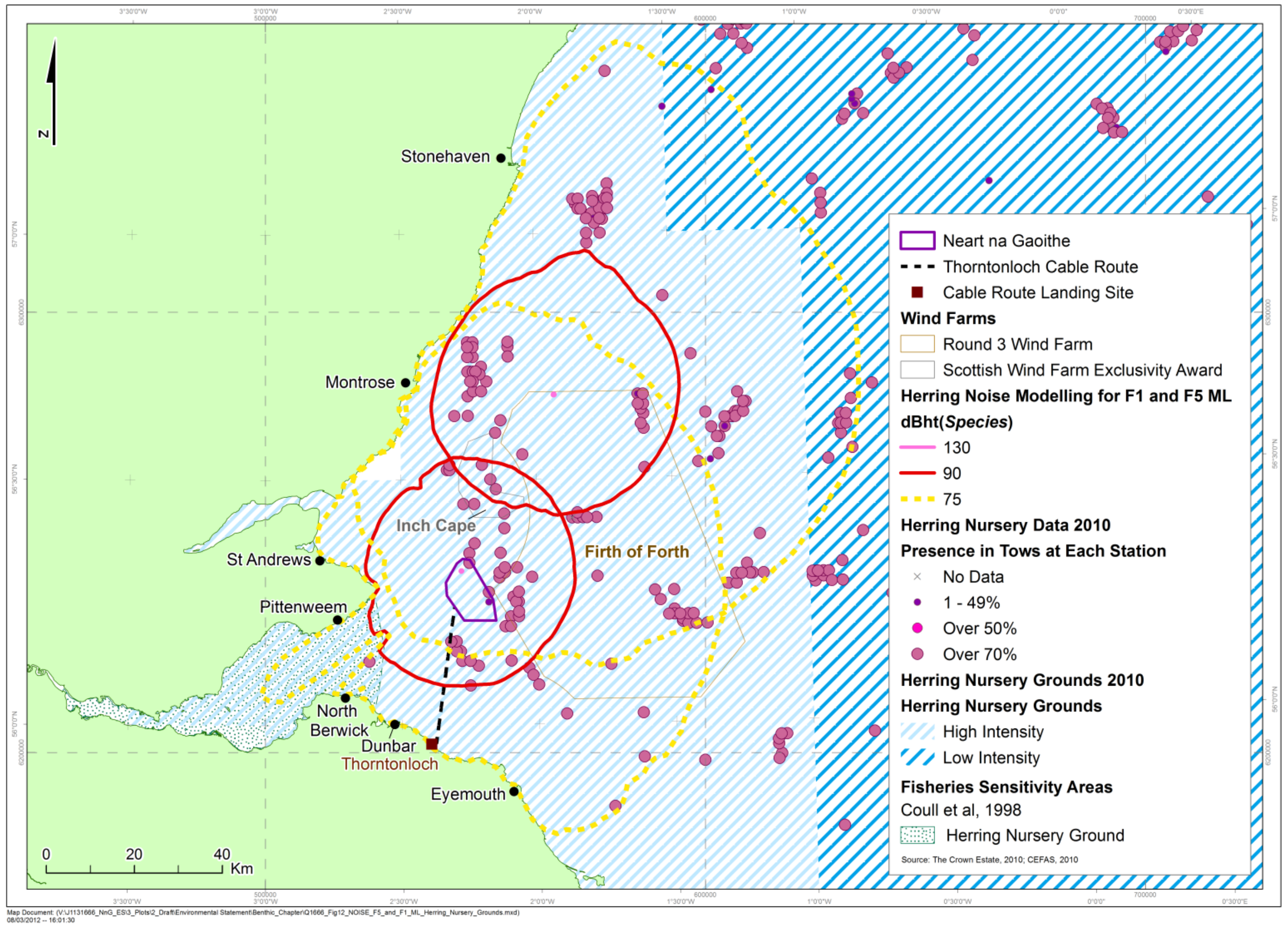


Figure 15.37: Contour plot showing the estimated 130, 90 and 75 dB_{ht} peak to peak impact ranges for Herring for the installation of simultaneous piles at Neart na Gaoithe and Firth of Forth superimposed onto herring nursery grounds (Coull *et al.*, 1998; Ellis *et al.*, 2012)

Neart na Gaoithe and the Firth of Forth Round 3 Zone 2 Development

250 When considering the cumulative impact of the Neart na Gaoithe with the Firth of Forth development, results of the modelling study indicate that overlap of the strong and significant avoidance behaviour is likely to occur only for herring (Figure 15.34). The extent of the behavioural avoidance radii is considerable, which may lead to a high exposure time of the animal to the sound and high energetic cost when fleeing the area. When superimposed onto the herring spawning grounds, it can be seen that the radius of significant avoidance behaviour encompass just over 31% of the herring spawning grounds as defined by Coull *et al.* (1998), whereas the strong avoidance behaviour radius covers nearly 6% (Figure 15.35). Figure 15.36 shows the output of the modelling study superimposed onto the herring nursery grounds. The radius of strong and significant avoidance behaviour covers 0.8% and 2.4%, respectively, of the total herring nursery area across the North Sea as defined by Ellis *et al.* (2012). With respect to the more inshore herring nursery area, as defined by Coull *et al.* (1998), 31% and 1.6% are encompassed within the radius of significant and strong avoidance behaviour respectively (Figure 15.37). The magnitude of the cumulative effect of pile driving onto herring, deriving from the simultaneous construction of Neart na Gaoithe and Firth of Forth developments is considered to be moderate, as although it is temporary, it has the potential to extend over a large area. The vulnerability of the herring to the cumulative impact is considered to be moderate as fish are likely to be exposed to these noise levels for prolonged periods of time. The overall impact of pile driving noise onto herring is considered to be of ***moderate significance*** with medium uncertainty.

251 With respect to dab, salmon, trout and sand eel, no degree of overlap is predicted by the simultaneous pile driving at Neart na Gaoithe and Firth of Forth (Figure 15.35 to 15.38). The magnitude of the effect on dab is considered to be low for the strong avoidance behaviour and moderate for the significant avoidance behaviour, based on their spatial extent, the temporary nature of the effect and effect intermittency during the construction phase. The vulnerability of dab is considered to be low and the overall impact on these fish population predicted to be of ***minor* to *moderate significance***. This assessment carries medium uncertainty.

252 The magnitude of the effect on salmon and trout is considered to be negligible for the strong avoidance behaviour and minor for the significant avoidance behaviour, based on the spatial extent of the radius, the temporary nature of the effect and effect intermittency during the construction phase. The vulnerability of salmon and trout is considered to be low and the overall impact on these fish populations predicted to be of ***minor significance***. This assessment carries medium uncertainty.

253 The magnitude of the effect on sandeel is considered to be low for the strong and significant avoidance behaviour, based on the spatial extent of the radius, the temporary nature of the effect and effect intermittency during the construction phase. The vulnerability of sandeel is considered to be low as the site specific survey results and data from Marine Scotland (2011a, pers. comm.) indicate that this species is unlikely to occur within the study areas in large number. However, in the absence of results from sandeel specific surveys, a precautionary approach has been taken for the assessment. The overall impact on these fish populations is predicted to be of ***minor significance***. This assessment carries medium uncertainty.

Neart na Gaoithe, Inch Cape Offshore Wind Farm and the Firth of Forth Round 3 Zone 2 Developments

254 The cumulative impact assessment also considers the potential impacts of pile driving on fish and shellfish populations should the three developments at the same time, i.e., piling occurs at Neart na Gaoithe, Inch Cape and Firth of Forth Round 3 Zone 2 simultaneously. Results of the modelling study indicate that there is a degree of overlap for the behavioural avoidance radii for all species with the exception of trout and sandeel.

255 The predicted radii of behavioural avoidance of herring show considerable degree of overlap (Figure 15.38). When superimposed onto spawning grounds (refer to Figure 15.38), the radius of strong avoidance behaviour encompasses just over 6% of the spawning grounds as reported by Coull *et al.* (1998), whereas the radius of significant avoidance behaviour covers just over 33%. When superimposed onto the herring nursery grounds (Figure 15.39), the strong and significant avoidance behavioural radii covers 1% and 2.6% respectively of the herring nursery area across the North Sea as reported by Ellis *et al*. (2010). The magnitude of the cumulative effect of pile driving onto herring, deriving from the simultaneous construction of Neart na Gaoithe, Inch Cape and Firth of Forth Round 3 Zone 2 is considered to be moderate, as although it is temporary, it has the potential to extent over a large area. The vulnerability of the herring to the cumulative impact is considered to be moderate to high as fish are likely to be exposed to elevated noise levels for prolonged periods of time.

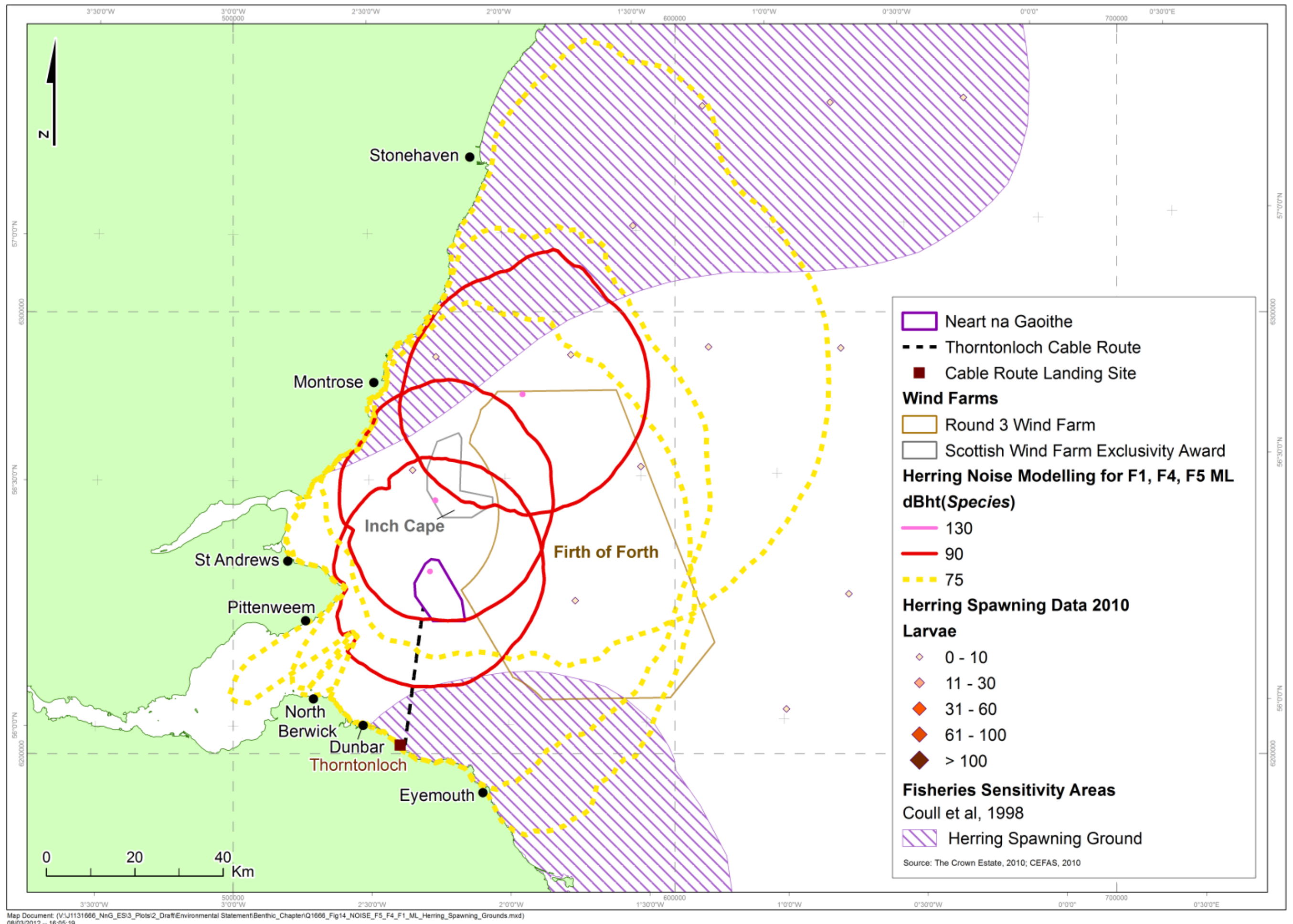


Figure 15.38 Contour plot showing the estimated 130, 90 and 75 dB_{ht} peak to peak impact ranges for Herring for the installation of simultaneous piles at Neart na Gaoithe, Inch Cape and Firth of Forth superimposed onto herring spawning grounds (Coull *et al.*, 1998)

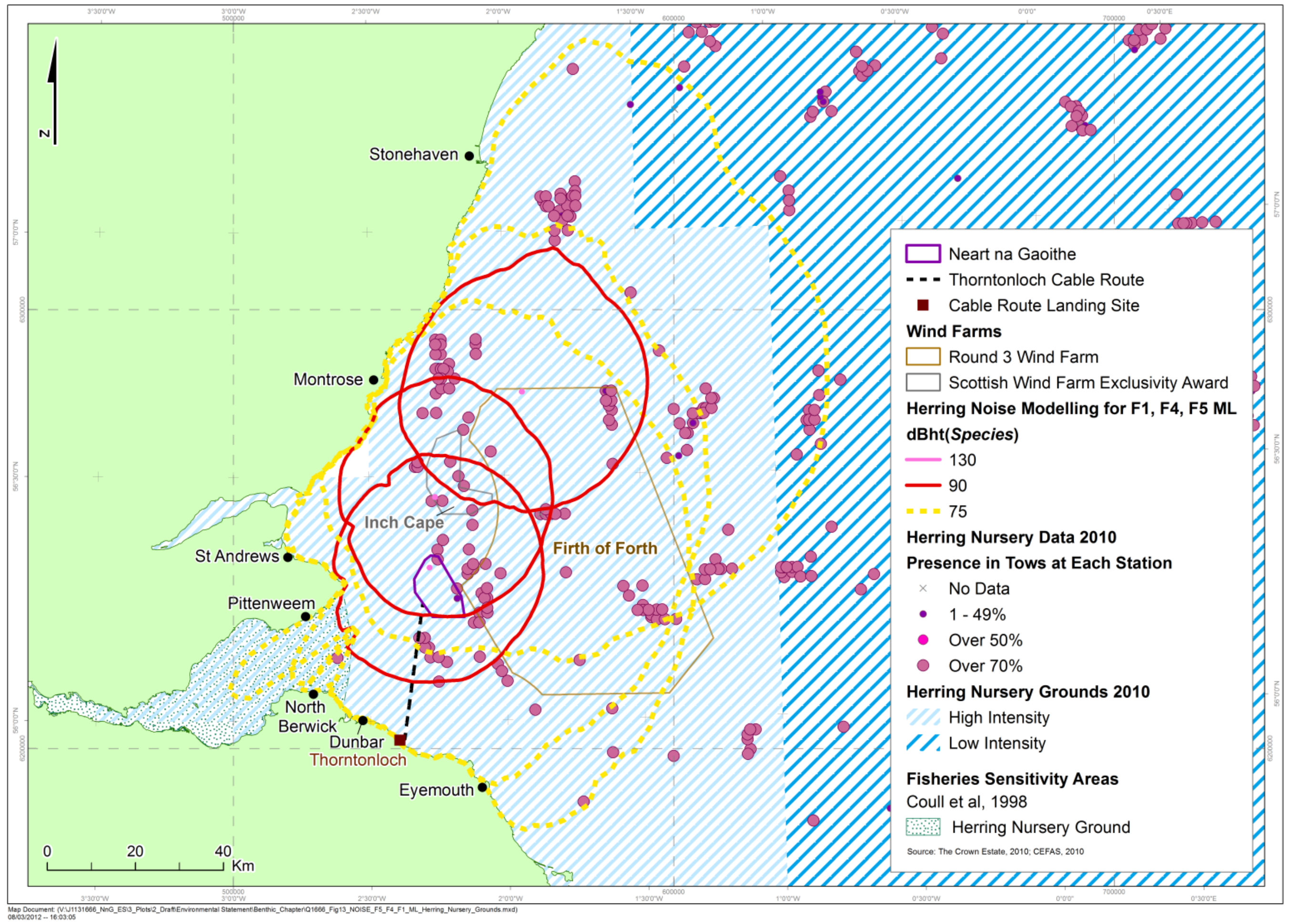


Figure 15.39: Contour plot showing the estimated 130, 90 and 75 dB_{ht} peak to peak impact ranges for Herring for the installation of simultaneous piles at Neart na Gaoithe, Inch Cape and Firth of Forth superimposed onto herring nursery grounds (Ellis *et al*., 2012; Coull *et al*., 1998)

256 The overall significance of impact of pile driving noise on herring is considered to be of ***moderate* to *major significance*** with medium uncertainty. Dab and salmon also show a degree of overlap with regard to the significant avoidance behaviour (Figures 15.40 and 15.41). The significance of the impact of behavioural avoidance on migratory species, e.g., salmon, depends on how easily these species can avoid the area. The cumulative effect of the pile driving noise will result in a larger radius which may be energetically costly for the species to avoid.

257 The magnitude of the effect is considered to be low with respect to the strong avoidance behaviour and moderate for the significant avoidance behaviour based on the output of modelling study. The vulnerability of dab and salmon is considered to be low for the strong avoidance behaviour and moderate for the significant avoidance behaviour and the overall impact is assessed to be of ***minor* to *moderate significance*** with medium uncertainty. This assessment is of particular relevance because of the close ecological relationship between salmon and fresh water pearl mussels.

258 Sandeel and trout are assessed to be of low vulnerability to cumulative impact from simultaneous pile driving at Neart na Gaoithe, Inch Cape and Firth of Forth based on the output of modelling study as the radii of strong and significant behavioural avoidance are very limited in extent (Figure 15.42 and 15.43). The magnitude of the effect is negligible and the impact on these species is assessed to be of ***minor significance*** with medium uncertainty.

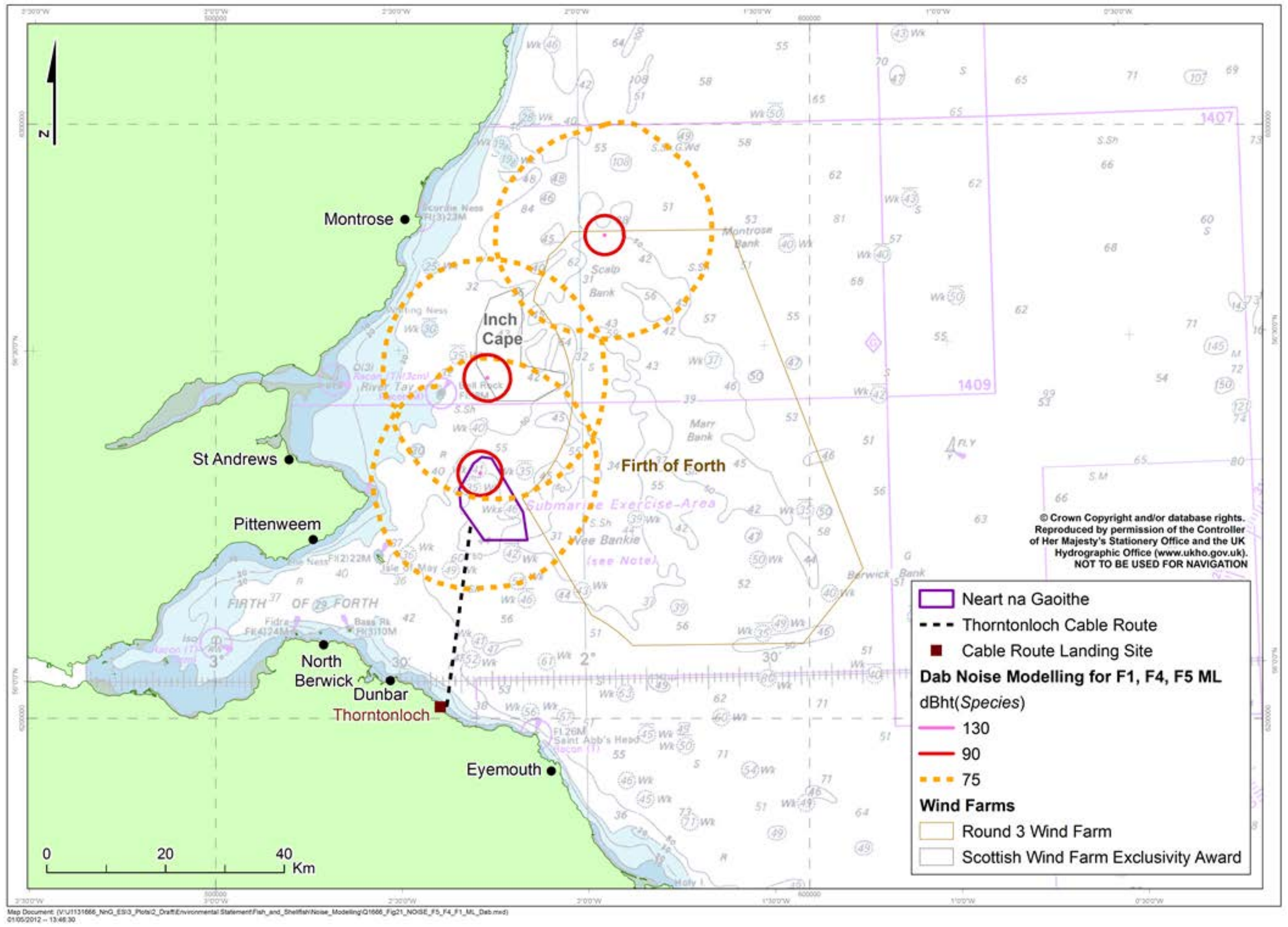


Figure 15.40: Contour plot showing the estimated 130, 90 and 75 dB_{ht} peak to peak impact for Dab for the installation of simultaneous piles at Neart na Gaoithe, Inch Cape and Firth of Forth

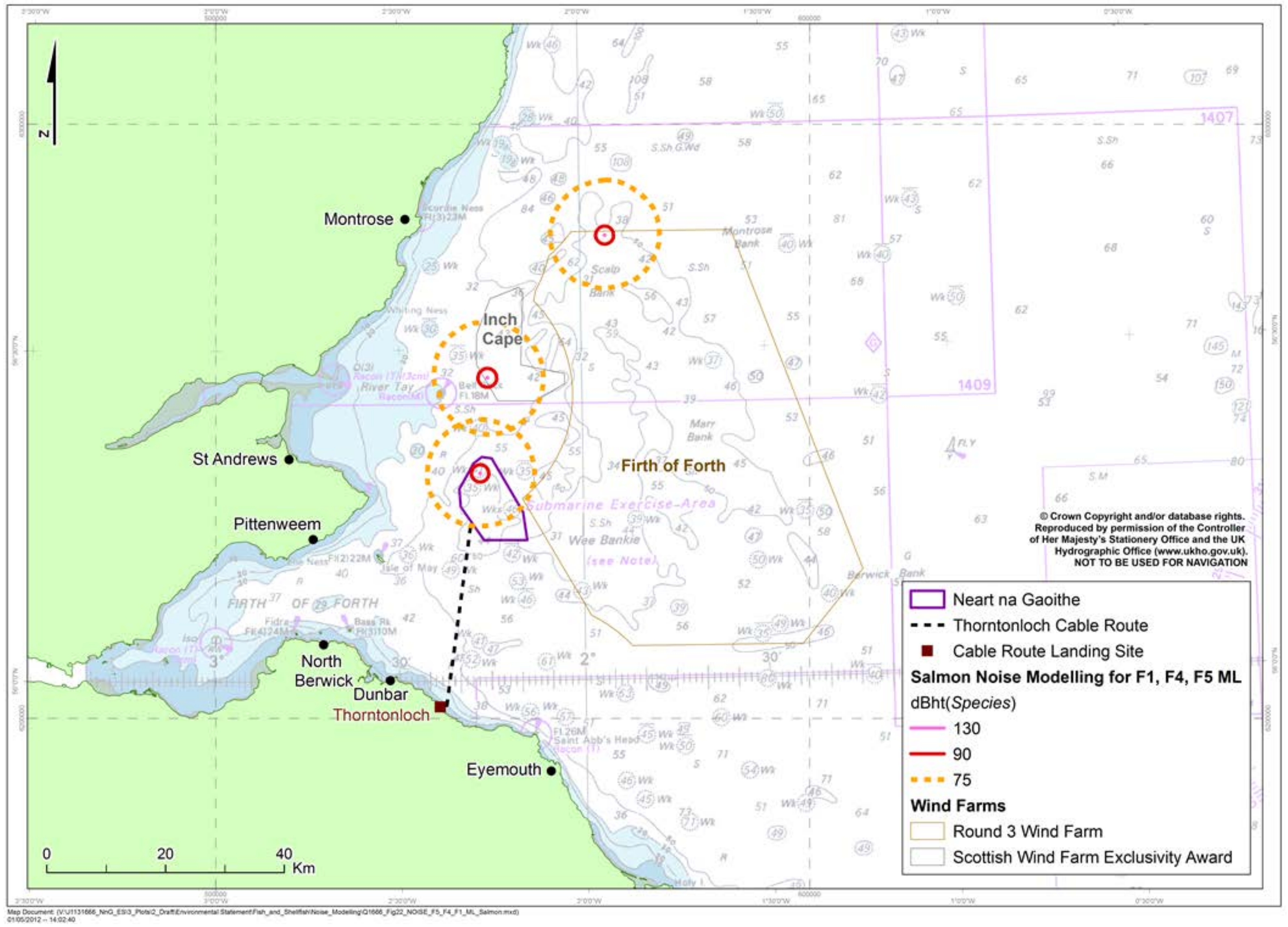


Figure 15.41: Contour plot showing the estimated 130, 90 and 75 dBht peak to peak impact for Salmon for the installation of simultaneous piles at Neart na Gaoithe, Inch Cape and Firth of Forth

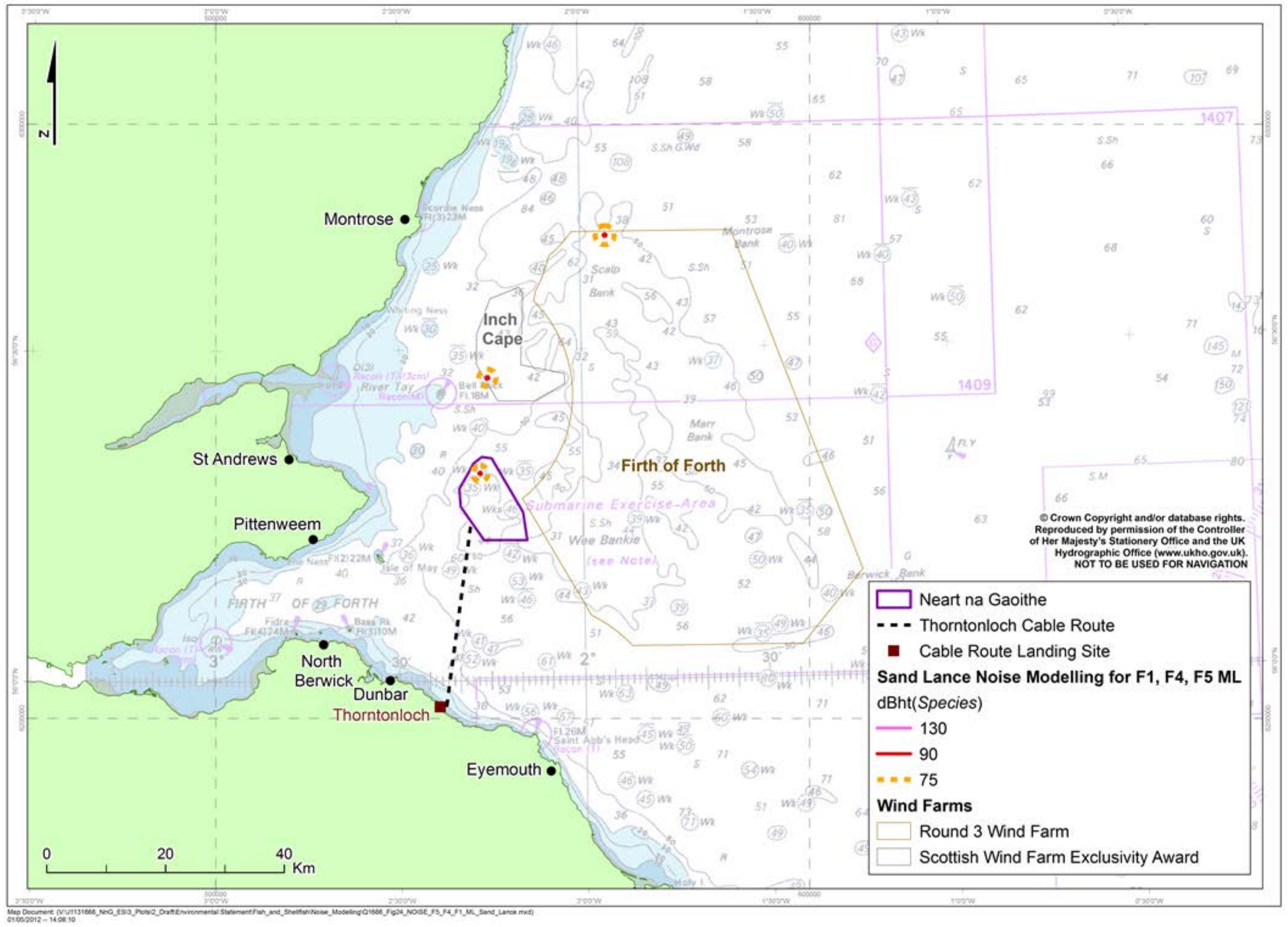


Figure 15.42: Contour plot showing the estimated 130, 90 and 75 dB_{ht} peak to peak impact for sandeel for the installation of simultaneous piles at Neart na Gaoithe, Inch Cape and Firth of Forth

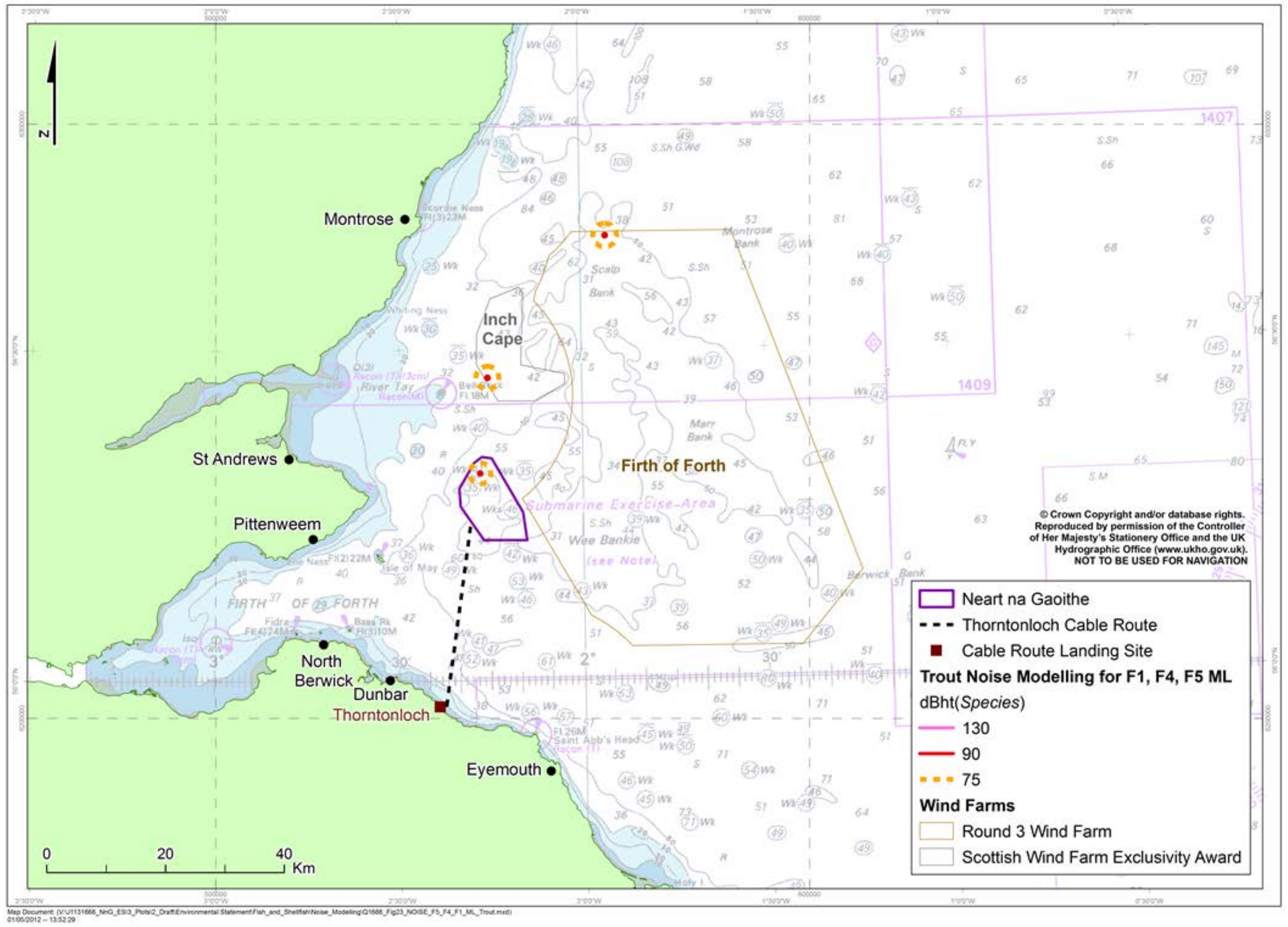


Figure 15.43: Contour plot showing the estimated 130, 90 and 75 dB_{ht} peak to peak impact for Trout for the installation of simultaneous piles at Neart na Gaoithe, Inch Cape and Firth of Forth

15.9.3 Cumulative Operation and Maintenance Impacts

259 Cumulative impacts in the operation and maintenance stage will arise on completion of the construction of the three developments.

260 Potential cumulative impacts, therefore, include:

- Loss of existing benthic habitat that may support fish and shellfish populations;
- Introduction of new substrate (the artificial reef effect) from the presence of offshore wind turbines and associated structures and scour protection on these and cables;
- Electromagnetic fields generated by inter-array, interconnector and export cables from the three development areas; and
- Operational noise from the operation of the developments.

261 Table 15.6 summarises the worst (realistic) case parameters in terms of development options at a cumulative level as assessed for fish and shellfish ecology.

15.9.3.1 Cumulative Permanent Habitat Loss

262 Habitat loss beneath the turbine and met masts installation and associated scour protection, and supporting infrastructures (e.g., offshore services platforms) is estimated to be up to 9.7 km^2 across all three sites based on the worst (realistic) case Rochdale scenario for each development, which assumes the largest gravity base foundations in most cases. Therefore, the overall impact is assessed as ***minor significance*** with low uncertainty.

15.9.3.2 Cumulative Changes in Hydrodynamic Regimes

263 The cumulative effects of the proposed Neart na Gaoithe, Inch Cape and Firth of Forth Round 3 offshore wind farms on the sediment regime have been modelled in-combination with analysis of the seabed sediment characteristics (Chapter 9: Physical Processes). Results of the modelling study indicate that the predicted cumulative changes to sediment transport processes due to the Neart na Gaoithe and other surrounding developments are likely to be small, (the predicted frequency of exceedance of the critical shear stress changing typically by 1-3% with a maximum difference of 6%) and restricted to the immediate vicinity of the development sites. Based on this information the likely impact on fish and shellfish is assessed to be ***minor significance*** with low uncertainty.

15.9.3.3 Cumulative Introduction of New Substrate

264 The potential scale of the three offshore wind farm developments introduces new substrates of approximately 9.69 km^2. This value is likely to be an underestimate, as turbine towers and any other vertical structures for Inch Cape offshore wind farm and the Firth of Forth Round 3 Zone 2 have not been taken into account in this calculation, which is very conservative. This is in despite of this assessment not taking account of different surface textures, gaps, and crevices which all affect the potential for new substrate and subsequent settlement (Linley *et al.*, 2007).

265 This change in habitat characteristics may compensate for losses of natural habitats in line with indications by the EU Marine Strategy Framework Directive (MSFD, 2008/56/EC). Current evidence indicates that modification of engineered structures can influence diversity and potentially increase the abundance of commercially exploited species. Further research is being undertaken to identify species-specific habitat preferences in the design of offshore energy foundations to optimise biomass of selected species. Scour protection can also be configured in terms of density of boulders and crevices; similarly frond mats may mimic artificial algae or sea grass beds, providing nursery areas for juvenile fish of selected species. For fish and shellfish species (e.g., crustaceans) limited by the amount of reef habitat refuge, territory, food and behavioural requirements, the new substrate may augment total stock size. However, even when considered cumulatively, the magnitude of habitat enhancement due to the introduction of artificial structures is considered low particularly when put into the wider geographical context.

266 Therefore, the impact of artificial reefs on fish and shellfish populations is assessed as being of ***minor significance*** and this assessment carries medium uncertainty, in view of the fact that proving the link between a wind farm and changes in fish and shellfish populations requires years of monitoring to distinguish the effects of the wind farm from natural annual variation. In addition, little is currently known on how fish perform ecologically (e.g., growth, reproduction, feeding) around turbines, or how any ecological changes associated the wind farms may affect the wider ecosystem.

15.9.3.4 Cumulative Operational Noise generated by Wind Turbines

267 Site specific numerical models on the noise likely to be generated by the operation of 1,376 wind turbines are not available, neither is information on the background ambient noise of the Firth of Forth region. The latter can play an important role in assessing the likely range of noise disturbance associated with the wind farms, particularly if the area is subject to heavy shipping traffic that can increase the background noise significantly (Nedwell *et al.*, 2003). Evidence from the current literature indicates that fish such as dab and salmon may detect operational noise of a wind turbine at relatively short distances (e.g., 1 km), whereas fish such as cod and herring may detect an operating wind turbine at 4-5 km from the source (Thomsen *et al.*, 2006). There is also evidence that fish may be able to distinguish between the nature of similar sounds and habituate to the continuous operational sound of wind turbines (Thomsen *et al.*, 2006). In view of this, the cumulative impact from operational noise on fish and shellfish populations is assessed to be of ***minor significance*** but with medium uncertainty as current data are based on field measurements of relatively small wind turbines. Higher sound levels are predicted in line with larger wind turbines and thus the radii of noise influence will probably increase, even under North Sea ambient noise conditions (Thomsen *et al.*, 2006).

15.9.3.5 Cumulative Electromagnetic Field

268 Cumulative effects from export and inter-array cables are of relevance to electro-sensitive species that will tend to respond to the EMF emitted by these cables, although over very small areas and local only to the area where the cables are buried. The total length of export and interconnecting cables for all three developments is estimated at 261 km, and inter-array cables 1,540 km (assuming inter-array cables for other developments are of a proportional length per MW of site capacity to Neart na Gaoithe).

269 The export cables for Neart na Gaoithe will be spaced at a minimum of 70 m apart, however, the spacing of the inter-array cables particularly at the offshore substations may be lower than this as the cables connect to the structures.as little as 10 m apart. Cable spacing in itself can influence the strength and extent of the EMF emitted. In addition, cable loading will affect the fields emitted. Evidence from the current literature indicates that EMF may be measurable within circa 17–20 m of a buried subsea cable and selected fish will respond to the presence of EMF at different distances and with different behavioural responses; however, whether this will translate into any impact on the animals is not yet clear. The potential cumulative impact from EMF of subsea cables on fish and shellfish communities is assessed to be of ***minor significance*** with a medium uncertainty, as further studies are needed to establish if the relationships between fish and EMF can cause any impacts on individuals.

15.9.4 In-Combination Impacts

270 In relation to other anthropogenic activities, which could potentially adversely affect the benthic environment in-combination with the Neart na Gaoithe offshore wind farm, the review of the regional area did not identify marine aggregate extraction areas, pipelines or cable routes within the study area. Fishing in the region is, therefore, the only activity with the potential to have an in-combination effect with the site development. It is expected that fishing will be allowed to continue within the wind farm, however, the effect of fishing activity on the fish and shellfish communities within the wind farm area is currently difficult to estimate especially when considering the potential changes in fishing capacity. Given the area of the wind farm compared to the wider available area for fishing and the widespread nature of the benthic communities across the region, in-combination impacts with fishing activities on the fish and shellfish communities are considered to be ***not significant***.

15.10 Monitoring

271 The abundance and distribution of fish stocks are influenced by several parameters, such as: natural variability (seasonal and annual); fishing effort; environmental conditions (including oceanographic and climate conditions); seasonal variability in distribution; predator/prey interactions; and food availability. When considering that these parameters are in addition to any potential effects associated with wind farms, it becomes apparent that robust time-series baseline data for the local abundance and distribution of fish and shellfish are necessary in any monitoring programme, to provide information against which the potential effects associated with wind farms can be assessed.

272 Specifically, monitoring should provide information aimed at supporting the assessment made within the EIA and future mitigation measures as necessary. To provide useful data and evidence, fish surveys will aim at investigating the local distribution and abundance of fish and shellfish species in relation to:

- Effects of construction and operational noise;
- Electromagnetic fields (particularly in relation to the electro sensitive species identified in the EIA); and
- Artificial reef effects (particularly in relation to species of commercial and conservation interest).

273 Fish surveys aimed at addressing the points above are particularly relevant, as currently a detailed overview of effects from construction and the influence of natural variability on fish and shellfish communities is lacking. As part of the artificial reefs and EMF investigations, few studies have analysed the stomach content of fish within and outside wind farms in order to determine any differences in feeding habits.

274 Implementation of monitoring fish surveys within wind farms has safety and logistical problems, particularly in terms of gathering data in close proximity of foundations. As a mitigation measure, traditional survey techniques may be supplemented with use of drop down still and video cameras. These types of survey have been successfully used in the collection of high quality information and are deemed to be suitable at inspecting the under-water sections of turbines for examining the colonisation of sessile fauna, or for checking the integrity of the structure itself as well as gathering information on fish in closer proximity to turbines and scour protection.

275 The requirements for and details of any site specific pre- and post-construction monitoring will be established through consultation with Marine Scotland and SNH prior to any works commencing.

15.11 Summary and Conclusions

276 The fish assemblages of the area are typical of the central North Sea and include pelagic (e.g., mackerel, whiting, sprat) and demersal species, the latter including elasmobranchs (e.g., spurdog, lesser spotted dogfish, rays, sharks), gadoids (cod, whiting, hake, haddock, pollack) and flatfish (e.g., plaice, dab, sole). Diadromous species (e.g., salmon, sea trout, eels, smelt and shad) may also be found in the area, particularly in coastal waters during migration from and to rivers. Shellfish present near the site include lobsters, crabs, shrimps and scallops.

277 The potential impacts of the Neart na Gaoithe wind farm project have been investigated and assessed with respect to the construction and operation phases; in addition, cumulative impacts have been considered to take into account the proposed Inch Cape and the Firth of Forth Round 3 offshore wind farms.

278 Table 15.24 summarises the conclusions.

Source	Pathway	Receptor	Impact significance pre-mitigation	Mitigation	Residual impact post-mitigation	Cumulative and in-combination impact	Qualification of significance
Construction							
Installation of turbines, subsea cables and associated structures	Habitat disturbance	Fish and shellfish populations	Minor significance	None identified		Minor significance	Probability is high. Uncertainty is low. Mobile species are expected to avoid disturbance and less mobile species are fairly widespread within the region.
Installation of turbines, subsea cables and associated structures	Increase in SSC	Fish and shellfish populations	Minor significance	None identified		Minor significance	Probability is high. Uncertainty is low. The increases in SSC predicted to occur during the construction phase (refer to Chapter 9: Physical Processes) are much lower than those reported to impair fish and shellfish
Installation of turbines, subsea cables and associated structures	Increase in sediment settlement/ smothering	Fish and shellfish populations	Minor significance	None identified		Minor significance	Probability is high. Uncertainty is low. Thick depositions of sediment are unlikely to occur on a wide enough area to impair fish and shellfish
Installation of jacket foundations	Pile driving creating noise and vibration	Fish and Shellfish Species – traumatic hearing loss	Minor significance	Soft start piling. Further mitigation measures are being actively researched through national research groups and other consortia.	Not significant		Probability is high. Uncertainty is high. The magnitude of the effect (e.g., radius of traumatic hearing loss) is anticipated to be low for each piling activity even at a cumulative area. It is recognised that most fish species will swim away from the noise source, though some may have specific habitat requirements or could insufficient swimming speeds. Mortality or traumatic hearing loss unlikely at a large population scale given the species characterising the wider region.
		Herring – behavioural response (avoidance)	Moderate significance		Minor to Moderate Significance	Moderate to major significance	Probability is medium. Uncertainty is high. The radius of strong and significant avoidance behaviour overlaps with herring (a hearing specialist) nursery and spawning grounds across the region.
		Cod – behavioural response (avoidance)	Minor to moderate significance		Minor significance	Minor to moderate significance	Probability is medium. Uncertainty is high. This is a qualitative assessment as the noise modelling did not profile cod. As a hearing specialist cod are sensitive to underwater noise, though not to the same degree as herring but more so than flatfish species.
		Flatfish species - behavioural response (avoidance)	Minor to moderate significance		Minor Significance	Minor to moderate significance	Probability is high. Uncertainty is medium. Dab are most affected by particle motion rather than sound pressure and so impacts are predicted to be low. However, at a cumulative level there is some overlap in zones of strong and significant avoidance behaviour predicted.
		Salmon and sea trout - behavioural response (avoidance)	Minor significance		Minor Significance	Minor to moderate significance	Probability is high. Uncertainty is medium. Salmon and sea trout are only predicted to be in the offshore area intermittently and are not a hearing specialist, hence their vulnerability remains low.
		Sandeel - behavioural response (avoidance)	Minor significance			Minor significance	Probability is high. Uncertainty is medium. Sandeel are not predicted to occur in the Neart na Gaoithe offshore works area though could be present in other wind farm areas. The radius of avoidance behaviour from the noise modelling is of low extent even at a cumulative level.

Source	Pathway	Receptor	Impact significance pre-mitigation	Mitigation	Residual impact post-mitigation	Cumulative and in-combination impact	Qualification of significance
Installation of export cables	Direct habitat disturbance	Fish and shellfish populations	Minor significance	None identified		Included in consideration of general cumulative habitat disturbance from construction	There are no records of shellfish beds along the Neart na Gaoithe cable route, and percentage of herring spawning grounds likely to be impacted is negligible by comparison to their extent within the region.
Sediment disturbance during export cable burial	Sediment re-suspension and smothering	Fish and shellfish populations	Not significant	Back filling of cable trenches will further minimise this magnitude of any effect		Included in consideration of general cumulative sediment disturbance from construction	SSC levels likely to impair fish and shellfish are much higher than those predicted to occur during the construction phase.
Operation							
Presence of turbine foundations and inter-array cabling with scour protection	Habitat loss	Fish and shellfish populations	Minor significance	None identified		Minor significance	The permanent habitat loss is estimated to be 0.28 km^2 of the Neart na Gaoithe offshore site which is considered low. At a cumulative level permanent habitat loss is 9.2 km^2. Although some habitats will support fish and shellfish populations, the region supports a wide range of these habitats (see Chapter 14: Benthic Ecology)
Presence of turbine foundations and inter-array cabling with scour protection	Tides, current speeds	Fish and shellfish populations	Minor significance	None identified		Minor significance	The changes of water level and tidal currents following installation of wind turbines are predicted to be very small based on the output of the modelling study
Presence of turbine foundations and inter-array cabling with scour protection	New substrate materials	Fish and shellfish populations	Minor significance	None identified		Minor significance	Probability is high (does not refer to collision risk which is assessed to be extremely unlikely). Uncertainty is medium. New substrates are unlikely to change the existing habitat relevant to supporting fish and shellfish species dramatically as hard substrates are already present within the development area. Some habitat for species such as Nephrops and scallops may be impacted at a cumulative level, Chapter 14: Benthic Ecology provides more detail.
Gearbox and generator of wind turbines	Operational noise	Fish and shellfish populations	Minor significance	None identified		Not assessed	Probability is high. Uncertainty is medium. To date there is no evidence that species capable of perceiving noise from operating wind turbines will be impaired in their biological activities
Subsea cables (inter-array and export cables)	Seabed sediment heating	Fish and shellfish populations	Not significant	Appropriate trenching depth (burial within sediment) will further reduce the magnitude of any effect	Not significant	Included in consideration of general cumulative sediment disturbance from operation and maintenance.	Probability is medium. Uncertainty is high. To date there are no robust data sets from field studies that quantify the amount of heating generated by subsea AC cables.
Subsea cables (inter-array and export cables)	Electromagnetic fields	Fish and shellfish populations	Minor significance	Appropriate trenching depth (burial within sediment)	Not significant	Minor significance	Probability is high. Uncertainty is high. To date there is no sufficient evidence that EMF can be detrimental to species capable of perceiving them.

Table 15.24: Summary of fish and shellfish impacts

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