ABERDEEN HARBOUR EXPANSION PROJECT
November 2015

Volume 2: Environmental Statement

CHAPTER 13: FISH AND SHELLFISH ECOLOGY

13. FISH AND SHELLFISH ECOLOGY

13.1 Introduction

This chapter presents an assessment of the potential effects of the construction and operation of the proposed Aberdeen Harbour Expansion Project at Nigg Bay (the development) on fish and shellfish ecology. Effects on fish and shellfish (principally Atlantic salmon *Salmo salar* and freshwater pearl mussel *Magaritifera margaritifera*) populations, which contribute to the designation of the local River Dee Special Area of Conservation (SAC), are also assessed in support of the Habitats Regulations Assessment (HRA) (see ES Volume 4: Habitats Regulations Appraisal).

Nature conservation designations are addressed in Chapter 10: Nature Conservation. Effects on commercial fisheries are addressed in Chapter 22: Commercial Fishing.

The project description upon which this assessment is made is presented in Chapter 3: Description of the Development.

This chapter is supported by, and should be read in conjunction with, the following appendices:

- ES Appendix 13-A: Fish and Shellfish Ecology Study;
- ES Appendix 13-B: Underwater Noise Impact Study;
- ES Appendix 12-B: Subtidal Benthic Ecological Characterisation Survey;
- ES Appendix 6-B: Hydrodynamic Modelling and Coastal Processes Assessment;
- ES Appendix 6-C: Water Quality Modelling Assessment; and
- ES Appendix 7-D: Sediment Plume Modelling.

Certain impacts arising from the construction and operation of the development and their corresponding effects on fish and shellfish ecology are relevant to the following chapters:

- Chapter 12: Benthic Ecology;
- Chapter 14: Marine Ornithology;
- Chapter 15: Marine Mammals; and
- Chapter 22: Commercial Fisheries.

13.2 Policy, Legislation and Guidance

This section outlines the policy, legislation and guidance that are relevant to the assessment of potential effects on the fish and shellfish ecology. Policy, legislation and guidance applicable to the wider project can be found in Chapter 4: Planning and Legislation.

Further advice in relation to the project, its perceived effects and the scope of the issues to be addressed has been sought through consultation with the both statutory and non-statutory authorities (see Section 13.3).

13.2.1 International Policy and Legislation

- United Nations Convention on Biological Diversity 1992 (the Rio Convention);
- The Convention on the Conservation of European Wildlife and Natural Habitats 1979 (the Bern Convention);
- Convention for the Protection of the Marine Environment of the north-east Atlantic 1992, (the OSPAR Convention);
- European Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora (the Habitats Directive);
- European Council Directive 2000/60/EC Establishing a Framework for Community Action in the Field of Water Policy (WFD); and
- European Council Regulation No 1100/2007 Establishing Measures for the Recovery of the Stock of European eel *Anguilla anguilla*.

13.2.2 National Policy and Legislation

- The Conservation (Natural Habitats, &c.) Amendment (Scotland) Regulations 2007 Explanatory guidance for species related activities;
- UK Post-2010 Biodiversity Framework (the successor to, Biodiversity: UK Action Plan 1994);
- The Wildlife and Countryside Act 1981 (WCA);
- Nature Conservation (Scotland) Act 2004;
- Conservation (Natural Habitats & c) Regulations 1994 (as amended);
- Marine (Scotland) Act 2010;
- Marine Works (Environmental Impact Assessment) Regulations 2007;
- UK Marine Policy Statement; and
- National Marine Plan (Scotland).

13.2.3 Guidance

Specific guidance and best practice used in the preparation of this chapter and associated data acquisition is provided below:

- Scottish Natural Heritage (SNH) Guidance on Habitats Regulation Appraisal of Plans (David Tyldesley and Associates, 2015), (as amended); and
- IEEM now CIEEM (2010). Guidelines for Ecological Impact Assessment in Britain and Ireland: Marine and Coastal.

13.3 Consultation

Table 13.1 presents the consultation that has been undertaken to date in that is relevant to fish and shellfish ecology. Consultation on commercial fisheries aspects are presented in Chapter 22: Commercial Fisheries.

Table 13.1: Summary of consultation undertaken

Consultee	Date	Summary of Consultation	Where Addressed in ES
Marine Scotland Science (MSS)	19 September 2013	The ES must consider the Beatrice Offshore Wind Farm (BOWL) in the cumulative and combined effects section.	Cumulative effects are discussed in Section 13.9.
		The ES must demonstrate consideration of the effects on local birds of potential effects on sandeels.	The potential effects to the sandeel population are discussed in Section 13.6.9.
		The ES must include an overview of the use or likely use of the proposed development area by salmon, sea trout and eels.	ES Appendix 13-A presents a review of migratory fish the area. Section 13.6 summarises this information.
		The ES must demonstrate consideration of the requirement for monitoring or mitigation measures in respect of diadromous fish.	Mitigation measures are discussed in Section 13.8.
		The ES must demonstrate consideration of the potential for cumulative effects from local developments and those further afield in respect of diadromous fish.	Cumulative effects are discussed in Section 13.9.
	12 March 2013	The review should consider factors which could occur in connection with the development which could have effects on diadromous fish, including underwater noise and vibration, changes in water quality, loss of or creation of habitat, increased vessel traffic during construction and operation and associated noise and vibration, or propeller or other impacts, and the possibility of direct interference with any salmon and sea trout net fisheries, and possible mitigation measures and monitoring needs.	Potential effects on diadromous fish are addressed in Section 13.6.9. Mitigation measures are discussed in Section 13.8. Potential effects on commercial fisheries are discussed within Chapter 22: Commercial Fisheries.
Dee District Salmon Fishery Board	20 August 2013	The ES must incorporate and detail, where risks of damage to fish populations have been highlighted, the appropriate mitigation or environmental offset that will be employed in the development plans in terms of species, particular life stage and stock component. The ES must consider both the economic and conservation value of the species detailed in the scoping response. As part of this a public relations strategy should be included.	Potential effects on species of conservation importance and associated mitigation, where relevant, are assessed in Section 13.6.9. Effects on species of economic value are assessed in Chapter 22: Commercial Fisheries.

Table 13.1: Summary of consultation undertaken continued

Consultee	Date	Summary of Consultation	Where Addressed in ES
Scottish Natural Heritage (SNH)	20 August 2013	The following species should be scoped in the Environmental Impact Assessment (EIA: Atlantic salmon, sea lamprey, river lamprey, sea trout, European eel, Atlantic herring, sandeels, basking shark. The following species should be considered in the EIA at cumulative level only: sand goby.	Considered in Section 13.6.9.
		The following effects for fish and shellfish should be addressed in the ES: • Habitat loss and disturbance from construction and presence of the development; • Habitat and substrate-type change from the presence of the development; • Increased suspended sediment concentrations during construction of the development, • Maintenance of dredged channels and propeller wash; • Potential contamination from on-site storage of fuels and chemicals.	Considered in Section 13.6.9.
		The noise assessment should take into account the likely behaviour responses of relevant fish. The assessment should focus on, but not be exclusive to, species with the highest sensitivities to underwater noise (e.g. herring, cod). It should also focus on Atlantic salmon as they are a feature of the River Dee SAC.	Considered in Section 13.6.9.
Dee River Trust	5 June 2015	Provision of historic commercial salmon catch statistics for marine netting stations within the Aberdeen region.	Considered in ES Appendix 13-A.

13.4 Baseline Study

This section defines the existing fish and shellfish ecological conditions within and around the development and those used to evaluate the significance of identified effects.

13.4.1 Study Area

A literature review was conducted to collect data on fish and shellfish ecology within Nigg Bay and across the wider area broadly corresponding to the International Council for the Exploration of the Sea

(ICES) statistical rectangles 43E7 and 43E8 (as shown on Figure 13.1). The study area selected accounts for permanent residents, which reside within and around the project boundaries all year round and those with wider range movements in terms of their likely foraging, spawning and nursery areas and which may occur temporarily within the local area as seasonal residents, i.e. during juvenile life stages. The study area also encompasses the River Dee SAC for which Atlantic salmon (*Salmo salar*) and freshwater pearl mussel (*Magaritifera margaritifera*) are qualifying features.

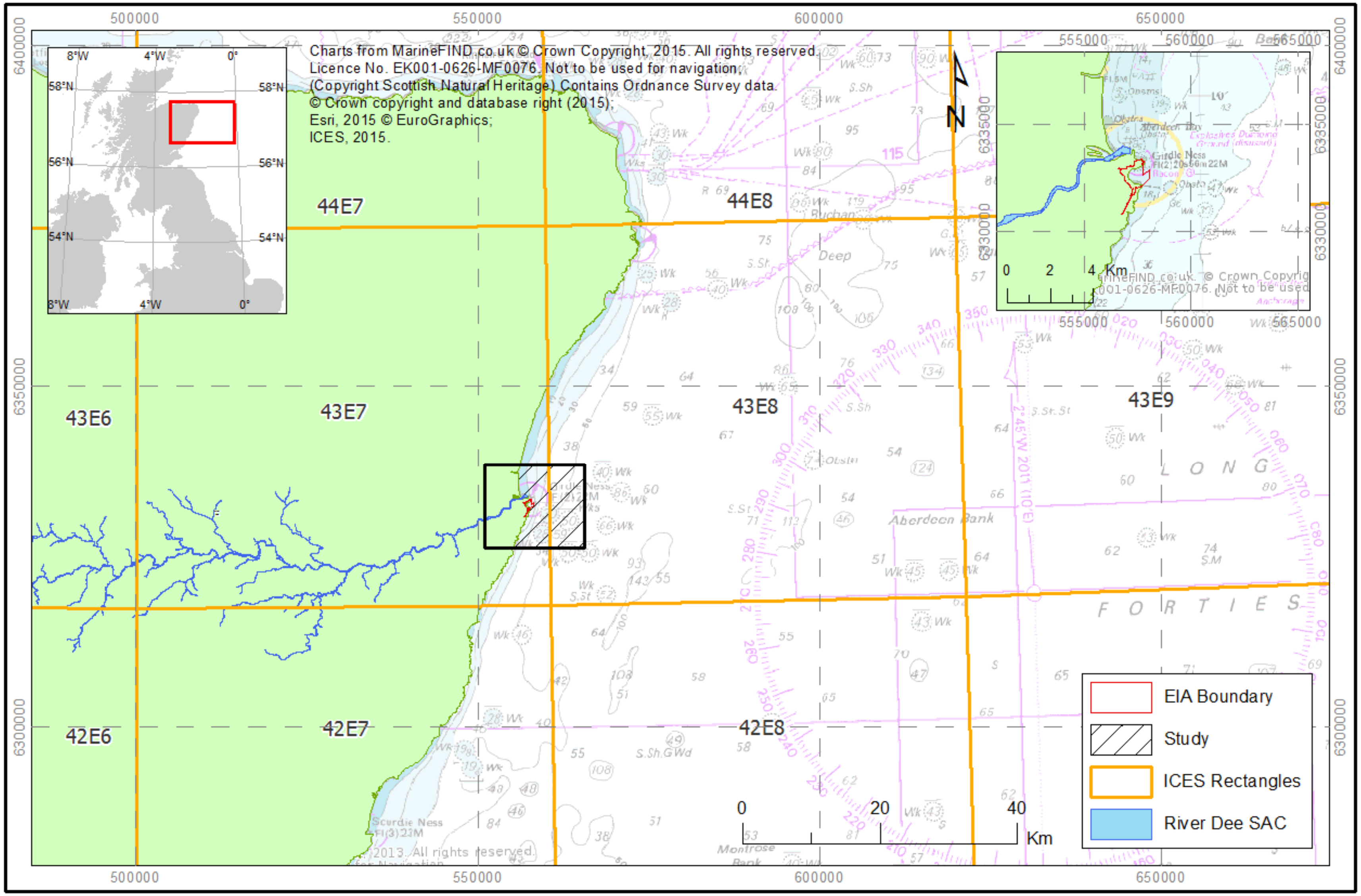

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Figure 13.1: Fish and shellfish ecology study area

13.4.2 Scope of the Assessment

The scope of this assessment has been determined through consultation with statutory and non-statutory organisations. Table 13.1 above shows the results of the consultation. The geographical scope of the assessment is presented in Figure 13.1.

The outcomes of the consultation identified a suite of fish and shellfish species for which assessment was requested (see ES Appendix 13-A: Fish and Shellfish Ecological Technical Report). In addition to this, site-specific sampling (beam trawling) identified a further set of species which reside either permanently or seasonally in and around Nigg Bay (see ES Appendix 12-B: Subtidal Benthic Ecological Characterisation Survey). Due to the large number of fish species identified during the baseline study, it is impractical to consider all effects on individual fish and shellfish species, so this assessment has grouped species into receptor groups on the basis of their life history traits, likely vulnerability to predicted effects and their relative value. Table 13.2 summarises the fish and shellfish receptor groups assessed in this chapter.

Table 13.2: Receptor groups used in the assessment

Receptor Group	Species and Rationale
SAC qualifying feature species	This group encompasses Atlantic salmon and freshwater pearl mussel as features for which the River Dee is designated as a SAC. Adult populations of freshwater pearl mussel are found in riverine environments only, but are dependent upon migrating salmonids. Although not a SAC qualifying species, sea trout also host freshwater pearl mussel during part of their life cycle and therefore sea trout are also included in this group. These species are grouped together on the basis of their migratory behaviour to and from the River Dee. This means that individuals may be vulnerable to a number of impacts arising from the construction and operation of the development as they approach, or emerge from, the River Dee. Impacts may relate to habitat change, temporary increases in suspended sediment concentrations (SSCs), underwater noise and shading, which may elicit avoidance effects and associated effects on migration and shoaling behaviours. As SAC qualifying features, these species will require Appropriate Assessment in the event that likely significant effects, either singly or in combination with other proposals, are identified (see ES Volume 4: Habitats Regulations Appraisal for further details).
Hearing specialists	This receptor group includes herring and cod on the basis of their comparatively enhanced sensitivity to noise. Certain fish have increased sensitivity to noise depending on the intricacy of the connection between the swim bladder and inner ear. Herring are known to have particularly intricate connections in this regard and have comparatively improved sensitivity over that exhibited by hearing generalists. Cod do not share the same intricate connections between the inner ear and swim-bladder as herring but are considered more sensitive to noise than other hearing generalists. It is also thought that cod use noise in their communication. Consequently, cod are also included within this receptor group. Relevant effects on hearing specialists will relate to impact piling, dredging, blasting and increased vessel movements. As highly mobile species, herring and cod are expected to be able to avoid significantly adverse areas and will able to return once underwater noise has returned to acceptable levels. Herring are benthic spawners, laying their eggs on the seabed, and have specific seabed spawning habitat requirements. Effects of noise on any local preferred spawning ground may displace herring from the spawning ground. Increased sediment deposition and smothering of eggs laid on the seabed may affect spawning success of herring.

Table 13.2: Receptor groups used in the assessment continued

Receptor Group	Species and rationale
Keystone species (i.e. key prey species, principally sandeel but also clupeids (i.e. herring) and sprat)	A number of fish and shellfish are taken as prey, either by other fish and shellfish or species higher in the food chain such as marine mammals and seabirds. Sandeel species are one of the most important food items and play a key role across a number of marine food webs. Any adverse effects on sandeel species may therefore affect feeding of a wide variety of other marine life. Sandeel are highly habitat specific and require clean, aerated coarse to medium grain sand. They are thus sensitive to habitat loss and habitat (particle size distribution) change from dredging and deposition of sediment plumes.
Resident species	This receptor group encompasses the generally small benthic fish and shellfish species which live within the Nigg Bay embayment and which have comparatively small range movements, such as gobies, blennies, hooknose, crabs and shrimps. These species are grouped on the basis of their comparatively limited mobility and therefore, their increased vulnerability to the impact of habitat disturbance and change, increased SSCs, deposition of fine sediments and underwater noise. Given their limited movement ability, these species may be vulnerable to impacts related with changes of habitat, such as depth or seabed sediment changes. Slow moving species such as crabs and juvenile resident fish may be entrained during the dredging process as they may not have the necessary movement or darting capabilities to avoid the dredger draghead on the seabed. Any eggs laid on the seabed and sediment burrows may be damaged or lost by dredging. Resident species will also be comparatively vulnerable to the impacts of shading from new infrastructure or over-water structures which may alter shoaling, foraging and feeding behaviours.
Seasonal residents	This final group contains the vast majority of fish species present within and around Nigg Bay. It includes mobile species with comparatively large range movements and which may temporarily use the bay and local surrounds as part of their life history stage or as part their normal feeding or spawning movements. This receptor group also includes those fish which use the bay as part of their nursery range during juvenile life stages, such as dab, whiting and cod, before moving to offshore feeding grounds as they mature. European eel is included within this group and is subject to a species specific plan. This group also includes basking shark which is considered an infrequent seasonal visitor at Nigg Bay. Seasonal residents are expected to be able to avoid any significantly adverse areas due to noise or sediment impacts, should these occur, and use other areas within their range until the impact has ceased. The possible exception to this is the European eel which return to the area in their larval stage and which may therefore have a comparatively reduced avoidance ability. Many of these species are broadcast spawners, releasing their eggs into the water column. Consequently, they are not limited to specific spawning habitats and will be comparatively less vulnerable to habitat loss or disturbance as a result of the construction and operation of the development.

13.4.3 Species Scoped Out

During consultation, SNH identified that European smelt/sparling *Osmerus eperlanus* and European spiny lobster *Palinurus elephas* do not require consideration in the ES as the Nigg Bay area is regarded as not important to these species. They are thus scoped out of this assessment. Furthermore, SNH considered that the sand goby *Pomatoschistus minutus* need only be considered at the cumulative level due to its ubiquitous nature and because the likely effects on this species at this scale are unlikely to be of concern.

Although other species of lamprey migrate to and from fresh and brackish or marine water environments, Brook lamprey *Lampetra planeri* are non-migratory and will remain within river environments and will not enter the sea. Consequently, they are also scoped out of the assessment. This means that the species will not encounter the development or incur any direct/indirect effects as a consequence of the development during their entire life history.

13.4.4 Data Sources

Data used to form the baseline of fish and shellfish ecology are presented and discussed in detail in ES Appendix 13-A. Data were collated through desk study and a site-specific benthic ecology survey which used a beam trawl to collect information on benthic fish and shellfish species within and around Nigg Bay (see ES Appendix 12-B).

Table 13.3 lists the organisations from which data were requested to inform the baseline. Further data sources used in the preparation of this document are credited within the text and full references are provided in the reference list at the end of the chapter.

Table 13.3: Summary of major data sources reviewed

Source	Area of Research
Centre for Environmental, Fisheries and Aquaculture Science (Cefas)	Areas of sensitivity nursery and spawning grounds; Details on feeding and predation of key species; General fish and shellfish ecology and biology.
The Joint Nature Conservation Committee (JNCC)	Overview of River Teith/Tay SAC and qualifying species for site selection.
Scottish Natural Heritage (SNH)	Guide to Scottish species of interest particularly migratory species like salmon, lamprey and eel.
FishBase	Fish biology and ecology.
UK Marine Life Information Network (MarLIN)	Guidance to the likely distribution and assemblage of the fish and shellfish species within the Firth of Forth.
Marine Scotland Science	Offshore renewable energy and general information on species found in Scottish waters; River Dee salmon rod and line catch data per month per year.
Scottish Government	Commercial fish and shellfish landing data; Salmonid catch and release data.
Oslo and Paris (OSPAR) Commission for the Protection of the Marine Environment of the north-east Atlantic	Impact guidance and legislation; Fish biology and ecology.
Dee District Salmon Fishery Board (DDSFB) and River Dee Trust	Catch and release data; General ecology of the Dee catchment and associated migratory fish; Historic catch (fixed engine) statistics for salmonids for the Aberdeen region.
Other	Journals, PhD theses, white papers, research articles.

13.5 Impact Assessment Methodology

This section explains the approach to identifying fish and shellfish ecological receptors, identifying impacts and impact pathways, defining effect magnitude and receptor value, and evaluating the significance of effects. The approach follows the general impact assessment methodology presented in Chapter 5: Environmental Impact Assessment Process, including the magnitude and value factors, but uses tailored definitions to address relevant aspects of fish and shellfish ecology. The magnitude of effects also considers the outputs of the sediment and underwater noise modelling (see ES Appendix 6-B: Hydrodynamic Modelling and Coastal Processes Assessment and ES Appendix 13-B: Underwater Noise Impact Study respectively) and supports quantitative assessment of the effects of the development on fish and shellfish ecology.

The impact assessment process starts with the identification of the impacts that are predicted to arise from the construction and operation of the scheme, based on the project description (see Chapter 3: Description of the Development) and the pathways through which those impacts are transmitted to receptors. Table 13.4 presents the potential construction and operational impacts of the development, together with the pathways through which fish and shellfish effects may occur. In general, impacts were found to relate to the placement of infrastructure on the seabed, seabed disturbances, increased levels of underwater noise, changes in lighting and shading, and changes in water quality.

Table 13.4: Predicted impacts and associated pathways for effects on fish and shellfish ecology

Activity	Impact Transmission Pathway	Receptor	Description of Impacts and Effects
Construction			
Piling, drilling and blasting	Increased levels of underwater noise	Species	Mortality, startle reaction and avoidance due to piling, drilling and blasting
Capital dredging	Increased physical seabed disturbance	Habitat and species	Temporary seabed disturbances due to dredging
	Increased suspended sediment concentrations	Habitat and species	Temporary increases in suspended sediment concentrations (SSCs) due to dredging
			Temporary deposition of sediment plumes arising from dredging and disposal and dispersal.
	Release of sediment contaminants	Species	Water quality changes and increase in bio-availability of sediment contaminants
Construction vessel and plant activities	Accidental spills of oil and fuels etc. into the marine environment during construction	Habitats and species	Accidental releases of pollutants during construction

Table 13.4: Predicted impacts and associated pathways for effects on fish and shellfish ecology continued

Activity	Impact Transmission Pathway	Receptor	Description of Impacts and Effects
Operation			
Infrastructure foundations and scour protection	Footprint on the seabed	Habitats	Reduction in extent of original seabed and pelagic habitat
		Habitat and species	Changes to hydrodynamic regime
	Colonisation	Species	Introduction of new seabed habitats
	Retention of pollutants entering Nigg Bay	Habitat and species	Changes in water quality
Vessel movements	Disturbance of seabed by propellers	Habitat and species	Temporary seabed disturbances and increases in SSCs due to propeller wash
	Vessel noise	Species	Avoidance due to increased vessel noise and presence
	Transport of species	Species	Introduction of invasive species
Maintenance dredging	Physical disturbance	Habitat and species	Seabed disturbances due to channel maintenance dredging
Safety or navigational lighting or shading from buildings or over-water structures	Change to the ambient underwater illumination	Species	Behavioural change due to changes in the ambient underwater illumination

13.5.1 Effect Magnitude

Effect magnitude is categorised as severe, major, medium, low or negligible based on the definitions presented in Table 13.5; these are based on the factors identified in Chapter 5: Environmental Impact Assessment Process.

Table 13.5: Categories of magnitude of effect and definition

Effect Category	Definition
Severe	The effect is permanent and occurs at national or transboundary scale. This may be reflected by a permanent loss of critical habitat and/or complete populations beyond the regional scale.
Major	The effect is long term or permanent and occurs at national scale. This may be reflected by a long term or permanent loss of critical habitat and/or fundamental alteration to populations and behaviours of populations beyond the regional scale.
Moderate	The effect is long term/permanent and occurs at regional or national scales. This may be reflected by a temporary or long term/permanent reduction of critical habitat and/or change to populations and behaviours of populations or individuals beyond the study area.
Low	The effect is temporary and/or intermittent and occurs at local or site specific scale. The species population is not predicted to be affected but individuals may be exposed to temporary effects or displaced to adjacent non-affected areas.
Negligible	No measurable effect on species populations or individuals above natural variation. The effect is intermittent.

13.5.2 Receptor Value

In this chapter, receptor value has incorporated the designation or level of local, national or international protection that each fish and shellfish feature receives. In addition to this, value has also incorporated the ecological function of the species, for example, as a key prey species. Table 13.6 presents the different value categories and associated definitions used in this chapter:

Table 13.6: Categories of receptor value and associated criteria

Category	Definition
Very high	The receptor is protected by international law and is a qualifying feature of a Natura 2000 site.
High	The receptor is protected by national law, is important for national biodiversity, restricted in its regional distribution and is subject to a species plan.
Medium	The receptor is locally or nationally important for nature conservation, widely distributed across the region, contributes to the selection of Scottish MPAs and/or has a key ecosystem role.
Low	The receptor does not hold any nature conservation designation but represents a healthy and productive example nonetheless or has a key ecosystem role.
Negligible	The feature is commonly occurring and widespread throughout the UK.

13.5.3 Evaluating the Significance of the Effect

The significance of an effect is assessed as major, moderate, minor or negligible by combining the magnitude with the receptor value using the matrix presented in Chapter 5: Environmental Impact Assessment Process. Within this chapter, minor significance relates to an effect which may be measurable, but from which receptors are expected to recover, either quickly or slowly, under natural processes.

The likelihood of the effect actually occurring has been used to contextualise the significance of an effect to provide a measure of risk. Likelihood has been largely applied subjectively based on experience, and considers whether the impact appears to occur often or occasionally or is unheard of within the industry, based on available knowledge. The timing of the impact has also been considered within measure of likelihood, and reflects the periodicity of the sensitivity of potential fish and shellfish receptors for example, during peak migration or spawning activities.

Finally, a level of certainty based upon the availability and quality of data sources used to underpin the assessment conclusions has been assigned as defined below:

- **High Certainty:** criteria affecting the assessment are well understood and documented. Literature and data available to quantify predictions. Information/data have very comprehensive spatial coverage/resolution; effects have been modelled;
- **Medium Certainty:** criteria affecting assessment reasonably well understood with some supporting evidence. The assessment may not be fully quantifiable and the information/data available might not fully incorporate the area of interest; and

- **Low Certainty:** criteria affecting assessment poorly understood and not documented. Predictions are made on expert interpretation using little or no quantitative data. Spatial coverage may only partly encompass area of interest.

13.5.4 Cumulative Impact Assessment Methodology

Potential cumulative effects on fish and shellfish receptors have been identified and assessed following the methodologies presented in Chapter 5: Environmental Impact Assessment Process. Relevant projects and activities taken forward for cumulative impact assessment on fish and shellfish ecology are identified in Section 13.9.

13.5.5 Limitations and Assumptions

Typically, data on fish spawning and nursery areas are provided at national level and may not provide the detailed distribution, or use, of grounds at the local or site-specific level. In this regard the areas of sensitivity defined in the baseline (Section 13.6) should be used as a guide and not considered in the literal sense to define areas of sensitivity within the wider regions of the study area.

The site specific 2 m benthic trawl survey (see ES Appendix 12-B: Subtidal Benthic Ecological Characterisation Survey) supplemented the literature review for fish and shellfish ecology. It is acknowledged that the trawling only provides a snap-shot of the distribution of demersal (bottom dwelling) fish and shellfish assemblages within the development area and does not target fast swimming adult, pelagic (mid-water) or migratory fish.

13.5.6 Measures Adopted as Part of the Project

An outline Environmental Management Plan (EMP) is provided in this Environmental Statement (see Chapter 26: Environmental Management Framework). This addresses the need for a pollution prevention plan including waste and oil spill contingency plans. The Plans will also incorporate measures, such as documented ballast water and anti-fouling management systems, to reduce the risk of the introduction of marine non-native species.

Further detail is provided in the outline EMP within Chapter 26 of this ES.

13.6 Baseline Conditions

13.6.1 Introduction to Baseline Conditions

The following section presents a summary of fish and shellfish ecological conditions within and around Nigg Bay based on the findings of a desk-based study and the site-specific 2 m beam trawl sampling. Further detail on the methods and findings of these studies are presented in ES Appendices 13-A and 12-B respectively.

13.6.2 Results of the Literature Review

Table 13.7 presents the typical fish and shellfish species found within the study area. Table 13.7 also shows how the different types of fish present relate to the receptor groups used in this assessment.

Table 13.7: Summary of characteristic fish and shellfish assemblages and species associated with the study area

Receptor group(s)	Species (Common Name)	Description	Value (see Table 13.6)
SAC qualifying feature species	• Salmon, sea trout, European eel*, European smelt, sea lamprey, river lamprey.	Migrate between fresh and marine water environments to spawn and forage.	High to very high
Keystone species	• Ammodytidae (sandeels)	Live in close association with the seafloor (sand substrates), but mainly feed in mid-water.	Medium
Hearing specialist Resident species Seasonal residents	• Gadoids (cods): cod, whiting, saithe, haddock, hake, Norway pout, ling; • Pleuronectiformes (flatfishes): plaice, lemon sole, turbot, brill, halibut, witch; • Gobiidae (gobies): sand goby, common goby, Fries's goby; • Elasmobranchs (sharks, skates and rays): small-spotted catshark, thornback ray, common skate.	Mostly bottom feeders that live on or near the seabed. Their distribution is often related to sediment type, hydrography, bathymetry, predator-prey interactions and competition for space.	Negligible to Low
Hearing specialist Seasonal residents SAC qualifying feature species	• Clupeidae (herrings): herring, sprat, pilchard, anchovy; • Scombridae (mackerels): mackerel, scad; • Elasmobranchs (sharks, skates and rays): basking shark; • Salmon, sea trout, European smelt; • European eel.	Inhabit the water column including the near surface where they feed on small zooplankton and other swimming animals. The spatial distributions of these fish are strongly influenced by hydrodynamic factors and may vary annually within the region. They can undergo extensive migrations linked to spawning and foraging opportunities.	Low to Very High
Resident species	• Crustaceans: brown crab, brown shrimp, European lobster, velvet swimming crab. • Molluscs: king scallop, common whelk, squid.	Shellfish is a broad term used in this chapter to describe all invertebrate species which are of commercial or ecological importance. Distribution may be based on substrate type.	Negligible to Low

Note:
*European eel is classed as a seasonal resident (Table 13.2) but is included within this group here as it protected by national legislation and is subject to a species plan and is thus a receptor of High importance. Eel will not be subject to an Appropriate Assessment as it is not a SAC qualifying feature

The majority of fish species are considered to be temporary or seasonal residents, inhabiting the local inshore area during specific lifecycle stages, i.e. as juveniles using the bay and local environments as nursery habitat. Typical species using the locale in this way include cod *Gadus morhua* , haddock *Melanogrammus aeglefinus* and whiting *Merlangius merlangus* as well as flatfish species such as plaice *Pleuronectes platessa* and dab *Limanda limanda*. As these species grow and mature, they move into deeper waters offshore. Brown shrimp *Crangon crangon* and female brown crab *Cancer pagurus* can undertake extensive spawning migrations and may occur seasonally within the locale. Comparatively high densities of brown shrimp were found within the outer bay on sandy sediment during the site specific beam trawl sampling during the month of March (see ES Appendix 12-B: Subtidal Benthic Ecological Characterisation Survey and Section 13.6).

Species more likely to be permanently resident within and around the local Nigg Bay area are the smaller bodied fish species like goby Gobbiidae, blennies Blenniidae and dragonets Callionymidae as well as shellfish species such as the common whelk *Buccinum undatum* and king scallop *Pectin maximus*. These residents often provide an important food source for larger commercial species such as cod, saithe *Pollachius virens* and thornback ray *Raja clavata*.

The general area is visited by migrant species including Atlantic salmon, sea trout *Salmo trutta*, European eel and sea lamprey *Petromyzon marinus.* Individuals of these species are likely to pass through, or close to, the site on their entry to, or emergence from, the River Dee and may make temporary or longer term use of the local area during their passage between marine and freshwater environments. Although frequent migrant visitors on the west coast of Scotland, basking shark *Cetorhinus maximus* occur only infrequently within the vicinity of Nigg Bay. No basking sharks were observed during annual site specific seabird and marine mammal observations (see ES Appendix 14-A: Marine Ornithology Vantage Point Survey Report).

Commercial fisheries data for the years 2009 to 2013 suggest a general inshore distribution for brown crab and squid *Loligo* spp. and a general offshore distribution for herring. Haddock, king scallop and mackerel occur prominently in catches from both inshore (i.e. ICES statistical rectangle 43E7) and offshore areas (i.e. ICES statistical rectangle 43E8) (see Chapter 22: Commercial Fishing and ES Appendix 22-A: Commercial Fisheries Technical Report for a full account of commercial fisheries activities).

Results of the literature review are presented in sub-sections 13.6.3 to 13.6.7 inclusive.

13.6.3 Spawning Activity

Many fish species within the study area are broadcast spawners, which mean they release eggs and sperm into the water column. Other species however, such as sandeel, herring and the oviparous (egg laying) elasmobranchs such as the thornback ray and small-spotted catshark *Scyliorhinus canicula,* deposit eggs directly on to the seabed. This latter process is dependent on spatially distinct, preferred spawning areas, relating to preferred seabed substrate types, and usually takes place in shallower waters (Ellis et al., 2012).

Shellfish such as the European lobster and common whelk are thought to spawn wherever they occur. Female brown crabs, on the other hand, undertake large scale (100s of km) migrations to reach offshore spawning and overwintering grounds. The preferred spawning grounds for brown crab are in clean coarse sediments within which egg-bearing females bury themselves prior to releasing larvae in the following spring.

Spawning of fish and shellfish typically occurs at a particular time of year and when environmental conditions are favourable. Table 13.8 shows the spawning periods for fish and shellfish within the study area.

Table 13.8: Spawning activity for fish and shellfish species present within the region of the study area

Scientific Name	Common Name	Seasonal spawning activity											
		J	F	M	A	M	J	J	A	S	O	N	D
Teleost													
Ammodytidae	Sandeel spp.												
Callionymus lyra	Common dragonet												
Clupea harengus	Herring												
Gadus morhua	Cod												
Lophius piscatorius	Monkfish												
Merlangius merlangus	Whiting												
Microstomus kitt	Lemon sole												
Molva molva	Ling												
Pleuronectes platessa	Plaice												
Pollachius virens	Saithe												
Pomatoschistus minutus	Sand goby												
Scomber scombrus	Mackerel												
Sprattus sprattus	Sprat												
Trisopterus esmarkii	Norway pout												
Elasmobranchs													
Raja clavata	Thornback ray												
Scyliorhinus canicula	Small-spotted catshark												
Galeorhinus galeus	Tope	Viviparous species (can be found gravid year round)											
Squalus acanthias	Spurdog												
Shellfish													
Cancer pagurus	Brown crab												
Hommarus gammarus	European lobster												
Nephrops norvegicus	Norway lobster												
Pecten maximus	King scallop												

Sources: Froese and Pauly, 2015; Ellis et al., 2012; Coull et al., 1998

Key:
Spawning Peak spawning Hatching

The study area is part of much larger regional spawning area for whiting, plaice, lemon sole *Microstomus kitt*, cod, herring and sandeel (Ellis et al., 2012; Coull et al., 1998). Figure 13.2 shows the broadscale distribution of the spawning areas for these species in relation to the development.

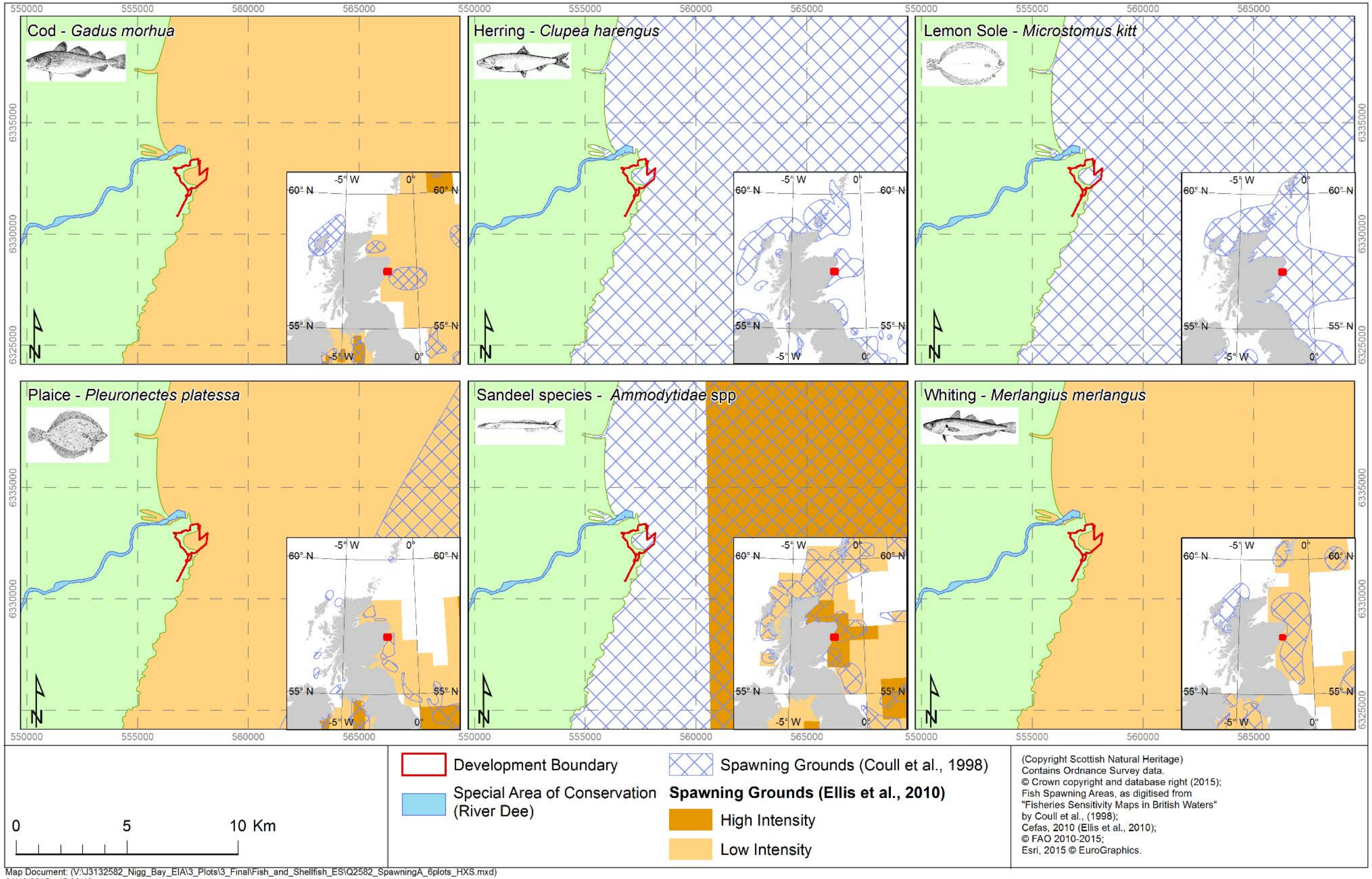

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Figure 13.2: Fish spawning grounds within the study area

13.6.4 Nursery Areas

Inshore waters throughout the UK receive juvenile fish due to the presence of feeding opportunities, comparative shelter and low abundance of predators.

The study area falls within wider regional nursery areas for 16 species of fish including blue whiting *Micromesistius poutassou*, cod, common skate *Dipturus batis*, hake *Merluccius merluccius*, herring, lemon sole, ling *Molva molva*, mackerel, monkfish *Lophius piscatorius*, saithe, sandeel spp., spotted ray *Raja montagui*, sprat, spurdog *Squalus acanthias*, tope *Galeorhinus galeus* and whiting (Ellis et al., 2012; Coull et al., 1998) (Figure 13.3 to Figure 13.5). In addition, data drawn from the site-specific survey suggest that juvenile plaice, whiting and dab use the local inshore area within and around Nigg Bay (refer to ES Appendix 12-B: Subtidal Benthic Ecological Characterisation Survey).

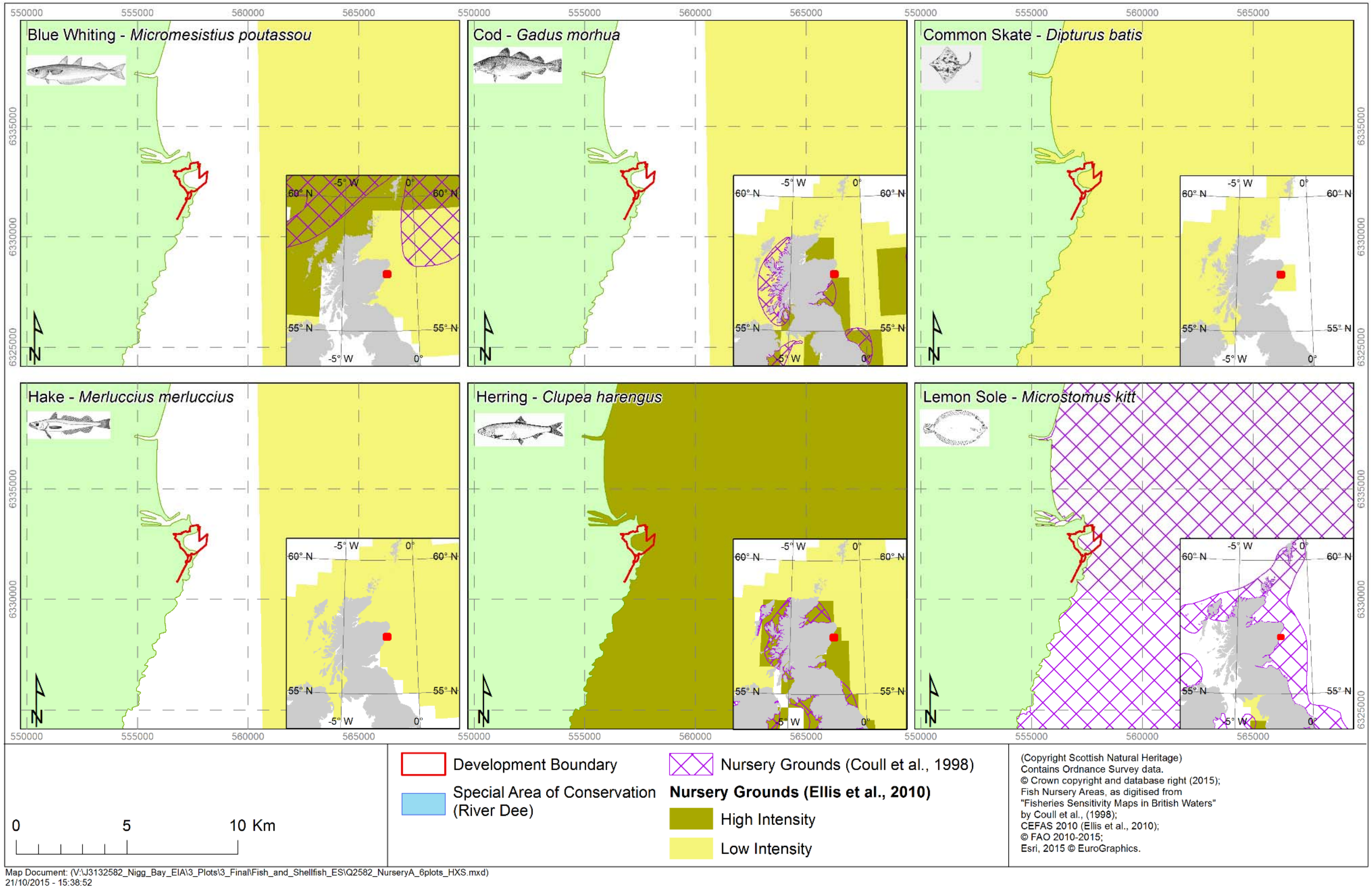


Figure 13.3: Fish nursery grounds within the study area

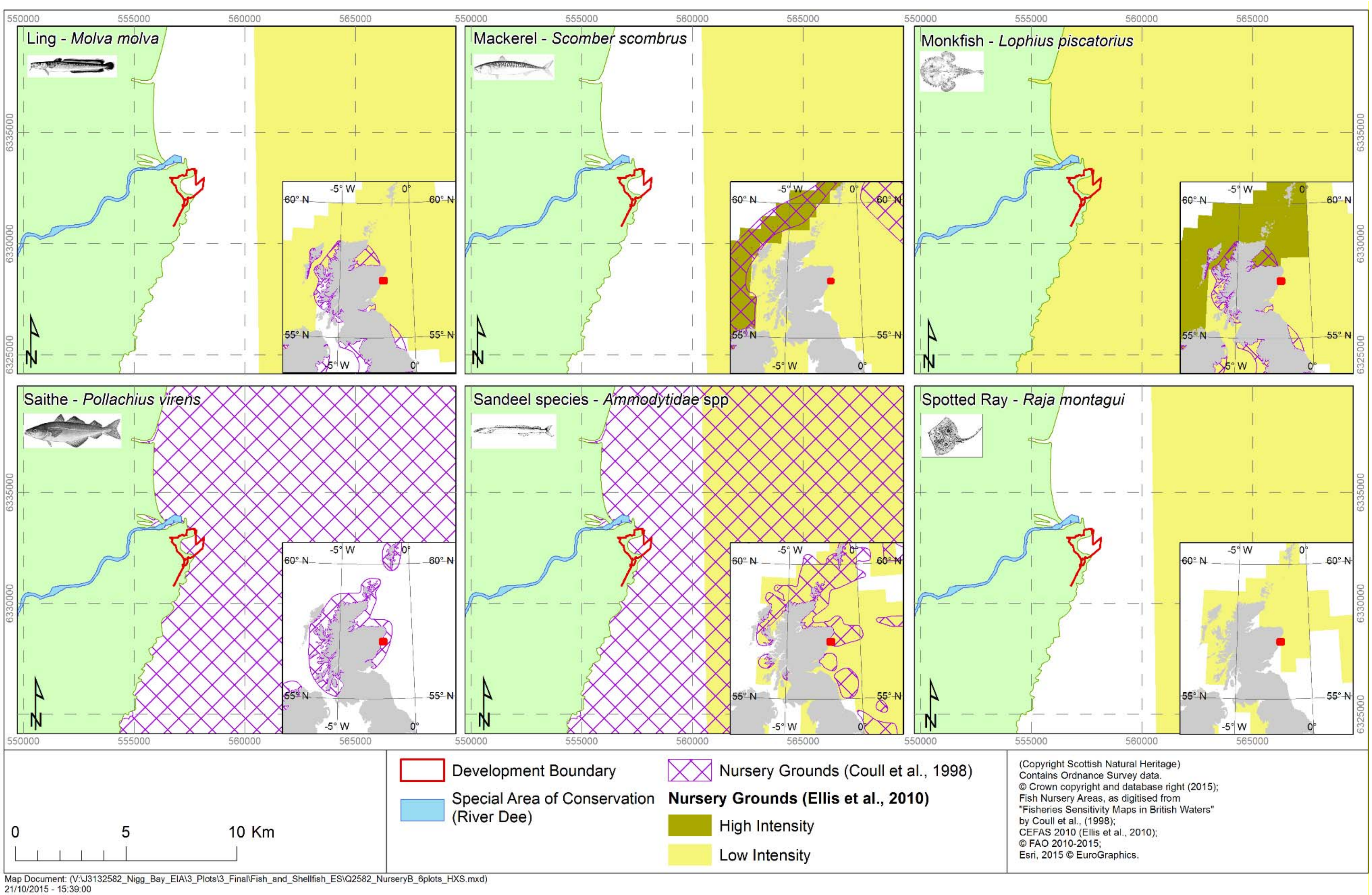


Figure 13.4: Fish nursery grounds within the study area

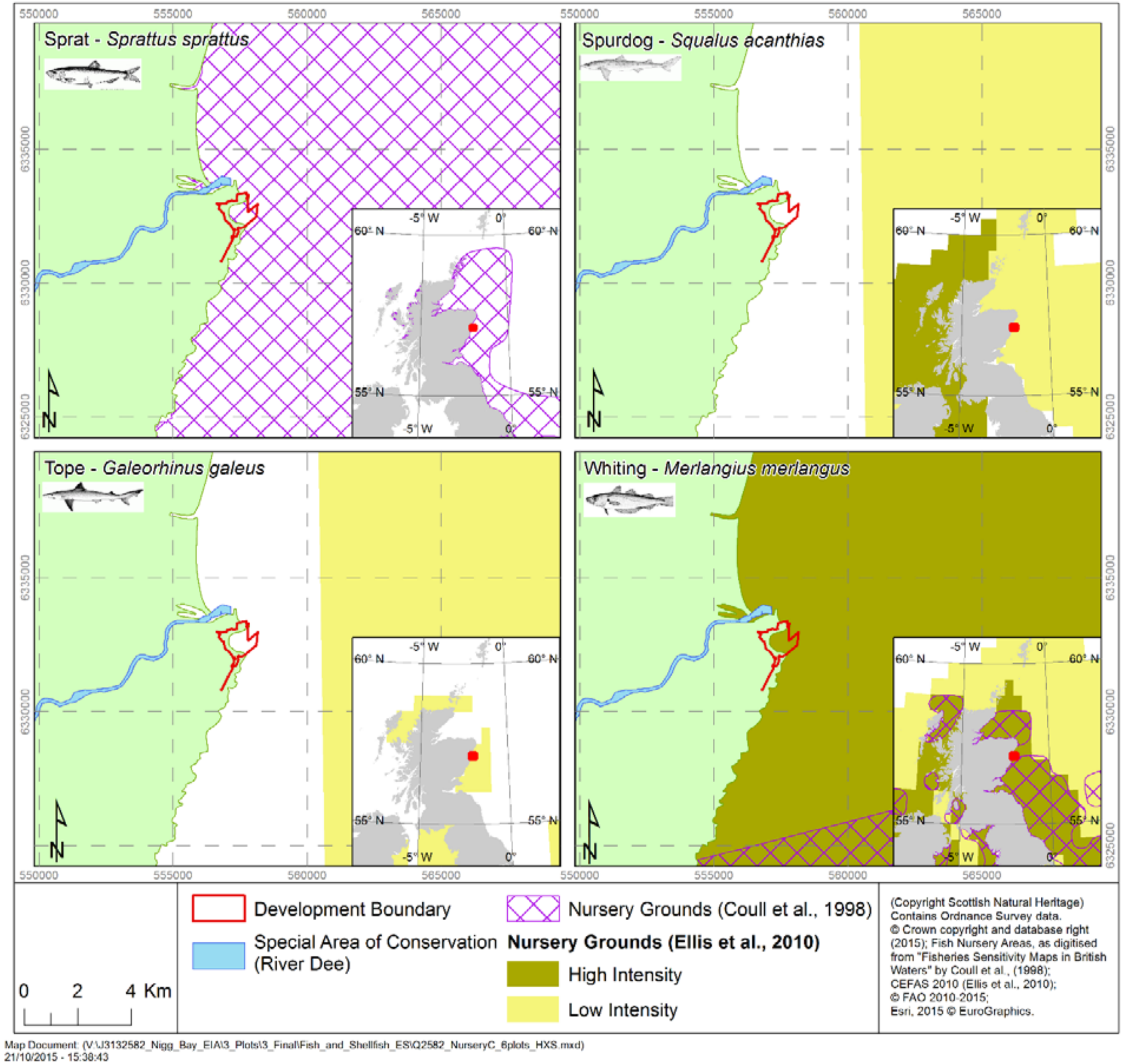


Figure 13.5: Fish nursery grounds within the study area

13.6.5 Species of Nature Conservation Interest

A number of fish species found locally are of value to nature conservation by virtue of their rarity or importance to ecosystem functioning. These include species for which conservation plans and strategies are established or which are listed to highlight their consideration during development planning and delineation of Marine Protected Areas (MPA). Species of conservation value within the study area are presented in Table 13.9.

Table 13.9: Current conservation designations of species known to occur within and around the study area

Scientific Name	Common Name	Conservation Designations					
		National Biodiversity Framework	Priority Marine Feature	IUCN Red List	OSPAR	EC Directive	BERN Convention
Teleost							
Ammodytes marinus	Raitt's sandeel	✓	✓				
Clupea harengus	Herring	✓	✓ (priority to juveniles and spawning adults)	LR/LC			
Gadus morhua	Cod	✓	✓	VU	✓		
Lophius piscatorius	Monkfish/ anglerfish	✓	✓ (priority to juveniles)				
Merlangius merlangus	Whiting	✓	✓ (priority to juveniles)				
Merluccius merluccius	Hake	✓					
Molva molva	Ling	✓	✓				
Pleuronectes platessa	Plaice	✓		LR/LC			
Pollachius virens	Saithe		✓				
Pomatoschistus minuts	Sand goby		✓	LR/LC			Appendix III
Scomber scombrus	Mackerel	✓	✓	LR/LC			
Trachurus trachurus	Horse mackerel/ Scad	✓					
Trisopterus esmarkii	Norway pout		✓				

Table 13.9: Current conservation designations of species known to occur within and around the study area continued

Scientific Name	Common Name	Conservation Designations					
		National Biodiversity Framework	Priority Marine Feature	IUCN Red List	OSPAR	EC Directive	BERN Convention
Elasmobranchs							
Cetorhinus maximus	Basking shark	✓	✓	VU	✓	V	
Dipturus batis	Common skate	✓	✓	CR	✓		
Galeorhinus galeus	Tope	✓		VU			
Scyliorhinus canicula	Small-spotted catshark			LR/LC			
Squalus acanthias	Spurdog	✓	✓	VU	✓		
Migratory Fish							
Alosa alosa	Allis shad	✓		LR/LC	✓	II and V	✓
Alosa fallax	Twaite shad	✓		LR/LC		II and V	✓
Anguilla angullia	European eel	✓	✓ (marine part of life cycle only)	CR	✓		
Lampetra fluviatilis	River lamprey	✓	✓ (marine part of life cycle only)	LR/LC		II and V	✓
Petromyzon marinus	Sea lamprey	✓	✓ (marine part of life cycle only)	LR/LC	✓	II	✓
Salmo salar	Atlantic salmon	✓	✓ (marine part of life cycle only)	LR/LC	✓	II and V	✓
Salmo trutta	Sea trout	✓	✓ (marine part of life cycle only)	LR/LC			
Shellfish							
Magaritifera margaritifera	Freshwater pearl mussel	✓		V		II	
Homarus gammarus	European lobster			LR/LC			
Nephrops norvegicus	Norway lobster			LR/LC			

Source: JNCC, 2014a; IUCN, 2012; OSPAR, 2008, 2012; Wildlife and Countryside Act, 1981

Key:		
CR = Critically endangered	VU = Vulnerable	LR = Low risk and associated subcategories
LC = Least concern	NT = Near threatened	II & IV= Annex II and IV of the Habitats Directive
✓ = Features under specific designation		

13.6.6 Special Areas of Conservation (SAC)

The study area does not directly coincide with any Natura 2000 sites but is likely to lie along the migratory pathway of species listed under Annex II of the Habitats Directive, and for which SACs on the east coast of Scotland have been designated. Table 13.10 presents the SACs within the wider region of the development together with the qualifying reasons (species) for their designation.

More detailed information on SACs and other designated sites is provided in Chapter 10: Nature Conservation.

Table 13.10: Scottish East Coast SACs designated for Annex II migratory fish

Scientific Name	Common Name	Natura 2000 SAC Rivers					
		Dee	Spey	South Esk	Tay	Teith	Tweed
Lampetra fluviatilis	River lamprey				*✓	✓	*✓
Petromyzon marinus	Sea lamprey	✓			*✓	✓	*✓
Salmo salar	Atlantic salmon	✓	✓	✓	✓	*✓	✓
Margaritiferaa margaritifera	Freshwater pearl mussel	✓	✓	✓			
Approximate distance (km) and direction from project		2 (N)	87 (NW)	53 (S)	87 (SW)	157 (SW)	152 (S)

Notes:
N = north NW = north-west S = south SW = south-west
✓ = primary reason for site selection
* = qualifying feature for site selection but not primary reason

Source: JNCC, (2014b)

13.6.7 Migratory Species

Many of Scotland's east coast rivers contain migratory fish populations. When in the marine environment these populations can range over considerable distances (100s of km). The closest migratory fish populations are found within the River Dee and include salmon, sea trout, sea/river lamprey and European eel.

Table 13.11 presents general seasonal migratory timings associated with the transition between the marine and freshwater environments for species present within the River Dee. The exact timing of the transition will vary slightly from year to year due to variations in environmental cues like temperature and water flow.

Table 13.11: Spawning and migration timings for migratory fish found within the river dee and surrounding area

Scientific Name	Common Name	Life History Stage	Seasonal Spawning Activity											
			J	F	M	A	M	J	J	A	S	O	N	D
Anguilla anguilla	European eel	Silver eel						↓	↓	↓	↓	↓	↓	
		Glass eels/elvers	↑	↑	↑					↑	↑	↑	↑	↑
Lampetra fluviatilis	River lamprey	Adult			Spawning	Spawning						↑	↑	↑
		Transformer							↓	↓	↓			
Petromyzon marinus	Sea lamprey	Adult				↑	↑ Spawning	Spawning						
		Transformer							↓	↓	↓			
Salmo salar	Atlantic salmon	MSW	Spawning	↑	↑	↑	↑	↑	↑	↑	↑	Spawning	Spawning	Spawning
		Grilse	Spawning	Spawning				↑	↑	↑	↑	↑ Spawning	Spawning	Spawning
		Smolt				↓	↓							
Salmo trutta	Sea trout	Adult	↓	↑	↑	↑	↑	↑	↑	↑	↑	↑ Spawning	Spawning	↓ Spawning
		Smolt						↓	↓					

Sources: Hendry and Cragg-Hine, 2003; McCormick et al., 1998; Maitland, 2003; Maitland and Hatton-Ellis, 2003; Malcolm et al., 2010

Key:
Spawning | ↑ Upstream migration | ↓ Downstream migration

13.6.7.1 Salmon

Salmon migrate to and from the River Dee and surrounding east coast catchments as part of their life cycle. Young salmon, known as smolt, generally migrate downstream between April and June (Hendry and Cragg-Hine, 2003). Malcom et al. (2015) further refine the smolt migration window as occurring between 3rd April and 25th May This period is characteristic of a national window of sensitivity for coastal developments in relation to smolt migration (Malcolm et al., 2015).

Upon entering the marine environment, salmon smolts are thought to utilise shallow (less than 10 m water depth) coastal areas, where water temperatures are warmer (Malcolm et al., 2010). After this, little is known about their subsequent dispersion and migration to their distant (sub-arctic) feeding grounds, particularly for those smolt emerging into the North Sea from rivers on the east coast of Scotland. For the purposes of this assessment, it is assumed that smolt will make some use of local waters although the degree to which they rely on Nigg Bay and local surrounding areas prior to their migration remains unclear. Malcolm et al. (2010) suggest that emerging smolt make rapid and active migration towards open marine areas and in general do not follow nearby shores.

At sea, small fish such as 0-group blue whiting and herring and sandeel and capelin, are important in the diet of post smolts in coastal waters, whilst amphipods are important food items in offshore waters in the north-west and north-east Atlantic (Haugland et al., 2006 and Malcolm et al., 2012). Prey which is higher in the food chain becomes more important to salmon that are returning to UK rivers as they increase in size (Malcolm et al., 2012). Salmon returning to natal rivers are thought not to feed, or to feed opportunistically.

On the east Scottish coast, adult salmon return to natal rivers from the south. This means that those returning to the River Dee will pass through, or close to, Nigg Bay. Tagging studies on the River Esk (Hawkins and Smith, 1986) have shown that on approach to a river mouth, salmon may enter immediately on arrival or may linger for some time (hours), moving back and forth across the river mouth before entering. Smith and Johnston (1996) found that salmon released 2 km to 4 km south of Nigg Bay in May and June, and during a period of relatively high river flow, reached to the non-tidal reaches of the River Dee within 7 days. Those released in August, and during drought conditions, reached the tidal freshwater reaches of the Dee within 4 days To 10 days of release. In general, entry to the River Dee is rapid during elevated flows but may be delayed during drought conditions Smith and Johnston (1996).

Once in the non-tidal portion of the river, upstream movement is rapid and initially may exceed 10 km per day. Tagging studies have recorded one fish achieving almost 22 km in 1 day (Hawkins et al., 1979). In the River Dee, most salmon were noted to make rapid progress upstream for 2 weeks before pausing in locations 17 km to 40 km upstream from the river mouth (Smith and Johnston, 1996).

Salmon that spend 1 year at sea (grilse) or multiple years at sea (multi sea winter (MSW) salmon), may return at any time during the year, so there is no defined period of entry into the River Dee. However, rod and line catch data (see ES Appendix 13-A: Fish and Shellfish Ecology Technical Report) indicate a biannual peak in returning salmon with the first peak occurring in May and the second in September. The earlier peak is attributed to the arrival of MSW salmon in spring, while the later peak is attributed to the arrival of grilse in autumn. Historic data from coastal netting stations shows peak abundance of grilse in July. Long term salmon catches in the mouth of the River Dee by the Aberdeen Harbour Board showed that most MSW salmon were caught before the end of May, at about the time of the commencement of the grilse run (Martin and Mitchell, 1985).

Overall there appears to have been a decline in the catch of spring salmon between the 1960s and 1990s, followed by a period of stabilisation to 2012. Summer and autumn catches, on the other hand, have followed an improving trend since 2000 but have declined sharply in 2013. For the Dee District salmon fishery as a whole, recent trend data shows that 2014 and 2015 catches are reduced compared to the 5 year average. It is estimated that current catches of salmon are 33% of the 5 year average for the River Dee (see ES Appendix 13-A: Fish and Shellfish Ecology Technical Report).

Salmon populations in the Aberdeenshire Dee share a close relationship with the Dee freshwater pearl mussel and act as host during the mussel’s larval stages in upstream river environments. Effects on the salmon population may therefore have consequences for the freshwater pearl mussel populations.

13.6.7.2 Sea Trout

Sea trout share much of their life history with salmon, spawning in upland rivers before migrating downstream into estuaries, sea lochs and the open sea to feed and mature. The River Dee has a comparatively high abundance of sea trout in comparison to other north-east salmonid rivers. Feeding is predominantly thought to take place in estuaries and coastal areas

Historic tracking studies reveal a variable pattern of migration with some adults being recaptured close to their natal rivers while others disperse over considerable distances (ca. 150 miles plus) (Malcolm et al., 2010). There have been no studies of swimming depths in Scottish waters, although studies from

Norway suggest shallow swimming of less than 3 m depth with occasional dives to ca. 30 m (Malcolm et al., 2010).

Marine bound sea trout, also known as smolts, emerge from the River Dee between June and July. Once in the marine environment smolts are thought to disperse slowly and remain inshore, often swimming in surface waters at a depth of less than 10 m (Malcolm et al., 2010). In addition smolts from east coast rivers such as the North Esk have been found to travel to neighbouring catchments such as the South Esk, Spey and Tweed (Malcolm et al., 2010) demonstrating potential connectivity between neighbouring sea trout populations.

Returning adults appear between February and October and again between December and January, when they make their return journey to the sea after spawning. Rod and line catch data for the River Dee shows peak numbers of returning sea trout in June (ES Appendix 13-A: Fish and Shellfish Ecology Technical Report). This coincides with peak occurrence of sea trout in historic coastal salmon net fisheries.

In common with salmon, sea trout act as host for the larval stages of the freshwater pearl mussel. As such, any adverse effect on trout could have negative consequences for the mussel population in the River Dee.

13.6.7.3 Sea and River Lamprey

Juvenile sea lampreys migrate downstream and into the marine environment between July and September. Adult sea lampreys migrate into freshwater to spawn between April and May. Very little is known about the marine phase of sea lamprey but what is known is that they feed on larger fish species such as cod, basking shark and salmon. This makes it likely that they move into deeper offshore waters on emergence from their rivers, where they are more likely to encounter their host.

River lamprey *Lampetra fluviatilis* has a similar life history to that of the larger sea lamprey, described above. They migrate downstream between July and September and return as adults between October and December (Maitland, 2003). When in the marine environment river lampreys undergo highly localised migrations, staying within their local estuary and surrounding coastal areas where they feed on a variety of fish, particularly herring, sprat and flounder (Maitland, 2003).

13.6.7.4 European Eel

In general, European eel make an outward spawning migration (of adults) between June and November and an inbound migration (of juveniles) between June and October.

Monitoring studies on the River Dee show that peak downstream migration occurs between August and September (Malcolm et al., 2010). Once in the marine environment there is some evidence to suggest that adult eel undergo a residency period in the immediate coastal area before heading off on their spawning migration (Malcolm et al., 2010).

Little is known about the sea phase migration of adult eel or the direction they are likely to take after leaving the River Dee. On emerging from the river, eels have two choices, either turn north and head against the prevailing current around the top of Scotland, or turn south with the current and enter the North Atlantic via the English Channel.

There are no direct accounts of larval return migration routes although it is likely they will approach the River Dee from the north given the southerly direction of the prevailing Fair Isle current. Eels do not go ‘home’ to natal rivers in the same way as salmon and trout but instead return to the same general region.

13.6.8 Results of the Site Specific Survey

This section summarises the results of a small (2 m) beam trawl sampling exercise which was undertaken as part of the sublittoral benthic ecology characterisation survey in March 2015 (see ES Appendix 12-B: Subtidal Benthic Ecological Characterisation Survey for full details). A total of five trawl tows of approximately 500 m in length were undertaken within and around Nigg Bay to help provide a qualitative indication of the distribution of benthic fish and shellfish species. Figure 13.6 shows the locations of the beam trawl samples.

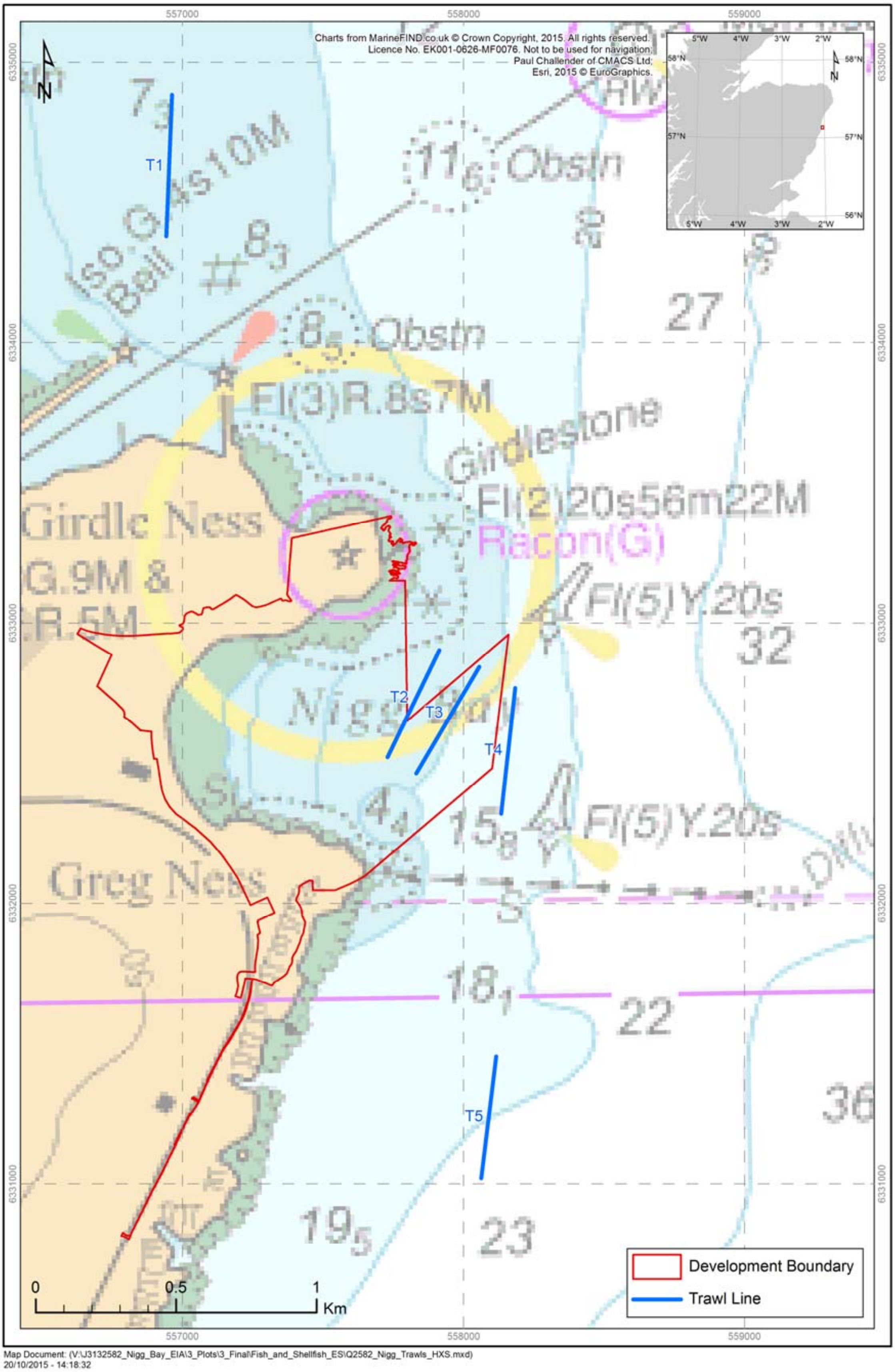


Figure 13.6: Location of the 2 m beam trawl samples during the benthic survey

A total of 664 fish and 1,123 invertebrate specimens were recorded from the trawls. Table 13.12 presents the abundance of the most conspicuous species caught in the trawls.

Table 13.12: Total ranked abundance of fish and shellfish recorded during the 2015 Nigg Bay 2 m scientific beam trawl survey

Scientific Name	Common Name	Total Abundance
Crangon crangon	Brown shrimp	1,066
Pleuronectes platessa	Plaice	246
Limanda limanda	Dab	167
Merlangius merlangus	Whiting	121
Liocarcinus holsatus	Flying crab	42
Ammodytes spp.	Sandeel species	37
Pomatoschistus minutus	Sand goby	28
Syngnathus acus	Greater pipefish	24
Sprattus sprattus	Sprat	21
Agonus cataphractus	Hooknose	17
Liocarcinus depurator	Harbour crab	7
Carcinus maenas	Shore crab	6

The most abundant fish species was plaice *Pleuronectes platessa.* This species was recorded both within Nigg Bay and to the north and south with greatest catches occurring within the bay. Dab *Limanda limanda* and whiting were also well represented in the beam trawl data with the highest catches occurring to the north in Aberdeen Bay, with comparatively lower numbers recorded within the vicinity of Nigg Bay. The lengths of the plaice, dab and whiting specimens caught were generally below the size typically achieved at sexual maturity, suggesting that inshore areas around Nigg Bay may be used by juveniles.

Sandeels *Ammodytes* spp were recorded from all the trawls but in comparatively lower numbers. Sandeels were also noted occasionally on seabed video surveillance and in seabed sediment samples collected within and outside of Nigg Bay. Sandeels are an important prey item for birds, including terns (Sternidae), kittiwakes (*Rissa tridactyla*) and auks (Alcidae), fish (e.g. salmon, pollock and mackerel) and certain marine mammals (e.g. seals and porpoises).

Sandeels exhibit a high degree of seabed sediment specificity, preferring medium to coarse sand sediments (particles ranging from 0.25 mm to 2.0 mm in diameter) over those containing fine sand, coarse silt, medium silt, and fine silt (particles < 0.25 mm in diameter) (Greenstreet et al., 2010). Examination of the site-specific particle size data for Nigg Bay (see ES Appendix 12-B: Subtidal Benthic Ecological Characterisation Survey for full details of the particle size data) suggested the presence of suitable sub-prime and prime sandeel habitat at some locations within the wider study area, although elevated levels of fine sand and silt within Nigg Bay suggests that conditions are unsuitable within the development boundary itself.

Using criteria laid out in Greenstreet *et al*. (2010) and the particle size distribution data collected during the benthic subtidal survey, sandeel habitat has been classified as prime, sub-prime, suitable and unsuitable sandeel habitat, and mapped as shown in Figure 13.8.

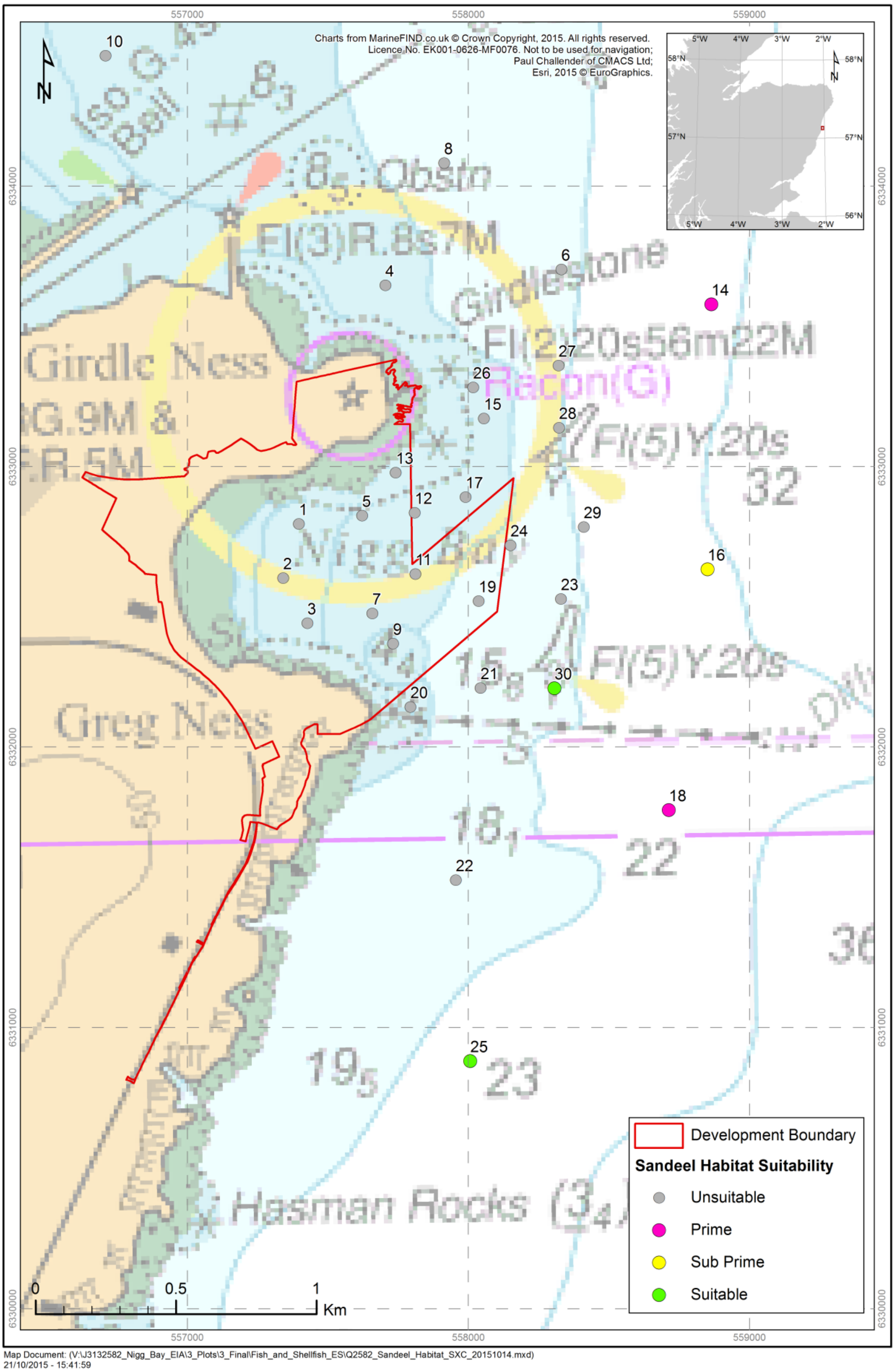


Figure 13.7: Distribution of sandeel habitat classifications (based on Greenstreet et al., 2010)

Other fish recorded during the beam trawl sampling included sand goby, greater pipefish and hooknose, which represent a food source for larger predatory species such as cod, pollack *Pollachius pollachius* and saithe.

Brown shrimp *Crangon crangon* was the most abundant invertebrate species, the majority of which were caught within Nigg Bay. Brown shrimp, together with other crustaceans caught in the trawls such as flying crab *Liocarcinus holsatus* and pink shrimp *Pandalus montagui,* are prey to a wide variety of fish.

13.6.9 Existing Maintenance Dredging in the mouth of the River Dee

The environmental baseline incorporates the current licensed annual maintenance dredging at the mouth of the River Dee. Annually, approximately 250,000 m^3 of river silt is dredged in the river mouth and disposed of at the licensed disposal site, approximately 3.5 km east-south-east of Greg Ness. Refer to Chapter 7: Marine Water and Sediment Quality for further details.

SSCs arising from the sediment disposal are greatest at the disposal site and caused principally by the silty fraction of the disposed material. Peak silty SSC at the disposal site at the time of disposal is 11,657 mg/l, and peak total SSC (all sediment fractions) is 19,524 mg/l. However, these levels are highly localised and decay very quickly after disposal, with average silty sediment concentration falling to 327 mg/l and total SSC falling to 527 mg/l at the disposal site. These levels also reduce rapidly with distance from the disposal site, with total SSC falling to 92 mg/l at 463 m to the north of the disposal site, and 99 mg/l at 463 m to the south.

13.7 Assessment of Effects

13.7.1 Project Description

Table 13.13 presents the project metrics used to assess each of the predicted impacts of the construction and operation of the proposals, and are taken from the full project description provided in Chapter 3: Description of the Development.

Table 13.13: Project metrics used in the assessment of impacts and effects on fish and shellfish ecology

Description of Impacts and Effects	Project Metrics Considered in Assessment of the Impacts and Effects
Construction	
Mortality, startle reaction and avoidance due to underwater drilling, blasting and piling	Blasting of the seabed will be undertaken using explosive in areas of rock to facilitate the dredging process. Drilling will be used to place the explosives within the rock. Piling will be undertaken to install piled walls as part of the construction of the quays .
Temporary seabed disturbances due to dredging	The seabed will be deepened within the harbour using a trailer suction and/or backhoe dredging method. The dredging will be undertaken continuously over 19 months. A portion of the material generated from the dredging and blasting operations is likely to be used within the reclamation, with the remainder transported away from site by bottom opening barge and disposed at an existing licenced marine disposal site.
Temporary increases in suspended sediment concentrations (SSCs) due to dredging	
Temporary deposition of sediment plumes arising from dredging	
Water quality changes and increase in bio-availability of sediment contaminants	

Table 13.13: Project metrics used in the assessment of impacts and effects on fish and shellfish ecology continued

Description of Impacts and Effects	Project Metrics Considered in Assessment of the Impacts and Effects
Operation and Maintenance	
Reduction in the extent of original seabed and pelagic habitat	There will be a permanent loss of 212,118 m^2 of seabed habitat within Nigg Bay as a result of the placement of the proposed harbour infrastructure on the seabed. Seabed depths within the site will be increased to 9.0 m below Chart Datum and 10.5 m below Chart Datum.
Changes to hydrodynamic regime	Changes to hydrodynamic regime as described in ES Appendix 6-B: Hydrodynamic Modelling and Coastal Processes Assessment.
Introduction of new seabed habitats	The proposed harbour infrastructure, including the vertical surfaces of breakwaters and quaysides together with the scour protection material on the seabed, will provide a new hard substrate refuge habitat for fish and shellfish. The dredging will deepen the seabed within the harbour creating a deeper water habitat compared to the baseline.
Changes in water quality	The presence of the breakwaters will increase retention of water within the harbour compared to the baseline.
Seabed disturbances and increases in SSCs due to propeller wash	The following vessel movements are anticipated: 550 commercial vessels; 1,700 Platform Supply Vessel (PSV)/Offshore vessels; 40 Diving Support Vessel (DSV) and 33 cruise ships The wash from operational propellers of vessels using the harbour may disturb seabed sediments and temporarily increase SSCs. The harbour and entrance channel will be dredged as required to ensure sufficient draught is maintained. Dredged material will be transported away from site and disposed at an existing licensed marine disposal site.
Avoidance due to increased vessel noise and presence	
Introduction of harmful species in ballast water or attached to vessel hulls or marine equipment,	
Seabed disturbances due to channel maintenance dredging	
Behavioural change due to changes in the ambient underwater illumination	Lighting at the new harbour will be directional and dimmable, and limited to operational and navigable areas.

13.7.2 Construction Phase

13.7.2.1 <u>Mortality, Startle Reaction and Avoidance Due to Underwater Drilling, Blasting and Piling</u>

The movement of construction vessels, pile driving, drilling, blasting and dredging will increase the level of underwater noise and vibration above natural background conditions and will have the potential to impact upon fish and shellfish populations causing startle reactions, avoidance and mortality. ES Appendix 13-B: Underwater Noise Impact Study presents the results of detailed underwater noise modelling and shows the predicted propagation of underwater noise from these sources.

Sound is the periodic disturbance in pressure from some equilibrium value. The unit of pressure is given in Pascals (Pa) or Newton per square metre (N/m^2). The measurements however cover a very wide range of pressure values, typically from 1×10^{-3} Pa for the hearing threshold value of a human diver, to 1 kHz to 1×10^{7} Pa for the sound of a lightning strike on the sea surface. Sound levels are expressed in decibels (dB) relative to a fixed reference pressure, commonly 1 μPa for measurements made underwater; this is described in more detail in ES Appendix 13-B: Underwater Noise Impact Study.

Piling noise is generated through the impacting of a hydraulically powered hammer onto the end surface of a foundation pile. The noise is dependent on the force applied and the dimensions of the impacting hammer, which for the harbour development will likely be 90 kJ force to 200 kJ force. For the purposes of this assessment, underwater noise modelling was undertaken based on a pile diameter of 1.5 m with generating levels of 209.3 dB_{peak} re 1 μPa at 1 m (see ES Appendix 13-B: Underwater Noise Impact Study).

For the removal of remove rock, holes of 0.125 m diameter will be drilled for the subsequent deployment of explosives. Noise is generated through the action of the drill bit on surrounding rocks. Noise levels created are dependent not only on the size of the drill but also on the consolidation of the surrounding seabed rock. Seabed substrates within the development site consist of sandy gravel overlying glacial till with a granitic schist type of basement rock, so considerable variation in the levels of noise arising the during the drilling task are expected. Blast noise will propagate from approximately 20 kg explosives contained within the pre-drilled holes. For a 20 kg charge, the peak pressure in open water is 259 dB re 1 μPa; however, the peak pressure underwater is expected to be significantly less (ES Appendix 13-B: Underwater Noise Impact Study).

Two forms of dredging will be undertaken in the removal of naturally laid seabed material and material resulting from blasting. A backhoe dredger consists of a barge fitted with a mechanically powered excavator. This is lowered over the side of the barge and scoops up the seabed sediment prior to depositing it into a hopper barge nearby. The sound arising from a dredging vessel consists of a number of discrete sources: the digging or scraping sound of the excavator on the seabed; the engine noise driving the excavator; and the noise of the barge engine or else the engines of the tug boat that has pulled the barge into position. A trailer suction hopper dredger is a fully powered sea-going vessel fitted with one or more large diameter suction pipes which descend to the seabed. A trailing draghead is connected to the end of the suction pipe. The seabed material is sucked up into the pipe then into a hopper installed on the vessel. The sources of noise include the draghead being trailed across the seabed; the suction pump; the seabed material being drawn up the suction tube; the ship's engine; propeller and the dynamic positioning systems fitted to the hull.

Material dredged from the seabed will be disposed using a dredge split hopper at a designated offshore dredge spoil site, with the exception of rock material which will be reused in the construction of the harbour. A review of the literature for the underwater noise modelling study found only one set of acoustic data relating to rock placement operations (ES Appendix 13-B: Underwater Noise Impact Study). The reviewed literature indicated no evidence that rock placement contributed to the noise level. For the purpose of this assessment of effects of noise on fish and shellfish, it is assumed therefore that noise levels associated with rock placement operations were equal to background noise levels and therefore are not considered further here.

13.7.2.2 Species sensitivity

Underwater noise and vibrations are detected by fish using the inner ear and the lateral line (Thomsen et al., 2006). The inner ear is sensitive to sound pressure, whilst the lateral line detects particle motion and vibration. Some species, such as sprat, have connections from the inner ear to the swim bladder making them more sensitive to noise. The majority of species do not have these connections to their swim bladders or have no swim bladders at all and so are less sensitive to sound pressure.

Fish responses to noise range from mild awareness to injury and death (Popper and Hastings, 2009). Fish without swim bladders such as flatfish and elasmobranchs are less susceptible to injury (Goertner et al., 1994).

Of all the fish species of interest to the Aberdeen Harbour Expansion Project only herring and, to a lesser degree, cod may be classed as having high auditory sensitivity. Eel, sea trout and salmon are moderately sensitive to underwater noise as they have a gas-filled swim bladder, which is vulnerable to sharp changes in pressure, but lack the connection between the swim bladder and the internal ear present in herring. There is a general lack of information on hearing in lamprey although given that they lack any specialist hearing structures, they are considered to have low sensitivity to underwater sound. Table 13.14 provides a summary of fish and shellfish considered in this assessment, their comparative hearing sensitivity and rationale for inclusion.

Table 13.14: Species considered within this assessment and rationale

Scientific Name	Common Name	Receptor/Inclusion Rationale	Physiological Hearing Characteristics	Hearing Sensitivity
Clupea harengus	Herring	Hearing specialist Identified within consultation Target offshore commercial fish species Spawning areas in vicinity of development	Particularly intricate connections between its swim bladder and inner ear resulting in comparatively improved sensitivity over that exhibited by hearing generalists	High
Gadus morhua	Cod	Hearing specialist Identified within consultation Seasonal resident Spawning & nursery areas in vicinity of development	Less intricate connections between its swim bladder and inner ear than herring, however, still considered more sensitive than other hearing generalists	High
Salmo trutta	Sea trout	SAC qualifying feature species Identified within consultation Migratory species	Swim bladder does not appear to be linked with the inner ear, therefore relatively insensitive to noise (Gill & Barlett, 2010)	Medium
Anguilla angullia	European eel	Identified within consultation Migratory species	Swim bladder does not appear to be linked with the inner ear, therefore relatively insensitive to noise (Gill and Barlett, 2010)	Medium
Salmo salar	Atlantic salmon	SAC qualifying feature species Identified within consultation Migratory species	Swim bladder is considered to play no part in the hearing of this species, therefore is considered to be most sensitive to vibration rather than sound pressure (Gill and Barlett, 2010) Adults have relatively poor hearing, limited to a narrow frequency band and limited ability to discriminate between sounds but smolts are considered to be more sensitive to very low frequency sounds (Knudsen et al., 2004; Gill and Barlett, 2010)	Low
Lampetra fluviatilis	River lamprey	SAC qualifying feature species Migratory species	Relatively simple ear construction so considered to be relatively insensitive to noise, or even that sound may not be relevant to them at all (Popper, 2005)	Low
Petromyzon marinus	Sea lamprey	SAC qualifying feature species Migratory species	Relatively simple ear construction so considered to be relatively insensitive to noise, or even that sound may not be relevant to them at all (Popper, 2005)	Low

Table 13.14: Species considered within this assessment and rationale

Scientific Name	Common Name	Receptor/Inclusion Rationale	Physiological Hearing Characteristics	Hearing Sensitivity
Other Species/Taxa for Information				
Ammodytidae	Sandeel	Keystone species Spawning areas in vicinity of project	Relatively insensitive to noise, due to the absence of a swim bladder, however noise may deter from nearby feeding, nursery and/or spawning grounds	Very low to negligible
Shellfish		Resident species Spawning areas in vicinity of project	Hear in a different way to vertebrates, e.g. arrays of sensory hairs on lobsters, crabs etc. or statocyct organs. Are able to sense vibrations and movements associated with sound production but the absence of gas-filled cavities indicates a lesser potential for injury and mortality	Very low to negligible
Elasmobranchs		Seasonal residents Spawning and nursery areas in vicinity of project	Relatively insensitive to noise, due to the absence of a swim bladder, however, noise may deter from nearby feeding, nursery and/or spawning grounds by the noise	Very low to negligible

13.7.2.3 Underwater Noise Modelling Approach

The degree to which a given species might be affected by underwater sound emissions depends on a number of factors, including the sensitivity of the species or individual to the sound, the level of sound on the receptor, its frequency content and the duration of the sound. The criteria upon which the modelling for noise assessment was undertaken to estimate impact zones around noise sources within the proposed development were based on best scientific practice, discussed extensively in the international peer-reviewed literature.

Effects on receptors were classified into three main criteria:

- Lethality and physical injury;
- Auditory damage; and
- Behavioural reactions.

Lethality and Physical Injury

Mortality or direct physical injury from noise and vibration propagated from a sound source is associated with very high peak pressure or impulse levels. Typically, these effects can be associated with blasting in open water or in the immediate vicinity of an impact piling operation. Mortality is related to the body mass of the receptor and the magnitude of the impulsive wave. Studies of blasting in open water showed mortality in fish when peak to peak sound levels exceeded 240 dB re. 1 μPa (Yelverton et al., 1975). However, for this development, explosive blasting takes place in predrilled boreholes hence the rock overburden will absorb much of the acoustic energy (ES Appendix 13-B: Underwater Noise Impact Study) and noise levels will be substantially lower.

A limiting threshold for physical injury of 100 kPa (corresponding to a peak to peak level of 220 dB re 1 μPa) was adopted for use during blasting work in Canadian waters (ES Appendix 13-B: Underwater Noise Impact Study).

With regard to a useful threshold indicating mortality, other observations have recorded cumulative Sound Exposure Level (SEL) at least 7 dB to 10 dB higher than those indicating the onset of physiological effects at an SEL of 207 dB re 1 μPa^2.s. However, fish without a swim bladder showed no effects even when exposed to piling noise having a cumulative SEL of 216 re 1 μPa^2.s.

Auditory Damage

Interim criteria for injury to fish from pile driving noise are proposed by the Fisheries Hydroacoustic Working Group (FHWG). This is a dual criteria including a peak level of 206 dB re 1 μPa and a cumulative SEL of 187 dB re 1 μPa^2 s for fish 2 grams and heavier; or a cumulative SEL of 183dB re 1 μPa^2 s for fish smaller than 2 grams with the peak SPL remaining unchanged. In the absence of any other guidance, these criteria will also be used to assess the effect of continuous noise.

Behavioural Reactions

At lower sound pressure levels, fish may exhibit changes in their normal behaviour. These changes range from a startle reaction to the sound, a cessation of their current activities (e.g. feeding, nursing, breeding) or the animals may leave the area for a period of time.

Nedwell et al. (2003) found that caged brown trout (*Salmo trutta*) exhibited no behavioural responses when exposed to vibro-piling at a distance of 25 m from the source. However, the sound pressure level at this range was not recorded. Similarly, no behavioural changes were observed in the fish when exposed to impact pile driving at a distance of 400 m from the source. At this range, sound pressure levels were estimated at 134 dB re 1 µPa.

Cumulative exposure

Acoustic impacts of piling may also occur when an animal is exposed to a sound which, in itself, may not be sufficiently loud to produce the onset of injury or to induce a behavioural reaction, but which will do so when the sound exposure is allowed to build up over a period of time. Southall et al. (2007) provides the metric of SEL in order to quantify this impact. The cumulative build-up of noise is explored using a fleeing–animal model, where the animal moves around through the noise field at various distances from the noise source and over a period of time. For each noise source/animal separation, the corresponding sound pressure level is computed. The SEL or the cumulative sound pressure level as a function of time is compared with threshold levels at which various acoustic effects are met. For most impact activities assessed, the literature only supports modelling of two broad-scale categories of fish based on weight: body weight greater than 2 g; and body weight less than 2 g.

Here, the SEL methodology has been applied to further explore likely impacts of potential cumulative noise on fish species. The criteria used potential mortal injury (PMI) and recoverable injury (RI) for low, medium and high auditory sensitivities.

Temporary hearing damage indicated by the temporary threshold shift (TTS) effect criterion has also been modelled for all fish included within this assessment. Note that with regard to fish, the current understanding does not support a correlation with sensitivity and this requires considerable further research. The value provided is an estimate of TTS for all fish and is precautionary for assessment purposes.

Behaviour of Fish and Shellfish

There is a paucity of information in peer reviewed literature on the effects of noise on the behaviour of fish and shellfish in the marine environment. Future research is required to describe the behavioural responses of fish and shellfish and to assess the implications of those responses in terms of risks to populations. Changes in behaviour may affect spawning or abandonment of spawning sites, movement away from preferred habitats, disruption of feeding, increased energy consumption, increased susceptibility to predation and diversion or delay of migrations.

Lab based experiments have shown that noise levels equivalent to those propagated by normal marine vessel traffic reduce foraging behaviour and increase susceptibility to predation of European eels (Simpson et al. 2014) and shore crab (Wale et al. 2013). However, the experiments do not have equivalent studies in the field, nor do they make reference to the likelihood of habituation to noise that may occur in an open sea environment. The existing Aberdeen Harbour receives heavy marine traffic and the existence of fish and shellfish species in this environment needs to be placed in context. Assessment results should also be put into the context of the experiments by Nedwell et al., (2003) in which no behavioural changes were observed in sea trout when exposed to impact pile driving at a distance of 400 m from the source. At this range, sound pressure levels were estimated at 134 dB re 1 μPa.

Weighted metrics such as the dB_{ht} effect criterion have been used in modelling areas of likely effect on the behaviour of species but the dB_{ht} metric has not been validated by either rigorous peer-review or extensive experimental study and therefore has not been used for this assessment. With the absence of a modelled metric to assess the impact of construction noise upon environmentally sensitive fish and shellfish within the proposed Aberdeen Harbour Expansion Project area, the modelled cumulative SEL metric is used as a gauge of the minimum distance from a source of noise at which behavioural effects may occur (as explained above). This should be taken in the same context that smaller fish individuals (<2 g) are less tolerant to cumulative acoustic impacts, than those >2 g. However, due to the large range of fish individual weights in the >2 g category, the results from the modelling for this weight range should be treated with caution and as highly precautionary.

Assessment of Underwater Noise from Piling

Table 13.15 presents the results of the noise modelling of peak pressure associated with piling activity, and shows the spatial extents over which physiological effects on fish and shellfish are predicted to occur. Results of the cumulative noise assessment for piling undertaken at representative locations on the south and north breakwaters are shown in Table 13.16. In both instances, both winter and summer values are shown, as noise propagation varies with the seasonal variation in seawater densities.

Table 13.15: Summary of acoustic effects for piling vessel spread

Exposure Limit	Effect	Southern Breakwater		Northern Breakwater	
		Winter	Summer	Winter	Summer
240 dB re 1 μPa pk	Lethality	<1 m	<1 m	<1 m	<1 m
213 dB re 1 μPa pk	Potential mortal injury in fish with low hearing sensitivity	<1 m	<1 m	<1 m	<1 m
213 dB re 1 μPa pk	Recoverable injury in fish with low hearing sensitivity	<1 m	<1 m	<1 m	<1 m
207 dB re 1 μPa pk	Potential mortal injury in fish with medium hearing sensitivity	<1 m	<1 m	<1 m	<1 m
207 dB re 1 μPa pk	Potential mortal injury in fish with high hearing sensitivity	<1 m	<1 m	<1 m	<1 m
207 dB re 1 μPa pk	Potential mortal injury in fish eggs and larvae	<1 m	<1 m	<1 m	<1 m
207 dB re 1 □Pa Peak	Recoverable injury in fish with medium hearing sensitivity	<1 m	<1 m	<1 m	<1 m
207 dB re 1 □Pa Peak	Recoverable injury in fish with high hearing sensitivity	<1 m	<1 m	<1 m	<1 m
206 dB re 1 μPa pk	Onset of injury in fish	1.5 m	1.5 m	1.5 m	1.5 m

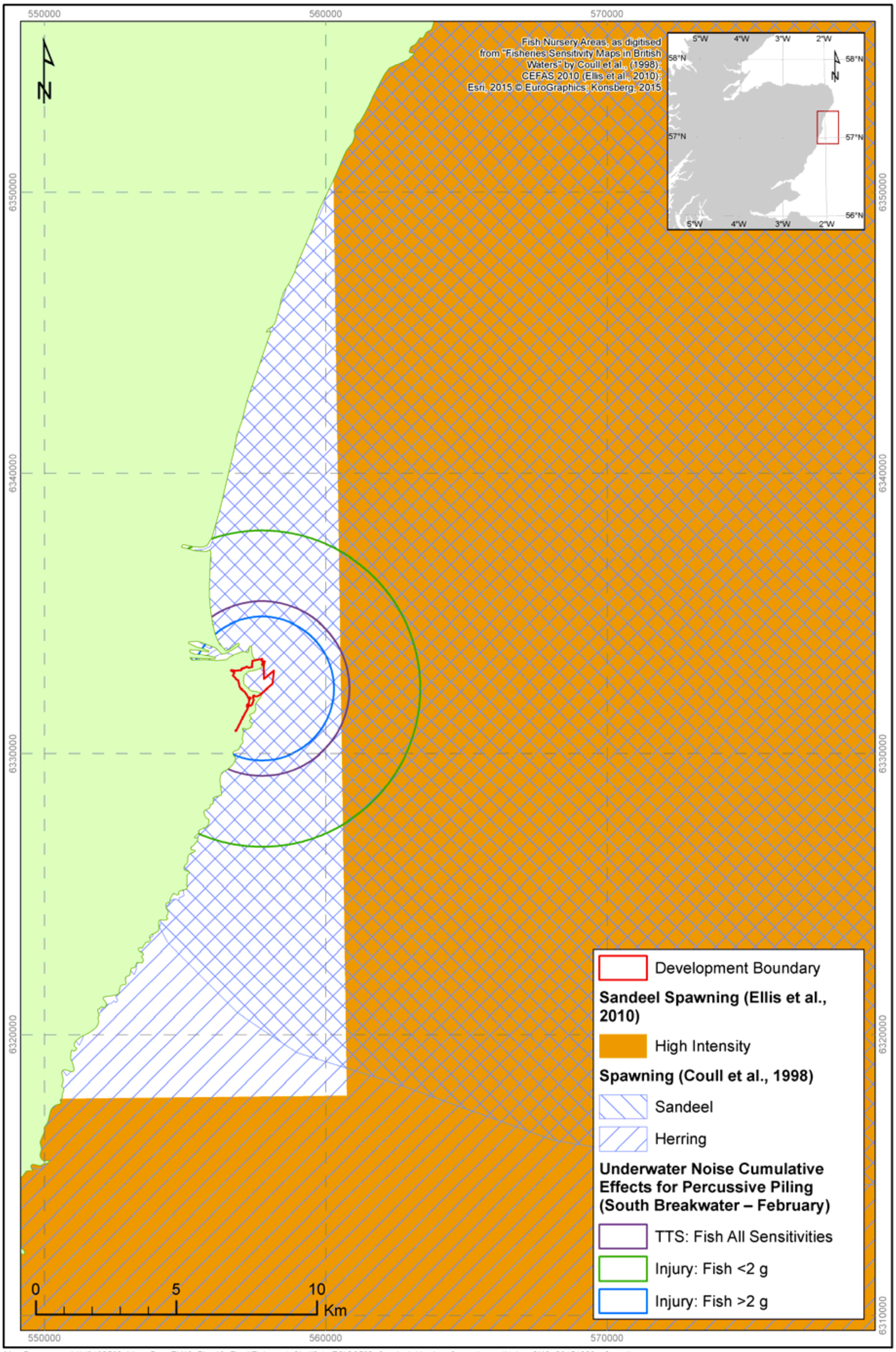
Table 13.16: Summary of cumulative acoustic effects for piling vessel spread

Species	Effect	Threshold dB re 1 μPa^2 s	South breakwater		North breakwater	
			Feb	Aug	Feb	Aug
Fish – low sensitivity	PMI	219	90 m	90 m	90 m	90 m
	RI	216	100 m	100 m	100 m	100 m
Fish – medium sensitivity	PMI	210	110 m	110 m	100 m	100 m
	RI	203	200 m	200 m	190 m	190 m
Fish – high sensitivity	PMI	207	110 m	110 m	100 m	100 m
	RI	203	200 m	200 m	190 m	190 m
Fish eggs, larvae	PMI	210	110 m	110 m	100 m	100 m
Fish – all sensitivities	TTS	186	3,110 m	2,620 m	2,670 m	2,190 m
Fish >2g	No-injury	187	2,560 m	2,180 m	2,190 m	1,860 m
Fish <2g	No-injury	183	5,630 m	4,110 m	4,680 m	3,540 m

Calculation of the ranges of peak pressure values causing physiological effects are very small and suggest that underwater noise levels from piling will be insufficient to cause lethality in any species, and that no injury for all fish will occur beyond 1.5 m from the vessels undertaking piling activity. However, when the impacts of cumulative noise are considered, i.e. during a continuous or repeated emission of noise, then the ranges over which physiological effects are predicted increase markedly. For example, potential mortal injury (PMI) and recoverable injury (RI) are predicted to occur within 90 m and 200 m of the piling activity respectively, depending on fish auditory sensitivity and season, but temporary hearing damage, as indicated by the TTS effect criterion, may occur at a maximum range of 3,110 m. Furthermore, the maximum 'no-injury' limit, i.e. the range within which onset of injury will likely occur, varies between 2,560 m and 5,630 m depending on the body weight of the fish considered.

Mobile species are expected to be able to avoid areas of significant adverse underwater noise, and implementation of a soft-start piling procedure would likely displace many fish out of the area before the onset of injury and mortality. Therefore, the effect of noise from piling is judged to be negligible as any death or injury of fish is unlikely to have significant negative consequences for the wider stock size and structure. Avoidance, however, as indicated by the TTS and 'no-injury' criteria, may occur over a wider area. Effects of avoidance will depend on the species in question and the life stage affected, but may include reduced access to spawning and feeding grounds or barriers to migration, which may have negative consequences for breeding success and stock recruitment.

Sandeel and herring will congregate over local grounds for spawning, for example, and any behavioural changes due to piling may result in avoidance of local critical habitat during the period of the piling activity. Avoidance of affected areas by sandeel may also reduce feeding for marine mammals and seabirds within the immediate locale for the duration of the piling. However, given the spatial extents of the noise impacts and the wider availability of spawning grounds within the wider region, no significant deleterious effects on sandeel breeding and stock size are forecast. As hearing specialists, herring will be affected by piling noise over a marginally greater distance. Again, the wider availability of herring spawning habitat available within the region suggests any temporary avoidance of affected areas will have negligible effects on herring stocks. Figure 13.8 shows the extents of the sandeel and herring spawning grounds overlaid with the maximum predicted noise contours presented in Table 13.16, to illustrate the area over which species may avoid during piling.



Map Document: (V:\J3132582_Nigg_Bay_EIA\3_Plots\3_Final\Fish_and_Shellfish_ES\Q2582_Sandeel_Herring_SpawningandNoise_SXC_20151020_v2.mxd)
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Figure 13.8: Herring and sandeel spawning grounds overlaid with the maximum noise contours arising from percussive piling activity at Nigg Bay

The predicted distance over which TTS could occur (for all species) encompasses the mouth of the River Dee. This may represent a barrier to salmonid migration and entry to the River Dee or avoidance of the local area during peak migration occasions. As a worst case, this will cause a temporary delay in the migration of adult Atlantic salmon, which is a SAC qualifying feature receptor, for the duration of the piling activity. Figure 13.9 shows how the maximum predicted noise contours overlap the entrance to the River Dee. Salmon are expected to be able to continue their migration during interim periods between piling events, i.e. due to vessel repositioning, subject to the frequency of the noise disturbance. Effects on salmon smolt emerging from the River Dee are unclear at present but may include similar barrier effects and delays to emergence into the marine environment during peak migration. Smolts and sea trout may also be temporarily excluded from the local coastal areas for feeding in areas of adverse underwater noise and may therefore be displaced to other areas nearby during piling.

Overall, fish are highly unlikely to be completely excluded from predicted areas of adverse noise around a noise source as they will also be responding to preferred habitat conditions and biological imperatives such as feeding and migration. Salmonids are comparatively insensitive to sound and as mentioned above, empirical observation shows no behavioural reaction in salmon and sea trout to piling beyond a few hundred metres. Furthermore, the rocky headland at Girdle Ness lies between the construction site and the mouth of the River Dee and is highly likely to provide significant protection from noise from piling in Nigg Bay. Therefore, it is reasonable to suggest that the modelled predictions can be moderated considerably.

In conclusion, the effects of underwater noise arising from piling events will be localised and intermittent and will last throughout the construction period (up to 3 years). All receptor groups are predicted to exhibit avoidance at the individual level only over the medium term. Effect magnitude is thus predicted to be **minor** on **low to very high** value receptors and effect significance is thus judged to be **minor to moderate adverse**, which is significant in EIA terms. Note that the final construction design has yet to be decided. The use of fewer or smaller piles would reduce the levels of adverse noise entering the marine environment, whilst the partial or complete construction of the north and south breakwaters prior to the onset of piling activity may attenuate significant noise propagation beyond the embayment. The assessment presented in this section is therefore considered to be a conservative worst case scenario.

The effects are certain to happen and thus risk is judged to be **high**. Certainty associated with this assessment is **high** as the spatial extents of the effects have been modelled.

Assessment of Underwater Noise from Drilling

Table 13.17 presents the spatial extents over which noise peak pressures are predicted to elicit physiological effects on fish as a result of underwater noise from drilling activities. This shows that the peak pressures generated by the spread of vessels associated with drilling operations are insufficient to cause lethality or onset of injury in all species.

Table 13.17: Acoustic effects for drilling vessel spread

Exposure limit	Effect	Southern breakwater		Northern breakwater	
		Winter	Summer	Winter	Summer
240 dB re 1 μPa pk	Lethality	<1 m	<1 m	<1 m	<1 m
206 dB re 1 μPa pk	Onset of injury in fish	<1 m	<1 m	<1 m	<1 m

Table 13.18 shows the results of the analysis of cumulative exposure to noise from drilling. This predicts potential adverse consequences for small fish (<2g) at distances of up to 870 m whilst larger species (>2 g) will only be potentially affected within 420 m.

Table 13.18: Summary of cumulative acoustic effects for drilling vessel spread

Species	Effect	Threshold dB re 1 μPa^2 s	South breakwater		North breakwater	
			Feb	Aug	Feb	Aug
Fish >2 g	No-injury	187	420 m	400 m	380 m	350 m
Fish <2 g	No-injury	183	870 m	830 m	690 m	660 m

The total area of effect is therefore predicted to be very small and components of all receptor groups are expected to be able to avoid adverse noise arising from the drilling before onset of significant injury or mortality. The resultant avoidance of affected areas may however, cause reduced feeding, where local species are displaced to lower quality habitats, or avoidance of critical spawning and nursery habitat. Species most likely to be affected include the permanent and juvenile components of the seasonal residents receptor groups as these will be the most likely to be present as the time of the drilling operations.

Barrier effects to migration of diadromous (migratory) species are not forecast given the small effect range, and no significant effects on the SAC qualifying receptor group are expected. Similarly, no significant adverse effects on sandeel and herring spawning are expected given the small area of effect and the wider availability of spawning ground throughout the wider region.

In conclusion, the effects of underwater noise from drilling operations will be temporary, short term and highly localised on permanent and seasonal receptor groups at the individual level only. Effect magnitude is thus judged to be **minor** on **low** value receptors. Significance of the effect is thus judged to be **minor adverse,** which is not significant in EIA terms.

The effects are certain to happen and thus risk is judged to be **high**. Certainty associated with this assessment is **high** as the spatial extents of the effects have been modelled.

Assessment of Underwater Noise from Blasting

Table 13.19 shows the limiting ranges at which fish of various body weights may survive the explosive blast. As shown, all effect ranges on all fish size classes are forecast to be very small. For example, for a fish of body weight 5 kg, the 50% mortality criterion lies at a range of 4 m while the no-injury impact range is 12 m. The permanent and seasonal receptor groups are likely to be the most susceptible to the impacts of noise from blasting as they will be most likely species to be present at the time of the operation. However, individuals will need to be very close (i.e. within 24 m for a fish of 0.2 kg) for any injury to occur.

Table 13.19: Effect ranges for lethality and no injury criteria for fish

Body weight [kg]	50% Lethality			1% Lethality			No Injury		
	Impulse [Pa s]	Range [m]	Peak pressure [dB]	Impulse [Pa s]	Range [m]	Peak pressure [dB]	Impulse [Pa s]	Range [m]	Peak pressure [dB]
0.2	202.3	8	234.4	112.9	12	228.8	39.5	24	219.2
0.5	271.2	6	238.4	151.4	10	231.3	52.9	20	221.7
1	338.6	5	241.0	189.0	8	234.4	66.1	18	223.2
2	422.7	5	241.0	236.0	7	236.3	82.5	15	225.7
5	566.8	4	244.1	316.5	6	238.4	110.6	12	228.8
10	707.6	3	248.1	395.1	5	241.0	138.1	11	230.0
20	883.4	2	253.7	493.2	4	244.1	172.4	9	232.8
50	1184.5	2	253.7	661.3	3	248.1	231.2	7	236.3
100	1478.7	1	263.3	825.6	3	248.1	288.6	6	238.4

The impact of underwater noise from rock blasting is therefore forecast to be highly localised and will be intermittent and of short duration on **low** value receptors. Magnitude of impact is thus considered to be **negligibl**e and thus the effect is considered to be of **negligible** significance, which is not significant in EIA terms**.**

Significant adverse effects are unlikely to occur and so risk is **low**. Certainty associated with this assessment is **high** as the results have been quantified through numerical modelling.

Assessment of Underwater Noise from Dredging

Table 13.20 shows that noise peak pressure values predicted from both the Trailer Suction Hopper Dredger (TSHD) and Backhoe (BH) dredgers are insufficient to cause mortality or physical injury to fish species.

Table 13.20: Summary of acoustic effects for TSHD and BH dredging vessel spread

Exposure Limit	Effect	Winter	Summer
240 dB re 1 µPa pk	Lethality	<1 m	<1 m
206 dB re 1 µPa pk	Onset of injury in fish	<1 m	<1 m

Cumulative exposure to noise from dredging, however, has the potential to have adverse effects on fish and shellfish over greater distances as presented in Table 13.21.

Table 13.21: Summary of cumulative acoustic effects for backhoe and trailing suction hopper dredging vessel spread

Species	Effect	Threshold dB re 1 μPa^2 s	Head of Nigg Bay		South breakwater		North breakwater	
			Feb	Aug	Feb	Aug	Feb	Aug
Backhoe Dredging								
Fish >2g	No-injury	187	680 m	610 m	1,340 m	1,280 m	1,000 m	960 m
Fish <2g	No-injury	183	1,150 m	1080 m	2,460 m	2,430 m	2060 m	1,910 m
Trailing Suction Hopper Dredging								
Fish >2g	No-injury	187	300 m	270 m	440 m	400 m	370 m	340 m
Fish <2g	No-injury	183	530 m	440 m	930 m	850 m	700 m	650 m

Again, species within all receptor groups are expected to be able to avoid significantly adverse areas of dredging-related noise prior to the onset of injury or mortality. Avoidance will last for the duration of the dredging activity (up to 19 months) and thus short term reductions in the abundance and diversity of species within the footprint of the development only. Significant adverse effects on stock size and structure over the wider region are therefore not forecast.

Significant barrier effects on diadromous species are not forecast to occur given the comparative insensitivity of salmonids to sound and the present levels of noise already present within and around Aberdeen Harbour to which salmonids will be tolerant. Sound emissions emanating from dredging are unlikely to be at levels preventing access to or emergence from the River Dee for salmonids.

In conclusion, the effects of underwater noise from dredging operations will be temporary, short term and highly localised on permanent and seasonal receptor groups at the individual level only. Effect magnitude is thus judged to be **minor** on **low** value receptors. Significance of the effect is thus judged to be of **minor adverse** significance, which is not significant in EIA terms.

The effects are certain to happen and thus risk is judged to be **high**. Certainty associated with this assessment is **high** as the spatial extents of the effects have been modelled.

A summary of the assessment of underwater noise impacts is provided in Table 13.22.

Table 13.22: Magnitude of underwater noise impacts

Activity	Effect magnitude	Receptor Value	Effect Significance
Piling	Minor	Low to Very High	Moderate adverse
Drilling	Minor	Low	Minor adverse
Blasting	Negligible	Low	Negligible
Dredging	Minor	Low	Minor adverse

13.7.2.4 Temporary Seabed Disturbances Due to Capital Dredging

Dredging of the seabed, including seabed preparatory works such as bed levelling and removal of rock, will disturb the seabed substrates and the animals living within and on them. The dredging will be continuous but temporary, lasting for 19 months and will be highly localised to within the dredge footprint. Effects on fish and shellfish receptors will relate to (i) reduced invertebrate prey availability, (ii) physical disturbance to critical habitats and (iii) direct uptake of individuals by the draghead or backhoe dredger, as addressed below.

(i) Reduced prey availability

The dredging will disturb the seabed resulting in abrasion and compaction effects on benthic habitats, increased sediment instability and uptake (entrainment) of sessile and sedentary benthic invertebrates via the action of draghead or backhoe on the seabed. This will result in the displacement, mortality and loss of seabed invertebrate prey species for fish and shellfish, such as polychaete worms and crustaceans, within the dredging footprint. Whilst some benthic fish and scavenging shellfish, such as crabs, may initially derive some benefit, due to the release of benthic resources within sediment plumes arising from seabed disturbances, this is likely to be very short-lived (hours or days) following each dredging event in any one area. As dredging progresses across the bay over time, an overall incremental reduction in local benthic invertebrate prey availability is expected. Chapter 12: Benthic Ecology provides a comprehensive assessment of the effects of dredging on benthic ecology.

A reduction in benthic prey will have negative consequences for the permanent residents and juvenile components of the seasonal resident fish and shellfish receptor groups. These species have limited range movement and may therefore have comparatively limited ability to relocate to neighbouring undisturbed areas during the capital dredge programme for feeding. Reduced feeding opportunities within dredged areas would likely result in reduced survivorship and a loss or reduction in the abundance of those fish and shellfish species in these receptor groups which rely on local benthic resources.

A significant reduction in the abundance of individuals would likely weaken the overall cohort strength within the bay over the affected seasons, limiting spawning success and recruitment potential post-construction. Recolonisation of affected areas will occur once the dredging has been completed but will depend on the severity of the original impact, the strength of the cohort of surviving species post construction, recruitment rates from outside of the bay and the subsequent restitution of benthic habitats and associated invertebrate faunal food resource.

Species comprising the SAC qualifying feature receptor group are forecast to remain comparatively unaffected by reduced benthic food resources in Nigg Bay. Returning adult salmon do not generally feed and thus will not be affected by reduced benthic prey items in Nigg Bay although any opportunistic benthic feeding by returning salmon in the area would be limited. Salmon smolt and sea trout may use the local area for feeding on emergence from the River Dee, but the extent to which they rely on local benthic resources is unclear and in any case, it is likely that they will preferentially target food items within the water column such as small pelagic shrimps. Furthermore, their mobility and wide range movement suggests that both salmon smolt and returning adult salmon would be able to utilise other food sources elsewhere outside of any negative sediment influences. Sea trout are thought to use inshore waters to a greater degree, but again are expected to preferentially target pelagic resources over a wide area and so may be relatively unaffected by a localised decline in benthic food items. Effects on migrating salmonids are thus anticipated to be negligible and any significant indirect effects on freshwater pearl mussel populations are therefore not forecast.

Similarly, the species belonging to the hearing specialists group are highly mobile and are expected to be able to move away from significantly adverse areas and use other local sites for feeding. As a mobile pelagic species, herring would not rely on a localised benthic food source and so are not expected to be significantly affected by reduced benthic prey availability within Nigg Bay. However, cod is a demersal species and will feed on a range of benthic invertebrates. As such any juvenile cod using Nigg Bay on a seasonal basis may be temporarily displaced from the development site due to reduced prey availability but would be expected to re-locate and use adjacent areas outside the influence of the capital dredge. Recolonisation of affected areas by juvenile cod will occur once the dredging has been completed but again, will depend on the severity of the impact and the subsequent restitution of benthic habitats and associated invertebrate fauna.

Sandeel are pelagic feeders and actively feed on small planktonic crustaceans or other planktonic prey items during a defined feeding season (April – September). Consequently, they are not expected to be significantly affected by reduced benthic invertebrates within Nigg Bay.

(ii) Physical disturbance to critical habitat

Disturbance or removal of particulate bottom sediments and/or rocky intertidal areas will result in the loss or displacement of the permanent and seasonal resident receptor groups which depend on these habitats for burial, burrow construction, feeding and refuge. As dredging progresses through the bay, the total area of habitat disturbance will increase, resulting in the incremental loss or reduced abundance of these types of species within Nigg Bay, although populations in adjacent undisturbed areas will remain unaffected. Species may be able to return to their pre-dredge habitats once the disturbance has abated, but this will be subject to the severity of the original impact and the degree to which pre-dredge benthic conditions will be restored.

The proposed dredging will disturb fish and shellfish spawning and nursery habitat within the footprint of the activity. The majority of the species that spawn within the locale are broadcast spawners and so any eggs in the water column will not be adversely affected by local disturbances to seabed habitats. Significantly disturbed seabed areas, however, may be unsuitable for settled fish and shellfish larvae, resulting in the loss of sensitive species from the dredge footprint.

Key ecosystem species and hearing specialist receptor groups include demersal spawning species such as sandeel and herring, which are comparatively less tolerant to seabed disturbances. Any eggs of these species deposited on or in the seabed prior to dredging may be lost or damaged by the activity. These species exhibit high site fidelity and would not be able to use other habitat types for spawning if excluded from their original habitat, and recruitment to subsequent cohorts may be affected over the period of the capital dredging operation. However, the development only occupies a very small portion of the total available sandeel and herring spawning habitat present within the region, so any effects of the scheme will likely to be negligible within this context.

(iii) Direct uptake of individuals by the draghead or backhoe dredger

The capital dredging may result in the loss of individuals through entrainment and uptake via the action of the draghead and backhoe on the seabed, leading to an overall reduction in the abundance of some fish and shellfish. Mobile species within the majority of receptor groups would be able to avoid the draghead or backhoe on the seabed and so are not expected to be entrained and lost. Demersal and sedentary species, young life stage fish and key ecosystem receptor group species (sandeels) on the other hand, may be comparatively more susceptible as a result of their sediment dwelling habitat and/or lower swimming speeds (ECORP Consulting Inc., 2009) and individuals may be lost to dredging, resulting in an overall decline in species abundance. Also, larvae and small juveniles may not have developed the necessary darting ability to avoid the dredging equipment and will be more vulnerable compared to larger juveniles and adults of the same species. Eggs laid on or in the seabed would also be susceptible to entrainment and uptake by dredging activities.

Comparative studies have shown a higher uptake of demersal sandeels as a result of dredging activities, compared to other fish (ECORP Consulting Inc., 2009). Sandeels and their eggs largely remain in their burrows during winter months so they are considered to be most at risk from physical disturbance and uptake by dredging at this time of year. Any herring eggs deposited on the seabed may also be lost or damaged if in the path of the dredger tool on the seabed. However, in this instance, the numbers of sandeel and herring present within the footprint of the capital dredge is likely to be very low in comparison to the availability of sandeel and herring spawning habitat across the wider region, and significant effects on overall stock abundance of these species across the wider region are not expected.

Resident and seasonal shellfish will also be comparatively susceptible to entrainment or uptake by dredging activities due to their reduced mobility and swimming speeds. Studies of entrainment rates of Dungeness crab by hopper dredge operations, for example, have calculated that between 0.040 to 0.592 crabs/y^3 are entrained with a mortality ranging from 5% to 86% (ECORP Consulting Inc., 2009). Mechanical dredgers (e.g. backhoe) were found to have the lowest entrainment and mortality rates of crabs (0.012 crabs per cubic yard and 10% respectively) compared to other methods. In addition, brown shrimp were found to have the highest entrainment rates of all marine organisms with rates of uptake calculated as 0.69 to 3.38 shrimp per cubic yard, depending on whether the draghead was on the seabed or just above it. The comparatively large numbers of brown shrimp found in Nigg Bay during the site-specific survey would therefore be vulnerable to uptake by the capital dredge operations, resulting in a loss or reduced abundance of this species. Recovery of shellfish populations is expected to occur but will be subject to the severity of the original impact, the nature of the seabed habitat post construction and availability of reproducing populations within and around Nigg Bay.

In conclusion, the effects of direct seabed disturbances will be temporary, highly localised and limited to the footprint of the dredging activity. Displacement or loss of fish and shellfish is expected at the individual level for permanent and seasonal resident receptor groups and for the key ecosystem species (sandeel) receptor group only. The impact will cease on completion of the capital dredging operation. Effect magnitude is, therefore, considered to be **minor** on **low** to **medium** value receptors. Effect significance is therefore judged to be of **minor adverse** significance, which is not significant in EIA terms.

The effect is **near-certain** to happen. Risk is therefore judged to be **medium.**

This assessment carries **medium** certainty as the temporal extents of the effect have been quantified, but the distribution of dredging effort throughout the programme is unclear and thus the ability for resident fish and shellfish to temporarily re-locate to undisturbed areas and associated energy expenditure, is not well understood.

13.7.2.5 Temporary Increases in Suspended Sediment Concentrations Due to Capital Dredging in Nigg Bay

Increases in suspended sediment concentrations (SSCs) will occur as a result of the action of the dredger draghead or the backhoe dredging tool on the seabed and also from any overspill from the dredger hopper. Suspended sediments will be initially transported from the point of release under their own momentum within a dynamic phase, and subsequently via tidal current movements within a passive phase, and will be eventually deposited back to the seafloor during periods of reduced tidal movement.

Greatest SSCs will be created during the trailer suction hopper dredging (TSHD) of the unconsolidated sediments and are assessed here as the worst case situation compared to the effects of backhoe dredging. Appendix 7-D: Sediment Plume Modelling, assumes that the northern and southern breakwaters have been partially constructed and predicts that most sediment fractions disturbed by TSHD will remain within the embayment at Nigg Bay, settling rapidly back to the seafloor close to the point of disturbance. This is due to the comparatively lower current velocities behind the partial breakwaters and enhanced settling of the larger particles. Mud particles will, however, remain in suspension for longer and will be transported outside of the bay via tidal currents. Dispersion will be mostly to the north towards the entrance of the River Dee following the dominant current movement.

The greatest SSCs will be produced during the trailer suction hopper dredger (TSHD) operations, compared to backhoe dredging. Maximum SSCs arising from this dredging are forecast to be above 8,000 mg/l at the immediate dredging location within the proposed harbour area (Figure 13.9). However, these events are intermittent and short-lived, and are highly localised (confined to within Nigg Bay itself). The low levels of tidal energy within the bay mean that sediment settles very quickly.

The silty fraction of the overspilled material disperses slightly further, reaching the entrance channel and the outer coastal area. The peak increases in SSC north of Girdle Ness are predicted to be no higher than 100 mg/l to 200 mg/l above background levels, and generally around 10-40 mg/l in front of the mouth of the River Dee, which is well within natural background variation. For this fraction, the peak values are very short-lived, returning to background levels before the next overspill episode (modelled as occurring every 90 minutes). The dredging is not forecast to affect the River Dee SAC (Appendix 7-D: Sediment Plume Modelling).

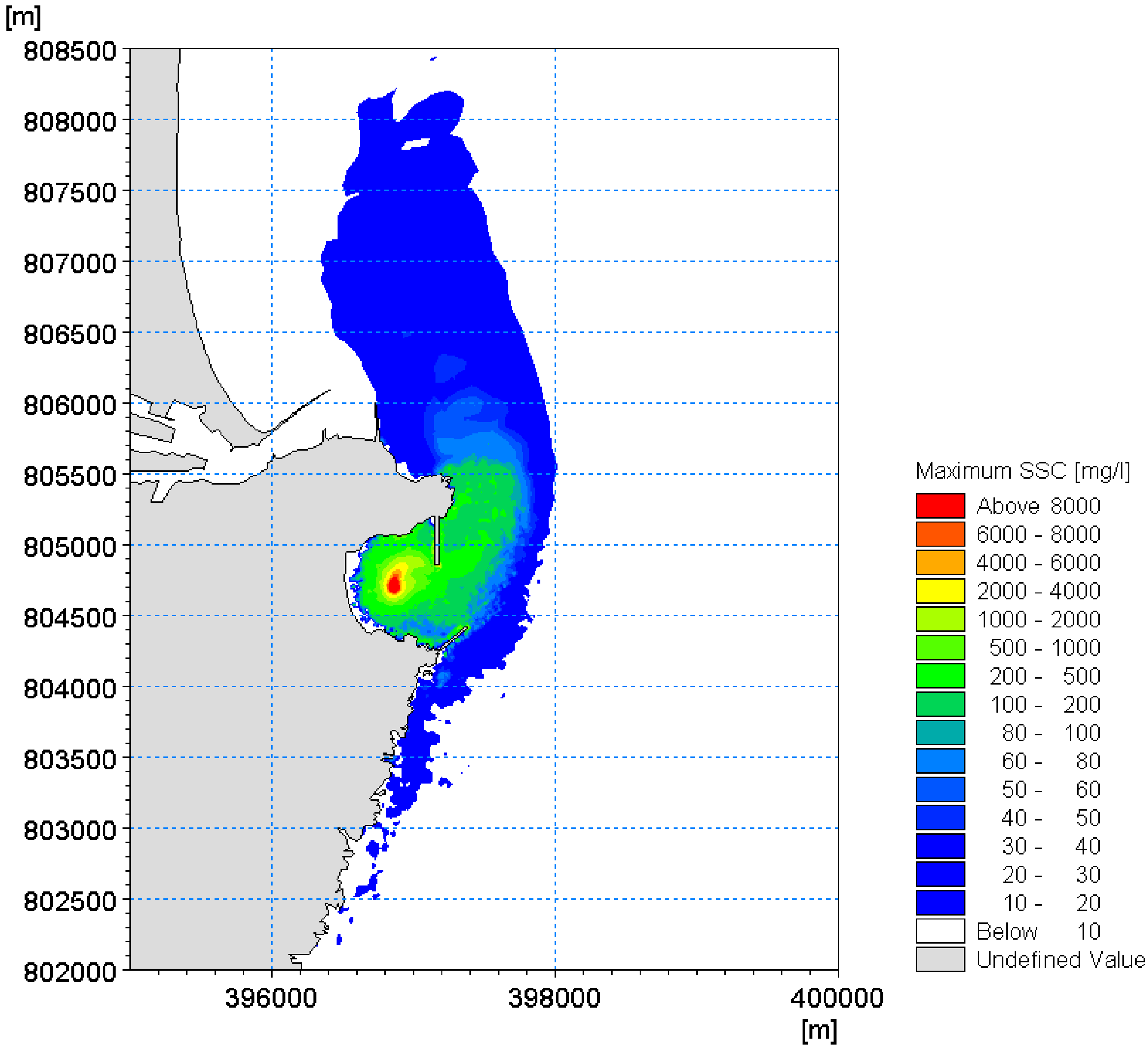

Figure 13.9: Contour plot of maximum SSC from construction TSHD overspill in Nigg Bay

The short-lived nature of these over-spill events is demonstrated by the lower values and much smaller extent of modelled average SSC. Conservative modelling of average SSC predicts that almost all the plume is predicted to stay within the bay, and that the majority of average plume concentrations are within the natural range of variation of SSC in the area (see Chapter 7: Marine Water and Sediment Quality). Average SSCs measured at Nigg Bay ranged between 24 mg/l and 144 mg/l, with high turbidity events raising SSC to levels of between 529 mg/l and 899 mg/l.

The impact will be continuous but temporary, lasting for the duration of the capital dredge (19 months) only, and will be localised to within the study area but slightly beyond the development boundary (seaward extents of the breakwaters). Effects of the impact will relate to (i) physiological effects and (ii) alteration to feeding and migration behaviours, as described below.

(i) Physiological effects

Much of the information on the tolerance of fish to increased SSCs derives from laboratory testing and observation. Whilst this produces potentially useful tolerance data for assessment purposes, some caution is needed in applying these to fish in the field. This is because other environmental factors, such as sediment types, water velocity, abrasive effects and feeding are unlikely to have been exactly replicated in the laboratory and may otherwise exacerbate the harmful effects of increased SSCs over those recorded from laboratory simulations.

From a review of the literature, it can be generalised that:

i. Estuarine and demersal fish are more tolerant to increased SSCs than pelagic species given their natural association with seabed habitats and estuarine environmental conditions. Robertson et al. (2006) report that both juvenile and adult fish can generally tolerate high concentrations of suspended sediment with direct mortality only occurring when concentrations are extremely high (i.e. in the 10,000 mg/l to 100,000 mg/l range);

ii. Eggs and larvae are more significantly affected by increased SSCs than juvenile or adult fish (Engell-Sørensen and Skyt, 2001); and

iii. With respect to broad threshold values for assessment purposes, concentrations in the range of milligrams per litre can be lethal for eggs and larvae, whilst concentrations in the range of grams per litre are lethal for juveniles and adults (Engell-Sørensen and Skyt, 2001).

Tolerance appears to be a function of size and temperature. For instance, newly emerged fish were reported to die at lower concentrations of 100 mg/l to 1,500 mg/l (Robertson et al., 2006), and juvenile coho salmon (*Oncorynchus kisutch*) exhibited greater tolerance to SSCs at moderate temperatures of 7 $^{\circ}$C compared to extreme temperatures of 1°C and 18°C (Birtwell, 1999).

Keller et al. (2006) explain that sensitivity of fish to SSCs is both species and life stage specific and is subject to the combination of physical variables of the disturbance itself, i.e. particle density and distribution, mineral composition, grain size and angularity, and prevailing oxygen and temperature conditions, as well as the duration of the impact. The fish's respiration rate is also a key factor in its sensitivity to SSC, as this relates to the degree to which their gills are exposed to the sediment in the water.

Pelagic eggs are particularly sensitive to increases in SSC, as any sediment particles adhering to their surface will cause them to become heavier and sink to the seabed where benthic predation, reduced oxygen and mechanical stresses can cause mortality. Sediment concentrations of 5 mg/l were found to increase the sinking rate of cod eggs, although increased mortalities of cod eggs were not found below concentrations of 100 mg/l (Keller et al., 2006). Demersal eggs are more tolerant to raised SSC, with herring being reported to be tolerant to a thin covering of sediment of concentration 7,000 mg/l. Furthermore, herring eggs exposed to constant SSCs of 5 mg/l to 300 mg/l and short-term exposure to 500 mg/l elicited no adverse response (ECORP, 2009).

Fish larvae are more sensitive to suspended sediments than fish eggs of the same species (Engelll-Sørensen and Skyt, 2001). Sensitivity relates to the adherence of fine sediment particles on their gills, which can cause suffocation, and reduced visibility of their planktonic prey in turbid conditions, which reduces feeding. Indicative thresholds are found in the literature (Keller et al., 2006) and include SSCs of 10 mg/l which increased mortality in cod larvae, and 20 mg/l which was found to reduce the ingestion rate of herring. Herring larvae exposed to SSCs of 540 mg/ showed significantly reduced growth rates.

(ii) Alteration to feeding and migration behaviours

Fish can have a range of behavioural responses to increases in SSCs, including altered schooling behaviour, cover abandonment, feeding and avoidance or attraction, some of which may relate to changes in light penetration (ECORP, 2009).

In general, the typical response of mobile species to adverse SSCs is avoidance although there appears to be a very wide range in the tolerance thresholds to increased SSCs between species. Demersal species tend to be more tolerant than pelagic fish. For example, smelt exhibited avoidance to SSCs as low as 22 mg/l whilst plaice survived suspensions of 3,000 mg/l for a period of fourteen days (Keller et al, 2006). Long term avoidance may have negative consequences for fish and shellfish as a result of displacement from feeding areas, reduced visual ability for locating prey, and interruptions or barriers to migration.

Significant avoidance behaviour of juvenile and adult herring has been found to occur at comparatively low levels of 10 mg/l to 12 mg/l. Other laboratory tests recorded tolerance thresholds of only about 3 mg/l in herring and cod. Herring may be particularly sensitive to increased SSCs due to their long, densely-spaced gill-rakers which makes them vulnerable to gill clogging (Engell-Sørensen & Skyt 2001). These components of the hearing specialists receptor group may therefore avoid much of the area influenced by sediment plumes for the duration of the dredging and use adjacent areas for spawning and feeding. Given their mobility and wide range movement throughout the region, any adverse effect of avoidance on the regional populations of this receptor group is likely to be negligible.

Migratory species such as salmon, European eel and sea lamprey are capable of migrating through areas of elevated SSCs (Newcombe and MacDonald, 1991). For salmonids, avoidance was found to occur at significantly higher SSCs (> 100 mg/l) (Newcombe and MacDonald, 1991). For instance, a seven day exposure to 650 mg/l of volcanic ash did not appear to have an effect on homing in chinook salmon (Robertson et al., 2006).

Salmonids tend to avoid excessively turbid water (Bash et al., 2001). For instance, a mean avoidance of 25% was discovered for juvenile coho salmon exposed to 7,000 mg/l suspended sediment (Bash et al., 2001). Other research has noted a threshold for the onset of avoidance at 300 mg/l in salmonids[1].

In terms of salmonid feeding, increased SSCs may have two competing effects: a reduction in foraging rate, due to reduced visibility of prey, on the one hand; but an increase in foraging rate due reduced predation risk, on the other, such that some salmon species may actually prefer slightly moderately turbid conditions for foraging. Greatest foraging rates in juvenile chinook salmon were found to occur at SSCs of 50 mg/l to 200 mg/l and were lowest when SSCs were 0 mg/l and 800 mg/l (Robertson et al., 2006). Subsequent research (Robertson et al, 2007) found that short term increases in sediment levels of 20 mg/l significantly influenced the behaviour of juvenile Atlantic salmon by increasing foraging activity, which then declined at concentrations of > 180 mg/l. Seasonal differences

[1] http://www2.epa.gov/sites/production/files/documents/mrsboappa.pdf

in avoidance behaviour of juvenile Atlantic salmon were also noted and suggested tolerance to SSCs is greater in winter than in autumn.

Other visually dependent predators like saithe may have a reduced foraging ability due to increases in SSCs but this only becomes significant at very high SSCs from 2,000 mg/l to 3,000 mg/l, at which visual acuity of predatory fish decreases, resulting in their reduced growth (Newcombe and MacDonald, 1991; Birtwell, 1999; Bash et al., 2001). It is not clear whether similar SSCs will elicit similar feeding and growth impairment in other species at Nigg Bay, although shifts in current predator-prey relationships could take place as a result of the increased cover afforded to prey items by increased SSCs.

Growth rates of brown crab have been shown to reduce in conditions of high suspended particulate matter concentrations (Last *et al*, 2011). Experimental trials during which crabs were exposed to concentrations of around 80 mg/l, and comparable to conditions that might be expected within a few hundred meters of an active commercial aggregate dredger, showed significantly reduced mass growth rate after 60 days' exposure compared to control specimens (no suspended particulate matter). This suggested that the crabs under treatment were either feeding less, had a higher energy expenditure or were ingesting a higher proportion of nutritionally inert or low value food.

Results of the predictive numerical modelling

With reference to the sediment plume modelling for the trailer suction hopper dredging technique, which results in the greatest sediment plumes (see ES Appendix 6-B), and the information presented above, the following effects can be forecast:

- Maximum peak SSCs of above 8,000 mg/l will occur at the immediate point of TSHD disturbance but will not extremely short-lived, and will reduce rapidly to between 100 mg/l and 200 mg/l around the mouth of the bay and Girdle Ness. Outside of the embayment, and in front of the mouth of the River Dee, SSCs will be very low (10 - 40 mg/l);
- Pelagic fish and shellfish eggs and larvae will likely be adversely affected or killed by the predicted SSCs within Nigg Bay and around the bay mouth for the duration of the capital dredge;
- Juveniles and adult pelagic fish, such as herring, are expected to avoid peak SSCs due to their comparatively greater sensitivity although demersal and shellfish species will likely be tolerant of predicted peak levels within Nigg Bay;
- Shellfish (such as crab) mass growth rate may be comparatively reduced within the embayment and close environs; and
- Significant barriers to migrating salmonids to and from the River Dee are not likely to occur.

Peak concentrations of SSCs will only last for seconds or minutes due to the predominant sand component settling back to the seafloor very quickly and in close proximity to the initial disturbance. Finer sediment particles are likely to stay in suspension for longer periods and will be subject to gradual dilution and dispersion out of the area (Guillou and Chapalain, 2010).

The greatest consequences of increased SSCs will be to the permanent resident receptor group whose pelagic eggs and larval stages will occur within the influence of the predicted dredge sediment plumes. Effects may include increased mortality of pelagic eggs and larvae which could result in reduced spawning success and recruitment of the species involved for the duration of the impact (19 months).

The duration of the dredging activity may also lead to long-term chronic or sub-lethal effects in some species within this receptor group. This may influence overall fish and shellfish health as well as spawning success and stock recruitment of the permanent resident species. Reduced mass growth rates of crab may also occur in areas of prolonged and significant SSC increases. Spawning and recruitment of these species in adjacent areas and outside of the influences of the sediment plumes will however remain unaffected and effects on the respective populations at the regional level will likely be negligible. Re-population of affected areas post dredging will be via spawning from the surviving adult stock or via immigration of individuals from neighbouring unaffected areas and will be dependent upon the degree of restitution and availability of suitable habitats post construction.

Seasonal residents will likely be comparatively less affected as their egg and larval stages will occur largely offshore and outside of the influences of the sediment plumes. Some species, such as cod, whiting and lemon sole have, however, been identified as having spawning habitats which overlap the current development (see ES Appendix 13-A: Fish and Shellfish Ecology Technical Report) and as such, their eggs and larvae may be affected where they interact with sediment plumes arising from the capital dredging. However, in the context of the wider availability of the spawning habitat of these species, any effect on regional spawning and on regional population levels is likely to be negligible. Juveniles of this receptor group use inshore waters during spring and summer months and, given their mobility and use of the wider inshore area, are expected to be able to move away from significantly adverse areas before lethal levels are experienced.

Sandeel deposit their eggs on the seabed by adhering them to grains of sand. These may subsequently be buried temporarily and re-exposed by the naturally shifting sands to which the eggs will be tolerant. Given the tolerance to naturally disturbed sediment conditions, it is expected that sandeel eggs will be largely tolerant to the predicted increases in SSCs.

Similarly, herring eggs are deposited on the seabed and with reference to the literature above, have been shown to be tolerant to adverse sediment effects. The larvae of these species, will, however be sensitive and will likely be killed if exposed to significant SSCs for prolonged periods. Both sandeel and herring larvae drift in the plankton for one to a few months prior to hatching and will thus be unable to avoid adverse areas. Sandeel larvae hatch in February or March and herring larvae may appear in the plankton around late autumn or winter time if spawning occurred within the typical period between August and September. However, the area predicted to be within the influence of raised SSCs is very small in comparison to the regional distribution of sandeel and herring spawning habitat, and thus any effects on spawning success and population levels of key ecosystem species and hearing specialists will likely be negligible.

SAC qualifying feature receptors will be exposed to raised SSCs arising from the development site only very briefly during either their inbound passage to the River Dee as adults or emergence to the marine environment as smolts. Lethal effects on salmonids are documented at concentrations from 1 49 g/l to 49 g/l and exposure times of four days (Keller et al., 2006) and sub-lethal effects, such as increased ventilation, gill damage, elevated blood sugar levels and reduced resistance to disease, in the range of 270 mg/l to 6,000 mg/l (Robertson et al., 2006).

Predicted SSCs arising from the dredging are expected to be within the lower range of tolerance for salmonids. Some avoidance of the development area by salmonids may therefore occur for the duration of the dredging programme and whilst SSCs exceed tolerable levels. The spatial extent over which lethal and sub-lethal effects are predicted to occur will be small. Given their mobility and wide range movement, Atlantic salmon, and other salmonids, are not considered to be solely reliant on Nigg Bay or local surrounds (within the influence of sediment plumes) for the viability of their populations, and are expected to be able to avoid significantly adverse SSCs before lethal levels are experienced.

On arrival at the coast, adults and smolts are expected to quickly disperse either upstream or out to sea, so long-term exposure to significantly increased SSCs are not forecast, and chronic or sub-lethal effects are not anticipated. Effects on salmonid eggs and larvae will not occur as these stages occur in riverine environments outside the influence of the sediment plume. Indirect effects on freshwater pearl mussel populations are not expected.

Peak SSCs to the north of Girdle Ness are predicted to be 10 mg/l to 40 mg/l suggesting that the spatial extents and distribution of the sediment plumes will be largely contained within the development site. Just outside of Nigg Bay (seaward extents of the breakwaters), predicted SSCs are forecast to be within the range of optimal foraging for other salmon species (see above). Furthermore, salmon will have some tolerance to elevated SSCs as they migrate through turbid estuarine environments during their up and down stream migration movements. Consequently, feeding and migration of the SAC qualifying features receptor group are not anticipated to be significantly affected by increased SSCs and this group may actually derive some benefit from reduced predation risk in conditions of moderate SSCs.

European eel will approach the local coast and riverine catchments in their larval form prior to river entry and upstream migration. The effects of the predicted SSCs on eel larvae are not known but given their migration route through estuary environments, some natural tolerance appears likely. Effects of raised SSCs will be localised, largely within Nigg Bay. Significant adverse effects on European eel are therefore not expected.

Prolonged periods of elevated SSCs may also reduce the amount of light available for photosynthesis for local benthic algae (seaweeds) and phytoplankton. This could reduce the rate of primary production within affected areas, resulting in reduced food availability, which may have negative consequences for species higher in the local food chain, including permanent and seasonal fish and shellfish residents. In addition, fish and shellfish receptors that use algae and algal habitats in Nigg Bay as food or refuge may be adversely affected by localised declines due to reduced light availability for photosynthesis.

In conclusion, the effects of increased SSCs will be temporary, localised and limited to the footprint of the sediment plumes. Displacement, reduced growth or loss of fish and shellfish is expected at the individual level for the permanent and seasonal resident receptor groups only. The effects will cease on completion of the capital dredging operation. Effect magnitude is, therefore, considered to be **minor** on **low** value receptors. Effect significance is therefore judged to be of **minor adverse** significance, which is not significant in EIA terms.

With regard to risk, the effects of SSCs on fish and shellfish are **near certain** to happen and have been verified through empirical observation. The presence of additional variables in the field however, caveats the predictions made. Risk is therefore judged to be **medium**.

This assessment carries **medium** certainty as the spatial extents of the impact have been modelled but the detailed species specific responses and tolerances in the field are subject to a number of physical and biological variables and have been estimated based on laboratory observation.

13.7.2.6 Temporary Deposition of Sediment Plumes Arising from Dredging

A temporary increase in sediment deposition on the seafloor will occur as a result of the settlement of sediment plumes that have been suspended by capital dredging operations. Heavier fractions of the sediment, including sand and gravel grade sediments, will fall back to the seabed quickly (within seconds or minutes) and in relatively close proximity to the original disturbance. Finer particles, such as silt and clay, will remain in suspension for longer and will be dispersed over a wider area, being eventually deposited on the next slack tide (within 6 hours). These fine sediment deposits will then be re-mobilised and further dispersed out of the area on subsequent tides. Significant deposition of plumes may lead to a net accumulation of deposits on the seafloor over the life of the capital dredge.

Effects of any significant deposition include: (i) burial of sessile or sedentary juveniles and adults and demersal eggs; and (ii) modification to sediment habitat as a result of a change in particle size distribution. In both instances, the effects will be temporary, lasting for the duration of the capital dredge only (19 months) and will cease on completion of the activity. The continual action of wave and tidal currents will re-mobilise any settled fine sediments and will eventually disperse fine material out of the wider area and restitution of habitats to baseline conditions will occur. Heavier particle grades will take longer to be dispersed and may require more energetic wave and tide events to be mobilised or they may become permanent features of the seabed.

(i) Burial

Significant deposition of sediments can have adverse effects on sessile or sedentary shellfish, such as scallop, fan mussel and common whelk, which may become buried, resulting in smothering, clogging and damage to feeding and respiratory apparatus. Prolonged deposition is likely to result in increased mortality (Szostek et al., 2013). Heavy and prolonged sedimentation may also affect the foraging activity of demersal species like cod, saithe and whiting by preventing access to prey.

Significant deposition of sediments can also smother fish eggs (Bash et al., 2001) which have been laid on the seabed, i.e. the eggs of herring, common whelk and oviparous elasmobranchs, causing egg mortality through inhibiting oxygen uptake.

Deposition of sediment on intertidal areas may infill rock pools and crevices which are otherwise used by small fish and crabs for foraging and refuge during low tide occasions. These species may need to temporarily relocate to adjacent rocky areas until subsequent tides and wave action has remobilised the deposited sediment.

(ii) Modification to sediment habitat

Effects of temporary increases in sediment deposition also include modification of the sediment grain size distribution of preferred sandeel habitat as a result of an overall fining of the substrate, leading to sub-prime condition. Sandeels are known to avoid areas of fine sediments (greater than 4% silt and greater than 20% fine sand) in favour of areas with medium to coarse-grained sand (Holland et al., 2005). This is because they derive their oxygen requirements from the water within the interstitial spaces between coarse sand grains, and any significant deposition of fine sediments within or on preferred substrates might clog or irritate gills and prevent respiration of both adults and eggs. Prolonged habitat change could lead to a reduction in the abundance of sandeels over affected areas for the duration of the impact although recovery of habitat conditions, via erosion and winnowing of fine sediments from the seabed by natural wave and tide action, and recolonisation of any denuded areas would be expected on cessation of the activity.

Female egg bearing brown crab require coarse, well oxygenated substrates in which they partially bury during winter periods. Significant deposition and fining of these substrates may displace over-wintering brown crab to other areas outside of the sediment influences.

Results of the numerical modelling

The numerical modelling (ES Appendix 7-D: Sediment Plume Modelling) showed that deposition of fine and very fine sand will be deposited quickly and close to the point of release within Nigg Bay. Mud particles will remain in suspension for longer and will be transported outside of Nigg Bay. Outside of the bay, deposition is only predicted to be very light producing a deposit of 1 mm depth at Girdle Ness. North of this point, deposition is forecast to be less than 1 mm.

The area over which increased temporary deposition is predicted to occur is very small, confined mostly to the development area, so that significant adverse effects of smothering of eggs of demersal spawners are not expected within the context of the wider regional distribution of herring spawning habitat. Similarly, the small area of effect outside of the proposed harbour is not expected to have any significant adverse consequences sandeel habitat across the wider region. Other species which spawn in the study area, such as cod, plaice and lemon sole, are broadcast spawners with buoyant eggs that are dispersed within the water column over a wide area, so their eggs will not be susceptible to potential sediment smothering.

Shellfish species, such as crab and lobster, may be temporarily displaced in the event of significant smothering and changes in sedimentary conditions. However, due to their mobility and ability to burrow out of sediments, no mortality is predicted (Neal and Wilson, 2008). Note that any sediment released as overspill will be removed by subsequent dredging. Local rocky areas used by these species are likely to be continually swept clear of excessive sediment deposits during and immediately following dredging activity due to on-going tide and wave action, so significant sedimentation of adjacent crab and lobster rock habitat is unlikely. There are no known brown crab over-wintering grounds within the study area but given the small area of impact, no significant adverse consequences on spawning brown crab populations within the wider region are forecast.

In conclusion, effects of increased sediment deposition will be local, temporary and intermittent. Many of the species found within the study area are regarded as having a degree of tolerance and recoverability to effects due to the naturally disturbed sediment conditions found inshore within and around Nigg Bay. Impacts will only occur over a very small portion of the available demersal herring and sandeel spawning habitat. The impact will cease on completion of the capital dredging operation. Effect magnitude is, therefore, considered to be **minor** on **low** and **medium** value receptors. Effect significance is therefore judged to be of **minor adverse** significance, which is not significant in EIA terms.

With regard to likelihood, the effect is **near-certain** to happen. Risk is therefore judged to be **medium.**

This assessment carries **high** certainty as the spatial extents of the impact have been modelled.

Temporary Release of Sediment Contaminants Due to Dredging

Site specific sediment analyses found all sediment contaminants tested to be below Marine Scotland’s Action Level One (see ES Appendix 12-B). This means that the levels of surface sediment contaminants within the development area are not considered a danger to the environment if disposed of at sea. Significant bio-accumulation of contaminants within fish and shellfish is not anticipated as a result of the capital dredging. Reduction in dissolved oxygen and chemical release from suspended sediments should be minimal and short lived (Lasalle, 1990 in Vivian et al., 2005).

Significant adverse effects on fish and shellfish receptors are therefore not expected and effect magnitude is therefore considered **negligible**. Consequently the effect is forecast to be of **negligible** significance**,** which is not significant in EIA terms.

The likelihood of the effect occurring is judged to be **extremely unlikely** and overall risk is thus **Low**.

The assessment is associated with **high** certainty as contaminants from site-specific seabed sediment samples have been tested within an accredited laboratory and results compared with Marine Scotland guideline values. Vivian et al. (2005) note that traditional fears of water quality degradation resulting from the re-suspension of sediment during dredging and placement operations are mostly unfounded.

13.7.2.7 Accidental Releases of Environmentally Harmful Substances

Releases of chemicals such as fuel, oil and lubricants into the marine environment during construction have the potential to be harmful to marine life. Fish and shellfish species have varying degrees of sensitivity to pollutants depending on the stage of their lifecycle, the type and quantity of substance entering the marine environment and the dilution and dispersion properties of the receiving waters.

Mobile fish and shellfish species would avoid significantly affected areas altogether and would return once conditions improve. Less mobile species, unable to avoid accidental pollution events, such as the permanent residents and juvenile components of the seasonal residents receptor groups, may experience high mortalities (Law and Hellou, 1999) depending on the type and nature of the spill.

The magnitude of this impact on fish and shellfish receptors depends upon the quantities and nature of the spillage/release, the dilution and dispersal properties of the receiving waters and the bio-availability of the spilt contaminant. Therefore, there is potential for an effect of **major adverse** significance on fish and shellfish receptors to occur. Note that this will be the significance of the unmitigated impact. Mitigation measures to reduce the likelihood of the impact occurring are presented in Section 13.8.

As presented in section 13.8, in the presence of mitigation, the likelihood of a potentially **major** effect occurring is **extremely unlikely**. Risk is therefore judged to be **medium**.

The certainty associated with this assessment is **high** as the mitigation proposed (see section 13.8) is commonly in place for UK ports and harbours to reduce the likelihood of a significant marine pollution event ever occurring.

13.7.2.8 Disposal of Dredged Material from the Capital Dredge at the Offshore Disposal Site

Although some dredged material may be beneficially used within the scheme design, it is expected that the majority of material arising from the capital dredging will be transported to a licenced offshore marine disposal site via hopper barge and disposed to the seabed. Figure 3.7 in Chapter 3: Description of the Development shows the location of the disposal site. Effects of offshore disposal will include localised and intermittent increase in SSC and sediment deposition throughout the period of the construction (3 years).

Sediment contaminant levels within Nigg Bay were found to be below guideline levels and so no adverse toxicity effects are expected as a result of disposal activity. Impacts associated with vessel movements to and from the disposal site on fish and shellfish ecology are considered to be negligible against the backdrop of the numbers of vessel movements within the locale. It should be noted that the proposed offshore disposal site is an existing licensed site which regularly receives material from maintenance dredging operations at the existing Aberdeen Harbour.

Numerical modelling (see Technical Appendix 7D: Sediment Plume Modelling) shows that upon release, the majority of the disposed dredge material (coarser sands and gravels) will settle rapidly to the seafloor in close proximity to the release point. Bed levels at the disposal site are predicted to increase following the disposal of material from backhoe dredging during the construction phase by 2.6 m at the disposal site but in combination with the on-going Aberdeen Harbour dredging disposals, the total bed change is forecast to be 4.0 m. Depth of burial following disposal of spoil from backhoe dredging operations are forecast to be 1.3 m but in combination with the disposal of material from the on-going Aberdeen Harbour works then depth of burial is predicted to be 2.4 m,

Peak SSC for TSHD disposal at the disposal site reaches 10,192 mg/l, but these peaks are very-short lived and SSC return to background concentrations very rapidly, before the next release, with average

SSC at the disposal site of 300 mg/l. Within 0.5 km from the disposal site peak SSC falls to between 872 mg/l and 974 mg/l on each release, for very short lived periods. Within 0.5 km from the disposal site average SSC falls to between 7 mg/l and 8 mg/l on each TSHD release. No discernible plumes are predicted over 750 m from the disposal site.

The peak for backhoe disposal SSC at the disposal site is 4,719 mg/l, though dredged material settles quickly, resulting in an average SSC of 309 mg/l. Within 2 km from the disposal site peak SSC fall to 207 mg/l to the north and 123 mg/l to the south on each release. Within 0.5 km from the disposal site average SSC falls to between 13 mg/l and 14 mg/l on each backhoe release.

It should be noted that this average is considered to be a worst case scenario as the release rate modelled is the maximum possible, which is 2.6 times greater than release rate required to achieve the programme.

Fish and shellfish may be initially attracted to the resulting sediment plume in the water column, for feeding on any released benthic resources or for cover from predation, or be repelled by it, i.e. due to adverse effects of increased SSCs, but any behavioural change would be very short lived (minutes or hours) lasting for the duration of the plume dispersion and settlement only.

On the seabed, significant deposition of dredged material may smother slow moving bottom dwelling fish and shellfish species as well as bury benthic invertebrate communities, causing a localised reduction in benthic prey items. Mobile fish would be expected to avoid being smothered or buried by the disposed dredge material and may derive some short term benefit from the benthic resources associated with the disposed material and associated sediment plumes. Sedentary or sediment dwelling shellfish species, however, may be buried within the footprint of the deposit. Eggs of fish laid on the seabed, such as herring, may also be smothered and may be killed during prolonged periods of burial.

Permanent resident receptors and juvenile components of the seasonal resident receptor groups are highly unlikely to be significantly affected by disposal activities at the offshore disposal site as this is remote to Nigg Bay. No interaction between these receptors and licenced disposal activities are therefore forecast.

Similarly, no significant interaction between the SAC qualifying feature receptor group and disposal activities are forecast given the wide ranging and temporary occurrence of component species within the locale during their migratory movements and the very short term nature of the effects after each disposal event. No significant barriers to migration are predicted.

Significant deposition of fine sediments however, may alter sandeel habitat causing a fining of the substrate. As assessed above, sandeel prefer clean, well oxygenated medium and coarse sand substrates in which they reside and lay their eggs. Accumulation of significant quantities of fine sediments may affect respiration of adults and egg development within the sediment, leading to localised displacement and reduction in sandeel abundance from affected areas. However, the hydrodynamic regime in the area around the disposal site is not predicted to be affected suggesting that the ambient wave and current conditions will be sufficient to return the substrate to baseline conditions through natural erosion and winnowing of fine substrates from the seabed. As such, long term change to sandeel habitat and abundance are not forecast. Effects will be localised and are not expected to significantly affect sandeel populations across the wider region.

In conclusion, the effects would be long term, lasting for the duration of the scheme but highly localised and intermittent and will affect receptors at the individual level only. Effect magnitude is thus judged to be **minor** on low to medium value receptors. Effect significance is therefore predicted to be **minor adverse**, which is not significant in EIA terms.

This assessment is associated with **low** certainty as the nature of the seabed habitat and associated fish and shellfish species within and around the disposal site is not known.

13.7.3 Operation and Maintenance

13.7.3.1 Reduction in the Extent of Original Seabed and Pelagic Habitat

There will be a permanent net loss of seabed habitat in Nigg Bay covering a total area of 212,118 m^2 as a result of the installation of the new quays, lay down areas and breakwaters. This includes a loss of 71,113 m^2 of intertidal habitat and 140,985 m^2 of subtidal habitat and equates to 57% of the total seabed habitat within the marine development area. This will result in important negative consequences for both the permanent and seasonal resident receptor groups which rely on the local benthic resource within Nigg Bay for feeding, spawning and refuge during part or all of their life stages, although effects will be highly localised to within the development area.

Individuals within these receptor groups and which currently use the seabed within the footprint of the infrastructure will be permanently displaced to adjacent unaffected areas. This is likely to lead to a decline in the abundance of fish and shellfish within the development area although populations outside of the bay are likely to remain unaffected. Some species, such as crabs, shrimps, hooknose and gobies may be able to use the vertical or sloping surfaces of the new submerged hard substrata, such as the breakwater walls or the interstitial spaces between any scour protection material, for feeding and refuge, thus partially offsetting the loss of original habitat for some species (further assessment of this is provided below). However, for those seasonal residents using the area for feeding as juveniles, such as plaice, dab, cod and whiting, the loss of over half the available seafloor within Nigg Bay is expected to represent a reduction in the value of this site as a feeding and nursery habitat, resulting in the potential displacement of individuals to other neighbouring unaffected inshore areas.

With regard to the other receptor groups, the effect of the expected net loss of seabed habitat will be negligible in the context of both the overall movement range of the component species and the regional extents of respective nursery and spawning habitats. For example, a small proportion of the available sandeel habitat may be lost as a result of the placement of the breakwaters on the seafloor but other areas of sandeel habitat will remain across the wider area. Effects on the wider sandeel populations are therefore regarded to be negligible. Similarly, herring spawning ground covers a wide area within the region, and a potential reduction in extent due to the placement of infrastructure on the seafloor is expected to be of negligible significance in this regard.

Returning adult salmon generally do not feed and would preferentially take pelagic food items in any case. A reduction in benthic resource and seafloor space in Nigg Bay may therefore be of little consequence to adult salmon although the ability to opportunistically feed may be lost or reduced. Given their wide range movements and lack of site fidelity, the significance of a reduction of inshore pelagic habitat in Nigg Bay on salmon returning to the River Dee (and associated freshwater pearl mussel populations) is not thought to be significant.

Similarly, salmon smolt emerging from the River Dee in April and May, and sea trout from the local and other river catchments, would likely make use of local inshore waters for feeding but would also preferentially take pelagic food items. Consequently, a loss of benthic resource in Nigg Bay may be relatively unimportant in this regard. Furthermore, a localised reduction in sandeel abundance within the footprints of the dredging and new harbour infrastructure would mean that salmon smolt, sea trout and other pelagic feeders would preferentially occupy other areas outside of the harbour where sandeel will remain unaffected. Again, the mobility, large range movements and apparent lack of site fidelity in the marine environment suggests that the effect of a net loss of habitat in Nigg Bay on salmon smolt and sea trout will be negligible.

In conclusion, the effect of a net loss of original seabed habitat will be permanent, lasting for the duration of the development but will be highly localised to within the development boundary. Displacement or loss of fish and shellfish as a result of the net loss of seabed and pelagic habitat is expected at the individual level for the permanent and seasonal resident receptor groups only. Effect magnitude is, therefore, considered to be **minor** on **low** value receptors. Effect significance is therefore judged to be of **minor adverse** significance, which is not significant in EIA terms.

With regard to likelihood, the effect is judged to be **near certain** and risk is therefore judged to be **medium**.

This assessment carries **medium** certainty as the spatial extents of the effect are known but the potential for recolonisation and use of the harbour by fish and shellfish post construction remains uncertain.

13.7.3.2 Changes to Hydrodynamic Regime

The presence of the breakwaters and other port infrastructure will result in localised changes to maximum water levels, current speeds, current directions and wave heights in and around Nigg Bay (see ES Appendix 6-B: Hydrodynamic Modelling and Coastal Processes Assessment).

Changes in water levels could change the availability of the intertidal habitats and associated shallow pools that remain within Nigg Bay following construction, which in turn may temporarily affect foraging and refuge behaviours during particular states of the tide for the permanent fish and shellfish residents. Increases in maximum water levels, as predicted for the area inside the northern breakwater, for example, might extend the upper vertical range of intertidal habitat whilst a lowering of water levels, as forecast for coastal areas to the south of the new harbour, would decrease the upper intertidal range. The predicted changes are, however, very small (4 mm to 5 mm under mean spring tide conditions and up to 11 mm under extreme conditions) and are thus likely to be well within the natural variation to which local species will be tolerant. No significant changes to water levels are predicted outside of the immediate vicinity of the harbour, with the exception of a slight decrease to the immediate south of the development, so effects will remain highly localised.

Changes to current speed, current direction and wave heights could change fish and shellfish habitat through increased sediment deposition or seabed erosion causing smothering and scouring effects or altering dispersal of eggs and larvae beyond natural ranges. The greatest change in current speed is forecast to occur at the southern breakwater where a maximum reduction in tidal current speed of 0.40 m/s is predicted during both spring and neap tide occasions. Within the harbour, average current speeds will be reduced by 0.10 m/s.

Wave action will also be reduced within the operational harbour compared to baseline conditions. The consequence of a reduction in wave action and tidal current speeds post construction will include a comparatively greater deposition of fine sediment. Effects of this on fish and shellfish species may include habitat change (sediment fining), smothering of eggs and sessile or sedentary species and increased egg and larval mortality as assessed above. The severity of these effects is difficult to forecast and will depend on the rates of the sediment deposition and re-suspension, the nature of the recovering seabed, and tolerance of re-colonising species following the capital dredge. Subtidal habitats will also be subject to disturbance by maintenance dredging. Needless to say, the greatest effects will be on the permanent and seasonal resident receptor groups which have been able to re-colonise the harbour following the capital dredge and which utilise the seabed resources during part or all of their life cycle. A change in seabed habitat may alter their benthic food supply whilst eggs laid on the seabed may be buried and lost. Species intolerant to these effects will be displaced to adjacent unaffected areas. Changes in water circulation patterns may alter dispersal of eggs and larvae. In this instance, the presence of the breakwaters is likely to limit passive dispersal (i.e. via tidal movements) beyond Nigg Bay and might also reduce influx of eggs and larval recruits into the bay for re-colonisation.

Other receptor groups are expected to be comparatively less affected by hydrodynamic changes. Migratory species, such as the salmonids, will experience a range of different hydrodynamic conditions during their sea passage and will be expected to be tolerant of the changes predicted here. These species may also have less reliance on benthic resources, as they will preferentially feed on pelagic food items, and thus are expected to be less affected by depositional effects. Migratory species will also spawn outside of the harbour and so changes in local water circulation patterns will be of no consequence. Outside of the harbour development, changes in current speed and associated effects on potential seabed sandeel habitat or herring spawning ground are considered to be inconsequential within the context of the regional availability of these habitat types.

In conclusion, the effects of changes to the hydrodynamic regime will be very small and highly localised resulting in the displacement of individuals of the permanent and seasonal resident receptor groups only. Effect magnitude is thus judged to be **minor** on **low** value receptors. Effect significance is therefore judged to be of **minor adverse** significance, which is not significant in EIA terms.

With regard to likelihood, the effect is **near-certain** to happen. Risk is therefore judged to be **medium.**

This assessment carries **high** certainty as the spatial extents of the effect have been modelled.

13.7.3.3 Changes in Water Quality

Numerical modelling (ES Appendix 7-B: Water Quality Modelling Assessment, as summarised in Chapter 7: Water and Sediment Quality) forecasts a reduction in water quality within the harbour during the operational phase of the scheme. This will occur gradually due to the continued wastewater discharges from diffuse and point sources into the bay and the reduced flushing capacity of the operational harbour compared to the baseline conditions in Nigg Bay, causing an overall build-up of contaminant levels within the harbour. Since there will be some water exchange between the harbour and wider receiving marine environment via tidal movements through the harbour entrance, the concentrations of the chemical constituents of the wastewater discharges will eventually achieve an equilibrium (or near equilibrium) status over time and a continuous deterioration in water quality inside the harbour is unlikely to occur throughout its operational phase. The gradual build-up of pollutants to a semi-equilibrium state within the harbour suggests that there will not be any sudden acute toxic effect resulting in any large scale mortalities. Instead, effects on fish and shellfish are likely to be chronic or sub-lethal resulting from accumulations of pollutants in tissues and organs, where species are exposed to significant levels for significant periods of time. This impact will be limited to species within the harbour itself.

Zeitoun and Mehana (2014) explain that fish living in polluted waters tend to accumulate contaminants in their tissues (principally the liver, kidney and gills) and that accumulation depends on the concentration present, the method of uptake, fish age, feeding habit and various environmental conditions (i.e. temperature, pH, hardness, salinity). Accumulation of contaminants in fish organs leads to structural lesions and functional disturbances (Zeitoun and Mehana, 2014) and also to immunosuppression, reduced metabolism and damage to gills, and epithelia (Austin, 1999) which could affect fish health and result in greater susceptibility to disease and infection. Whilst coastal pollution can affect any life stage of fish, it is during their first year of life that fish are particularly sensitive to toxic contaminants (Sindermann, 1994). The viability of eggs can also be affected due to potential toxic effects on developing embryos, resulting in poor recruitment of subsequent cohorts.

The potential for, and nature of, any sub-lethal effects on fish and shellfish within Nigg Bay are difficult to predict and will depend upon the different species specific and life stage tolerances, rates of uptake and bioaccumulation, and the nature and equilibrium concentration of the contaminants present, as well as the presence of any synergistic effects between different contaminants. In terms of developing possible threshold values for current assessment purposes, Pascoe et al. (1986) found abnormal swimming behaviour in rainbow trout following exposure to 10 mg/l of cadmium for five hours. All fish were dead at this concentration after 50 hours. Vieira et al (2009) found LC_{50}s of copper and mercury at 96 hours for the common goby *Pomatoschistus microps* were 568µg/l and 62µg/l respectively. These concentrations are far higher than those that are predicted to occur within the operational harbour and thus these types of effects are not expected to occur at Nigg Bay.

In addition to contaminants levels, the water quality modelling also predicts a decrease in dissolved oxygen (DO) concentrations within the operational harbour. Minimum predicted concentrations are forecast to be as low as 0 mg/l at some locations on some occasions although levels of 2.69 mg/l are forecast in the southern part of the bay. It should be noted that the water quality modelling was undertaken using a highly conservative assumption that some of the wastewater discharges into the operational harbour comprised a DO concentration of 0 mg/l.

A lowering of DO could have negative consequences for fish and shellfish which require oxygen within the water for respiration. The Water Framework Directive (WFD) standard for oxygenation in marine waters has been developed with reference to the likely biological responses of salmonids and other fish species, and is useful in this instance as a potential predictor of the possible consequences of future water quality on local fish life in Nigg Bay. The upper WFD DO standard for marine waters is 5.7 mg/l, indicating high status and which is required to protect all stages of salmonid fish (UK TAG, 2008). Levels of 1.6 mg/l and below indicate bad status, which would exclude salmonids and result in the marginal survival of resident species. A DO concentration of 2.69 mg/l, as forecast for the southern portion of the operational harbour, falls within a moderate classification suggesting that oxygenation is sufficient to protect most life stages of non-salmonid adults.

Immediately outside of the harbour, DO is forecast to be 6.70 mg/l suggesting well-oxygenated, high status conditions. It also suggests that depressed oxygenation values are only predicted to occur within the operational harbour and will thus be highly localised.

Given the modelled DO predictions, fish and shellfish are likely to be displaced from some areas of the operational harbour as there could be insufficient oxygen to permit respiration. Those that rely on Nigg Bay for some or part of their life cycle stages will be most affected and thus the abundance and diversity of the permanent and seasonal resident receptor groups may decrease within the harbour in response to poor oxygen conditions, although populations immediately outside the development will remain unaffected. Such low DO conditions are not expected to be suitable for salmonids and these species may avoid the operational harbour where DO levels fall below 1.6 mg/l. Given their mobility and wide range movement, the potential exclusion of salmonids from the operational harbour is not considered to be significant as they will be able to exploit other areas within the wider region for feeding. Similarly, other receptor groups occupy very wide areas within the region for feeding and spawning and thus a localised change in water quality is unlikely to significantly affect populations at regional levels.

Salmonids and other migratory species will not be exposed to elevated levels of contaminants for long periods of time as they will pass through the area very quickly during their migration movements to and from the River Dee, and other river systems. Furthermore, the modelling suggests that the spatial extents of the changes to the modelled water quality parameters will be very limited so that there will be little, if any, overlap with the range movements of migratory fish in the region. No significant sub-lethal effects on migratory species are therefore expected. Significant adverse bio-accumulation effects on marine mammals as a result of feeding on contaminated salmonids are therefore not predicted. Marine mammal feeding is addressed in Chapter 15: Marine Mammals.

The modelling also indicates that there will be reductions in the predicted concentrations of contaminants in the area around Girdle Ness suggesting a degree of local improvement following the construction of the scheme. As such, no water quality barrier to migration to and from the River Dee is forecast. A change in DO deficit is forecast for the wider area outside of Nigg Bay but this is predicted to be only a 1 – 5 % increase and is thus unlikely to significantly affect fish and shellfish ecology.

In conclusion, the effects of water quality changes will be permanent, lasting for the duration of the development but will be highly localised to within the operational harbour. Displacement of, or avoidance by, fish and shellfish is expected at the individual level only for permanent and seasonal resident receptor groups only. Effect magnitude is, therefore, considered to be **minor** on **low** value receptors. Effect significance is therefore judged to be of **minor adverse** significance, which is not significant in EIA terms.

The effect is judged to be **near certain** and risk is therefore judged to be **medium**.

This assessment carries **medium** uncertainty as the spatial extents and severity of the effect are known from modelling but the degree to which, and significance of, the displacement of high value SAC qualifying receptors from Nigg Bay is not known.

13.7.3.4 <u>Introduction of New Seabed Habitats</u>

New marine habitats will be introduced into Nigg Bay as a result of the project due to:

iv. The placement of artificial hard substrata represented by new port infrastructure on the seabed; and

v. The deepening of the seabed in Nigg Bay to 9.0 m and 10.5 m below Chart Datum.

The following subsections describe the potential effects of the new habitat conditions and assess their potential effect on fish and shellfish ecology.

i. New Port Infrastructure

New hard seabed and mid-water habitats will be created by the placement of the new quays and associated lay down areas as well as from the installation of the breakwaters and any associated scour protection material. Once in place these structures will become a permanent feature within the development area.

The addition of seabed infrastructure will act to increase the structural complexity of the existing habitats and will introduce new hard substrate. This will provide additional niche habitats and colonisation and refuge opportunities for both fish and shellfish over those that exist at present. Growth of fouling communities will provide food and colonisation, and algae will provide cover and spawning habitat for plant spawners. Kramer et al. (2015) presents a review of submarine artificial structures acting as reefs and includes observations of artificial reefs created in Puget Sound, which provide fish habitat and enhanced recreational fisheries. The reefs were colonised rapidly by fish (within weeks) with climax communities becoming established in about 2 years. The researchers also cite other observations of an artificial reef placed close (<50 m) to a natural reef and which was rapidly colonised by adult fish with a matter of days. Also, an artificial reef placed on sand flats exhibited a higher abundance and diversity of fish than those placed on or near natural reefs. This effect was attributed to the relative isolation of the sand flat which conferred several advantages to colonising fish including reduced predations, competition and nest disturbance.

The observations above suggest that the submerged components of the harbour development would likely be colonised by fish within a short period of time and once construction disturbance effects have abated. Those species living within the immediate vicinity of the new harbour and which are capable of exploiting fouling communities on, or below, hard vertical surfaces, such as crabs and other members of the permanent resident receptor group, are likely to derive the greatest benefits from the greater availability of foraging habitat and refuge. Seasonal residents such as cod and whiting may also derive some improved feeding benefit or cover provided by the new structures.

The creation of new hard substrata habitats will also offer alternative settlement areas, which could provide attachment opportunities for elasmobranch eggs and refuge to juvenile populations of shellfish. In time, this may support existing populations of fish and shellfish in the surrounding areas by acting as a foraging resource and area of refuge. However, it remains unclear whether new habitat increases regional fish and shellfish production or merely concentrates species that would otherwise be dispersed throughout the wider area (Grossman et al., 1997). It is likely that if any observable changes were to occur to fish communities within the study area, they would be highly localised.

Within the centre of the bay where sandy sediments currently dominate, the placement of hard seabed infrastructure will constitute a change to the existing baseline conditions and may cause a localised community shift. This will be particularly evident in flatfish species such as plaice and dab and in brown shrimp because they utilise the softer sandier areas of Nigg Bay for nursery and foraging purposes. A reduction in these habitats may ultimately cause flatfish and brown shrimp to be displaced in favour of hard habitat preference species, as assessed above. Sandeels and brown shrimp, together with some of the flatfish species, may not derive the same degree of benefit from the presence of the new habitat as they would naturally inhabit soft seabed sediments.

ii. Seabed Deepening

Compared to current conditions, the deepening of the seabed within Nigg Bay may:

- Reduce access to benthic food resources for fish and shellfish;
- Reduce light availability; and
- Reduces wave exposure and shear bed stresses at the seabed allowing the accumulation of finer sediment deposits.

The target depths proposed are within the depth range of the species present, so access to benthic food resources is not expected to be significantly affected. Shallower water areas and intertidal areas for fish and shellfish feeding will still remain in the vicinity of Nigg Bay following construction of the harbour, although the total area available for feeding will be reduced, as assessed above. This may result in a reduction in the abundance of affected species, although populations over the wider region will remain unaffected.

The deepening of the harbour basin may change the seabed habitat, resulting in a modified benthic invertebrate community food resource. Perturbed substrates during and immediately following the capital dredge programme are expected to be initially colonised by small mobile invertebrates of low biomass. This may reduce feeding opportunities for the permanent and seasonal residents receptor groups which rely on benthic resources within the bay, leading to a local reduction in abundance or their displacement to adjacent unaffected areas during the period of recovery. Any recolonisation by larger invertebrate species, and improvement in feeding opportunities for fish and shellfish, will be subject to the degree of seabed recovery and stabilisation post construction (see Chapter 12: Benthic Ecology).

The effects of increased sediment deposition as a result of a reduced hydrodynamic regime within the harbour on fish and shellfish ecology have been addressed above and are expected to relate to habitat changes (sediment fining) and smothering of eggs or sessile and sedentary species within the permanent residents receptor group. The deeper water conditions associated with the new basin are likely to exacerbate fine sediment deposition and accumulation on the seabed as the reduced wave action may be insufficient to re-suspend and winnow the fine sediment at greater depths.

In conclusion, the presence of new artificial structures will provide additional hard substrata habitat and micro-niches for colonisation and associated feeding and refuge opportunities for the permanent residents and components of the seasonal resident receptor groups. Effects will be long term, lasting for the duration of the harbour development, but highly localised. Magnitude is thus considered to be **minor** on **low** value receptors. Consequently, the effect significance is judged to be **minor** positive, which is not significant in EIA terms. A deepening of the harbour due to the capital dredge of the basin is not expected to preclude benthic feeding of fish (subject to the status of the post construction benthic communities) but may increase sediment deposition rates and associated adverse smothering effects on **low** value receptor within the site. Effect significance is therefore judged to be overall of **minor** adverse significance, which is not significant in EIA terms.

The effect is near certain to happen and so risk is **medium**.

Certainty associated with the assessment is **low** as the evidence for fish colonisation relates to artificial reefs, which are used as proxies for the submerged components of the port and harbour infrastructure.

13.7.3.5 <u>Temporary Seabed Disturbances and Increases in SSCs Due to Propeller Wash</u>

Seabed disturbances relating to propeller wash have the potential to occur every time a vessel enters or leaves the harbour. This may occur several times a day throughout the operational phase of the project resulting in temporary sediment disturbances, areas of localised scour and temporary increases in SSCs. It is not possible to determine the exact magnitude of the effects from an individual vessel due to the number of potential influencing variables including vessel size, number/position of propellers, water depth, sediment characteristics and the level of shipping activity (UK Marine SAC Project, 2015).

Effects are likely to be highly localised around the area of disturbance and increased SSCs will be very short lived as sediments will settle rapidly back to the seabed following disturbance. Any scour depressions may develop near quaysides during final vessel positioning operations and are likely to persist as long-term features on the seabed. The base and sides of such depressions are likely to be comparatively unstable, supporting little, if any, benthic invertebrate food items for fish and shellfish. Fish and shellfish species may therefore avoid significantly scoured areas for feeding. Elsewhere the vessels will be moving very slowly within the operational harbour and so significant scour effects on the seabed are not anticipated.

Being situated inshore means that the area of the project is already likely to be exposed to variations in SSC and sediment disturbance as a result of wind and wave action on the seabed to which fish and shellfish will be naturally tolerant. Effects from propeller wash are likely to mimic these natural processes representing a minor source of regular disturbance, although the effect will occur on a much smaller scale and will be limited to a highly localised area around the turning basin and berths. Some species may derive marginal benefit from any sediment plumes arising from areas disturbed by propeller wash through increased cover from predation or enhanced feeding opportunities (ECORP, 2009) due to the release of benthic prey.

Receptor groups likely to be affected include the permanent residents and juvenile components of the seasonal residents which have recolonised the harbour post construction.

The operational harbour and channel will be subject to regular maintenance dredging to ensure that navigable depths are maintained for vessel transport. Against the effects of the maintenance dredging (which is assessed below), the effects of any seabed scouring from ships' propellers are expected to be minor or negligible.

In conclusion, effects will be highly localised, very short lived and intermittent but will occur frequently throughout the operational phase at the individual level for the permanent and seasonal receptor groups only. In areas of the harbour that are subject to regular maintenance dredging, the effects of seabed disturbance by ships' propellers are expected to be minor or negligible. The magnitude of the impact is therefore considered to be **minor** on **low value** receptors. Consequently, the significance of the effect is forecast to be of **minor adverse** significance, which is not significant in EIA terms.

The effect is near certain to happen and so risk is **medium**.

Certainty associated with this assessment is **low** as the likely severity of the interactions between the vessel propellers and seabed sediments is not known.

13.7.3.6 Avoidance Due to Increased Vessel Noise and Presence

The forecast increase in vessel traffic and associated noise is unlikely to significantly affect fish and shellfish ecology given the current levels of shipping activity within the locale. Migratory species, for example, already pass through the busy harbour at Aberdeen at the mouth of the River Dee during their migration and so are not expected to be significantly disturbed by vessel movements in the vicinity of the development. Their exposure to vessel traffic using the ports would, in any case, be very brief as they will pass through the local area during their natural northerly migration movements. Any effects on high value SAC qualifying feature receptors are therefore considered to be negligible.

With regard to other receptor groups, those species not displaced or disturbed by construction noise and associated disturbances are unlikely to be significantly affected by noise from vessel traffic using the operational harbour. Effect magnitude is therefore expected to be **negligible** on all receptor groups and overall effect significance is thus considered to be **negligible**, which is not significant in EIA terms.

Significant avoidance due to vessel noise and presence is unlikely to happen and so risk is **low**. Certainty associated with this assessment is **high** as the effects will be within those already quantified and modelled and as assessed above.

13.7.3.7 Introduction of Harmful Species

Vessels using the operational harbour, as well as those involved in its initial construction, can act as vectors for the introduction of various marine species via attachment to hulls or in ballast waters, for example. These may include potential harmful species which, if detached from the hull or discharged via ballast exchanges, may colonise local habitats and compete with indigenous species, resulting in adverse effects on biodiversity. Chapter 12: Benthic Ecology provides a comprehensive assessment of the risk of the introduction of potentially harmful species and highlights the necessary protocols that will be implemented to reduce risk in this regard, such as vessel ballast water management and maintenance of anti-fouling systems.

With respect to the consideration of potential effects on fish and shellfish, the leech-like species *Gyrodactylus salaris* has relevance as a parasite of Atlantic salmon and trout, and has been raised by consultees as a concern during scoping. Detailed information on this species is provided by the European Network on Invasive Species (NOBANIS[2]), and the Department of Environment, Food and Rural Affairs (Defra) has produced a Code of Practice to avoid its introduction to Great Britain[3].

Its natural range is the Baltic regions and its principal distribution is within riverine and brackish water conditions. It is not known in the UK and is intolerant to fully marine conditions, and hence is not anticipated to be able to survive and colonise the habitats within and around the new harbour at Nigg Bay. The risk of its introduction to the UK is associated with the movement of infected fish or materials and related equipment, although Marine Scotland Science note that transfer from, or to, full strength seawater poses a negligible level of risk. As such the introduction of this species to Nigg Bay via attachment to ships' hulls or in ballast waters during the construction and operational phase is highly unlikely.

In conclusion, harmful marine species do have the potential to be introduced through the movement of vessels into the port but the development of, and adherence to, controls such as documented ballast water exchange and anti-fouling management systems within the project Construction and Operational Environmental Management Plans will reduce the risk of this occurring at Nigg Bay. The introduction of harmful species such as *Gyrodactylus salaris* have the potential to have a **major** effect as they could affect high value salmonid fisheries, although in place of mitigation, the likelihood of this occurring as a result of the current proposals is considered to be **extremely unlikely.** Section 13.8 presents mitigation measures.

Uncertainty associated with this assessment is **low** as proposed mitigation measures described in Section 13.8 will reduce the risk of the introduction of marine non-native species.

13.7.3.8 Temporary Seabed Disturbances Due to Channel Maintenance Dredging

Ongoing maintenance dredging within the harbour and entrance channel will increase SSCs and increase local sediment deposition.

[2] https://www.nobanis.org/globalassets/speciesinfo/g/gyrodactylus-salaris/gyrodactylus_salaris.pdf

[3] http://www.gov.scot/Uploads/Documents/CoPGyrod.pdf

Predicted effects on fish and shellfish are likely to be well within those arising from the capital dredging operations and which have been assessed above as **minor adverse.** The exception to this is the on-going, repeated nature of the activity throughout the life of the project such that the seabed habitat and associated assemblages within the dredge footprint (approach channel and inner harbour) will remain in a continual, or near-continual, perturbed state. Full recovery of seabed habitats would therefore be unlikely. Depending upon the extent of each dredging episode, local fish and shellfish populations with high habitat fidelity, such as sandeel or brown shrimp, may avoid the dredged area due to regular habitat disturbances. Recovery of denuded areas may only partially occur at best during interim periods, resulting in a potential permanent depression in the abundance of these species within dredged areas. The effect will be highly localised to the area of the dredging and no significant adverse effects on populations within the wider region are considered likely to occur.

Mobile species with low affinity with the local sediment habitats will be expected to be able avoid areas of adverse seabed disturbance and utilise other areas outside of the influence of maintenance dredging activities.

Temporary local deposition of fine sediments on the seabed may cause a fining of local sandeel habitat resulting in unsuitable conditions. However, wave and tidal action is expected to quickly erode and winnow fine material from the seabed substrate allowing rapid recovery of sandeel habitat after each maintenance dredging operation. Adverse effects on demersal eggs, such as herring eggs, are not forecast due to the short-lived nature of the activity and the tolerance of herring eggs to sediment deposition.

In conclusion, the impacts of each maintenance dredging event on fish and shellfish is considered to be the same or less than those assessed for the capital dredge programme. Long term suppression of demersal species abundance may occur within dredged areas due to repeated sediment disturbance events although this will be highly localised. Effect significance is thus judged to be of **minor adverse** significance, which is not significant in EIA terms.

The effect is considered to be near certain to occur and so risk is **medium**. Certainty associated with this assessment is **medium** as the potential for the recovery of the habitats and associated assemblages within the channel dredge is presently unclear.

13.7.3.9 <u>Behavioural Change due to Changes to the Ambient Underwater Illumination</u>

Changes to ambient light conditions may occur as a result of:

i. The installation of artificial lighting around the new harbour, including navigational lights; and

ii. Shading from new buildings and structures.

The following subsections describe the potential impacts of both artificial lights and shading and assess associated effects on fish and shellfish ecology.

i. Installation of Artificial Lighting

The installation of new infrastructure associated with development will include an increase in artificial night lighting around berthed vessels, walkways and navigational markers. The implications of these unnatural lighting regimes for fish fauna in coastal ecosystems are relatively unknown (Becker et al., 2013). However, artificial night lighting is described by Nightingale et al., (2006) as being capable of influencing foraging, shoaling, migration and reproduction behaviours, as well as altering the predation risk to fish.

Experiments manipulating light conditions have shown clear differences in fish abundance and behaviour, with an increased number of large predatory fish as well as small shoaling fish observed when artificial lights were switched on (Becker et al., 2013). It is likely that conditions created by artificial lighting benefit visually dependent predators like saithe, cod and whiting, by enhancing their foraging opportunities (Becker et al., 2013). This could potentially affect small shoaling species and juvenile fish in nurseries that occur within the illuminated area due to increased predation. Sea trout disperse slowly upon entering the marine environment (Malcolm et al., 2010) and use shallow inshore waters to feed. This means that in sea trout, smolt may face a higher risk of predation should they use the area of the development at night following emergence from the River Dee.

The type and wavelength of lighting used may also have an influence on the nature of the behavioural response elicited. Marchesan et al., (2004) found that flathead grey mullet *Mugil cephalus* showed a strong positive attraction to shorter wavelengths, whereas sea bass *Dicentrarchus labrax* were negatively affected, showing a strong repulsion especially in the presence of colours such as blue and green.

Street lighting has been shown to disrupt the onset of salmon smolt migration, making it more random throughout the day as opposed to being naturally correlated to sunset, when in a riverine environment (Riley et al., 2012). This is considered to affect the overall fitness of salmon smolt which can influence the scale of mortality and strength of the cohort (Riley et al., 2012). However, upon entering the marine environment, salmon smolt rapidly migrate towards open marine areas and in general do not follow nearby shores (Malcolm, 2010). The influence of artificial lighting from the development is therefore considered to be small or negligible, in this regard, and within the context of the artificial lighting conditions already in operation at Aberdeen Harbour. Lighting at the new harbour will be directional and dimmable, and limited to operational and navigable areas, so the impacts are expected to be limited to the immediate vicinity of the new harbour.

ii. Shading:

The presence of docks, buildings and overwater structures will create areas of shading where underwater illumination is reduced. Within the completed development, structures and buildings that may cause shading of marine areas will be very limited (see Figure 3.3 in Chapter 3: Description of the Development). The extents of these shaded areas will alter daily with the movement of the sun and also seasonally with changing sunlight hours available throughout the year. Effects of shading on fish are likely to relate to vision and associated behavioural changes such as orientation, schooling/dispersal, altered predator - prey relationships, and migration direction change and delay (Nightingale and Simenstad, 2001).

Swimming and feeding behaviour in juvenile fish has been observed to reduce in low light conditions as their ability to see prey is limited. In very dark under-pier conditions, for instance, fish were noted to be unable to feed or capture prey (Nightingale and Simenstad, 2001). In other observations, fish abundance under piers was found to be reduced when compared to open-water areas (Nightingale and Simenstad, 2001).

Within the operational harbour, the ability to capture prey may affect growth and survival of juveniles, depending on the extent of underwater shadow conditions and associated prey capture success, and may be confounded or ameliorated by increased SSCs from propeller wash, to which fish may be attracted or avoid. As juvenile fish mature, and prepare to move into deeper waters offshore, visual acuity increases and their ability to see in lower light conditions improves. Larger fish using the harbour, therefore, may be comparatively less susceptible to the effects of low light levels.

Significant shading may also affect habitat conditions, including reduction in the abundance of or complete loss of vegetation, such as seaweed, as a result of reduced light availability for photosynthesis. This may affect both the permanent and seasonal fish and shellfish residents which may use such vegetated habitats as cover and also as feeding areas where prey items, such as small crustaceans, may congregate.

With regard to migrating species, most research on the shading effects of coastal structures relate to the downstream movement of juvenile salmonids (Thom et al., 2006; Ono et al., 2010) and include reluctance of juveniles to pass through areas of low light, such as under piers and delays in migration (hours) until tidal and sunlight conditions are suitable. These aspects are considered not to be of particular concern for the current project as juvenile salmon will migrate down the River Dee and emerge to the marine environment at Aberdeen Harbour where harbour infrastructure already exists.

Returning adult salmon will likely pass close to the new harbour during their inshore northwards migration back to the River Dee, and may experience contrasts in underwater illumination subject to the position and brightness of the sun and dimensions of the harbour structures casting any shadow(s). Effects on returning salmon may include minor directional change or a small delay to entry to the River Dee although the significance of these effects at individual or population level is not understood at present. Within the context of the harbour structures and buildings already present at Aberdeen Harbour, and the historic return salmon migration to the River Dee, the significance of this may be small or negligible.

In conclusion, changes in ambient light conditions will be highly localised to the development area and will occur frequently (daily) throughout the operational phase of the scheme. The magnitude of the shading impact will alter daily and seasonally and may be confounded by increases in SSCs from ships' propeller wash, but will remain within the site. Feeding and growth of permanent and seasonal residents may be reduced in low light conditions, which may affect survivability, although fish and shellfish outside of shading influences and in adjacent areas will remain unaffected. Effect magnitude is therefore considered to be **minor** on **low** value receptors. Consequently, the significance of the effect is judged to be **minor adverse**, which is not significant in EIA terms.

The effect is near certain to occur and so risk is judged to be **medium**.

This assessment is associated with **low** certainty as the final design and lighting plan and associated effects on underwater illumination are not known at present.

13.7.3.10 Disposal of Dredged Material from Maintenance Dredging at the Offshore Disposal Site

Material from the planned maintenance dredging will be disposed at the licenced offshore marine disposal site on a regular basis during the operation of the scheme. Figure 3.7 in Chapter 3: Description of the Development shows the location of the disposal site. Impacts will only occur off site at the disposal location and will be long term, lasting for the duration of the scheme, but intermittent relating to each discrete disposal operation.

Sediment contaminant levels within Nigg Bay were found to be below guideline levels and so no adverse toxicity effects are expected as a result of disposal activity. Maintenance dredge material will be subject to regular contaminant testing in accordance with Marine Scotland requirements. Impacts associated with vessel movements to and from the disposal site on fish and shellfish ecology are considered to be negligible against the backdrop of the numbers of vessel movements within the locale. It should be noted that the proposed offshore disposal site is an existing licensed site which regularly receives material from maintenance dredging operations at the existing Aberdeen Harbour.

Planned maintenance dredging for Nigg Bay will be undertaken to maintain minimum design depths (9 m and 10.5 m below CD). It is anticipated that the dredge volumes required will be significantly smaller than for the ongoing maintenance dredging at the mouth of the River Dee. Therefore, whilst the activity is likely to increase SSCs and introduce noise into the environment, it is considered that magnitude of effects upon fish and shellfish from maintenance dredging will be less than those outlined for the capital dredge construction, which was assessed as **minor** for all species. This is because maintenance dredging will be undertaken on a smaller scale and will occur over a shorter timeframe than that outlined for construction. However, maintenance dredging activities will occur on an intermittent basis throughout the operational life of the project resulting in minor periodic disturbances.

Fish and shellfish may be initially attracted to the resulting sediment plume in the water column, for feeding on any released benthic resources or for cover from predation, or be repelled by it, i.e. due to adverse effects of increased SSCs, but any behavioural change would be very short lived (minutes or hours) lasting for the duration of the plume dispersion and settlement only.

On the seabed, significant deposition of dredged material may smother slow moving bottom dwelling fish and shellfish species as well as bury benthic invertebrate communities, causing a localised reduction in benthic prey items. Mobile fish would be expected to avoid being smothered or buried by the disposed dredge material and may derive some short term benefit from the benthic resources associated with the disposed material and associated sediment plumes. Sedentary or sediment dwelling shellfish species, however, may be buried within the footprint of the deposit. Eggs of fish laid on the seabed, such as herring, may also be smothered and may be killed during prolonged periods of burial.

Permanent resident receptors and juvenile components of the seasonal resident receptor groups are highly unlikely to be significantly affected by disposal activities at the offshore disposal site as this is remote to Nigg Bay. No interaction between these receptors and licenced disposal activities are therefore forecast.

Similarly, no significant interaction between the SAC qualifying feature receptor group and disposal activities are forecast given the wide ranging and temporary occurrence of component species within the locale during their migratory movements and the very short term nature of the effects after each disposal event. No significant barriers to migration are predicted.

Significant deposition of fine sediments however, may alter sandeel habitat causing a fining of the substrate. As assessed above, sandeel prefer clean, well oxygenated medium and coarse sand substrates in which they reside and lay their eggs. Accumulation of significant quantities of fine sediments may affect respiration of adults and egg development within the sediment, leading to localised displacement and reduction in sandeel abundance from affected areas. However, the hydrodynamic regime in the area around the disposal site is not predicted to be affected suggesting that the ambient wave and current conditions will be sufficient to return the substrate to baseline conditions through natural erosion and winnowing of fine substrates from the seabed. As such, long term change to sandeel habitat and abundance are not forecast. Effects will be localised and are not expected to significantly affect sandeel populations across the wider region.

In conclusion, the effects would be long term, lasting for the duration of the scheme but highly localised and intermittent and will affect receptors at the individual level only. Effect magnitude is thus judged to be **minor** on low to medium value receptors. Effect significance is therefore predicted to be **minor adverse**, which is not significant in EIA terms.

This assessment is associated with **low** certainty as the nature of the seabed habitat and associated fish and shellfish species within and around the disposal site is not known.

13.8 Mitigation and Residual Effects

With the exception of marine impact piling (see below), effects on fish and shellfish have been judged to be of **negligible** or **minor adverse** significance based on the localised and temporary nature of the effects and the widespread distribution of fish and shellfish receptors across the region. In order to further protect local marine life, a pollution prevention plan and protocols to control the introduction of potentially harmful species will be developed and will be incorporated into an overall Environmental Management Plan as outlined in Chapter 26: Environmental Management Framework).

Underwater noise and vibration

The effects of marine impact piling is judged to be of **moderate adverse** significance as a result of predicted adverse noise levels on a sensitive and high value receptor, salmon. Proposed mitigation measures for piling operations include:

- Impact piling will be restricted to day-time hours only (Monday to Friday 0700 to 1900; Saturday 0900 to 1600) during periods of peak sensitivity (see Table 13.23);
- Application of soft start procedures prior to full energy impact and following JNCC guidance (JNCC, 2010);
- Where practical, vibro-piling will be used instead of hammer piling (pile driving by vibration is often implemented to mitigate adverse noise (van den Akker and van der Veen, 2013);

- Bubble curtains, foam sheeting or mattresses to be investigated to establish their suitability and effectiveness in reducing propagation of underwater noise; and
- Contribution to relevant salmon monitoring efforts to inform mitigation, where appropriate.

The period of peak sensitivity is April to July, within which no impact piling will take place during the night. This period covers the timing of the peak emergence of salmon smolts, the peak return of spring MSW salmon and the peak occurrence of returning autumn grilse in local coastal waters.

Table 13.23: Period of peak salmon sensitivity within which restricted hammer piling may be required

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Atlantic salmon												

= hammer piling throughout day and night

= no hammer piling at night

With these mitigation measures in place, significant adverse underwater noise impacts on high value salmon receptors during peak periods of sensitivity will be removed. Instead, the effects of underwater noise are forecast to result in a temporary and intermittent displacement of, and avoidance by, resident and seasonal resident receptor groups from the local area for the duration of the activity only. Consequently, effect magnitude is judged to be **minor** on **low** value receptors in the presence of mitigation. Residual effect significance is thus predicted to be of **minor adverse** significance, which is not significant in EIA terms.

The final design and implementation of the mitigation measures will be developed and agreed in consultation with the regulators and stakeholders for subsequent incorporation within the Environmental Management Plan (EMP). Further detail is provided in the outline EMP within Chapter 26 of this ES.

It should be noted that the assessment of piling noise is highly precautionary and reflects a worst case scenario of large piles installed over months or years during the construction period. Once the final detail of the construction design is determined, the significance of effects may reduce accordingly. For example, a reduction in the size or number of piles to be installed would reduce the levels of adverse noise entering the marine environment, whilst the partial or complete construction of the north and south breakwaters prior to the onset of piling activity may attenuate noise propagation beyond the embayment. As such, the final design itself may offer sufficient in-built mitigation to ameliorate the predicted effects on migrating salmon.

13.9 Cumulative Effects

Cumulative effects have been identified and assessed where the potential zone of influence and receptor footprints relevant to the current scheme overlap with the effects that are predicted to arise from other developments. The projects listed in Table 13.24 have been selected from the list provided in Chapter 5: Environmental Impact Assessment Process.

Table 13.24: Projects and plans considered within the assessment of effects on fish and shellfish ecology

Project/Proposed Development	Approximate Distance to Project [km]	Status	Cumulative impacts identified
Aberdeen Maintenance Dredging	2	On-going	Underwater noise and vibration, increased SSCs, deposition of sediment plumes, net loss of seabed habitat, introduction of new habitat and operational noise.
European Offshore Wind Deployment Centre	10	Consent approved	
Kincardine Offshore Wind Farm	12	Application	

13.9.1 Cumulative Underwater Noise (Offshore Wind Farms)

The European Offshore Wind Deployment Centre (EOWDC) is located 10 km north of the Aberdeen Harbour Expansion Project and involves the installation of around eleven monopiles of 8.5 m diameter (worst case) or jacket structures. As an experimental development site to trial various foundation types, the exact number and type of installations is not known at present and the final number installed foundations may be less (Aberdeen Offshore Wind Farm Limited, 2011).

Numerical modelling predictions of noise propagation from worse case piling (8.5 m diameter piles) at the EOWDC (Aberdeen Offshore Wind Farm Limited, 2011) show that levels of noise which would result in traumatic hearing damage in salmon would occur out to a distance of 20 m from the activity. The modelling also showed that strong behavioural reactions in salmon would be expected at a range of up a maximum of 4.7 km. Within the vicinity of the River Dee, underwater noise arising from worse case piling at EOWDC was predicted to be at levels at which 85% of individuals would react, although effects will probably be limited due to habituation (Aberdeen Offshore Wind Farm Limited, 2011).

A cumulative effect could therefore occur in the event of any consecutive piling activity at Aberdeen Harbour Expansion Project and the EOWDC. This would increase the period over which piling is undertaken and would therefore potentially prolong avoidance behaviour in certain individuals of salmon. Where respective underwater noise impact ranges overlap the mouth of the River Dee, any prolonged avoidance behaviour may increase the period of delayed migration either upstream (adult salmonids) or downstream (smolts) compared to the delay that might be caused by the schemes in isolation.

As noted by Aberdeen Offshore Wind Farm Limited (2011), the assessment of underwater noise effects on salmon was undertaken using a worst case scenario using the maximum number (eleven) of the largest piles (8.5 m). It was also noted that piling at EOWDC will not be continuous and that under normal conditions, piling of foundations for offshore wind farms usually takes between 20 minutes and thirteen hours. Therefore, once commenced, the piling activity at EOWDC is likely to be completed in a very short space of time and so the duration of any cumulative effects will be short lived.

The imposition of restricted percussive piling at night during peak migration periods as mitigation within the current project (as discussed in Section 13.8) would reduce the significance of the potential cumulative effects of piling on salmon.

Levels of underwater noise from the Nigg Bay and EOWDC developments will not be additive in the event that piling is undertaken simultaneously. Levels of noise in the marine environment are therefore not considered to be elevated above those generated by the individual schemes in isolation.

The Kincardine and offshore wind farm project plans to install floating structures so significant effects of underwater noise from impact piling operations on salmon will not occur.

13.9.2 Cumulative Effects of Raised Sediment Plumes

13.9.2.1 Kincardine and European Offshore Wind Farms

Significant interaction with plumes originating from the construction of the EOWDC and the Kincardine Floating Offshore Wind Farm is not expected (located 10 km and 12 km away respectively), due to the limited spatial extents of the predicted plumes and the distance separation between respective projects. These schemes will not involve extensive bed levelling or dredging works and so seabed disturbances and associated raised sediment plumes will be minimal and short lived. Also, the tidal currents will disperse the respective plumes along parallel axes so that significant convergence and coalescence are unlikely to occur.

13.9.2.2 Existing AHB Maintenance Dredging

The characteristics of the disposed sediment and local hydrodynamic regime predicted quick settling times and extremely localised high SSC predicted for coarse sediments for both baseline maintenance dredging and construction dredging individually. This is also the case for modelling cumulative impacts for maintenance and construction dredging combined.

Peak rates were modelled for cumulative TSHD and AHB maintenance disposal, but this is unlikely to have any relevance to real world scenarios as the peak SSC are extremely short-lived events at the point of release, and two vessel would be unlikely to release at the same time. However comparisons between the disposal site and nearby data extract points, and comparisons between peak and average SSCs demonstrates the localised and short-lived nature of these events, even when considered cumulatively.

Peak SSC for cumulative TSHD and AHB at the disposal site was 29,169 mg/l, falling more than an order of magnitude to 2,774 mg/l at 708 m to the north, and to 2,363 mg/l at 886 m to the south. Average SSC was more than 35 times lower at the disposal site, at 813 mg/l. Average SSC falls to 101 mg/l at 463 m to the north and to 106 mg/l at 463 m to the south. These cumulative average levels are within natural background variability less than 0.5 km from the disposal site.

13.9.2.3 Cumulative Effects of Elevated SSC for All Projects

Diadromous species, such as salmon, are highly mobile and wide ranging and may therefore encounter two or more separate sediment plumes arising from separate construction projects. A cumulative effect may occur in this regard if the effect of a repeat encounter adds to the effect of the previous one, for instance if a fish repeatedly fails to feed due to repeated startle and avoidance reactions to successive plumes. The significance of the effect of multiple exposures to separate plumes by wide ranging species is considered to be negligible. This is because the likelihood of this occurring will be remote due to the limited spatial extents and temporary nature of the plumes.

Migratory species, such as salmon, would also be expected to be able to avoid adverse conditions due to their mobility and large range movement, and will be tolerant to a certain degree due to their natural tolerance to turbid estuarine environments through which they pass on their migration. In conclusion, no significant cumulative effects of raised sediment plumes on fish and shellfish ecology are forecast.

13.9.3 Introduction of New Habitat

The introduction of new habitat created by the project and the installation of offshore wind turbines and cable protection materials will cause a small scale change to the natural habitat characteristics of the region. There is evidence to show that engineered structures can influence diversity and potentially increase the abundance of fish and shellfish species by altering the community structure (Linley et al., 2007, Langhamer and Wihelmsson 2009). For fish and shellfish species (e.g. European lobster) limited by the natural amount of available territory, refugia and food, the introduction of new habitat may augment colonisation. Any potential shifts in community structure however, are likely to be highly localised around the structures, and significant cumulative effects with other projects are not forecast.

13.10 Summary and Conclusions

Fish and shellfish within the locale include species from the pelagic, bentho-pelagic and demersal assemblages, with the latter being the most diverse containing several members of the cod family, flatfish and elasmobranchs. Migratory species such as salmon, sea trout and eel are present within the study area, particularly within coastal waters during migration to and from Scotland's east coast rivers, the closest to the Project being the River Dee. Salmon, as well as freshwater pearl mussel, are qualifying features of the River Dee SAC.

Shellfish communities within the wider area include brown shrimp, brown crabs and scallop. Sandeel were recorded during the site-specific survey and represent important prey for marine birds and mammals. The study area is regarded as part of a wider fish spawning and nursery area for various fish species.

In general, effects of the harbour construction and operation are forecast to be localised and temporary on low value receptors and thus are judged to be not significant. No significant cumulative effects were identified.

The use of hammer piling during the construction phase is predicted to have a moderate adverse effect on high value salmon receptors including avoidance and alteration of migration behaviour. When the proposed mitigation is implemented, including a night-time restriction on impact piling during peak periods of sensitivity, the residual effect significance is reduced to minor adverse. The final design and construction methodology are not yet known and may include a number of in-built measures that reduce the significance of the predicted effects over those assessed.

Table 13.25 summarises the fish and shellfish assessment conclusions.

Table 13.25: Summary of effects

Effect	Significance of Effect	Mitigation Proposed	Residual Significance of Effect
Construction			
Underwater noise and vibration	Moderate adverse	Construction design Hammer piling during the day and vibration piling by night during sensitive periods.	Minor adverse
Seabed habitat disturbances	Minor adverse	No mitigation proposed	Minor adverse
Increased SSCs	Minor adverse	No mitigation proposed	Minor adverse
Deposition of sediment plumes	Minor adverse	No mitigation proposed	Minor adverse
Temporary Release of Sediment Contaminants Due to Dredging	Negligible	No mitigation proposed	Negligible
Accidental spills	Up to major adverse	Development of, and adherence to, an EMP	Negligible
Operation			
Operational noise	Minor adverse	None proposed	Minor adverse
Reduction in the extent of original habitat	Minor adverse	None proposed	Minor adverse
Change to the hydrodynamic regime	Minor adverse	None proposed	Minor adverse
Change to water quality	Minor adverse	None proposed	Minor adverse
Introduction of new seabed habitats	Minor beneficial (new hard substrata) Minor adverse (seabed deepening)	None proposed	Minor beneficial) (new hard substrata) Minor adverse (seabed deepening)
Temporary seabed disturbances and increases in SSCs due to prop wash	Minor adverse	None proposed	Minor adverse
Avoidance due to increased vessel noise and presence	Minor adverse	None proposed	Minor adverse
Introduction of harmful species	Up to major adverse	Development of, and adherence to, relevant protocols.	Negligible
Seabed disturbances due to channel maintenance dredging	Minor adverse	None proposed	Minor adverse
Behavioural change due to changes to the ambient underwater illumination	Minor adverse	Lighting will be directional and dimmable to minimise light spillage.	Minor adverse
Disposal of spoil at the offshore disposal site	Minor adverse	None proposed	Minor adverse

13.11 References

1. ABERDEEN HARBOUR BOARD. Harbour Entrance Improvement Works Environmental Statement. Volume 1. March 2012.

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