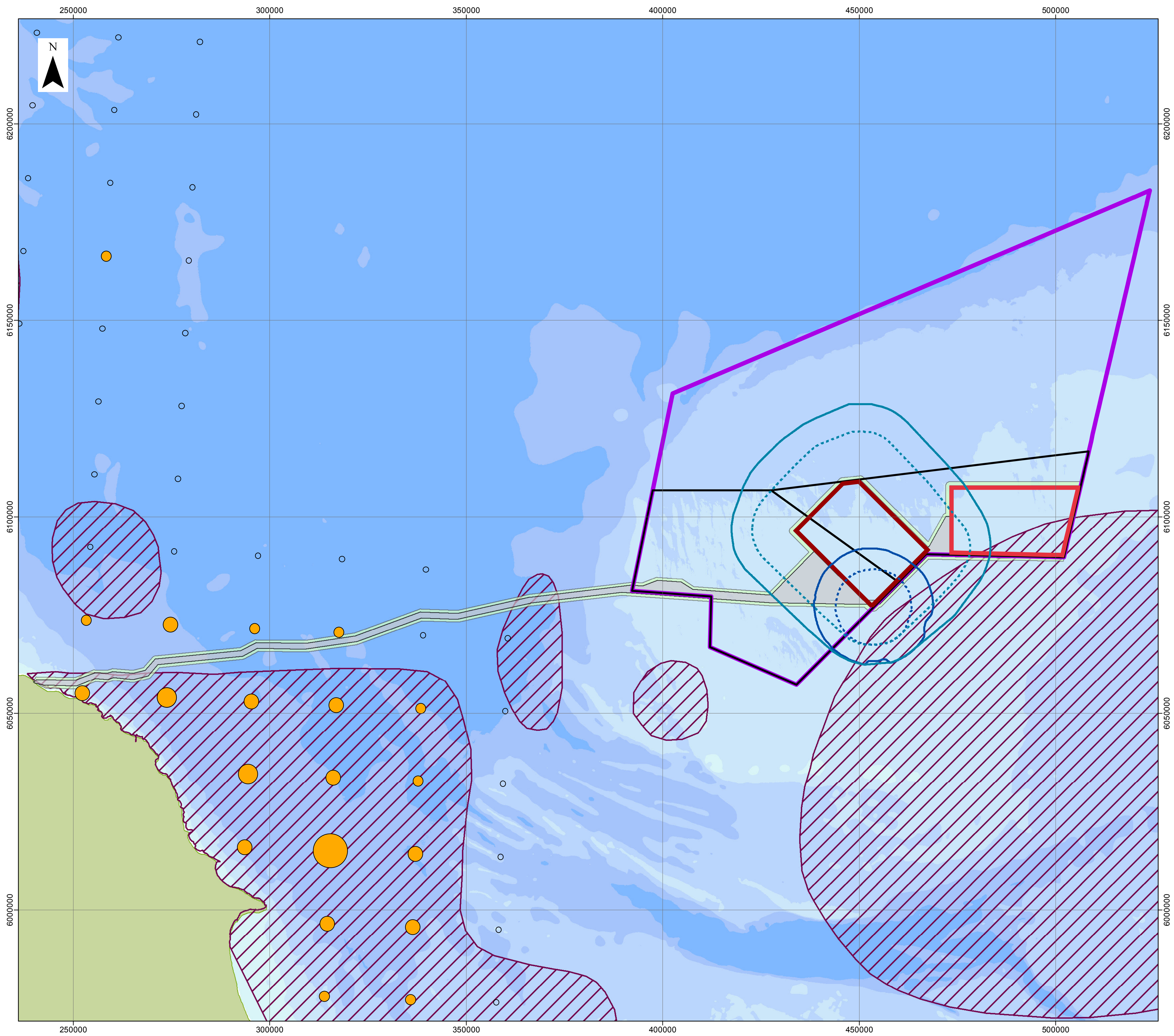
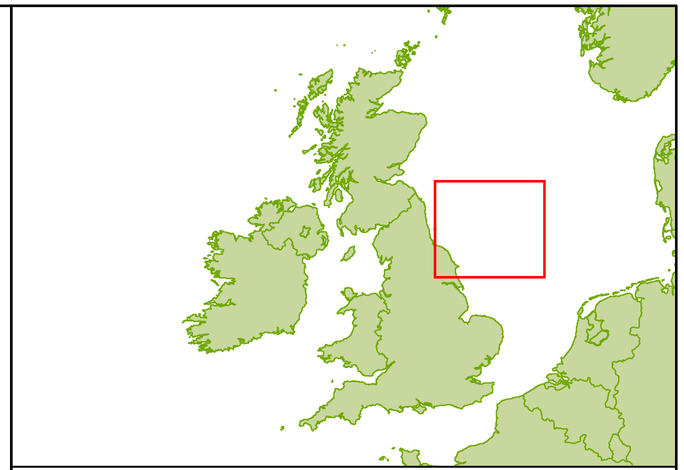




LEGEND

Data Source:
Modelling © NPL Management, 2013
Herring larvae © IHLS, 2013
Spawning Grounds © Cefas, 2012
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

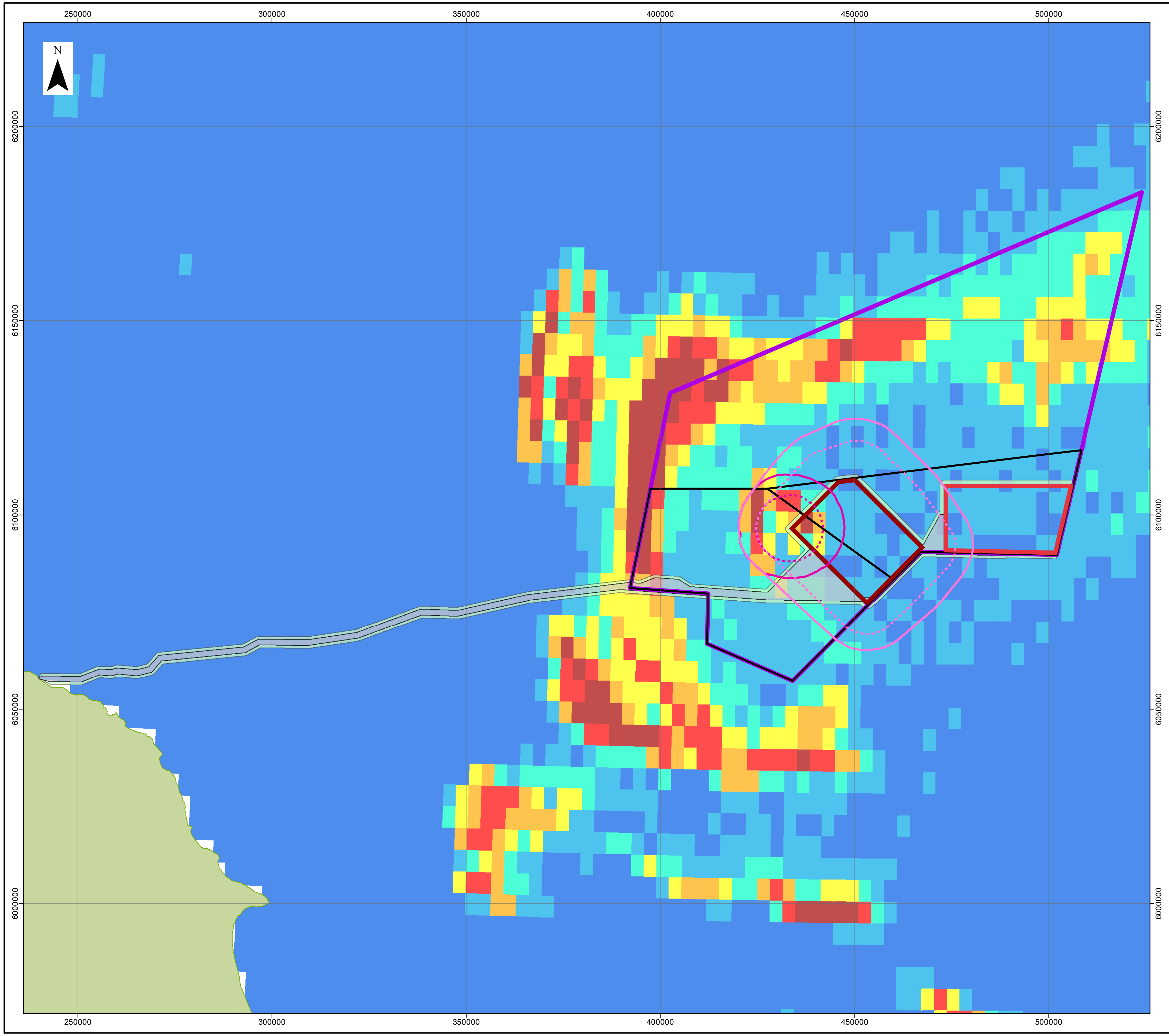
Figure 6.11 Dogger Bank Teesside B noise ranges for a single pile construction (hammer energy 2300kJ) in relation to herring spawning grounds

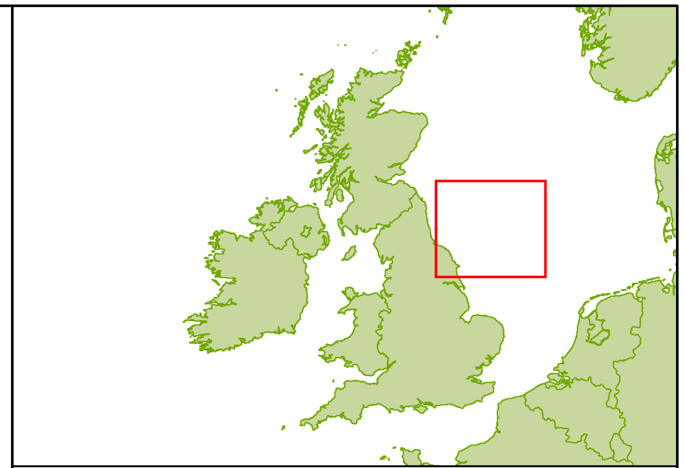
VER	DATE	REMARKS	Drawn	Checked
1	07/10/2013	PEI3	LW	TR
2	20/02/2014	DCO Submission	LW	TR

DRAWING NUMBER: **F-OFL-MA-257**

SCALE	1:1,000,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside A & B Export Cable Corridor
- Temporary works area

Danish sandeel satellite (VMS) density

- 0 to 2
- 3 to 5
- 6 to 10
- 11 to 20
- 21 to 40
- 41 to 80
- Over 80

Dogger Bank Teesside B 2300kJ demersal footprint (level)

- 168
- 173

Dogger Bank Teesside B 2300kJ demersal pile (level)

- 168
- 173

0 5 10 20
Kilometres

Data Source:
Modelling © NPL Management, 2013
VMS © Ministeriet for Fødevarer, Landbrug og Fiskeri, 2014

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 6.12 Dogger Bank Teesside B noise ranges for a single pile construction (hammer energy 2300kJ), in relation to Danish VMS (2008-2012)

VER	DATE	REMARKS	Drawn	Checked
1	07/10/2013	PEI3	LW	TR
2	20/02/2014	DCO Submission	LW	TR

DRAWING NUMBER:

F-OFL-MA-258

SCALE	1:1,000,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND

Dogger Bank Teesside A

6.9.25. As described in **Appendix 13A**, diadromous species are only expected to be found occasionally in the area of Dogger Bank Teesside A. Given the distance between Dogger Bank Teesside A and the coast, these species will not be disturbed by construction noise immediately prior to entering, nor immediately after leaving natal rivers.

6.9.26. Assuming that diadromous species and other migratory species occasionally transit Dogger Bank Teesside A then there is a potential for short term, localised, disturbance to migration if fish encounter noise levels that induce avoidance reactions. Given the relatively constricted ranges at which these reactions occur, it is expected that in the event of such disturbance fish would be able to utilise the wider area for migration.

6.9.27. In light of these considerations, the degree of effect-receptor interaction is considered to be small. Diadromous and other fish species potentially migrating through Dogger Bank Teesside A are therefore assigned a receptor sensitivity of low based on their low vulnerability, high recoverability and national/international importance. Given the low magnitude assigned to construction noise, behavioural effects on diadromous species and elasmobranchs are assessed to result in a **minor adverse** impact.

Dogger Bank Teesside B

6.9.28. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B

6.9.29. As described above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B Export Cable Corridor

6.9.30. Due to the position of the Dogger Bank Teesside A & B Export Cable Corridor relative to rivers such as the Tees and Esk there is an increased potential for diadromous species, such as salmon, sea trout and eel to be affected by noise associated with installation of the Dogger Bank Teesside A & B Export Cable Corridor. This is due to the position of the cable landfall relative to the mouths of these rivers and the tendency for migration close to the coast during some stages of the life history of these species. For these reasons diadromous species are assigned a receptor sensitivity of medium based on their medium vulnerability, medium recoverability and national/international importance. With the magnitude of the effect considered to be low the impact is considered to be **minor adverse**.

Behavioural effects of noise on prey species/feeding

6.9.31. The principal fish and shellfish species found in Dogger Bank Teesside A, Dogger Bank Teesside B and the Dogger Bank Teesside A & B Export Cable Corridor feed on a combination of invertebrate and fish prey. They may, therefore, be affected if construction results in decreased feeding opportunities (e.g. if the availability of prey is reduced due to behavioural responses of prey species to noise).

Dogger Bank Teesside A

6.9.32. The fish assemblages and the benthic communities are relatively homogenous across Dogger Bank Teesside A and adjacent areas. If prey is temporarily displaced as a result of piling noise, fish will be able to find suitable prey in adjacent areas. In addition, as indicated in **Chapter 12**, significant adverse effects (above minor) on benthic ecology are not predicted to occur as a result of the construction phase of Dogger Bank Teesside A, Dogger Bank Teesside B and the Dogger Bank Teesside A & B Export Cable Corridor.

6.9.33. Taking the above into account, prey species are considered to be of low vulnerability, medium recoverability and local to regional importance. Their sensitivity is low and considered in terms of the low magnitude of the effect of construction noise on prey species and feeding behaviour in the Dogger Bank Teesside A area, the impact is assessed to be **minor adverse**.

Dogger Bank Teesside B

6.9.34. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B

6.9.35. As assessed above for Dogger Bank Teesside A.

Behavioural effect of noise on shellfish

6.9.36. Shellfish are generally of limited mobility and, when in close proximity to construction activities, they may be exposed to potentially significant noise levels.

6.9.37. The principal shellfish VERs present in Dogger Bank Teesside A, Dogger Bank Teesside B and the Dogger Bank Teesside A & B Export Cable Corridor include *Nephrops*, edible crab and lobster. Other species such as whelks, scallops, brown shrimp and other brown shrimp species such as *Crangon almanni* which occur in the study area were not assigned VER status but are they are referred to in the following section.

6.9.38. The hearing mechanism of invertebrate species is currently not well understood, however, they are generally assumed to be less sensitive to noise than fish, due to the lack of a swim bladder. Research on the effect of noise on species such as the common prawn *Palaemon serratus* and the longfin squid *Loligo pealeii*, however, found these species to be sensitive to acoustic stimuli and it has been suggested that they may be able to detect sound similarly to most fish, via their statocysts (Lovell *et al*. 2005; Mooney *et al*. 2010).

6.9.39. Given the limited information currently available on shellfish hearing mechanisms, a conservative approach has been taken which assumes that the noise modelling carried out for fish, also applies to shellfish species. The limitations of the current available information in relation to the hearing ability of shellfish species, particularly in the case of molluscs such as whelks and scallops (both commercial species found in the area), which may be considerably less sensitive to noise than crustaceans, are however fully recognised.

Dogger Bank Teesside A

6.9.40. The principal shellfish species found in Dogger Bank Teesside A have wide distribution ranges. The areas where lethal and behavioural impacts associated with pile driving may occur are comparatively small and the effect-receptor interaction is also considered to be small. Shellfish species are considered to be receptors of low vulnerability, high recoverability and of local to regional value. The sensitivity of the receptor is considered to be low and in conjunction with the associated low magnitude, the effect of construction noise is considered to result in a **minor adverse** impact.

Dogger Bank Teesside B

6.9.41. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B

6.9.42. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B Export Cable Corridor

6.9.43. *Nephrops*, crab and lobster are targeted by the commercial fishery in the inshore area. There is potential for shellfish larvae to be present within and/or in the vicinity of the Dogger Bank Teesside A & B Export Cable Corridor. The noise associated with installation of the Dogger Bank Teesside A & B Export Cable Corridor potentially may result in behavioural reactions in fish and shellfish. However, it is anticipated that behavioural responses would be limited to the area close proximity to any construction activity. These areas are proportionally very small in the context of the wide distribution of shellfish larvae in the region. The effect-receptor interaction is expected to be small. Shellfish are deemed to be receptors of low vulnerability, high recoverability and of local to regional value. The sensitivity of the receptor is considered to be low and in conjunction with the associated low magnitude, the effect of construction noise is considered to result in a **minor adverse** impact.

6.10. Construction noise impact assessment summary

6.10.1. A summary of the construction noise impact assessment is given in **Table 6.9** below.

Table 6.9 Construction noise impact assessment summary

Potential Effect	Magnitude*		Receptor		Sensitivity				Impact			
	Dogger Bank Teesside A, Dogger Bank Teesside B and Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor			Dogger Bank Teesside A	Dogger Bank Teesside B	Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor	Dogger Bank Teesside A	Dogger Bank Teesside B	Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor
Construction noise												
	Negligible	Negligible	Fish	Adult and juvenile fish	Low	Low	Low	Low	Negligible	Negligible	Negligible	Negligible
				Larvae	Medium	Medium	Medium	Low	Minor adverse	Minor adverse	Minor adverse	Negligible
Behavioural	Low			Adult and juvenile fish	Low	Low	Low	Low	Minor adverse	Minor adverse	Minor adverse	Negligible
				Herring	Medium	Medium	Medium	Medium	Minor adverse	Minor adverse	Minor adverse	Minor adverse
				Sandeel	Low	Medium	Medium	Low	Minor adverse	Minor adverse	Minor adverse	Minor adverse
				Diadromous species	Low	Low	Low	Medium	Minor adverse	Minor adverse	Minor adverse	Minor adverse
				Other fish species	Low	Low	Low	Medium	Minor adverse	Minor adverse	Minor adverse	Minor adverse
Prey species/ Prey species feeding				Fish in general	Low	Low	Low	Low	Minor adverse	Minor adverse	Minor adverse	Negligible
General			Shellfish		Low	Low	Low	Low	Minor adverse	Minor adverse	Minor adverse	Negligible

7. Impacts during Operation

7.1. General

7.1.1. The following potential impacts associated with the operational phase are assessed below:

- Loss of habitat;
- Introduction of hard substrate;
- EMF;
- Operational noise; and
- Changes to fishing activity.

7.1.2. In the Dogger Bank Teesside A & B Export Cable Corridor only EMF and loss of habitat related effects are considered relevant during the operational phase.

7.1.3. It should also be noted that the assessment of impacts during operation takes account of any relevant embedded mitigation as identified in Section 3.3.

7.2. Permanent loss of habitat - effects

7.2.1. The introduction of foundations and, where required, scour protection will result in a permanent loss of seabed habitat for the duration of the operational phase. As described in **Chapter 12** the greatest net loss of seabed would result from the introduction of 200 GBS foundations in each Dogger Bank Teesside A & B wind farm project.

7.2.2. In addition to turbine foundations, further loss of habitat will result from the footprint of the foundations of up to five met masts, four collector substations, one converter substation, two accommodation blocks per Dogger Bank Teesside A & B wind farm project, cable protection of array and inter-platform cables where required, cable crossings and vessel moorings. The worst case net loss of seabed is anticipated to be 3.77km^2 per Dogger Bank Teesside A & B wind farm project (**Table 5.2**).

7.2.3. In the particular case of the export cable the loss of seabed habitat may occur during the operational phase as a result of cable protection measures and crossings. This is estimated to cover a worst case area of 2.67km^2.

7.2.4. The worst case scenario for total permanent loss of seabed habitat is 6.44 km^2, equivalent to a maximum of 1.15% of the total area of each Dogger Bank Teesside A & B wind farm project (**Table 5.2**).

7.2.5. The loss of seabed described above (all footprints for foundations are inclusive of scour protection) and any associated loss of habitat will be constant and last for the duration of the operational phase. Given its small spatial extent, however, it is considered to result in an effect of low magnitude. This is considered to be the case for Dogger Bank Teesside A, Dogger Bank Teesside

B, Dogger Bank Teesside A & B and for the Dogger Bank Teesside A & B Export Cable Corridor.

7.3. Permanent loss of habitat - impacts

Dogger Bank Teesside A

7.3.1. The installation of turbine foundations, scour protection and cable protection has the potential to result in the permanent removal of fish and shellfish habitat. The majority of fish and shellfish species present in Dogger Bank Teesside A have wide distribution ranges and comparatively large spawning, nursery and feeding areas within the region. They are, therefore, expected to remain unaffected by the small predicted loss of seabed and the effect-receptor interaction is anticipated to be small. Most fish and shellfish receptors in the study area are deemed to be of low vulnerability, high recoverability and of local or regional importance therefore they are considered to be of low sensitivity. The effect of loss of habitat on fish and shellfish species is therefore expected to result in a **minor adverse** impact.

7.3.2. Sandeel is substrate specific, requiring the presence of an adequate sandy substrate in which to burrow. As suggested by fisheries data and the results of the sandeel survey carried out in tranches A and B, they are present within Dogger Bank Teesside A. This area however supports very small numbers of sandeel in the context of the Dogger Bank SA1. The degree of interaction between loss of habitat associated with Dogger Bank Teesside A and sandeel is therefore considered to be very small. Taking this into account sandeel is considered to be a receptor of medium vulnerability, medium recoverability and regional value, therefore a receptor of medium sensitivity. Together with the low magnitude of the effect, the loss of habitat is considered to result in a **minor adverse** impact.

7.3.3. It should be noted that specific post-construction monitoring for sandeel undertaken at Horns Rev Offshore Wind Farm has not found evidence of a long term effect on the sandeel population seven years after construction (Stenberg *et al*. 2011).

7.3.4. In the case of herring, Dogger Bank Teesside A overlaps a small area of former herring spawning grounds (as defined by Coull *et al*. 1998). As suggested by the distribution of sediment types within the study area, there is potential for discrete areas of suitable herring spawning substrate to occur within Dogger Bank Teesside A. If re-colonisation of the former herring spawning grounds occurs, there may be potential for these coarse sediment and gravelly areas to be lost. The potential loss of spawning grounds, however, is proportionally small in the context of the extent of available gravelly areas in the vicinity of Dogger Bank Teesside A. It should also be noted that the presence of coarse sediment in a given area does not necessarily constitute a preferred herring spawning ground.

7.3.5. Taking the potential extent of interaction described above into account, herring are considered receptors of medium vulnerability, medium recoverability and regional value, therefore they are deemed to be receptors of medium sensitivity.

The magnitude of the effect is considered to be low therefore the impact of loss of habitat is considered to be **minor adverse**.

Dogger Bank Teesside B

7.3.6. As described above for Dogger Bank Teesside A, the fish and shellfish species present in Dogger Bank Teesside B have wide distribution ranges, being able to use comparatively large areas for spawning, nursery and feeding. They are, therefore, expected to remain unaffected by the small predicted loss of seabed and are considered to be receptors of low vulnerability, medium recoverability and of regional value, therefore they are deemed to be receptors of low sensitivity. The impact of loss of habitat on fish and shellfish species is therefore expected to be **minor adverse.**

7.3.7. Fisheries data and the results of the sandeel survey carried out in tranches A and B show that sandeel are expected to be found within Dogger Bank Teesside B. This area is, however, very small in the context of the distribution of sandeel in the wider Dogger Bank SA1. Forewind have taken the presence of sandeel into account when defining the western boundary of tranche A (Section 3.3). In this respect, sandeel species are, therefore, considered receptors of medium vulnerability, medium recoverability and regional importance, therefore they are deemed to be receptors of medium sensitivity and the effect of loss of habitat is considered to result in a **minor adverse** impact. As previously mentioned for Dogger Bank Teesside A, the wide distribution of high density sandeel areas outside Dogger Bank Teesside B should be noted in this context (see **Appendix 13A**).

7.3.8. In the case of herring, Dogger Bank Teesside B does not fall within the defined former herring spawning grounds or their immediate vicinity (Coull *et al*. 1998). It is recognised, however, that there is potential for discrete suitable herring spawning substrate to be found within Dogger Bank Teesside B as suggested by the distribution of sediment types within Dogger Bank Teesside B (see **Appendix 13A**). As described above for Dogger Bank Teesside A, the potential loss of spawning grounds associated with this is very small in the context of the extent of available gravelly areas on the Dogger Bank and the extent of the former spawning grounds (see **Appendix 13A**). Furthermore the presence of adequate coarse sediment does not necessarily imply that herring will use a given area for spawning.

7.3.9. Taking the above into account together with the distance from Dogger Bank Teesside B to the defined former herring spawning grounds (Coull *et al*. 1998), herring are considered receptors of low vulnerability, medium recoverability and regional value, therefore sensitivity is deemed to be low. The impact of the loss of spawning habitat is considered to result in a **minor adverse** impact.

Dogger Bank Teesside A & B

7.3.10. As assessed above for Dogger Bank Teesside A and Dogger Bank Teesside B.

Dogger Bank Teesside A & B Export Cable Corridor

7.3.11. The loss of seabed habitat associated with the Dogger Bank Teesside A & B Export Cable Corridor during the operational phase is very small in the context of the distribution of fish and shellfish species present in the area of the export cable, including areas used for spawning, as nursery, feeding or overwintering grounds. With respect to this small interaction, fish and shellfish are therefore considered receptors of low vulnerability, medium recoverability and local to international importance, therefore they are receptors of medium sensitivity. Since the magnitude of effect is low the loss of habitat is considered to result in a **minor adverse** impact.

7.3.12. In the particular case of spawning herring, as previously mentioned, they are substrate specific spawners, needing the presence of an adequate substrate on which to lay their eggs. The Dogger Bank Teesside A & B Inshore Export Cable Corridor Study Area falls within known active herring spawning grounds and, therefore, there may be potential for a loss of spawning grounds to occur associated with the Dogger Bank Teesside A & B Export Cable Corridor. However the small spatial extent of the Dogger Bank Teesside A & B Export Cable Corridor it is considered to result in an effect of low magnitude. As shown in **Appendix 13A** the extent of the defined grounds, and of coarse sediment and gravelly areas within those grounds, is very wide in comparison to the potential loss of habitat associated with export cable protection during the operation phase. Taking the above into account it is considered that there will be a low degree of interaction between the active herring spawning grounds and areas where the export cable may be protected during the operational phase. Herring are therefore considered receptors of medium vulnerability, medium recoverability and regional importance and therefore of medium sensitivity. The effect of loss of spawning habitat on herring is considered to result in a **minor adverse** impact.

7.3.13. Sandeel is present in the vicinity of the Dogger Bank Teesside A & B Export Cable Corridor. The proportional loss of sandeel habitat to the introduction of hard substrate is small compared to the extensive area occupied by the Dogger Bank SA1 sandeel population in the North Sea. However displaced sandeel may be vulnerable to increased levels of predation or unable to relocate successfully. The level of interaction is considered to be medium and given the small spatial extent of the Dogger Bank Teesside A & B Export Cable Corridor an effect of low magnitude is assigned. Sandeel is considered to be a receptor of medium vulnerability, medium recoverability and regional importance. The species is deemed to be a receptor of medium sensitivity and the effect of the loss of spawning habitat is anticipated to result in a **minor adverse** impact.

7.4. Permanent loss of habitat impact assessment summary

7.4.1. The loss of habitat impact assessment on fish and shellfish species is summarised in **Table 7.1** below.

Table 7.1 Permanent loss of habitat impact assessment summary

Potential effect	Magnitude of effect	Receptor	Receptor sensitivity				Impact
	Dogger Bank Teesside A, B and Dogger Bank Teesside A & B		Dogger Bank Teesside A	Dogger Bank Teesside B	Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor	All areas
Permanent loss of habitat	Low	Fish and Shellfish in general	Low	Low	Low	Low	Minor adverse
		Sandeel	Medium	Medium	Medium	Medium	
		Herring	Medium	Medium	Medium	Medium	

7.5. Introduction of hard substrate-effects

7.5.1. Dogger Bank Teesside A and Dogger Bank Teesside B are located in a predominantly soft seabed environment. The sub-surface sections of turbine towers, the foundations and where required, the placement of scour and cable protection material will result in the introduction of hard substrate in areas previously characterised by the presence of soft sediment.

7.5.2. The introduced hard substrate is expected to be colonised by a number of organisms, including a range of encrusting and attaching species such as ascidians, bryozoans and bivalve molluscs (**Chapter 12**). This is likely to increase local species diversity as well as the abundance and biomass of epifaunal organisms.

7.5.3. The increase in diversity and productivity of seabed communities may have an effect on fish, resulting in either attraction or increased productivity (Hoffman *et al*. 2000). The potential for marine structures, whether man-made or natural, to attract and concentrate fish is well documented (Sayer *et al*. 2005; Bohnsack, 1989; Bohnsack and Sutherland 1985). Whether these structures act only to attract and aggregate fish or actually increase biomass is, however, currently unclear.

7.5.4. During post-construction monitoring work at Horns Rev Offshore Wind Farm, it was estimated that the introduction of hard substrate resulted in 60 times increased food availability for fish and other organisms in the wind farm area compared to the native infaunal biomass (Leonhard and Pedersen 2005). A succession in the number of fish species was observed when comparing the results of surveys undertaken in March and in September. It was suggested that this could be a result of seasonal migrations of fish species to the turbine site for foraging. Bib *Trisopterus luscus* and schools of cod were observed, presumably partly feeding on crustaceans on the scour protection. Other species such as rock gunnel *Pholis gunnellus* and dragonet were commonly found inhabiting caves and crevices between the stones. In addition, pelagic and semi-pelagic fish such as sprat, mackerel and lesser sandeel seemed to be more frequently recorded than previously (Leonhard & Pedersen 2005).

7.5.5. Andersson *et al*. (2009) compared the epibenthic colonisation of concrete and steel experimental pillars with natural areas and sampled fish assemblages. The study found overall higher abundance and species numbers on the pillars (with no difference between steel and concrete pillars) compared to the surrounding soft bottom habitats. A reef effect was detected in species such as two-spotted goby *Gobiusculus flavescens* and goldsinny wrasse *Ctenolabrus rupestris*. This preference was, however, not observed on bottom-dwelling species such as gobies.

7.5.6. Studies carried out in operational wind farms in Sweden (Wilhelmsson *et al*. 2006) found greater fish abundances in the vicinity of the wind turbines than in surrounding areas and no evidence of associated effects in terms of diversity. On the monopiles of the wind turbines, however, the structure of the fish community found was different, with the total fish abundance being greater and diversity lower than in the surrounding seabed.

7.5.7. The Horns Rev Offshore Wind Farm monitoring follow-up report recently published (Stenberg *et al*. 2011) examined the changes in the fish community seven years after construction. This report suggests that the introduction of hard substrate has resulted in minor changes in the fish community and species diversity. Fish community changes were observed due to changes in densities of the most commonly occurring fish, whiting and dab. However, this reflected the general trend of these fish populations in the North Sea.

7.5.8. The introduction of hard substrate was, however, found to result in higher species diversity close to each turbine with a clear (horizontal) distribution, which was most pronounced in the autumn, when most species occurred. New reef habitat fish such as goldsinny wrasse, viviparous eelpout *Zoarces viviparous* and lumpsucker *Cyclopterus lumpus* were found to establish themselves on the introduced reef area. In the particular case of sandeel, it should be noted that sandeel specific monitoring carried out in Horns Rev Offshore Wind Farm suggests that the construction of the wind farm has not resulted in a detrimental long-term effect on the overall occurrence of sandeel in the area (Stenberg *et al*. 2011).

7.5.9. A review of the short term ecological effects of the offshore wind farm Egmond aan Zee (OWEZ) in the Netherlands, based on two year post-construction monitoring (Lindeboom *et al*. 2011) found minor effects upon fish assemblages, especially near the monopiles, and it was suggested that species such as cod may find shelter within the wind farm. At OWEZ, a study of the residence time and behaviour of sole and cod was also undertaken (Winter *et al*. 2010). Some sole were found in the wind farm area for periods of up to several weeks during the growing season, suggesting there was no large scale avoidance of the wind turbines. Evidence of sole being attracted to monopile habitats was, however, not found. For cod, it was found that at least part of the juvenile population, spend long periods within the wind farm. Near-turbine fish observations carried out at OWEZ (Couperus *et al*. 2010) using high resolution sonar suggest that fish around the monopiles exhibit relatively stationary behaviour and occur in loose aggregations rather than dense schools. The aggregations found in the study area consisted primarily of horse mackerel and cod.

7.5.10. Similarly, the results of fish monitoring programmes carried out in operational wind farms in the UK do not suggest that major changes in fish species composition, abundance or distribution have occurred. At North Hoyle, a change in the diversity of organisms or the species composition of the benthic and demersal community was not found. The annual post-construction beam trawl surveys indicated that most of the fish species considered were broadly comparable to previous years and within the long-term range. Some species showed recent increases and decreases, but broadly mirrored regional trends (Cefas 2009). At Barrow offshore wind farm, pre and post-construction otter trawl survey results from the wind farm area showed similar patterns of abundance, with the most frequently caught fish being dab, plaice, whiting and lesser spotted dogfish. Results from control locations showed a similar pattern, and found no significant differences between the catches of the two most abundant species (dab and plaice) before and after installation of the wind farm. No differences were found between the numbers caught at control locations and within the wind farm area after the wind farm was constructed (Cefas 2009).

7.5.11. Langhamer and Wilhelmsson (2009) carried out a field experiment to study the potential for fish and crabs to colonise wave energy foundations and the effects of manufactured holes. This study recorded a significantly higher abundance of fish and crabs on the foundations compared to the surrounding soft substrate.

7.5.12. It is likely that the greatest potential for positive effects exists for crustacean species, such as crab and lobster, due to expansion of their natural habitats (Linley *et al*. 2007) and the creation of additional refuge areas. Where foundations and scour protection are placed within areas of sandy and coarse sediments, this will represent novel habitat and new potential sources of food in these areas and could potentially extend the habitat range of some shellfish species. Post-construction monitoring surveys at the Horns Rev Offshore Wind Farm noted that the hard substrates were used as a hatchery or nursery grounds for several species, and was particularly successful for brown crab.

7.5.13. Linley *et al*. (2007) suggest that the introduction of wind farm related structures could extend the distribution of some shellfish mobile species such as crabs and lobsters, as a result of increased habitat opportunities. At Horns Rev Offshore Wind Farm, for example, it was found during post construction monitoring that the wind farm site was being used as a nursery area by juvenile edible crabs (Leonhard and Pedersen 2005). Colonisation of structures by commercial shellfish species has also been reported at the artificial reef constructed in Poole Bay in 1989, where attraction and fidelity was demonstrated for lobster and edible crabs within three weeks of construction (Collins *et al*. 1992; Jensen *et al*. 1994). In addition, evidence of reproductive activity for a number of shellfish species such as spider crabs, velvet crabs and presence of berried female lobster was also found (Jensen *et al*. 1992).

7.5.14. Based on the experience at Horns Rev Offshore Wind Farm and Poole Bay, Linley *et al*. (2007) suggested that edible crab may be among the early colonisers of operational wind farms. Experiments to study the potential for fish and crabs to colonise wave energy foundations and the effects of manufactured holes (Langhamer & Wilhelmsson 2009) recorded a significantly higher abundance of fish and crabs on the foundations compared to the surrounding soft substrate.

7.5.15. The colonisation of the new habitats may potentially lead to the introduction of non-native and invasive species. With respect to fish and shellfish populations, this may have indirect adverse effects on shellfish populations as a result of competition. However, no non-native species were identified as present in the area during the site-specific surveys. Some of the more common non-native species that are now found in the waters of the UK such as the slipper limpet *Crepidula fornicata* and the Chinese mitten crab *Eriocheir sinensis* prefer more estuarine conditions and more sheltered, lower energy environments. There is little evidence of adverse effects resulting from colonisation of other offshore wind farms by non-native species; the post construction monitoring report for the Barrow offshore wind farm demonstrated no evidence of invasive or alien species on or around the monopiles (EMU 2008a), and a similar study of the Kentish Flats monopiles only identified slipper limpet (EMU 2008b). A more recent survey of wrecks on the Dogger Bank showed that the predominant species found were typical of a North Sea rocky reef in moderate to strong currents (Envision 2011). The main species found included the coral (dead mans fingers) *Alcyonium digitatum*, plumose anemone *Metridium senile*, cod, lobster, edible crab, tube worm *Spirobranchus sp*. and various ascidians.

7.6. Introduction of hard substrate-impacts

7.6.1. The impact of the introduction of hard substrate is predicted to be of local spatial extent, long term duration (for the life-time of Dogger Bank Teesside A & B), continuous and irreversible (during the lifetime of Dogger Bank Teesside A & B). The impact is expected to have direct and indirect effects on fish and shellfish receptors. The magnitude of effect is considered to be low for Dogger Bank Teesside A, Dogger Bank Teesside B and Dogger Bank Teesside A & B.

7.6.2. It is anticipated that any hard substrate associated with cable protection in the Dogger Bank Teesside A & B Export Cable Corridor will only be introduced in discrete areas and will not be continuous along large lengths of the Dogger Bank Teesside A & B Export Cable Corridor. The magnitude of effect of the introduction of hard substrate in this case is therefore considered to be **negligible.**

Dogger Bank Teesside A

7.6.3. As suggested by the findings of the above monitoring studies, there may be potential for Dogger Bank Teesside A & B to be used as nursery and spawning area and/or provide shelter and increased feeding opportunities to some fish and shellfish species.

7.6.4. The dominant natural substrate character of the construction area, (e.g., soft sediment or hard rocky seabed), will determine the number of new species found on the introduced vertical hard surface and associated scour protection. When placed on an area of seabed which is already characterised by rocky substrates, few species will be added to the area, but the increase in total hard substrate could sustain higher abundance (Andersson & Öhman 2010). Conversely, when placed on a soft seabed, most of the colonising fish will be from rocky (or other hard bottom) habitats, thus the overall diversity of the area will increase (Andersson *et al*. 2009).

7.6.5. The introduction of hard substrate has the potential to result in minor effects on fish and shellfish; typically on an individual species basis rather than on the fish and shellfish assemblage as a whole. Fish and shellfish are therefore considered to be receptors of medium vulnerability, medium recoverability and of local to international value. The sensitivity of the receptors is deemed to be medium. Considering the low magnitude of the effect of the introduction of hard substrate on fish and shellfish species, the impact is assessed as **minor**. Whether this impact is beneficial or adverse will depend on the particular species in question.

7.6.6. In the event that there is a requirement for the seabed to be returned to its original condition prior to the installation of Dogger Bank Teesside A & B infrastructure, any beneficial effects arising from the introduction of hard substrate will be removed during the decommissioning phase.

Dogger Bank Teesside B

7.6.7. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B

7.6.8. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B Export Cable Corridor

7.6.9. Cable protection may be required in discrete areas along the Dogger Bank Teesside A & B Export Cable Corridor. The introduction of hard substrate is not expected to be spatially continuous and will have little potential to result in aggregation effects and/or changes to the fish and shellfish assemblage of the area. Fish and shellfish are therefore considered as receptors of low vulnerability, medium recoverability and of local to regional value. The sensitivity of the receptors is therefore deemed to be low. When considered in terms of the negligible effect, the impact of the introduction of hard substrate associated with the Dogger Bank Teesside A & B Export Cable Corridor and the impact is assessed to be **negligible**.

7.6.10. In terms of hard substrate resulting in a loss of suitable substrate for herring spawning, the worst case proportional loss of spawning area (assuming that the total length of the cable corridor is protected) is anticipated to be $0.81km^2$, equivalent to 0.008% of the total area of the inshore Flamborough herring spawning grounds.

7.6.11. The introduction of hard substrate has the potential to result in a loss $1.67km^2$ of habitat and spawning area for sandeel, equivalent to 0.006% of the total area of suitable habitat within the SA1 management area.

7.6.12. Fish and shellfish (including herring and sandeel) are therefore considered as receptors of low vulnerability, medium recoverability, and of local to regional importance and therefore their sensitivity to the introduction of hard substrate associated with the Dogger Bank Teesside A & B Export Cable Corridor is deemed to be low. As the magnitude of the effect is negligible, and the impact is assessed to be **negligible**.

7.7. Introduction of hard substrate impact assessment summary

7.7.1. A summary of the introduction of hard substrate impact assessment is given in **Table 7.2**.

Table 7.2 Introduction of hard substrate impact assessment summary

Potential effect	Magnitude of effect		Receptor	Receptor sensitivity		Impact	
	Dogger Bank Teesside A, B and Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor		Dogger Bank Teesside A, B and Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor	Dogger Bank Teesside A, B and Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor
Introduction of hard substrate	Low	Negligible	Fish and shellfish (general)	Medium	Low	Minor adverse	Negligible

7.8. Increases in suspended sediment concentration and sediment re-deposition due to scour associated with foundations - effects

7.8.1. Over the period of operation, there is the potential for creation of sediment plumes caused by seabed scour around non-scour protected wind turbine foundations after they have been installed. No potential operational effects are considered for the export and inter-array cables since they will be buried or surface-layed and protected where cable burial is not feasible and protrude (with armouring) only a small distance above the seabed.

7.8.2. In **Chapter 9** the effect of scour on sediment transport was modelled using a worst case scenario with a gridded layout of 6MW conical GBS#1 foundations at their minimum 750m spacing with a wider spaced grid of foundations across the rest of each Dogger Bank Teesside A & B wind farm project, including platforms, meteorological masts and vessel moorings. Two scenarios were tested as the worst case for plume dispersion using a minimum construction period of two years. These are a scenario after one year when 200 foundations are operational subject to a 30-day simulation including a one-year storm, and a scenario after two years when all 400 foundations are operational and subject to a 30-day simulation including a larger 50-year storm. This modelling scenario is actually based on Dogger Bank Teesside A & B being constructed together (400 turbine foundations in total, 200 constructed each year; 100 in Dogger Bank Teesside A and Dogger Bank Teesside B respectively).

7.8.3. The results show that the maximum suspended sediment concentration after one year of operation at any time throughout the 30-day simulation period was predicted to be 50-100mg/l above natural background levels (2mg/l). Maximum concentrations reduce to background levels up to approximately 37km from the project boundaries. The highest average suspended sediment concentration was 10-20mg/l reducing to background levels up to approximately 28km from the project boundaries.

7.8.4. After two years, the maximum concentration was predicted to increase to greater than 200mg/l in areas up to 20km long and 6km wide along the boundaries of the projects. Across the whole of both projects, maximum suspended sediment concentrations were greater than 20mg/l reducing to background levels (2mg/l) up to approximately 54km from the project boundaries. The highest average concentrations after two years were 10-50mg/l within the projects and up to 19km outside their boundaries. Average concentrations reduce to background levels (2mg/l) up to approximately 36km from the project boundaries.

7.8.5. After one year, maximum sediment deposition of 0.1-0.5mm occurs within both projects during the 30-day simulation period, reducing to 0.1mm up to approximately 30km outside the project boundaries. Average deposition was predicted to be mainly less than 0.1mm. Time series of bed thickness show that throughout the footprint the maximum within the foundation layout doesn't exceed 0.7mm. The predicted bed thickness at the end of the 30-day simulation period was effectively zero across much of the depositional area.

7.8.6. After two years, maximum deposition of 0.5-5mm occurs across each project with deposition reducing to less than 0.1mm up to 35km from the boundaries. Average deposition is predicted to be 0.5-5mm between the projects reducing to less than 0.1mm up to approximately 23km outside the project boundaries.. Time series of bed thickness show that the thickness within the foundation layout may exceed 1mm continuously for up to 3.00 days. The predicted bed thickness at the end of the 30-day simulation period was less than 0.1mm across much of the depositional area.

7.8.7. A comparison of operational scour volumes with naturally occurring release of sediment during a one-year storm shows that predicted scour volumes are five times less than half the volume that would be suspended without the foundations in place. For a 50-year storm, scour volumes are six times less than the volumes that would be suspended without the foundations in place during a storm of the same magnitude.

7.9. Increases in suspended sediment concentration and sediment re-deposition due to scour associated with foundations - impacts

Dogger Bank Teesside A

7.9.1. The modelled outputs from **Chapter 9** predict that concentrations of suspended sediment and levels of sediment re-deposition during the operational phase (**Table 7.3**) will be less than the potential effects of suspended sediment concentrations and sediment re-deposition described for the construction phase (see **Table 6.4**). The magnitude of the effect is judged to be low.

7.9.2. The sensitivity of fish and shellfish receptors to suspended sediment and sediment deposition are described previously in Section 6.5. Any such events will have varying levels of effect dependent on the species and life history stage of the species. The sensitivity of fish and shellfish receptors is considered to be low to medium. The significance of the impact is assessed to be **minor adverse**.

Dogger Bank Teesside B

7.9.3. As described above for Dogger Bank Teesside A (see **Table 7.3**).

Dogger Bank Teesside A & B

7.9.4. As described above for Dogger Bank Teesside A and Dogger Bank Teesside B (see **Table 7.3**).

Table 7.3 Increases in suspended sediment concentration and sediment re-deposition due to scour associated with foundations impact assessment summary

Potential effect	Magnitude of effect		Receptor	Receptor sensitivity		Impact	
	Dogger Bank Teesside A, B and Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor		Dogger Bank Teesside A, B and Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor	Dogger Bank Teesside A, B and Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor
Increases in suspended sediment concentration and sediment re-deposition due to scour associated with foundations	Low	-	Fish and shellfish (general)	Low/ Medium	-	Minor adverse	-

7.10. Electromagnetic fields (EMF) - effects

7.10.1. Molluscs, crustaceans, elasmobranch fish and teleost fish are able to detect applied or modified magnetic fields. Species for which there is evidence of a response to E and B fields include elasmobranches (sharks, skates and rays), river lamprey, sea lamprey, cod (E field only), European eel, plaice and Atlantic salmon (Gill *et al*. 2005). Data on the use that marine species make of these capabilities is limited, although it can be inferred that the life functions supported by an electric sense may include detection of prey, predators or conspecifics to assist with feeding, predator avoidance, and social or reproductive behaviours. Life functions supported by a magnetic sense may include orientation, homing, and navigation to assist with long or short-range migrations or movements (Gill *et al*. 2005; Normandeau *et al*. 2011). Therefore, the EMF emitted by subsea cables may interfere with these functions in areas where the cable EMF levels are detectable by the organism. This may cause an expenditure of energy in moving to areas which may not be suitable for finding either prey species or members of the same species, or in moving away from areas where predators are mistakenly located.

7.10.2. As previously mentioned the potential effects associated with EMF will be mitigated through the use of armoured array and export cables. In addition, cables will be buried where feasible, further mitigating potential EMF associated impacts on fish and shellfish receptors. In instances where adequate burial cannot be achieved, alternative protection measures, as described in **Chapter 5**, will be used.

7.10.3. A number of different cabling options are included in the project description for array and export cables. For the purposes of defining the worst case scenario the highest rating option for each type of cable and the maximum cabling length are considered to constitute the worst case, as this is expected to result in the strongest associated fields and total area affected. A summary of the parameters used in the assessment for each cable type is given below.

Array cables per project

Inter-Array cables

- Alternating Current (AC) three core cable of maximum voltage 72.5kV;
- Maximum length of cabling: 950km; and
- Protected with concrete mattresses, pipes, half pipes or cable clips where burial is not feasible.

Inter-Platform cables

- High Voltage Alternating Current (HVAC) cables of maximum voltage 400kV;
- Maximum number of cables: eight;
- Maximum length of cabling: 320km; and
- Protected with rock placement, concrete mattresses, steel bridging or concrete bridging where burial is not feasible.

7.10.4. AC cables generate an electric field (E) and a magnetic field (B). The total E field cancels itself out to a large extent and the remaining E is shielded by the metallic sheath and cable armour. The B fields generated by AC cables are, however, constantly changing. The varying B produce associated induced electric fields (iE), therefore both B and iE will be generated by inter array cables during the operational phase of Dogger Bank Teesside A & B.

7.10.5. Export cables per project:

- HVDC of maximum voltage of 550kV;
- Maximum number of cables: one pair (two cables per circuit);
- Maximum length of export cable Dogger Bank Teesside A: 573km
- Maximum length of export cable Dogger Bank Teesside B: 484km
- Protected with rock burial, concrete mattresses, pipes, half-pipes, or cable clips where burial is not feasible.

7.10.6. Unlike AC cables, iE fields will not be produced directly by Direct Current (DC) cables. In the marine environment, however, organisms and tidal streams will pass through the static B field and this will indirectly result in the production of an iE field. As a result, both B and iE fields will also be produced during the operational life of the export cables. It should be noted, that in the particular case of DC cables, if these are bundled, the strength of the B field will be significantly reduced.

7.10.7. The strength of the B fields generated by both AC and DC cables decreases exponentially, horizontally and vertically, with distance from the source. An indication of this is given for AC and DC cables in **Table 7.4** and **Table 7.5** respectively. These show averaged predicted magnetic fields at intervals above and horizontally along the seabed for a number of AC and DC projects, as provided in Normandeau *et al*. (2011). Since the strength of the magnetic field decreases with distance from the source, the potential effect of EMF on fish and shellfish will likely be influenced by the position of particular species in the water column and water depth.

Table 7.4 Averaged magnetic field strength values from AC cables

Distance (m) above seabed	**Magnetic field strength (μT)**		
	Horizontal distance (m) from cable		
	0	**4**	**10**
0	7.85	1.47	0.22
5	0.35	0.29	0.14
10	0.13	0.12	0.08

Table 7.5 Averaged magnetic field strength values from DC cables above and horizontally along the seabed assuming 1m burial (Normandeau *et al*. 2011)

Distance (m) above seabed	Magnetic field strength (μT)		
	Horizontal distance (m) from cable		
	0	4	10
0	78.27	5.97	1.02
5	2.73	1.92	0.75
10	0.83	0.74	0.46

7.10.8. Although cable burial does not completely mitigate B or iE fields, it reduces exposure of electromagnetically sensitive species to the strongest EMF that exist at the 'skin' of the cable, owing to the physical barrier of the substratum (OSPAR 2008). In instances where adequate burial cannot be achieved, it is anticipated that alternative protection, as described in **Chapter 5**, will be used. Fish and shellfish species will, therefore, not be directly exposed to the strongest EMF as a result of the physical barrier provided by either cable burial or cable protection.

7.10.9. Given the EMF related effects may potentially occur in a relatively small area, limited to the immediate vicinity of the cables, the magnitude of the effect of EMF is considered to be low for Dogger Bank Teesside A, Dogger Bank Teesside B, Dogger Bank Teesside A & B and for the Dogger Bank Teesside A & B Export Cable Corridor.

7.10.10. A summary of species for which there is evidence of a response to E and B fields is provided in **Table 7.6** and **Table 7.7** as provided in Gill *et al*. (2005)

Table 7.6 Species found in UK coastal waters for which there is evidence of a response to E fields. Gill *et al*. (2005)

Species / species groups	Latin name
Elasmobranchs	
Lesser Spotted Dogfish	*Scyliorhinus canicula*
Blue shark	*Prionace glauca*
Thornback ray	*Raja clavata*
Round ray	*Rajella fyllae*
Agnatha	
River lamprey	*Lampetra fluviatilis*
Sea lamprey	*Petromyzon marinus*
Teleosts	
European eel	*Anguilla anguilla*
Cod	*Gadus morhua*
Plaice	*Pleuronectes platessa*
Atlantic salmon	*Salmo salar*

Table 7.7 Species found in UK waters for which there is evidence of a response to B fields.

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

7.11. Electromagnetic fields (EMF) - Impacts

7.11.1. The principal species groups potentially present in Dogger Bank Teesside A, Dogger Bank Teesside B and the Dogger Bank Teesside A & B Export Cable Corridor for which there is evidence of a response to EMF are as follows:

- Elasmobranchs;
- Diadromous migratory species: European eel, river and sea lamprey and salmon and sea trout;
- Other fish species: cod and plaice; and
- Shellfish species.

Elasmobranchs

7.11.2. Elasmobranchs are the major group of organisms known to be electrosensitive. They possess specialised electroreceptors called Ampullae of Lorenzini. These species naturally detect bioelectric emissions from prey, conspecifics and potential predators/competitors (Gill *et al*. 2005). They are also known to either detect magnetic fields using their electronsensory systems or through a yet-to-be described magnetite receptor system (Normandeau *et al*. 2011). Magnetic field detection is thought to be used as a means of orientation in elasmobranches, however, evidence for magnetic orientation by sharks and rays is limited to date (Meyer *et al*. 2005) and there is currently debate on the actual mechanisms used (Johnsen and Lohmann 2005).

7.11.3. Elasmobranchs may be confused by anthropogenic E field sources that lie within similar ranges to natural bioelectric fields. Both attraction and repulsion reactions have been observed associated with E-fields in elasmobranch species. Gill and Taylor (2001) found limited laboratory based evidence that the lesser spotted dogfish avoids DC E-fields at emission intensities similar to those predicted from offshore wind farm AC cables. The same fish were attracted to DC emissions at levels predicted to emanate from their prey. Laboratory studies have found both AC and DC artificial electric fields stimulated feeding responses in elasmobranchs (Kalmijn 1982; Tricas and Sisneros 2004; Kimber *et al*. 2011). Research by Gill *et al*. (2009) found that lesser spotted dogfish were more likely to be found within the zone of EMF emissions, and some thornback ray showed increased movement around the cable when the cable was switched on. Responses were, however, unpredictable and did not always occur, appearing to be species dependent and individual specific. Recent research on lesser spotted dogfish (Kimber *et al*. 2011) suggests that although they possess the ability to distinguish certain artificial E fields, sharks are either unable to distinguish, or showed no preference between similar strength, anthropogenic (dipole) and natural (live crab) DC E fields.

7.11.4. Information gathered as part of the monitoring programme undertaken at Burbo Bank suggest that certain elasmobranch species (sharks, skates and rays) do feed inside the wind farm and demonstrated that they are not excluded during periods of low power generation (Cefas 2009). Monitoring at Kentish Flats found an increase in thornback ray, smooth hound and other elasmobranchs during post construction surveys in comparison to surveys before construction. It appeared, however, that there was no discernible difference between the data for the wind farm site and reference areas, including population structure changes. It was therefore concluded that the population increase observed was unlikely to be related to the operation of the wind farm (Cefas 2009).

Dogger Bank Teesside A

7.11.5. Few sharks and rays were captured in fish characterisation surveys and their relative abundance in the vicinity of Dogger Bank Teesside A is considered to be low. However, elasmobranchs typically have wide distribution ranges and defined nursery grounds for spurdog and tope overlap with both Dogger Bank Teesside A and Dogger Bank Teesside B. Therefore, there is considerable potential for these species to transit Dogger Bank Teesside A.

7.11.6. EMF produced by the array cables is expected to result in temporary behavioural reactions, rather than long term impacts on feeding, migration or confusion in elasmobranch species. A medium level of interaction between elasmobranchs and EMF is therefore expected. Elasmobranch species are considered as receptors of medium vulnerability, medium recoverability and local value, therefore they are receptors of medium sensitivity. As previously defined, the magnitude of the effect is considered to be low. EMF related effects are therefore assessed to result in a **minor adverse** impact.

Dogger Bank Teesside B

7.11.7. As described for Dogger Bank Teesside A.

Dogger Bank Teesside A & B

7.11.8. The assessment for both Dogger Bank Teesside A and Dogger Bank Teesside B individually also applies to Dogger Bank Teesside A & B combined.

7.11.9. As described in detail in **Appendix 13A**, a number of elasmobranch species are expected to be found along the Dogger Bank Teesside A & B Export Cable Corridor. Starry smoothhound, lesser spotted dogfish, spotted ray and thornback ray were all recorded in the Dogger Bank Teesside A & B Inshore Export Cable Corridor Study Area in trammel net surveys. In addition, the Dogger Bank Teesside A & B Export Cable Corridor falls within the wide nursery grounds defined for spurdog.

7.11.10. Elasmobranchs are expected to make limited use of the Dogger Bank Teesside A & B Export Cable Corridor Study Area in the context of their wide distribution ranges. In addition, EMF associated with export cables are only expected to result in temporary behavioural reactions, rather than long term impacts on feeding, migration or confusion. In light of this, elasmobranchs are considered to be receptors of medium vulnerability, medium recoverability and local value; therefore they are receptors of medium sensitivity. The magnitude of the effect is assessed as low and EMF is anticipated to result in a **minor adverse** impact.

Diadromous migratory species

7.11.11. European eel possess magnetic material of biogenic origin of a size suitable for magnetoreception (Hanson *et al*. 1984; Hanson and Walker 1987; Moore and Riley 2009) and are thought to use the geomagnetic field for orientation (Karlsson 1985). In addition, their lateral line has been found to be slightly sensitive to electric current (Berge 1979; Vriens and Bretschneider 1979). Research carried out on salmon and sea trout also indicates that these species are able to respond to magnetic fields (Formicki *et al*. 2004; Tanski *et al*. 2005; Sadowski *et al*. 2007; Formicki and Winnicki 2009). The presence of magnetic material suitable for magnetoreception has been found in Atlantic salmon (Moore *et al*. 1990), as has the ability of this species to respond to electric fields (Rommel and McLeave 1973).

7.11.12. Lampreys possess ampullary electroreceptors that are sensitive to weak, low-frequency electric fields (Bodznick and Northcutt 1981; Bodznick and Preston 1983); however, information on the use that they make of the electric sense is limited. It is likely however that they use it in a similar way as elasmobranchs to detect prey, predators or conspecifics and potentially for orientation or navigation (Normandeau *et al*. 2011).

Dogger Bank Teesside A

7.11.13. Dogger Bank Teesside A is located 196km offshore, therefore it is expected that diadromous migratory species will not be subject to EMF associated with array cables prior to river entry or immediately after leaving rivers. They may, however, occasionally transit Dogger Bank Teesside A, and there is, therefore, potential for EMF associated with the array to affect these species during migration and/or feeding activity.

7.11.14. As previously mentioned, the strength of E and B fields decreases quickly with distance to the source, hence potential effects on movement and behaviour in salmonids, likewise in other pelagic species, would be closely linked to the proximity of the fish to the source of EMF. Gill and Bartlett (2010) suggest that any potential EMF associated effect on the migration of salmon and sea trout is dependent on the depth of water and the proximity of natal rivers to development sites. The migration of Atlantic salmon in the Baltic Sea for example seems to continue unaffected, despite the presence of a number of operating HVDC cables in the path of the migration route (Walker 2001). The level of effect-receptor interaction between EMF associated with the array cables and salmon and sea trout is considered to be small. These species are considered to be receptors of medium vulnerability, medium recoverability and regional to national importance therefore they are deemed to be of medium sensitivity. The magnitude of the effect is considered to be low therefore the effect of EMF on salmonids is assessed to result in a **minor adverse** impact.

7.11.15. As suggested above for salmonids, European eel may also occasionally transit Dogger Bank Teesside A as part of their migration. A number of studies have been carried out in relation to the migration of eels and the effects of EMF derived from offshore wind farm cables. Experiments undertaken at the operational wind farm of Nysted detected barrier effects. However, correlation analysis between catch data and data on power production showed no indication that the observed effects were attributable to EMF. Furthermore, mark and recapture experiments showed that eels did cross the export cable (Hvidt *et al*. 2005). Similarly research by Westerberg (1999) on HVDC cables and eel migration found some effects associated with the magnetic disturbance were likely to occur although the consequences appeared to be small. In addition, no indication was found that the cable constituted a permanent obstacle to migration, either for adult eels or for elvers.

7.11.16. Further research, where 60 migrating silver eels were tagged with ultrasonic tags and released north of a 130 kV AC cable, found swimming speeds were significantly lower around the cable than in areas to the north and south (Westerberg and Lagenfelt 2008). It was noted that no details on the behaviour during passage over the cable were recorded and possible physiological mechanisms explaining the phenomenon were unknown. Based on the results of Westerberg and Lagenfelt (2008) before publication, Öhman *et al*. (2007) suggested that even if an effect on migration was demonstrated, the effect was small, and on average the delay caused by the passage was approximately 30 minutes. Based on the above, a medium degree of interaction between EMF and European eel is expected to occur. European eel are therefore considered to be receptors of medium vulnerability, medium recoverability and national importance, therefore they are deemed to be of medium sensitivity. The magnitude of the effect is considered to be low thus EMF related effects are assessed to result in a **minor adverse** impact.

7.11.17. The information available to date on the response lamprey have to E fields is limited. Chung-Davidson (2008) found that weak electric fields may play a role in their reproduction and it was suggested that electrical stimuli provoke different behaviour in feeding-stage and spawning-stage sea lampreys. Lampreys spawn in freshwater therefore will only be exposed to EMF if migration routes to freshwater spawning sites cross areas with EMF influence. The degree of interaction between lampreys and EMF is anticipated to be very small. Lampreys are considered of low vulnerability, medium recoverability and international importance, therefore they are deemed to be of low sensitivity and effects associated with EMF are assessed to result in a **minor adverse** impact.

Dogger Bank Teesside B

7.11.18. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B

7.11.19. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B Export Cable Corridor

7.11.20. Diadromous species are more likely to cross export cables than array cables, particularly in the Inshore Dogger Bank Teesside A & B Export Cable Corridor Study Area. The Dogger Bank Teesside A & B Export Cable Corridor landfall is situated between two designated ‘principal salmon rivers’; the Yorkshire Esk to the south and the Tees immediately to the north. Both of these rivers support populations of salmonids. However, given the distance between the landfall site and the mouths of the Esk and the Tees, it is not expected that diadromous species will be subject to the effect of EMF prior to or immediately after leaving the rivers.

7.11.21. The effect-receptor interaction for diadromous species is anticipated to be low. Salmon and sea trout are considered to be receptors of low vulnerability, medium recoverability and national importance, therefore they are deemed to be receptors of low sensitivity. The magnitude of the effect is low and the effect of EMF on salmonids is, therefore, assessed to result in a **minor adverse** impact.

7.11.22. European eel is considered as a receptor of low vulnerability, medium recoverability and national value, therefore European eel is deemed to be a receptor of low sensitivity. The magnitude of the effect is low and the impact associated with EMF is considered to be **minor adverse.**

7.11.23. Lampreys are considered as receptors of low vulnerability, medium recoverability and international value, therefore they are deemed to be receptors of low sensitivity. The magnitude of the effect is low and the impact associated with EMF is considered to be **minor adverse**.

Other Fish Species

7.11.24. Further to the species described above, as shown in **Table 7.6** and **Table 7.7** there is some evidence of a response to EMF in other fish species, such as cod and plaice VERs (Gill *et al*. 2005).

Dogger Bank Dogger Bank Teesside A

7.11.25. The results of post-construction monitoring carried out in operational wind farms do not suggest that EMF have resulted in significant detrimental impacts on these species. Lindeboom *et al*. (2011) suggests that the presence of the foundations and scour protection and potential changes in the fisheries related to offshore wind farm development would have the most impact upon fish species. Similarly, Leonhard and Pedersen (2006) indicate that noise from the wind turbines and EMF from cabling do not seem to have a major impact on fish and other mobile organisms attracted to the hard bottom substrates for foraging, shelter and protection. In line with this, research carried out at the Nysted offshore wind farm (Denmark), focused on detecting and assessing possible effects of EMF on fish during power transmission, and found no differences in the fish community composition after the wind farm was operational (Hvidt *et al*. 2005). Whilst effects on the distribution and migration of four species were observed (European eel, flounder, cod and Baltic herring), it was recognised that the results were likely to be valid on a very local scale, and only on the individual level, and that an impact on a population or community level was likely to be very limited.

7.11.26. Taking the above into account, it is expected that EMF will only result in short term, temporary behavioural effects on these species. All other fish and shellfish receptors are deemed to be of low vulnerability and are of local to regional importance in the fish and shellfish study area. The sensitivity of these receptors is therefore, considered to be low. Magnitude is deemed to be low therefore the impact is assessed as **minor adverse**.

Dogger Bank Teesside B

7.11.27. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B

7.11.28. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B Export Cable Corridor

7.11.29. There is some evidence of a response to EMF in teleost species such as cod and plaice. The results of monitoring programmes carried out in operational wind farms do not suggest that EMF have resulted in a detrimental impact on these species. Leonhard and Pedersen (2006) indicate that EMF from cabling do not seem to have a major impact on fish and other mobile organisms attracted to the hard bottom substrates for foraging, shelter and protection.

7.11.30. It is therefore expected that EMF will at worst, result in short term, temporary behavioural effects on these species. The “other fish species” receptor group are deemed to be of low vulnerability and are of local to regional importance in the study area. The sensitivity of these receptors is therefore, considered to be low. Magnitude is deemed to be low therefore the impact is assessed as **minor adverse**.

Shellfish

7.11.31. Research on the ability of marine invertebrates to detect EMF has been limited. Although there is no direct evidence of effects to invertebrates from undersea cable EMF (Normandeau *et al*. 2011), the ability to detect magnetic fields has been studied for some species and there is evidence in some of a response to magnetic fields, including molluscs and crustaceans (**Table 7.6**).

7.11.32. Crustacea, including lobster and crabs, have been shown to demonstrate a response to B fields, with the spiny lobster *Panulirus argus* shown to use a magnetic map for navigation (Boles and Lohmann; 2003). However, it is uncertain if other crustaceans including commercially important brown crab and European lobster are able to respond to magnetic fields in this way. Limited research undertaken with the European lobster found no neurological response to magnetic field strengths considerably higher than those expected directly over an average buried power cable (Normandeau *et al*. 2011; Ueno *et al*. 1986). Indirect evidence from post construction monitoring programmes undertaken in operational wind farms do not suggest that the distribution of potentially magnetically sensitive species of crustaceans or molluscs have been affected by the presence of submarine power cables and associated magnetic fields.

Dogger Bank Teesside A

7.11.33. The principal shellfish species identified in **Appendix 13A** appear to be more abundant in areas closer to shore, making them more relevant to the Dogger Bank Teesside A & B Export Cable Corridor than within the boundaries of Dogger Bank Teesside A. Species such as brown shrimp and velvet crab have, however, been found within Tranche A in relatively high numbers. Other species such as edible crab and queen scallop have also been found occasionally during survey work within Tranche A.

7.11.34. Research undertaken by Bochert and Zettler (2004), where a number of species, including the brown shrimp and mussels *Mytilus edulis* both found in UK waters, were exposed to a static magnetic field of 3.7mT for several weeks, found no differences in survival between experimental and control animals. The effect of EMF on shellfish is, therefore, expected to be limited to behavioural responses.

7.11.35. The role of the magnetic sense in invertebrates has been hypothesised to function in relation to orientation, navigation and homing, using geomagnetic cues (Cain *et al*. 2005; Lohmann *et al*. 2007). Research undertaken on the Caribbean spiny lobster *Panulirus argus* (Boles and Lohmann 2003) suggests that this species derives positional information from the Earth's magnetic field which is used during long distance migration. *Nephrops* and European lobster belong to the same taxonomic family (Nephropidae) and neither are known to undertake significant long distance migrations. Indeed limited research undertaken with the European lobster found no neurological response to magnetic field strengths considerably higher than those expected directly over an average buried power cable (Ueno *et al*. 1986; Normandeau *et al*. 2011).

7.11.36. Indirect evidence from monitoring programmes undertaken in operational wind farms do not suggest that the distribution of potentially magnetically sensitive species of crustaceans or molluscs have been affected by the presence of submarine power cables and associated magnetic fields. In this context, however, the lack of shellfish specific EMF monitoring programmes should be recognised. As a result of the information provided above shellfish species are considered receptors of low vulnerability, medium recoverability and local regional importance. Their sensitivity is low, the magnitude is low and EMF related effects are assessed to result in a **minor adverse** impact.

Dogger Bank Teesside B

7.11.37. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B

7.11.38. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B Export Cable Corridor

7.11.39. The degree of interaction between shellfish species and B fields associated with the Dogger Bank Teesside A & B Export Cable Corridor is expected to be very small. Whilst some species may use the earth's magnetic field for orientation, there is no evidence to date to suggest that EMF associated with offshore wind farms have potential to result in significant effects on shellfish species. Indirect evidence from monitoring programmes undertaken in operational wind farms do not suggest that the distribution of potentially magnetically sensitive species of crustaceans or molluscs have been affected by the presence of submarine power cables and associated B fields. Research undertaken by Bochert and Zettler (2004), where a number of commercially important shellfish species such as brown shrimp and mussels were exposed to a static magnetic field of 3.7 mT for several weeks. This field strength was chosen to represent a maximum value which could be emitted by cables associated with offshore wind farms and is considerably higher than the averaged values outlined in **Table 7.4** and **Table 7.5** (Normandeau *et al*. 2011). The experiment tested both long term survival and fitness (measured by condition and gonosomatic indices) in experimental and control animals and found no significant differences between treatments. The functional role of the magnetic sense in invertebrates is hypothesized to be for orientation, navigation and homing using geomagnetic cues (Cain *et al*. 2005; Lohmann *et al*. 2007). As a result of research undertaken by Bochert and Zettler (2004), in addition to that of Normandeau *et al.* (2011) and Ueno *et al.* 1986, it is assumed that *Nephrops* will not be impacted by EMF.

7.11.40. There is a general lack of information and research on the potential changes in water/sediment temperature as a result of the installation of sub-sea power cables. When electric energy is transported, increased temperature of the cable surface can sometimes lead to subsequent warming of the surrounding environment. The two main types of offshore cable used in the offshore wind sector are HVAC and HVDC. In general, thermal radiation can be expected to be greater for HVAC cables than for HVDC cables at equal transmission rates (OSPAR commission; 2009). This is because transmission losses for HVDC cables are significantly lower than for HVAC cables. Field measurements carried out to assess thermal radiation from wind farm cables at the Nysted wind farm (Denmark) showed an average variation of 0.8K directly above (25cm) an installed 132kV HVAC cable relative to a control site. Less deviation was found in lateral locations (30cm to the side) indicating attenuation was rapid within the sediment (Meibner *et al*. 2007). Measurements at the sediment surface however were the same as ambient conditions suggesting little heating effect on the overlying water column. Therefore, it is not expected that temperature radiation as a result of EMF will impact shellfish species in the area.

7.11.41. Taking the degree of interaction between shellfish receptors and the effect of EMF, and the fact that shellfish are receptors of low vulnerability, medium recoverability and local importance. Their sensitivity is low, the magnitude is low and the impact is therefore anticipated to be **minor adverse**.

7.12. EMF impact assessment summary

7.12.1. A summary of the EMF impact assessment is given in **Table 7.8**.

Table 7.8 EMF impact assessment summary

Potential effect	Effect magnitude	Receptor		Receptor sensitivity		Impact
	Dogger Bank Teesside A, B Dogger Bank Teesside A & B Dogger Bank Teesside A & B Export Cable Corridor			Dogger Bank Teesside A, B Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor	All areas
EMF	Low	Elasmobranchs		Medium		Minor adverse
		Diadromous migratory species	Salmon and sea trout	Medium	Medium	
			European sea eel	Medium	Medium	
			Lamprey	Low	Low	

7.13. Operational noise-effects

7.13.1. The main source of noise during operation originates from the wind turbines gearbox and generator. In addition, noise would also result from surface vessels servicing the wind farm. The radiated levels from the wind turbines are low and the spatial extent of the potential effect on marine receptors is generally considered to be small and unlikely to result in injury. Measurements of operational noise at a series of UK wind farm sites (Nedwell *et al*. 2007) found that in general, the noise levels generated were very low, being only marginally above ambient noise levels.

7.13.2. In this context a major contribution to the ambient noise would result from sea-state, which would be expected to increase as the wind turbine rotational speed increases with wind speed. Increased ambient noise may, therefore, exceed wind turbine noise (Tougaard and Henriksen 2009). Furthermore, considering the operational noise of the wind farm and any associated service vessels, the ambient noise levels within Dogger Bank Teesside A and Dogger Bank

Teesside B would be expected to be lower than those present in the vicinity of the shipping lanes to the north and south.

7.13.3. Given the low noise levels predicted, any risk of significant behavioural disturbance on fish would be limited to the area immediately surrounding the wind turbine, which represents a very small proportion of the area of Dogger Bank Teesside A & B. Similarly, the combined area affected taking account of Dogger Bank Teesside A & B would be small.

7.13.4. Taking the above into account, the magnitude of the effect of operational noise on fish and shellfish receptors is considered to be low for Dogger Bank Teesside A, Dogger Bank Teesside B and Dogger Bank Teesside A & B.

7.14. Operational noise- impacts

Dogger Bank Teesside A

7.14.1. Research by Wahlberg and Westerberg (2005) found that operational noise did not have any destructive effect upon the hearing ability of fish, even within distances of a few meters. It was estimated that fish would only be consistently scared away from wind turbines at ranges shorter than 4m and only at high wind speeds (higher than 13 m/s).

7.14.2. Post-construction monitoring of hard substrate communities at Horns Rev Offshore Wind Farm (Leonhard and Pedersen 2005) found, based on comparisons with fish fauna on shipwrecks in other parts of the North Sea, that there was great similarity in the species observed, including benthic species. The authors note that there was no indication that noise or vibrations from the wind turbines had any impacts on the fish community. This is in line with the findings of post construction monitoring carried out in other wind farms described in the 'Introduction of Hard Substrate' section above (i.e. Winter *et al*. 2010; Stenberg *et al*. 2011; Lindeboom *et al*. 2011; Couperus *et al*. 2010).

7.14.3. Taking the above into account it is reasonable to assume that the effect of operational noise on fish and shellfish will be limited and the level of interaction is low. Fish and shellfish receptors are therefore, considered to be of low vulnerability, high recoverability and of local to international value. The sensitivity of these receptors is deemed to be low and in the context of the low magnitude of the operational noise, the effect is assessed to result in a **minor adverse** impact.

Dogger Bank Teesside B

7.14.4. As assessed above for Dogger Bank Teesside A.

Dogger Bank Teesside A & B

7.14.5. As assessed above for Dogger Bank Teesside A.

7.15. Operational noise impact assessment summary

7.15.1. A summary of the operational noise impact assessment on fish and shellfish receptors is given below in **Table 7.9**

Table 7.9 Operational noise impact assessment summary

Potential effect	Magnitude	Receptor	Sensitivity	Impact
	Dogger Bank Teesside A, B and Dogger Bank Teesside A & B		Dogger Bank Teesside A, B and Dogger Bank Teesside A & B	Dogger Bank Teesside A, B and Dogger Bank Teesside A & B
Operational noise	Low	Fish and shellfish (general)	Low	Minor adverse

7.16. Changes to fishing activity

7.16.1. Changes to fishing activity as a result of the installation of Dogger Bank Teesside A and Dogger Bank Teesside B could potentially affect fish and shellfish species. Primarily this would be species commercially targeted and/or caught as by-catch, although a wider range of organisms may also be affected due to changes in seabed communities associated with seabed disturbance. Physical disturbance of habitat arising from the passage of fishing gear over the seabed occurs in a number of ways (Kaiser *et al*. 2003):

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

7.16.2. A reduction in fishing activity in Dogger Bank Teesside A & B may benefit seabed communities, this could in turn have a positive effect on fish and shellfish species, provided the productivity of the area increases. In addition, target and by-catch species would be positively affected through a direct decrease in fishing mortality on a site specific basis. The potential displacement of fishing into other sensitive areas should, however, be recognised.

7.16.3. As indicated in **Chapter 15** there may be potential for some decrease in fishing effort within Dogger Bank Teesside A and Dogger Bank Teesside B during the operational phase. In the case of the Dogger Bank Teesside A & B Export Cable Corridor it is expected that fishing activities will continue at levels similar to those prior to cable installation (see **Chapter 15,** paragraph 8.2.35). Taking the relatively small levels of change expected in fishing activity during the operational phase, the magnitude of the effect is considered to be low. This is considered to be the case for Dogger Bank Teesside A, Dogger Bank Teesside B and Dogger Bank Teesside A & B Export Cable Corridor.

7.16.4. The sensitivity of fish and shellfish species to changes in fishing activity will vary depending on the species under consideration and where fishing effort is displaced to. It is not possible however to undertake a detailed assessment at this early stage. It is considered that if there is a small to medium degree of interaction between fish and shellfish receptors then the effect may occur. Fish and shellfish receptors are therefore expected to, at worst, be of medium vulnerability, medium recoverability and regional importance, therefore they are deemed to be of medium sensitivity. The magnitude is considered to be low as a result the effect associated with changes to fishing activity is not anticipated to result in an impact above **minor adverse**.

7.17. Changes to fishing activity impact assessment summary

7.17.1. A summary of the changes to fishing activity impact assessment is given in **Table 7.10**.

Table 7.10 Changes to fishing activity impact assessment summary

Potential effect	Magnitude of effect	Receptor	Receptor sensitivity	Impact
	Dogger Bank Teesside A, B and Dogger Bank Teesside A & B		Dogger Bank Teesside A, B and Dogger Bank Teesside A & B	Dogger Bank Teesside A, B and Dogger Bank Teesside A & B
Changes to fishing activity	Low	Fish and shellfish (general)	Medium	Minor adverse

8. Impacts during Decommissioning

8.1.1. The principal potential effects on fish and shellfish species associated with decommissioning are as follows:

- Physical disturbance of seabed habitat;
- Increased suspended sediment concentrations and increased sediment deposition;
- Noise; and
- Loss of artificial habitat/colonising structures.

8.1.2. For the purposes of this assessment and in the absence of detailed information on decommissioning schedules and methodologies at this early stage, it is assumed that any impacts derived from the decommissioning phase will at worst be of no greater impact than those during the construction. Impacts during construction are not anticipated to be greater than **minor adverse**.

8.1.3. As indicated in **Chapter 5** it is currently envisaged that piled foundations would be cut below seabed level with the protruding section being removed. In the case of GBS foundations it may be preferable to leave the structures on the seabed to preserve the marine habitat that has been established there during the operational phase, subject to discussion with key stakeholders and regulators. This may also be the case in terms of removal of scour protection.

8.1.4. Foundation cutting or dredging and seabed disturbance resulting from removal of cables and cable protection may cause short-term increases in suspended sediment concentrations, however since there will be no need for seabed preparation or pile drilling, and considering the possibility that cables will be left in situ, any increase in suspended sediment concentration will be less than that described for the construction phase.

8.1.5. It should be noted that pile driving is not expected to be required during decommissioning. As a result, noise related effects associated with this phase are expected to be considerably below those previously assessed for the construction phase.

9. Inter-relationships

9.1.1. The assessment of the impacts arising from construction, operation and decommissioning of Dogger Bank Teesside A, Dogger Bank Teesside B and the Dogger Bank Teesside A & B Export Cable Corridor given above, indicates that impacts on receptors addressed in other ES chapters may potentially further contribute to the impacts assessed on fish and shellfish species and vice versa. The objective of this section is to identify where the accumulation of residual impacts on a single receptor, and the relationship between those impacts, gives rise to a need for additional mitigation.

9.1.2. The principal linkages identified are summarised in **Table 9.1** below. No inter-relationships have been identified where an accumulation of residual impacts on fish and shellfish ecology gives rise to a need for additional mitigation.

Table 9.1 Fish and shellfish ecology inter-relationships

Inter-relationship	Relevant sections	Linked chapters
Impacts on seabed habitats	Impact assessment sections 6 - 8	**Chapter 9 Marine Physical Processes**
		Chapter 12 Marine and Intertidal Ecology
Impacts on commercial species	Commercial species have been taken into account across the whole of this chapter.	**Chapter 15 Commercial Fisheries**
Impacts on fish species due to pollutants from sediment and accidental spillage as well as an increase in turbidity	Impact assessment Section 6.2 and throughout **Chapter 10 Marine Water and Sediment Quality**	**Chapter 10 Marine Water and Sediment Quality**
Effects on key prey species	Key prey species have been taken in to account across both **Appendix 13A**: **Fish and Shellfish Technical Report** and throughout this chapter.	**Chapter 14 Marine Mammals**
		Chapter 11 Marine and Coastal Ornithology
		Chapter 12 Marine and Intertidal Ecology

10. Cumulative Impacts

10.1. CIA Strategy and screening

10.1.1. This section describes the cumulative impact assessment for fish ecology, taking into consideration other plans, projects and activities. A summary of the cumulative assessment is presented in **Chapter 33**

10.1.2. Forewind has developed a strategy (the ‘CIA Strategy’) for the assessment of cumulative impacts in consultation with a number of statutory stakeholders, including the MMO. Further details of the approach to CIA that has been adopted for this ES are provided in **Chapter 4**.

10.1.3. In its simplest form the strategy involves consideration of:

- Whether impacts on a receptor can occur on a cumulative basis between the wind farm project(s) subject to the application(s) and other wind farm projects, activities and plans in the Dogger Bank Zone (either consented or forthcoming); and
- Whether impacts on a receptor can occur on a cumulative basis with other activities, projects and plans outwith the Dogger Bank Zone (e.g. other offshore wind farm developments), for which sufficient information regarding location and scale exist.

10.1.4. In this manner, the assessment considers (where relevant) the potential for cumulative impacts in the following sequence:

- The cumulative impacts associated with Dogger Bank Teesside A & B and the Dogger Bank Teesside A & B Export Cable Corridor and Dogger Bank Creyke Beck A & B and Dogger Bank Teesside C & D including their respective Export Cable Corridors;
- The cumulative effects of Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D with other planned, consented or under construction wind farm developments outside of the Dogger Bank Zone; and
- The cumulative effects of Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D with other planned, consented or under construction wind farm developments outside the Dogger Bank Zone and other future installations, regulated activities such as aggregate dredging and possible marine conservation areas which may exclude or restrict commercial fishing activities.

10.1.5. The strategy recognises that data and information sufficient to undertake an assessment will not be available for all potential projects, activities, plans and/or parameters, and seeks to establish the ‘confidence’ we can have in the data and information available.

10.1.6. In order to identify the activities, projects and plans to take forward in the detailed assessment that follows, a two-step screening process is undertaken:

- Impact screening (**Table 10.1**): consideration of the potential for each impact, as assessed for Dogger Bank Teesside A & B in isolation, to contribute to a cumulative impact both within and outwith the Dogger Bank Zone. This step also involves an appraisal of the confidence in the information available to inform the screening decision (following the methodology set out in **Chapter 4**); and
- Project screening (**Table 10.2**): the identification of the actual individual plans, projects and activities that may result in cumulative impacts for inclusion in the CIA. In order to inform this, Forewind has produced an exhaustive list of plans, projects and activities occurring within a very large study area encompassing the greater North Sea and beyond (referred to as the 'CIA Project List', see **Chapter 4**). The list has been appraised, based on the confidence Forewind has in being able to undertake an assessment from the information and data available, enabling individual plans, projects and activities to be screened in or out.

10.1.7. Installed infrastructure including wind farms, oil and gas installations and sub-sea cables are considered to form part of the existing environment and are not considered in the following assessment. Similarly, military activities are also considered to be part of the existing environment to which fish and shellfish are currently exposed, and therefore have not been included in the current assessment.

10.1.8. In addition to the above, the potential impact of Dogger Bank Teesside A & B with possible marine conservation areas (which may exclude or restrict commercial fishing activities) is discussed separately at the end of this section.

10.1.9. The potential impacts considered for cumulative assessment are those associated with the construction phase:

- Temporary disturbance of seabed; and
- Construction noise.

10.1.10. Cumulative effects derived from the operational phase (loss of habitat, introduction of hard substrate, operational noise and EMF), have not been considered for assessment of cumulative impacts with other developments/activities, given the limited and site specific nature of the predicted impacts as demonstrated in the Dogger Bank Creyke Beck specific impact assessment given above (see Section 6).

10.1.11. In the particular case of impacts associated with the decommissioning phase, given the limitations in relation to final decommissioning methodologies, not only in relation to Dogger Bank Teesside A & B, but other projects included in this assessment, potential effects associated with this phase have not been considered for the purposes of the cumulative impact assessment.

10.1.13. Furthermore, the evaluation of magnitude of effects and sensitivities of receptors carried out in this assessment are, to a large extent, of a subjective nature. This is a result of the lack of detailed information on the existing environment descriptions and impact assessments for the various other developments and measures being considered in this assessment, with the exception of Dogger Bank Teesside A & B. As such, impact significance has only been applied to the cumulative assessment to wind farm projects within the Dogger Bank Zone.

Table 10.1 Potential cumulative impacts (impact screening)

Impact	Potential cumulative impact in the Zone & Dogger Bank Teesside A & B Export Cable Corridor	Potential cumulative impact outside the Zone	Data confidence (Zone and Dogger Bank Teesside A & B Export Cable Corridor)	Data confidence (outside the Zone)
Temporary physical disturbance/loss of seabed habitat	Yes	Yes	Medium	Medium
Construction noise	Yes	Yes	Medium	Medium
Permanent loss of habitat	Yes	Yes	Medium	Medium
Introduction of hard substrate	Yes	Yes	Medium	Medium
Operational noise	Yes	Yes	Medium	Medium
EMF	No	No	N/A	N/A

10.1.14. The plans, projects and activities relevant to other marine users are presented in **Table 10.2** along with the results of the screening exercise that identifies whether there is sufficient confidence to take these forward in a detailed cumulative assessment.

10.1.15. It should be noted that:

- Where Forewind is aware that a plan, project or activity could take place in the future, but has no information on how the plan, project or activity will be executed, it is screened out of the assessment;
- Existing projects, activities and plans are already having an impact and so are part of the existing environment as it has been assessed throughout this ES. Therefore these projects have not been included in the cumulative assessment;
- Military exercises and firing ranges are also considered to be part of the existing environment to which fishermen have adapted and have, therefore, also not been assessed; and
- With the exception of Dogger Bank Teesside A & B and Dogger Bank Creyke Beck, detailed existing baseline descriptions, impact assessments and measures being considered are not available for every development included in the CIA project list.

10.1.16. Forewind is intending to develop four other projects within the Dogger Bank Zone in addition to Dogger Bank Teesside A & B. Project information and boundaries are available for Dogger Bank Creyke Beck and Dogger Bank Teesside C & D, which are shown in **Figure 10.1.**

10.1.17. Dogger Bank Teesside A & B comprise two wind farms, each with a generating capacity of up to 1.2GW, which will connect into the national grid at Lackenby substation. Dogger Bank Teesside A & B will have a total generating capacity of up to 2.4GW. Dogger Bank Teesside C & D will comprise two wind farms, each with a generating capacity of up to 1.2GW, which will connect into the national grid just south of the Tees Estuary. Dogger Bank Teesside C & D will have a total generating capacity of up to 2.4GW.

10.1.18. Dogger Bank Creyke Beck will comprise two wind farms (Creyke Beck A and Creyke Beck B), each with a generating capacity of up to 1.2GW, and will connect to the existing National Grid substation at Creyke Beck, in the East Riding of Yorkshire. Dogger Bank Creyke Beck A & B will have a total generating capacity of up to 2.4GW. As suggested in **Chapter 9**, the worst case scenario in terms of increased suspended sediments would be for all six projects to be constructed at the same time over a six-year period.

Table 10.2 Cumulative Impact Assessment screening for fish ecology (project screening)

Type of project	Project title	Project status	Predicted construction/ development period	Distance from Dogger Bank Dogger Bank Teesside (km)	Confidence in project details	Confidence in project data	Carried forward to cumulative impact assessment?	Rationale for where no cumulative impact is expected
Offshore wind farm	Dogger Bank Creyke Beck	Pre-Application	Construction may start from 2016	Dogger Bank Teesside A approximately 35. Dogger Bank Teesside B approx. 5	High	High	Yes	N/A
Offshore wind farm	Dogger Bank Teesside C & D	Potential	Not confirmed	Dogger Bank Teesside A approximately 27. Dogger Bank Teesside B approx. 8	High	High	Yes	N/A
Offshore wind farm	Hornsea Project One	Pre-consent	Project One may start construction 2015	Approx. 64 to the south of Dogger Bank Teesside A	Medium	Medium	Yes	N/A
Offshore wind farm	Hornsea Project Two	Potential	Not confirmed	Approx. 59 to the south of Dogger Bank Teesside A	Medium	Medium	Yes	N/A
Offshore wind farm	Hornsea Zone – other future development	Potential	Not confirmed	Not confirmed	Low	Low	No	Low confidence in project details and data

Type of project	Project title	Project status	Predicted construction/ development period	Distance from Dogger Bank Dogger Bank Teesside (km)	Confidence in project details	Confidence in project data	Carried forward to cumulative impact assessment?	Rationale for where no cumulative impact is expected
Offshore wind farm	Westernmost Rough	Consented	2012-2014	Approx. 25 to the south of the export cable	High	Medium	Yes	N/A
Offshore wind farm	H2-20	Pre-consent	Not confirmed	Approx. 150 to the north-east of Dogger Bank Teesside A and Dogger Bank Teesside B	Medium	Medium	No	Distance (see Section 10.3.4)
Offshore wind farm	Firth of Forth	Pre-Application	Not confirmed	Approx. 211 to the north-west of Dogger Bank Teesside B	Medium	Low	Yes	N/A
Offshore wind farm	East Anglia One	Pre-consent	2015-2017	Approx. 250 to the south of the export cable and Dogger Bank Teesside A.	Medium	Medium	Yes	N/A
Offshore wind farm	East Anglia Zone- other future developments	Potential	Not confirmed	Not confirmed	Low	Low	No	Low confidence in project details and data
Offshore wind farm	Triton Knoll	Consented	Construction may start from 2017	Approx. 145 to the south of Dogger Bank Teesside A	Yes	Medium	Yes	N/A

Type of project	Project title	Project status	Predicted construction/ development period	Distance from Dogger Bank Dogger Bank Teesside (km)	Confidence in project details	Confidence in project data	Carried forward to cumulative impact assessment?	Rationale for where no cumulative impact is expected
Aggregate extraction	Area 466	Application area	Awaiting decision	Approx. 3 to the north of Dogger Bank Teesside B	Medium	Medium	Yes	N/A
Aggregate extraction	Area 485	Application area	Not confirmed	Approx. 5 to the south-west of the Dogger Bank Teesside A and 20 south of the export cable	Medium	Medium	Yes	N/A
Aggregate extraction	Area 448	Application area	Not confirmed	Approx. 50 to the south-west of the export cable	Medium	Medium	No	Distance & subsequent low likelihood of interaction (see Section 10.4)
Aggregate extraction	Area 449	Application area	Not confirmed	Approx. 50 to the south-west of the export cable	Medium	Medium	No	As above
SACs with Marine Components	Dogger Bank	Potential cSAC	In consultation	0	Medium	Medium	Yes	N/A
SACs with Marine Components	North Norfolk Sandbanks & Saturn Reef	Potential cSAC	In consultation	104	Medium	Medium	Yes	N/A

Type of project	Project title	Project status	Predicted construction/ development period	Distance from Dogger Bank Dogger Bank Teesside (km)	Confidence in project details	Confidence in project data	Carried forward to cumulative impact assessment?	Rationale for where no cumulative impact is expected
Nature Conservation	NG 12, Compass Rose	Potential Netgain rMCZ	In consultation	80	Medium	High	Yes	N/A
Nature Conservation	RA 10, Compass Rose RA	Potential Netgain rRA	In consultation	90	Medium	High	Yes	N/A
Nature Conservation	NG 11, Runswick Bay	Potential Netgain rMCZ	In consultation	139	Medium	High	Yes	N/A
Nature Conservation	NG 9, Holderness Offshore	Potential Netgain rMCZ	In consultation	117	Medium	High	Yes	N/A
Nature Conservation	NG 8, Holderness Inshore	Potential Netgain rMCZ	In consultation	141	Medium	High	Yes	N/A
Nature Conservation	Doggersbank pSCI	Potential SCI designation	Not known	47	Medium	Medium	Yes	N/A

Type of project	Project title	Project status	Predicted construction/ development period	Distance from Dogger Bank Dogger Bank Teesside (km)	Confidence in project details	Confidence in project data	Carried forward to cumulative impact assessment?	Rationale for where no cumulative impact is expected
Nature Conservation	NG 7, Markham's Triangle	Potential Netgain rMCZ	In consultation	84	Medium	High	Yes	N/A
Nature Conservation	Klaverbank pSCI	Potential SCI designation	Unknown	74	High	Medium	Yes	N/A
Nature Conservation	NG 6, Silver Pit	Potential Netgain rMCZ	In consultation	136	Medium	High	Yes	N/A
Nature Conservation	NG 5, Lincs Belt	Potential Netgain rMCZ	In consultation	162	Medium	High	Yes	N/A
Nature Conservation	RA 6, Dogs Head Sandbanks	Potential Netgain rRA	In consultation	204	Medium	High	Yes	N/A
Nature Conservation	NG 2, Cromer Shoal Chalk Beds	Potential Netgain rMCZ	In consultation	188	Medium	High	Yes	N/A

Type of project	Project title	Project status	Predicted construction/ development period	Distance from Dogger Bank Dogger Bank Teesside (km)	Confidence in project details	Confidence in project data	Carried forward to cumulative impact assessment?	Rationale for where no cumulative impact is expected
Nature Conservation	RA 1, North Norfolk Blue Mussel Beds	Potential Netgain rRA	In consultation	196	Medium	High	Yes	N/A
Nature Conservation	NG 1b, Orford Inshore	Potential Netgain rMCZ	In consultation	280	Medium	High	Yes	N/A
Nature Conservation	Outer Banks/Zeeuwse Banken	Potential Dutch MPA's	In consultation	327	Low	High	Yes	N/A
Nature Conservation	Coastal Sea/Kustzee	Potential Dutch MPA's	In consultation	280	Low	High	Yes	N/A
Nature Conservation	Brown Ridge	Potential Dutch MPA's	In consultation	212	Low	High	Yes	N/A
Nature Conservation	RA 7, Seahenge Peat and Clay	Potential Netgain rRA	In consultation	210	Medium	High	Yes	N/A

Type of project	Project title	Project status	Predicted construction/ development period	Distance from Dogger Bank Dogger Bank Teesside (km)	Confidence in project details	Confidence in project data	Carried forward to cumulative impact assessment?	Rationale for where no cumulative impact is expected
Nature Conservation	RA 5, Blakeney Seagrass	Potential Netgain rRA	In consultation	198	Medium	High	Yes	N/A
Nature Conservation	Frisian Front	Potential Dutch MPA's	In consultation	171	Medium	High	Yes	N/A
Nature Conservation	Borkham Reef	Potential Dutch MPA's	In consultation	266	Low	High	Yes	N/A
Nature Conservation	Central Oyster Grounds	Potential Dutch MPA's	In consultation	112	Low	High	Yes	N/A
Nature Conservation	Gas Leaks	Potential Dutch MPA's	In consultation	157	Low	High	Yes	N/A
Nature Conservation	NG 10, Castle Ground	Potential Netgain rMCZ	In consultation	134	Medium	High	Yes	N/A

Type of project	Project title	Project status	Predicted construction/ development period	Distance from Dogger Bank Dogger Bank Teesside (km)	Confidence in project details	Confidence in project data	Carried forward to cumulative impact assessment?	Rationale for where no cumulative impact is expected
Nature Conservation	NG 16, Swallow Sand	Potential Netgain rMCZ	Put forward for designation in 2013	49	Medium	High	Yes	N/A
Nature Conservation	NG 13, Coquet to St Mary’s	Potential Netgain rMCZ	In consultation	181	Medium	High	Yes	N/A
Nature Conservation	NG 14, Farnes East	Potential Netgain rMCZ	In consultation	169	Medium	High	Yes	N/A
Nature Conservation	RA 12, Farnes Clay	Potential Netgain rRA	In consultation	178	Medium	High	Yes	N/A
Nature Conservation	NG 15, Rock Unique	Potential Netgain rMCZ	Put forward for designation in 2013	139	Medium	High	Yes	N/A
Nature Conservation	RA 13, Rock Unique RA	Potential Netgain rRA	In consultation	149	Medium	High	Yes	N/A

Type of project	Project title	Project status	Predicted construction/ development period	Distance from Dogger Bank Dogger Bank Teesside (km)	Confidence in project details	Confidence in project data	Carried forward to cumulative impact assessment?	Rationale for where no cumulative impact is expected
Nature Conservation	NG 17, Fulmar	Potential Netgain rMCZ	In consultation	110	Medium	High	Yes	N/A
Nature Conservation	Scottish MCZ project A	MCZ recommendation for site designations	In consultation	205	Medium	Low	Yes	N/A
Nature Conservation	Scottish MCZ project B	MCZ recommendation for site designations	In consultation	325	Medium	Low	Yes	N/A
Nature Conservation	Scottish MCZ project C	MCZ recommendation for site designations	In consultation	535	Medium	Low	Yes	N/A
Nature Conservation	Scottish MCZ project D	MCZ recommendation for site designations	In consultation	594	Medium	Low	Yes	N/A
Nature Conservation	RA 6, Dogs Head Sandbanks	Potential Netgain rRA	In consultation	178	Medium	High	Yes	N/A

Type of project	Project title	Project status	Predicted construction/ development period	Distance from Dogger Bank Dogger Bank Teesside (km)	Confidence in project details	Confidence in project data	Carried forward to cumulative impact assessment?	Rationale for where no cumulative impact is expected
Nature Conservation	Western Fladen (WFL)	Proposed Nature Conservation MPA	In consultation	435	Medium	High	Yes	N/A
Nature Conservation	South-east Fladen (SEF)	Proposed Nature Conservation MPA	In consultation	372	Medium	High	Yes	N/A
Nature Conservation	North-east Faroe Shetland Channel (NEF)	Proposed Nature Conservation MPA	In consultation	845	Medium	High	Yes	N/A
Nature Conservation	Faroe-Shetland sponge belt (FSS)	Proposed Nature Conservation MPA	In consultation	719	Medium	High	Yes	N/A
Nature Conservation	Norwegian boundary sediment plain (NSP)	Proposed Nature Conservation MPA	In consultation	342	Medium	High	Yes	N/A
Nature Conservation	Turbot Bank (TBB)	Proposed Nature Conservation MPA	In consultation	338	Medium	High	Yes	N/A

Type of project	Project title	Project status	Predicted construction/ development period	Distance from Dogger Bank Dogger Bank Teesside (km)	Confidence in project details	Confidence in project data	Carried forward to cumulative impact assessment?	Rationale for where no cumulative impact is expected
Nature Conservation	East of Gannet and Montrose Fields (EGM)	Proposed Nature Conservation MPA	In consultation	258	Medium	High	Yes	N/A
Nature Conservation	Firth of Forth Banks Complex (FOF)	Proposed Nature Conservation MPA	In consultation	301	Medium	High	Yes	N/A
Nature Conservation	Southern Trench (STR)	MPA search location	In consultation	413	Medium	High	Yes	N/A
Nature Conservation	Bancs des Flandres	Potential SCI designation	In consultation	428	Medium	High	Yes	N/A
Nature Conservation	Pobie Bank Reef	Candidate SAC	In consultation	636	Medium	High	Yes	N/A

10.2. Cumulative impact of Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D.

10.2.1. The CIA adopts an additive approach whereby the cumulative effects of the following interactions are progressively assessed:

- The cumulative impacts associated with Dogger Bank Teesside A & B and the Dogger Bank Teesside A & B Export Cable Corridor and Dogger Bank Creyke Beck and Dogger Bank Teesside C & D, including their respective Export Cable Corridors;
- The cumulative effects of Dogger Bank Teesside A & B and Dogger Bank Teesside C & D with other planned, consented or under construction wind farm developments outside of the Dogger Bank Zone; and
- The cumulative effects of Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D with other planned, consented or under construction wind farm developments outside the Dogger Bank Zone and other future installations, regulated activities such as aggregate dredging and possible marine conservation areas which may exclude or restrict commercial fishing activities.

10.3. Temporary physical disturbance/loss of seabed habitat

10.3.1. There is potential for cumulative temporary habitat loss to occur as a result of construction operations within the Dogger Bank Teesside A & B, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D sites. The worst case scenario is for construction activities occurring within all six project areas simultaneously. The proportional area of temporary disturbance/habitat loss within all sites is expected to be of a similar magnitude. The cumulative effect will be highly localised, with only a relatively small proportion of habitat disturbance /loss occurring at any one time.

10.3.2. The cumulative effect of temporary physical disturbance/habitat loss will be of medium duration, intermittent and reversible and the magnitude is considered to be low.

10.3.3. Most fish species are predicted to have a relatively low level of vulnerability to temporary habitat loss, though sandeel and other demersal spawning species and shellfish species, both of which have specific habitat resource requirements are deemed to be more sensitive to this type of disturbance.

10.3.4. In the context of sandeel spawning habitat, the cumulative habitat loss may potentially result in a loss of up to 0.52% of the available preferred sandeel habitat within the Dogger Bank SA1 management area.

10.3.5. Temporary disturbance/habitat loss within the inshore Flamborough herring spawning grounds resulting from the installation of export cables has the potential to affect a maximum area equivalent to 0.02% of the total Flamborough inshore spawning grounds. The methodology used to derive estimates of the spatial extent of the overlap of the development site with herring spawning areas) is described in **Appendix 13G**. Estimates of the area of herring spawning grounds in the vicinity of the development site are based on the mapping layers presented in Coull *et al.* (1998). The limitations of the data sets used to provide these mapping layers are acknowledged by Coull *et al.* (1998) and, by extension, these limitations apply to the overlap estimates presented in this assessment.

10.3.6. Cumulative effects of temporary disturbance/habitat loss may potentially affect brown crab and lobster populations in the inshore areas but it is anticipated that these effects will be limited in their spatial and temporal extent and the proportion of the available habitat affected is predicted to be small.

10.3.7. Most fish and shellfish receptors in the fish and shellfish study area are deemed to be of low vulnerability, high recoverability and of local to international importance within the fish and shellfish study area. The sensitivity of these receptors is therefore considered to be low and the impact is assessed as **minor adverse**.

10.3.8. Sandeel and herring are deemed to be of medium vulnerability, medium recoverability and of regional importance within the fish and shellfish study area. The sensitivity of these receptors is therefore considered to be medium and the impact is assessed as **minor adverse**.

10.3.9. Edible crab and European lobster are deemed to be of low vulnerability, high recoverability and of regional importance within the fish and shellfish study area. The sensitivity of these receptors is therefore considered to be low and the impact is assessed as **minor adverse**.

10.4. Suspended sediment and sediment re-deposition

10.4.1. Cumulative effects, in terms of seabed disturbance, will be restricted to interaction of sediment plumes and sediment deposition on the seabed. Given the potential worst case construction programme, cumulative effects may arise if the construction of foundations in different projects is synchronous and the plumes that are created by the construction overlap spatially. If a similar construction sequence is adopted for sets of foundations in the other Dogger Bank projects at the same time as Dogger Bank Teesside B, then the respective plumes may potentially interact, to create a larger overall plume, with higher suspended sediment concentration and, potentially, a greater depositional footprint on the seabed.

10.4.2. Given that the maximum thickness of sediment that remained deposited on the seabed at the end of the 30-day simulation period for Dogger Bank Teesside A & B was less than 0.1mm (for conical GBS, 12m monopole and 10m monopole scenarios), the potential for accumulating persistently thick sequences of sediment due to plume interaction is low. This assumes that the worst case methodology used for Dogger Bank Teesside B, is duplicated for Dogger Bank Teesside A, Dogger Bank Creyke Beck and Dogger Bank Teesside C & D.

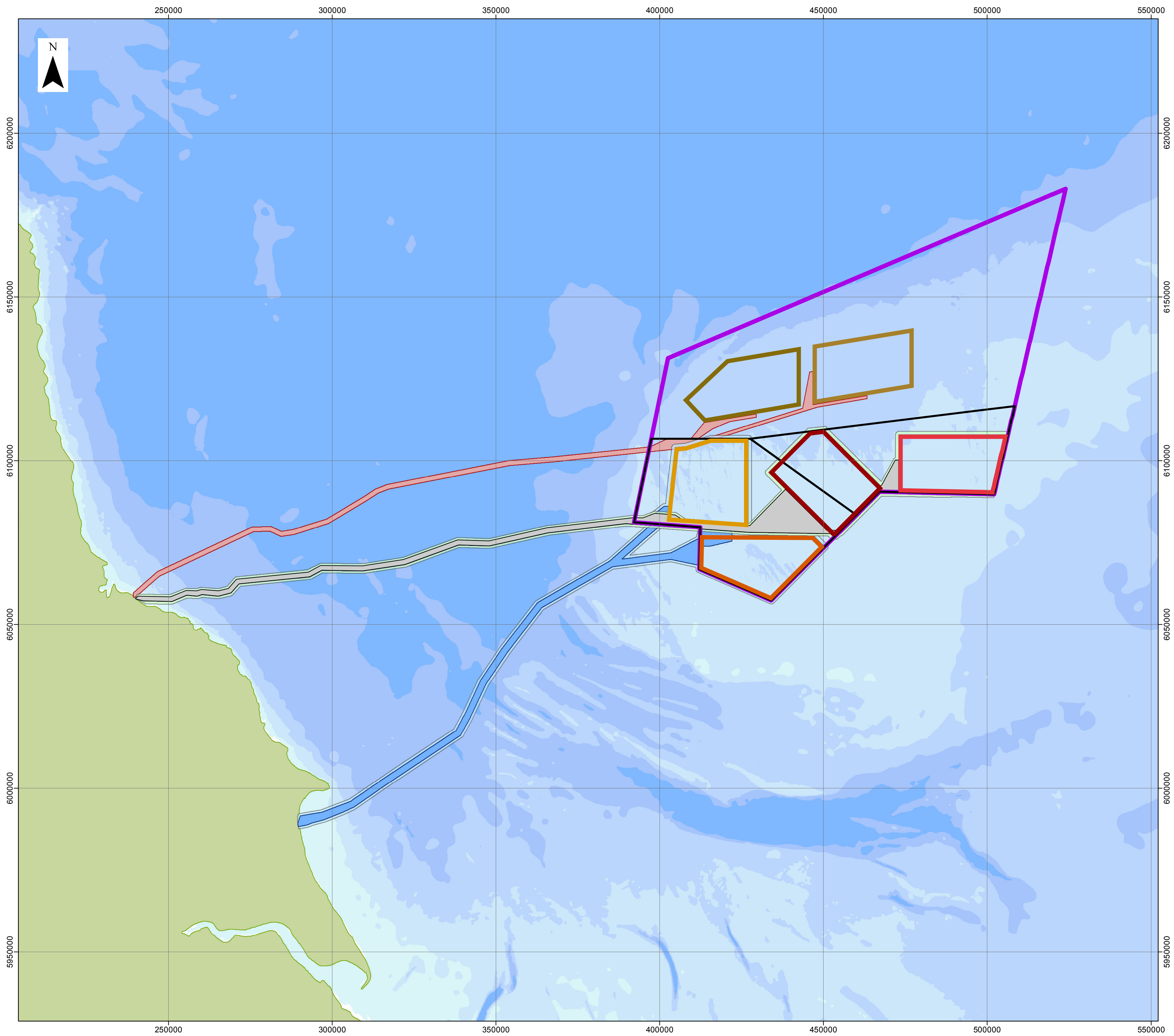
10.4.3. Taking the above into account the magnitude of the effect of increased suspended sediment concentrations resulting from simultaneous construction of Dogger Bank Teesside A and Dogger Bank Teesside B, Dogger Bank Creyke

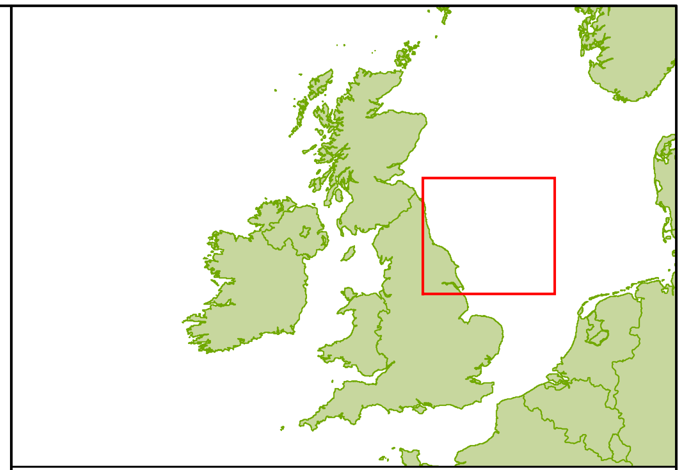
Beck and Dogger Bank Teesside C and D, is considered to be low, as previously assessed for Dogger Bank Teesside A & B (Section 5.1) .

10.4.4. Given the wide distribution ranges of fish and shellfish and eggs and larvae in comparison to the areas potentially affected and, in the particular case of adult and juvenile fish, their ability to avoid areas of elevated suspended sediment concentrations, the interaction between the effect and receptors will be small. In this respect they are considered to be receptors of low vulnerability, medium recoverability and local to regional value therefore they are deemed to be receptors of low sensitivity (**Table 6.5**). Any potential cumulative impact is therefore assessed to be **minor adverse**.

10.4.5. Sandeel and herring are considered of higher sensitivity given their dependence on the presence of an adequate substrate in which to deposit their eggs. An indication of the distribution of high density areas for sandeel is given in **Figure 10.2** based on Danish sandeel fishing density satellite (VMS) data (average 2007-2011). As shown, Dogger Bank Teesside A and Dogger Bank Teesside B are located at considerable distance from high sandeel density areas but there is potential for construction activities in Dogger Bank Teesside C and D to have a greater impact on preferred habitat areas for sandeel. However, in the context of the large area of preferred habitat for sandeel available within the Dogger Bank SA1 sandeel management area, the degree of effect-receptor interaction is not expected to vary substantially from that presented in Section 6 for Dogger Bank Teesside A and Dogger Bank Teesside B. Sandeel is therefore considered of medium vulnerability, medium recoverability and regional importance, therefore their sensitivity is deemed to be medium. As a result of the low magnitude, seabed disturbance related effects are assessed to result in a **minor adverse** impact.

10.4.6. In the particular case of herring, Dogger Bank Teesside A & B is located in the immediate vicinity of the historic spawning grounds (**Figure 10.3**). Assuming those grounds are re-colonised by the time that construction activity is taking place, there may be potential for disturbance via sediment re-deposition to occur on herring eggs. The large areas available for spawning which are undisturbed in relation to the areas potentially affected by elevated suspended sediment concentrations and sediment deposition should be noted in this context. Taking the potential interaction into account herring are considered of medium vulnerability, medium recoverability and regional importance therefore their sensitivity is deemed to be medium. The cumulative impact of temporary seabed disturbance on spawning herring is assessed to be **minor adverse**.





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area
- Dogger Bank Creyke Beck Export Cable Corridor
- Dogger Bank Creyke Beck temporary works area
- Dogger Bank Teesside C & D Export Cable Corridor

0 10 20 40
Kilometres

Data Source:
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

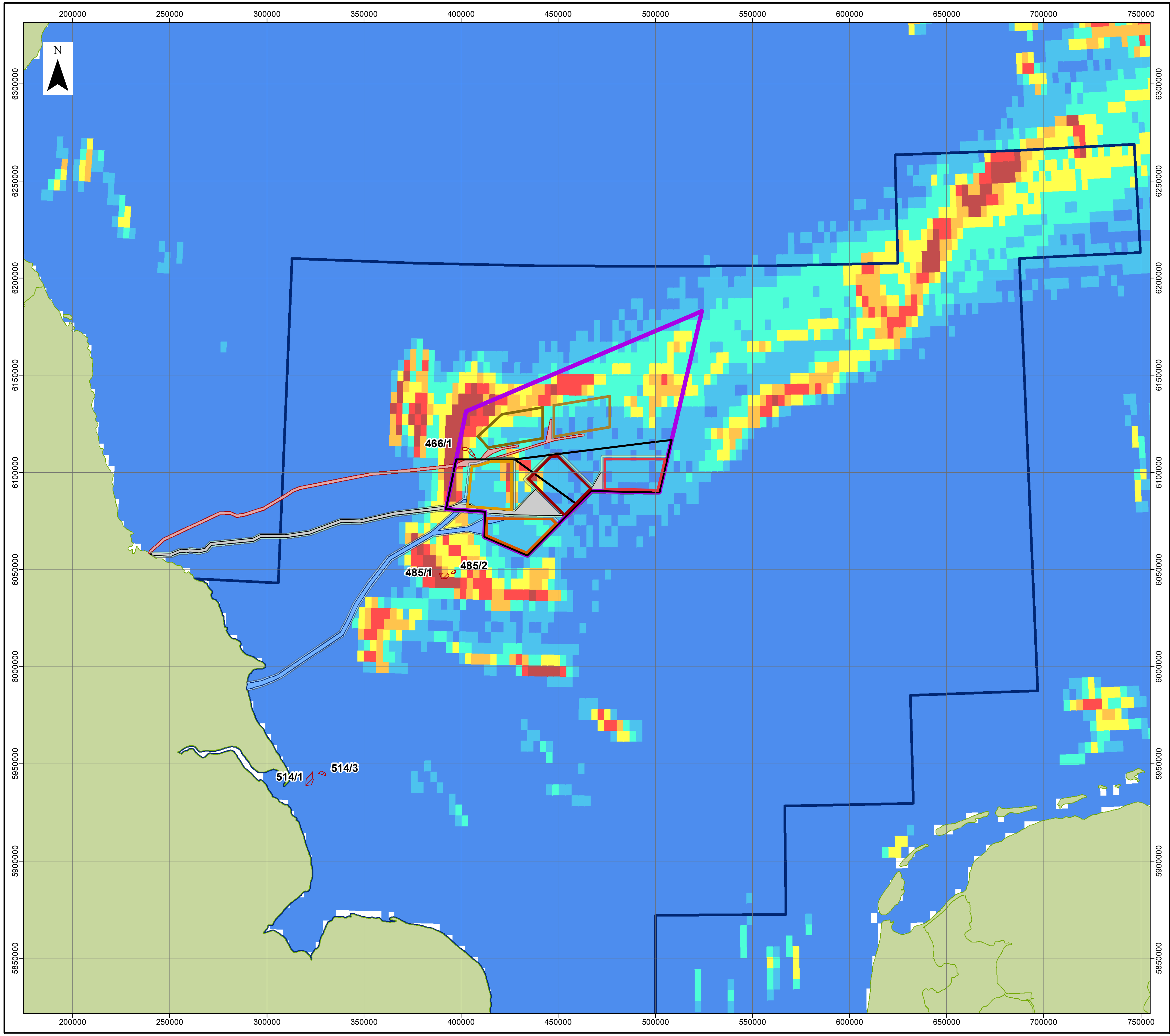
Figure 10.1 Dogger Bank Teesside A & B, Dogger Bank Teesside C & D, Dogger Bank Creyke Beck A & B and export cable corridors

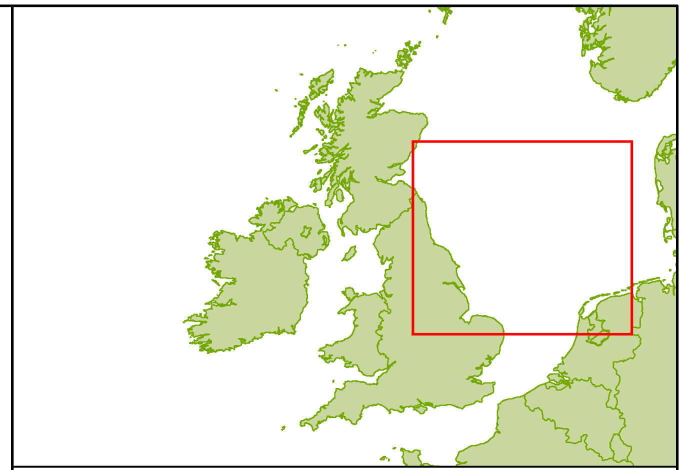
VER	DATE	REMARKS	Drawn	Checked
1	20/09/2013	Draft	LW	TR
2	07/10/2013	PEI3	LW	TR
3	14/02/2014	DCO Submission	LW	TR

DRAWING NUMBER: **F-OFL-MA-259**

SCALE	1:1,200,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area
- Dogger Bank Creyke Beck Export Cable Corridor
- Dogger Bank Creyke Beck temporary works area
- Dogger Bank Teesside C & D Export Cable Corridor
- ICES sandeel area
- Aggregate application area

Danish sandeel satellite (VMS) density

- 0 to 2
- 3 to 5
- 6 to 10
- 11 to 20
- 21 to 40
- 41 to 80
- Over 80

0 10 20 40
Kilometres

Data Source:
Aggregate Areas © The Crown Estate, 2013
VMS © Ministeriet for Fødevarer, Landbrug og Fiskeri, 2014

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

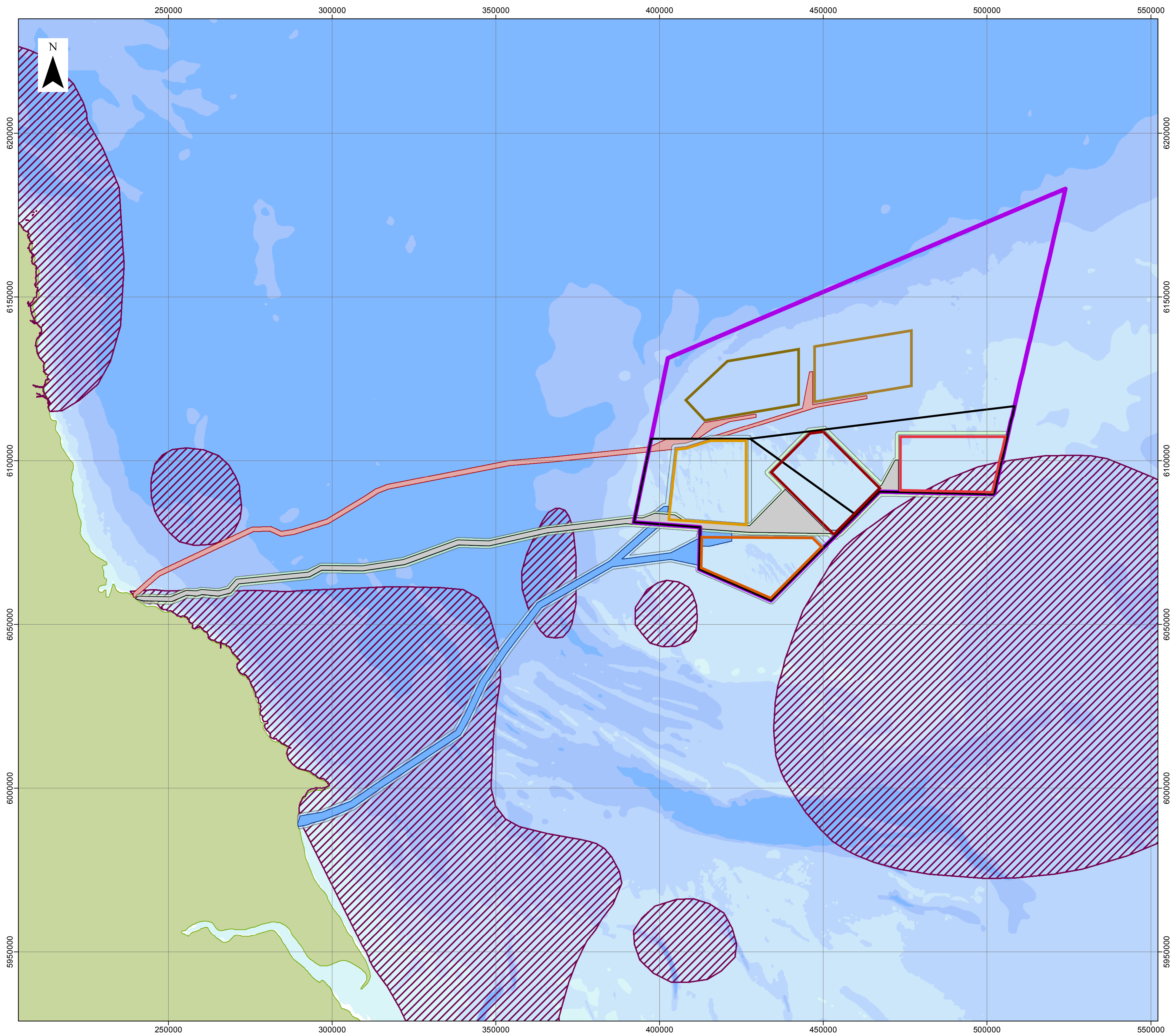
Figure 10.2 Danish sandeel fishing, satellite VMS density (average 2008-2012)

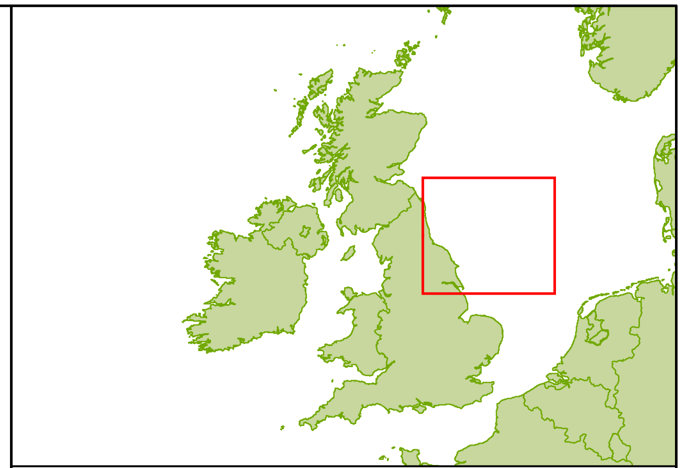
VER	DATE	REMARKS	Drawn	Checked
1	07/10/2013	PEI3	LW	TR
2	14/02/2014	Pre-DCO Submission	LW	TR

DRAWING NUMBER: **F-OFL-MA-260**

SCALE	1:2,000,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area
- Dogger Bank Creyke Beck Export Cable Corridor
- Dogger Bank Creyke Beck temporary works area
- Dogger Bank Teesside C & D Export Cable Corridor
- Herring spawning ground (Coull *et al.* 1998)

0 10 20 40
Kilometres

Data Source:
Spawning Grounds © Cefas, 2012
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 10.3 Herring spawning grounds

VER	DATE	REMARKS	Drawn	Checked
1	20/09/2013	Draft	LW	TR
2	07/10/2013	PEI3	LW	TR
3	14/02/2014	DCO Submission	LW	TR

DRAWING NUMBER: **F-OFL-MA-261**

SCALE	1:1,200,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND

10.5. Construction noise

10.5.1. Impact piling during construction is the activity with the potential to result in the most detrimental impact on fish and shellfish species. Sequential construction of Dogger Bank Teesside A, Dogger Bank Teesside B, Dogger Bank Creyke Beck A & B and Dogger Bank Teesside C & D, has been considered the worst case scenario in relation to fish and shellfish receptors. This would result in the construction phase taking place for up to 11 years and six months. As presented in Section 6 injury or lethal effects associated with piling noise would only occur at very small ranges and are therefore not considered further in the cumulative assessment. The assessment below is therefore focused on the potential for cumulative impacts at the behavioural level to occur.

10.5.2. The worst case spatial range of disturbance resulting from two pile driving operations per project taking place at Dogger Bank Teesside A, Dogger Bank Teesside B, Dogger Bank Creyke Beck A & B and Dogger Bank Teesside C & D is shown in **Figure 10.4** (based on a larger 2300kJ hammer being used as this is the worst case for 10+MW jacket foundations and hence provides the biggest spatial range). It should be noted that piling can occur on a maximum of two piles at any one time per project and that a maximum of 12 piling rigs can be in use across the Dogger Bank Zone at any one time (**Chapter 5**). This means that for Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B construction could occur concurrently with two piling vessels active in each project.

10.5.3. In order to assess the worst case scenario (maximum spatial range and longest duration) it is assumed that construction of the first of Dogger Bank Teesside A & B's projects commences within 18 months of consent (as soon as possible) and lasts for a duration of six years (the longest possible duration). It is further assumed that another Dogger Bank Teesside project starts seven years post consent (as late as possible) and lasts for as long as possible (six years, as construction must be completed 13 years post consent). Another assumption is that concurrent construction of the Dogger Bank Creyke Beck A & B, Dogger Bank Teesside A & B and Dogger Bank Teesside C & D projects being considered will take six years (maximum construction period) and will be constructed in a way which ensures constant piling in the Zone through the simultaneous construction of Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B.

10.5.4. Taking the relatively small ranges of behavioural response impact associated with concurrent pile driving operations, and the intermittent and short term nature of pile driving activity, the magnitude of the effect is considered to be low.

10.5.5. As described for Dogger Bank Teesside A & B, the distribution of most fish and shellfish species (including spawning, nursery and feeding areas) is wide in relation to the areas where behavioural reactions may be triggered by piling noise at a given time. The potential interaction between the effects of noise and fish and shellfish receptors is small due to their wide spatial distribution. Fish and shellfish (with the exception of sandeel and herring) are considered to be receptors of low vulnerability, medium recoverability and of local to regional importance; they are considered to have low sensitivity to the effects of underwater noise. The magnitude is anticipated to be low therefore the cumulative impact is assessed to be **minor adverse**.

10.5.6. In the particular case of herring, assuming the former grounds are re-colonised by the time that construction activity is taking place, as assessed for Dogger Bank Teesside A & B above (Section 6) avoidance of small sections of the former grounds resulting from pile driving activity at Dogger Bank Teesside A & B may occur. This would however only be the case during installation of foundations in the vicinity of the grounds. In addition, impact ranges at which behavioural responses would be expected will only overlap with a small section of the defined former grounds. Taking the medium degree of interaction as described above into account, spawning herring are considered receptors of medium vulnerability, medium recoverability and regional value. They are deemed to be receptors of medium sensitivity. The effect of construction noise on spawning herring is therefore assessed to result in a minor adverse impact. This should, however, be taken in the context of the extent of suitable substrate for herring spawning in other areas and on the relatively wide extension of the former spawning grounds.

10.5.7. With respect to sandeel, Dogger Bank Teesside C & D is located in areas which may potentially support higher densities of sandeel than either Dogger Bank Creyke Beck A & B or Dogger Bank Teesside A & B. However, given the spatial extent of preferred habitat available within the SA1 management area, the area affected by construction noise is proportionally small. The assessment carried out for Dogger Bank Teesside A (Section 6) is considered to apply in cumulative terms. Sandeel is therefore considered of medium sensitivity and the cumulative impact is assessed to be **minor adverse**.

10.6. Permanent habitat loss

10.6.1. Cumulative long term habitat loss is predicted to occur as a result of the presence of all offshore wind farm structures (i.e., foundations, scour protection and cable protection). The maximum adverse scenario for permanent habitat loss assumes the minimum amount of cable burial (although it is unlikely that the maximum amount of cable protection will be required) and the maximum foundation footprint i.e. GBS foundations inclusive of scour protection.

10.6.2. In assessment terms, it is difficult to quantify the cumulative effect of permanent habitat loss of seabed habitat. However, as described in **Chapter 12**, comparable seabed habitats are relatively widespread throughout the central North Sea and the loss is not anticipated to impact on ecosystem function. The magnitude of the impact is considered to be low.

10.6.3. Sensitivities of fish and shellfish receptors in the fish and shellfish study area to long term habitat loss are summarised in Section 7. Most fish and shellfish receptors in the fish and shellfish study area are deemed to be of low vulnerability, high recoverability and of local to international importance within the fish and shellfish study area. The sensitivity of these receptors is therefore considered to be low. The impact is assessed as **minor adverse**.

10.6.4. The fish and shellfish species considered to be most vulnerable to habitat loss are demersal spawning species such as sandeel and herring which have specific spawning habitat requirements. In addition, sandeel have specific habitat resource requirements with a preference for sediment with high sand low silt content. In relation to the potential impact on sandeel habitats the project boundaries intentionally avoid the area of high density sandeel in the western section of Tranche A in order to minimise the potential impact of the Dogger Bank Zone. This will minimise the potential effects on the sandeel, the sandeel fishery and also on predators such as seabirds, marine mammals and other fish which exploit sandeel as a key prey species (see **Chapter 6 Site Selection and Alternatives**).

10.6.5. The Flamborough herring spawning ground is not expected to be affected by long term habitat loss since the proportion of seabed affected is negligible compared to the total area designated as herring spawning habitat by Coull *et al*. 1998.

10.6.6. Cumulative effects on sandeel are also likely to be small given that the relative area of sandeel habitat lost represents such a small proportion of the total area of available sandeel habitat within the SA1 management area.

10.6.7. Sandeel and herring are deemed to be receptors of medium vulnerability, medium recoverability and of regional importance, therefore their sensitivity is deemed to be medium. The impact is assessed as **minor adverse**.

10.6.8. Cumulative effects on shellfish species as a result of permanent habitat loss are not anticipated to have a negative effect. There is the potential for the introduction of hard substrate and the formation of artificial reefs to result in positive effects for edible crab and lobster. Shellfish receptors are deemed to be of medium vulnerability, high recoverability and of regional importance within the fish and shellfish study area. The sensitivity of these receptors is therefore considered to be medium. The impact is assessed as **minor adverse**.

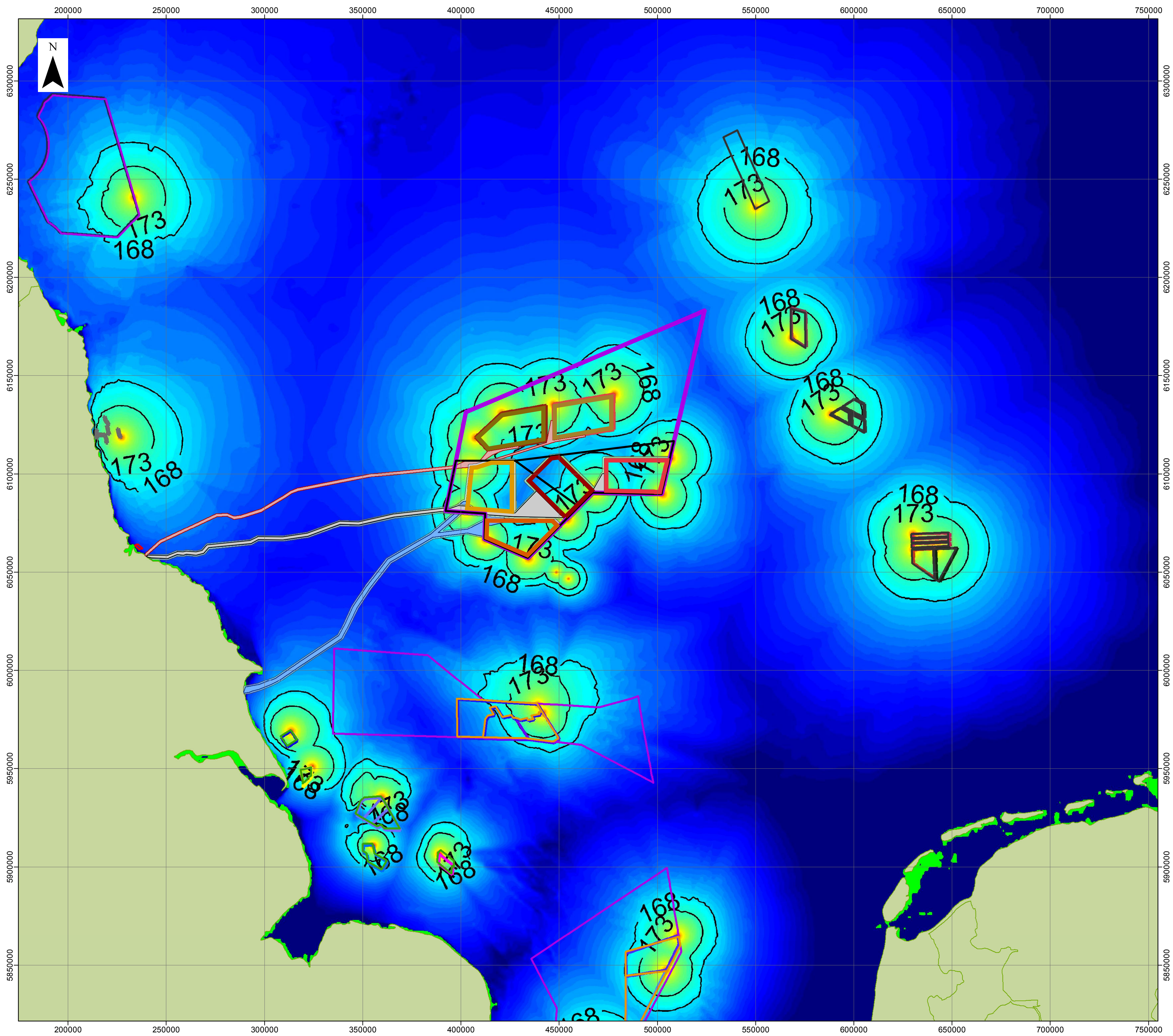
10.7. Summary

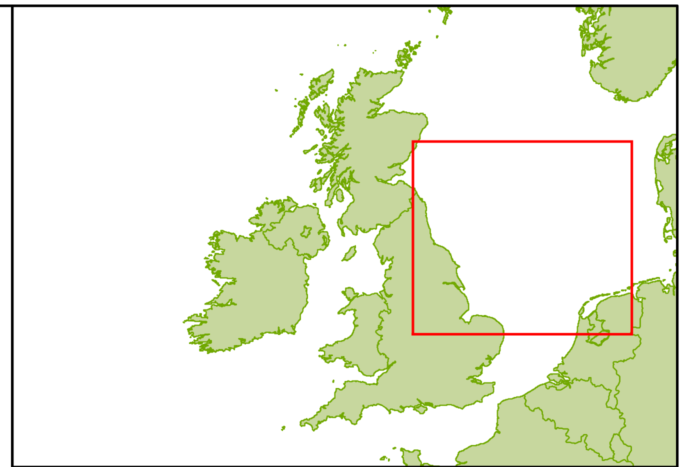
10.7.1. The cumulative impact assessment described above for Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B is summarised in **Table 10.3** below.

Table 10.3 Cumulative impact assessment summary

Potential effect	Effect magnitude	Receptor	Receptor sensitivity	Cumulative impact
Temporary physical disturbance/loss of seabed habitat	Low	Fish and shellfish in general	Low	Minor adverse
		Herring	Medium	Minor adverse
		Sandeel	Medium	Minor adverse
		Shellfish	Low	Minor adverse

Potential effect	Effect magnitude	Receptor	Receptor sensitivity	Cumulative impact
Suspended sediment and sediment re-deposition	Low	Fish and shellfish in general	Low	Minor adverse
		Herring	Medium	Minor adverse
		Sandeel	Medium	Minor adverse
Construction noise	Low	Fish and shellfish in general	Low	Minor adverse
		Herring	Medium	Minor adverse
		Sandeel	Medium	Minor adverse
Permanent loss of seabed habitat	Low	Fish and shellfish in general	Low	Minor adverse
		Herring	Medium	Minor adverse
		Sandeel	Medium	Minor adverse
		Shellfish	Medium	Minor adverse



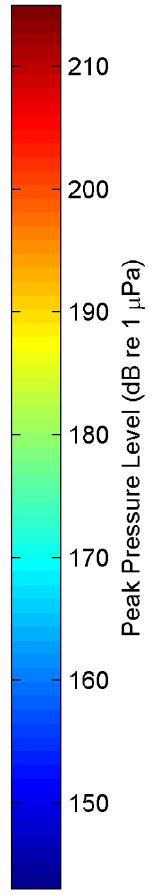


LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area
- Dogger Bank Creyke Beck Export Cable Corridor
- Dogger Bank Creyke Beck temporary works area
- Dogger Bank Teesside C & D Export Cable Corridor

Wind energy project

- Round 1
- Round 2
- Round 3
- Round 3 zone
- Non-UK wind farm development



Data Source:
UK offshore wind farms © The Crown Estate, 2014
Non-UK offshore wind farms © Marine Find, 2013
Modelling © NPL Management, 2013

0 10 20 40
Kilometres

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 10.4 Noise generation from pile driving at other projects in relative proximity to Dogger Bank Teesside A & B

VER	DATE	REMARKS	Drawn	Checked
1	07/10/2013	PEI3	LW	TR
2	14/02/2014	DCO Submission	LW	TR

DRAWING NUMBER:

F-OFL-MA-262

SCALE	1:2,000,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND

10.8. The cumulative impact of Dogger Bank Teesside A & B, Dogger Bank Creyke Beck A & B, Dogger Bank Teesside C & D and other projects outside the Dogger Bank Zone

Seabed disturbance due to sediment deposition

10.8.1. As indicated in **Chapter 9** the following proposed wind farm projects have been taken into account for cumulative assessment in terms of temporary disturbance of the seabed during construction:

- Project One Hornsea Offshore Wind Farm;
- Westermost Rough; and
- H2-20 offshore wind farm (German sector of the North Sea).

10.8.2. As stated in **Chapter 9** it is unlikely that the construction plumes of Project One Hornsea Wind Farm would interact with the construction plumes of Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B. There is therefore little potential for cumulative impacts on fish and shellfish receptors to occur.

10.8.3. Sediment plumes associated with installation of the Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B Export Cable Corridors may potentially interact with construction plumes of Westermost Rough if both are synchronous. As stated in **Chapter 9**, however, this potential interaction is not expected to result in significant effect. It is, therefore, considered that there is little potential for cumulative impacts on fish and shellfish receptors to occur.

10.8.4. In the particular case of the H2-20 offshore wind farm, given its distance to Dogger Bank Teesside A & B (approx.150km east-northeast of Dogger Bank Teesside A & B), **Chapter 9** concluded that there is not potential for cumulative effects in relation to seabed disturbance during construction to occur. As a result cumulative impacts associated with this are not expected on fish and shellfish receptors.

10.8.5. There may be potential for aggregate dredging taking place in the vicinity of Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B to result in a cumulative impact on fish and shellfish receptors resulting from the effects of seabed disturbance.

10.8.6. The following dredging areas have been included for assessment of cumulative impacts:

- Aggregates Area 466: Located at the northern boundary of Dogger Bank Teesside B;
- Aggregates Dredging Area 485: Located approximately 25km south west of Dogger Bank Teesside A and 20km south of the Dogger Bank Teesside A & B Export Cable Corridor; and

- Aggregate Dredging Areas 448 and 449: Located at the entrance of the Humber Estuary, approximately 50km to the south-southwest of the Dogger Bank Teesside A & B Export Cable Corridor.

10.8.7. The location of these areas are shown in relation to the distribution of herring and spawning grounds and high density areas for sandeel is given in **Figure 10.5** and **Figure 10.6**.

10.8.8. Areas 466 and 485 are located in known high density areas for sandeel (**Figure 10.6**). Area 485 also falls within a discrete section of the former herring spawning grounds, whilst Areas 448 and 449 are both located within the currently active inshore herring spawning grounds (**Figure 10.5**).

10.8.9. As indicated in **Chapter 9** analysis of time series of sediment deposition from the Dogger Bank Teesside A & B worst case construction plume at the southern corner of Area 466 shows that sediment thickness at any time is generally less than 1mm. Occasionally, sediment is thicker than 1mm and can be continuously greater than 1mm for a maximum period of 42 hours. Sediment deposition out of the Dogger Bank Teesside A & B construction plume would have little effect on the characteristics of the seabed sediment in Area 466. With regards to Area 485, it was assumed that the dredging process and sequencing is similar to that at Area 466.

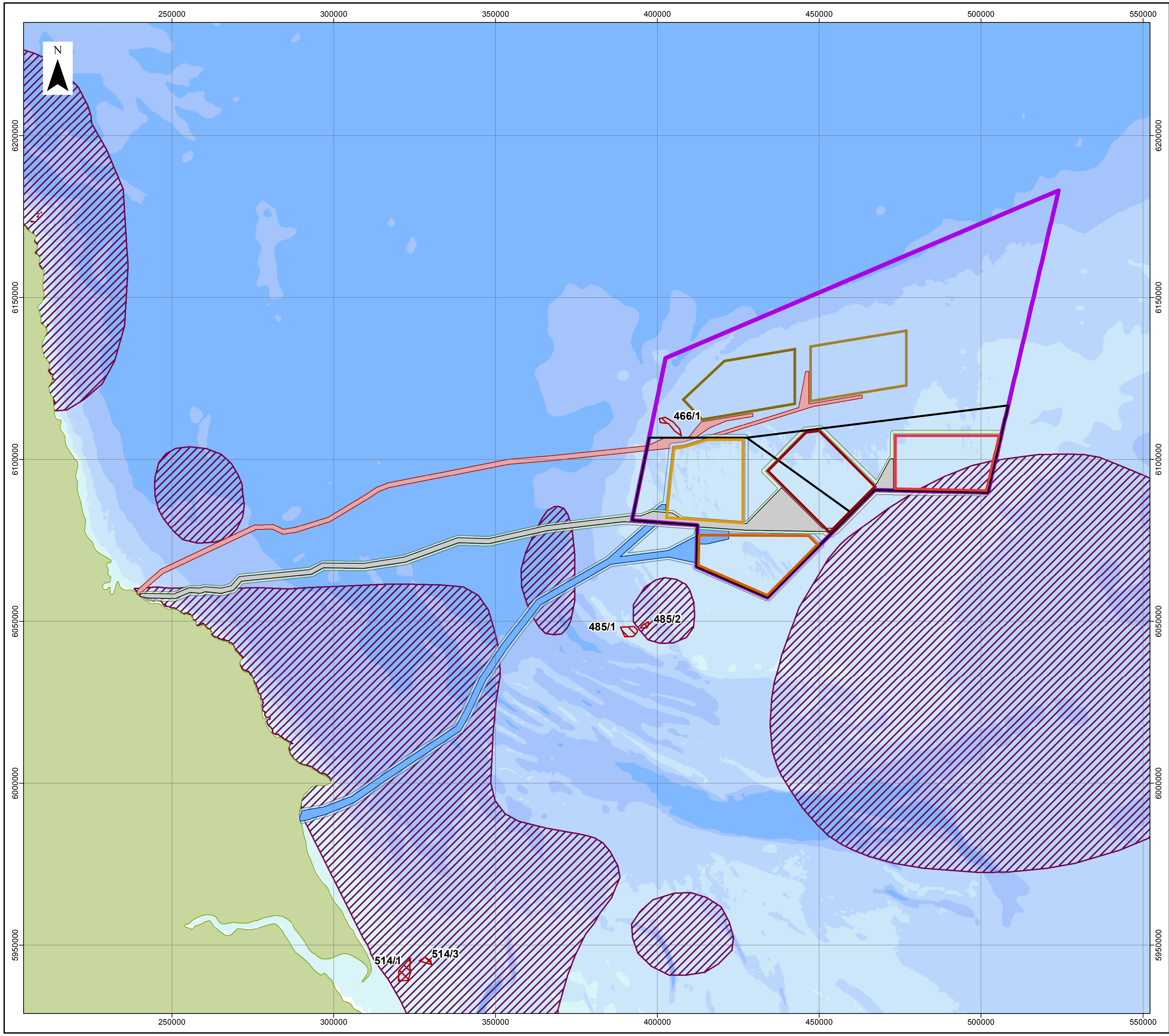
10.8.10. In the particular case of dredging areas 448 and 449, as suggested in **Chapter 9** it is unlikely that any interaction with the sediment plume associated with the Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B cable installation will occur, given the small size of the plume generated by the cable and the low likelihood that the cable will be excavated on the same day as the aggregate extraction is being undertaken.

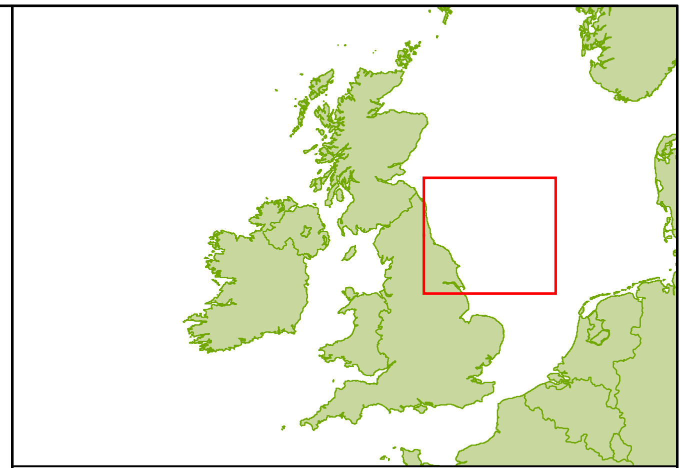
10.8.11. Taking the above into account it is not considered that dredging activities will contribute significantly to the cumulative impact effect on fish and shellfish in general, nor in the particular case of spawning herring and sandeel. Therefore **no cumulative impact** is anticipated.

Noise

10.8.12. As presented in **Appendix 5A**, the spatial range of potential behavioural effects associated with pile driving noise on fish were modelled for the following wind farms located in the proximity of the Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B:

- Firth of Forth;
- East Anglia;
- Hornsea; and
- Triton Knoll.





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Herring spawning ground (Coull *et al.* 1998)
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area
- Dogger Bank Creyke Beck Export Cable Corridor
- Dogger Bank Creyke Beck temporary works area
- Dogger Bank Teesside C & D Export Cable Corridor
- Aggregate application area

0 10 20 40
Kilometres

Data Source:
Spawning Grounds © Cefas, 2012
Aggregate Areas © The Crown Estate, 2013
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

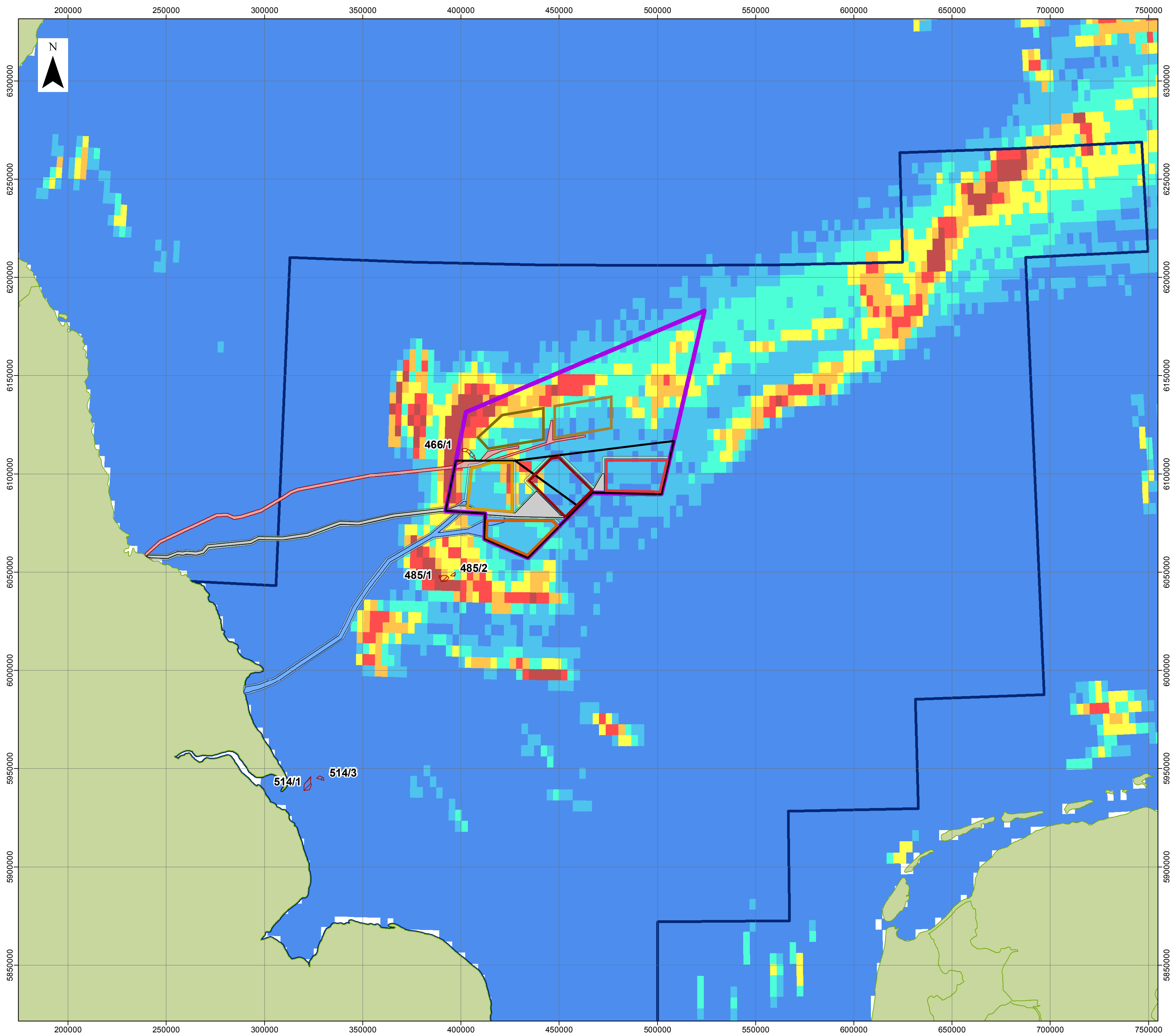
Figure 10.5 Dredging areas in the vicinity of Dogger Bank Teesside A & B and herring spawning grounds

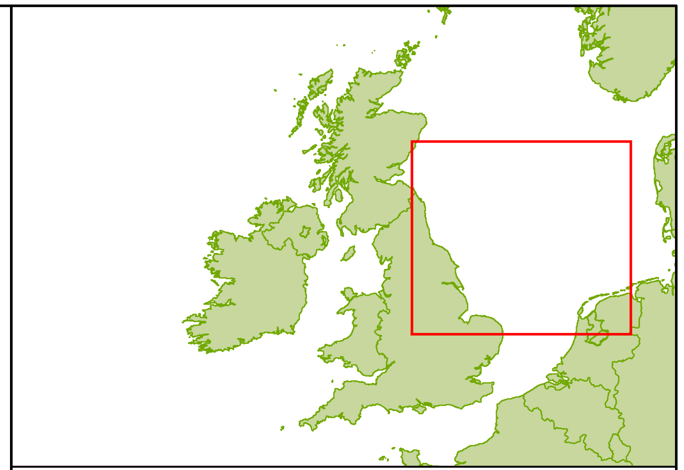
VER	DATE	REMARKS	Drawn	Checked
1	20/09/2013	Draft	LW	TR
2	07/10/2013	PEI3	LW	TR
3	14/02/2014	DCO Submission	LW	TR

DRAWING NUMBER: **F-OFL-MA-263**

SCALE	1:1,200,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND





LEGEND

- Dogger Bank Zone
- Tranche boundary
- Dogger Bank Creyke Beck A
- Dogger Bank Creyke Beck B
- Dogger Bank Teesside A
- Dogger Bank Teesside B
- Dogger Bank Teesside C
- Dogger Bank Teesside D
- Dogger Bank Teesside A & B Export Cable Corridor
- Dogger Bank Teesside A & B temporary works area
- Dogger Bank Creyke Beck Export Cable Corridor
- Dogger Bank Creyke Beck temporary works area
- Dogger Bank Teesside C & D Export Cable Corridor
- ICES sandeel area
- Aggregate application area

Danish sandeel satellite (VMS) density

- 0 to 2
- 3 to 5
- 6 to 10
- 11 to 20
- 21 to 40
- 41 to 80
- Over 80

0 10 20 40
Kilometres

Data Source:
Aggregate Areas © The Crown Estate, 2013
VMS © Ministeriet for Fødevarer, Landbrug og Fiskeri, 2014

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 10.6 Dredging areas in the vicinity of Dogger BankTeesside A & B and density of Danish fishing (satellite VMS average 2008-2012)

VER	DATE	REMARKS	Drawn	Checked
1	07/10/2013	PEI3	LW	TR
2	14/02/2014	Pre-DCO Submission	LW	TR

DRAWING NUMBER:

F-OFL-MA-264

SCALE	1:2,000,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND

10.8.13. The outputs of the noise modelling undertaken for these developments, is given in **Figure 10.4**. This illustrates the extent of behavioural disturbance for fish in mid water.

10.8.14. As shown, assuming simultaneous piling at the closest locations from other wind farm developments to Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B there will not be spatial overlap of noise levels at which behavioural reactions may occur in pelagic fish. In the unlikely event that simultaneous piling was happening at all of the locations modelled above, the total area affected at behavioural levels would still be relatively small in the context of the wide distribution ranges (including spawning, nursery grounds and feeding grounds) of fish and shellfish receptors and any simultaneous disturbance would be temporary and very short term.

10.8.15. As described in **Appendix 5A** and summarised below, in addition to pile driving associated with wind farm installation, shipping, oil and gas related activities and dredging may further contribute to wind farm related noise.

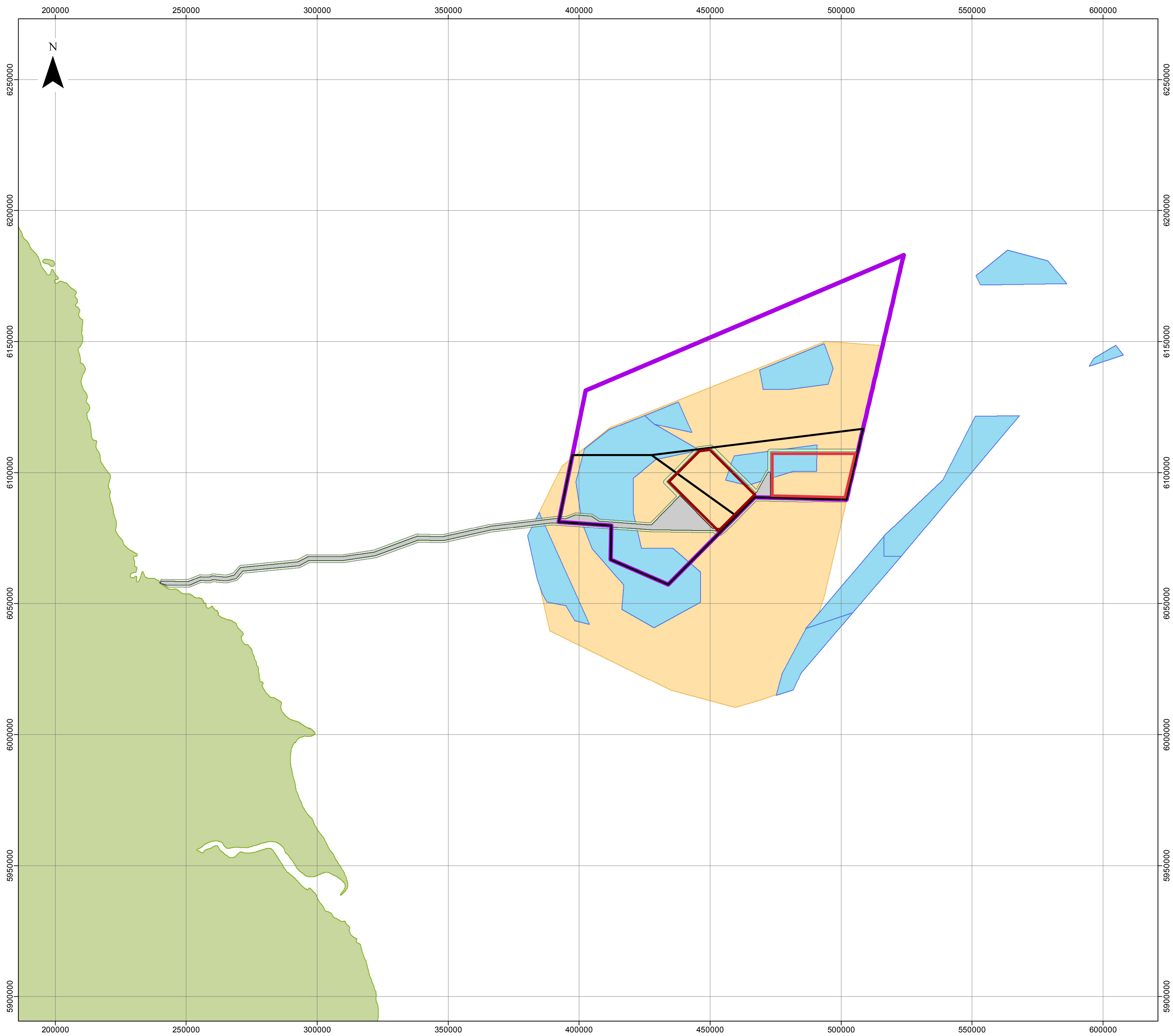
10.8.16. Shipping density local to Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B is generally lower than closer inshore or in some of the surrounding areas, including areas to the south. Commercial shipping, fishing and dredging all radiate substantially lower noise levels compared to impact piling and are unlikely to increase the risk of physiological damage to marine fauna compared to the construction of Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B and other wind farms alone. In general, noise generated by transiting surface vessels will result in a very small contribution to the overall noise level resulting from impact pile driving activities.

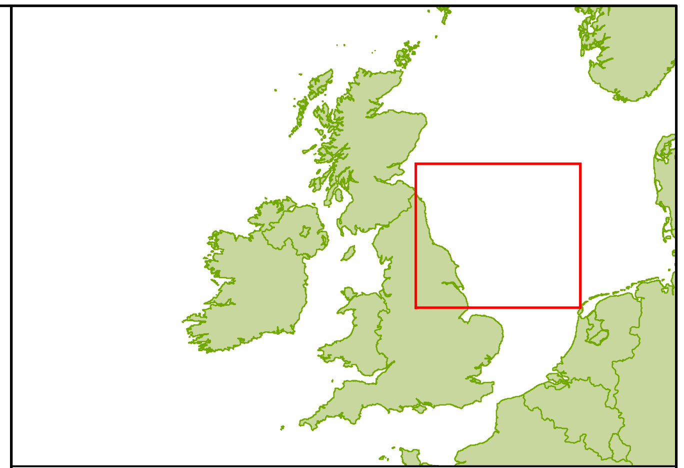
10.8.17. It is therefore not considered that additional noise associated with other activities has potential to significantly contribute to the cumulative impact of noise on fish and shellfish species associated with the Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B and other wind farm developments.

10.9. Dogger Bank Teesside A & B, Dogger Bank Creyke Beck, Dogger Bank Teesside C & D and marine conservation areas

10.9.1. Dogger Bank Teesside A & B, Dogger Bank Teesside C & D and Dogger Bank Creyke Beck A & B fall within an area currently outlined as the Dogger Bank candidate Special Area of Conservation (cSAC). Conservation measures associated with the introduction of marine conservation areas may result in a beneficial cumulative impact on fish and shellfish receptors on a site specific area, particularly if fishing activity in the area changes substantially from measures which may be implemented. However, the potential for fishing effort to be displaced into sensitive areas should be noted in this context.

10.9.3. **Figure 10.7** shows a chart reproduced from a paper prepared on behalf of the Danish, Dutch, English and German fishermen organisations titled “Fisheries Spatial Management Measures for the Dogger Bank SAC: Fishing Industry Amendment Proposal”. The sections marked in purple are those proposed by the fishing industry to be under fisheries management within which towed bottom gears are prohibited from operating. The potential for a likely beneficial impact on target species and benthic habitats associated with the exclusion of towed gear should be noted. As described in **Chapter 15** although the proposed sectors overlap the majority of Dogger Bank Creyke Beck A & B, and small sections of Dogger Bank Teesside A & B and Dogger Bank Teesside C & D the areas proposed by the fishing industry may not be adopted. Furthermore, the proposed sectors align with the areas which the UK, Danish and German VMS and UK surveillance suggest sustain low levels of fishing activity.





Data Source:
Management Sectors © NFFO 2012
Background bathymetry image derived in part from TCarta data © 2009

PROJECT TITLE

DOGGER BANK TEESSIDE A & B

DRAWING TITLE

Figure 10.7 Proposed fisheries management sectors within Dogger Bank cSAC

VER	DATE	REMARKS	Drawn	Checked
1	20/09/2013	Draft	LW	TR
2	07/10/2013	PEI3	LW	TR
3	14/02/2014	DCO Submission	LW	TR

DRAWING NUMBER:

F-OFL-MA-265

SCALE	1:1,500,000	PLOT SIZE	A3	DATUM	WGS84	PROJECTION	UTM31N

FOREWIND

11. Transboundary Issues

11.1. General

11.1.1. The distribution of fish and shellfish species is independent of national geographical boundaries. The impact assessment presented in this section has therefore been undertaken taking account of the distribution of fish stocks and populations irrespective of political limits. As a result it is considered that the assessment of transboundary effects is already integrated in the assessment given above.

11.1.2. The location of Dogger Bank Teesside A & B is an important consideration with respect to potential transboundary effects. Although Dogger Bank Teesside A & B does not lie in international waters the eastern boundary of the Dogger Bank Zone is synonymous with the international boundary bordering Dutch and German waters. Also of note is that the eastern boundary of Dogger Bank Teesside A is in close proximity to an international boundary with The Netherlands.

11.1.3. With regard to the effects of noise (namely from percussive piling, Section 6.6), the assessment has shown that behavioural impacts (including spawning behaviour) are not anticipated beyond 13.5km and 19km from the noise source. With regard to the potential effects of increased suspended sediment concentrations and deposition of sediment on the seabed (Section 6.4), the assessment indicates that any transboundary effects would be negligible. All other potential impacts, such as loss of habitat, will be contained within or in close proximity to the project boundaries, and no significant transboundary effects are anticipated.

12. Summary

12.1.1. This chapter of the ES has provided a characterisation of the existing fish and shellfish environment based on both existing and site specific survey data. As discussed in Sections 6, 7 and 8 of this chapter fish and shellfish may be affected as a result of temporary physical disturbance during construction, and permanent loss of habitat during operation of Dogger Bank Teesside A & B. All residual impacts identified for fish and shellfish ecology are minor adverse or negligible, with no significant residual impacts. **Table 12.1** provides a summary of the potential impacts on fish and shellfish arising from the realistic worst case scenarios set out in **Table 5.2** earlier in the chapter.

Table 12.1 Summary of potential impacts on fish and shellfish ecology

Description of impact	Receptor	Residual impact			
		Dogger Bank Teesside A	Dogger Bank Teesside B	Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor
Construction / decommissioning phase					
Temporary physical disturbance/ loss of seabed habitat	Eggs and larvae of pelagic fish spawners	Negligible	Negligible	Negligible	Negligible
	Eggs and larvae of demersal fish spawners	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Eggs and larvae of sandeel	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Eggs and larvae of herring	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Eggs and larvae of shellfish	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Adult and juvenile fish	Minor adverse	Minor adverse	Minor adverse	Minor adverse

Description of impact	Receptor	Residual impact			
		Dogger Bank Teesside A	Dogger Bank Teesside B	Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor
	Sandeel	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Shellfish	Minor adverse	Minor adverse	Minor adverse	Minor adverse
Increased suspended sediment concentrations and sediment re-deposition	Eggs and larvae (general)	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Herring eggs	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Sandeel eggs	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Adult and juvenile fish (general)	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Sandeel	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Shellfish	Minor adverse	Minor adverse	Minor adverse	Minor adverse
Construction noise	Adult and juvenile fish	Negligible	Negligible	Negligible	Negligible
	Larvae	Minor adverse	Minor adverse	Minor adverse	Negligible
	Fish in general	Minor adverse	Minor adverse	Minor adverse	Negligible
	Herring	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Sandeel	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Diadromous species	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Other fish species	Minor adverse	Minor adverse	Minor adverse	Minor adverse
	Fish in general	Minor adverse	Minor adverse	Minor adverse	Negligible
	Shellfish	Minor adverse	Minor adverse	Minor adverse	Negligible

Description of impact	Receptor	Residual impact			
		Dogger Bank Teesside A	Dogger Bank Teesside B	Dogger Bank Teesside A & B	Dogger Bank Teesside A & B Export Cable Corridor
Operational Phase					
Loss of habitat	Fish and shellfish in general	Minor adverse			
	Sandeel				
	Herring				
Introduction of hard substrate	Fish and shellfish (general)	Minor adverse	Minor adverse	Minor adverse	Negligible
EMF	Elasmobranchs	Minor adverse			
	Salmon and sea trout				
	European eel				
	Lamprey				
	Other fish				
	Shellfish				
Operational noise	Fish and shellfish (general)	Minor adverse			N/A
Changes to fishing activity	Fish and shellfish (general)	Minor adverse			N/A

13. References

Aarestrup, K. Økland, F. Hansen, M.M. Righton, D. Gargan, P. Castonguay, M. Bernatchez, L. Howey, P. Sparholt, H. Pedersen, M.I. and McKinley, R.S. 2009. Oceanic spawning migration of the European eel (*Anguilla anguilla). Science* 325, pp. 1660.

Acolas, M. L. Begout Anras, M. L. Veron, V. Jourdan, H. Sabatie, M. R. and Bagliniere, J. L. 2004. An assessment of the upstream migration and reproductive behaviour of allis shad (*Alosa alosa* L.) using acoustic tracking. ICES *Journal of Marine Science* 61, pp. 1291-1304.

Ager, O. 2008. *Buccinum undatum*. Common whelk. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=2815 [Accessed 17 September 2012].

Amara, R. Mahe, K. LePape, O. and Desroy, N. 2004. Growth, feeding and distribution of the solenette *Buglossidium luteum* with particular reference to habitat preference. *Journal of Sea Research* 51(3-4), pp. 211-217.

Andersson, M.H. Berggren, M. Wilhelmsson, D. and Ohman, M.C. 2009. Epibenthic colonization of concrete and steel pilings in a cold-temperate embayment: a field experiment. *Helgoland Marine Research* 63 (3), pp. 249-260.

Appleby, J.P. and Scarratt, D.J. 1989. Physical effects of suspended solids on marine an estuarine fish and shellfish with special reference to ocean dumping: a literature review. *Canadian Technical Report of Fisheries and Aquatic Science* No.1681.

Arnett, R.T.P. and Wheland, J. 2001. Comparing the diet of cod (*Gadus morhua*) and grey seals (*Halichoerus grypus*): and investigation of secondary ingestion. *Journal of Marine Biological Association of the UK* 81,pp. 365-366.

Bannister, R.C.A. Addison, J.T. and Lovewell, S.R.J. 1994. Growth, movement, recapture rate and survival of hatchery-reared lobsters (*Homarus gammarus* Linneaus, 1758) released into the wild on the English East coast. *Crustaceana* 67(2), pp.156-172.

Barnes, M. 2008a. *Eutrigla gurnardus*. Grey gurnard. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=3327. [Accessed 13 June 2012].

Barnes, M. 2008b. *Merlangius merlangus*. Whiting. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=3794. [Accessed 19 September 2012].

Barnes, M. 2008c. *Melanogrammus aeglefinus*. Haddock. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 20/09/2012]. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=3783. [Accessed 20 September 2012].

Barnes, M. 2008d. *Micromesistius poutassou*. Blue whiting. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=3808. [Accessed 27 September 2012].

Barnes, M. 2008e. *Merluccius merluccius*. European Hake. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=3797. [Accessed: 27 September 2012].

Barnes, M. 2008f. *Osmerus eperlanus*. European smelt. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=3993. [Accessed: 11 September 2012].

Beard, T.W. and McGregor, M. 1991. *Storage and care of live lobsters*. Ministry of Agriculture, Fisheries and Food. Laboratory Leaflet Number: 66.

Beare, D. Rijnsdorp, A. Van Kooten, T. Fock, H. Schroeder, A. Kloppman, M. Witbaard, R. Meesters, E. Schulze, T. Blaesbjerg, M, Damm, U. and Quirijns, F. 2010. Study for the Revision of the plaice box- Final Report. IMARES Report Number C002/10.

Behrens, J.W. Stahl, H.J. Steffensen, J.F. and Glud, R.N. 2007. Oxygen dynamics of buried lesser sandeel *Ammodytes tobianus* (Linnaeus 1785): mode of ventilation and oxygen requiremetns. *J.Exp.Bio.* 210 (6), pp.1006-14.

Bennett, D.B. 1995. Factors in the life history of the edible crab (*Cancer pagurus* L.) that influence modelling and management. *ICES Marine Science Symposium* 199, pp. 89-98.

Bennett, D. Nichols, J and Huntington, T. 2006. Certification Report for NESFC Lobster Fishery. Moody Marine Ltd. Ref.802020 vl.

Berge, J.A. 1979 The perception of weak electric A.C. currents by the European eel, *Anguilla anguilla*. *Comparative Biochemistry and Physiology*. Part A. Physiology. 62(4), pp. 915-919.

Bergstad O.A., Hoines A.S. and Kruger J.E.M. 2001. Spawning time, age and size at maturity, and fecundity of sandeel, *Ammodytes marinus*, in the north-eastern North Sea and in unfished coastal waters off Norway. Aquatic Living Resources 14(5), pp. 293-301.
Birklund, J. Wijsman, J.W.M. 2005. Agregate extraction: A review on the ecological functions. DHI water and environment report Z3297.

Birtwell, I.K. 1999. The effects of sediment on fish and their habitat. Fisheries and Oceans Canada. Canadian Stock Assessment Secretariat. Research Document 99/139.

Bloomfield, A. and Solandt, J.L., 2006. Basking Shark Watch 20 year report (1987-2006). The Marine Conservation Society. Available at: http://www.mcsuk.org/downloads/wildlife/basking_sharks/BSW20%20Report.pdf [Accessed 19 September 2012].

Bochert, R. and Zettler, M.L. 2004. Long -term exposure of several marine benthic animals to static magnetic fields. *Bioelectromagnetics* 25, pp. 498-502.

Bodznick, D. and Preston, D.G.1983. Physiological characterization of electroreceptors in the lampreys *Ichthyomyzon uniscuspis* and *Petromyzon marinus*. *Journal of Comparative Physiology* 152, pp. 209-217.

Bodznick, D. and Northcutt, R.G.1981. Electroreception in lampreys: evidence that the earliest vertebrates were electroreceptive. *Science* 212, pp. 465-467.

Boehlert, G.W. and Morgan, J. B. 1985. Turbidity enhances feeding abilities of larval Pacific herring, *Clupea harengus pallasi. Hydrobiologia* 123, pp. 161-170.

Bohnsack, J.A. 1989. Are high densities of fishes at artificial reefs the result of habitat limitation or behavioural preference? *Bull. Mar. Sci*. 44, pp. 631-645.

Bohnsack, J.A. and Sutherland, D.L.1985. Artificial reef research: a review with recommendations for future priorities. *Bull. Mar. Sci*. 37, pp. 11-39.

Bolle, L.J. de Jong, C.A.F. Bierman, S. de Haan, D. Huijer, T. Kaptein, D. Lohman, M. Tribuhl, S. van Beek. P. van Damme, C.J.G. van den Berg, F. vand der Heul, J. van Keeken, O. Wessels, P. and Winter, E. 2011. Effect of piling noise on the survival of fish larvae (pilot study). Shortlist Masterplan Wind. Report number C092/22. IMARES.

Bone, Q. and Moore, R.H. 2008. *Biology of Fish*. Third edition. Taylor and Francis Group

Bonfil, R.1994. Overview of world elasmobranch fisheries. *FAO Fisheries Technical Paper* No 341, pp. 119.

Bolle, L.J., de Jong, C.A.F., Bierman, S., de Haan, D., Huijer, T., Kaptein, D., Lohman, M., Tribuhl, S., van Beek., P., van Damme, C.J.G., van den Berg, F., vand der Heul, J., van Keeken, O., Wessels, P., and Winter, E. 2011. Effect of piling noise on the survival of fish larvae (pilot study). Shortlist Masterplan Wind. Report number C092/22. IMARES.

Boles, L.C. and Lohmann, K.J. 2003. True navigation and magnetic maps in spiny lobsters. *Nature* 421, pp. 60-63.

Brand, A. R. 2006. Scallop ecology: distribution and behaviour In: “*Scallops: biology ecology and aquaculture”*. S.E. Shumway and G.J. Parsons (eds), Elsevier Press, pp. 651-744.

Brander, K.M. 1975. The population dynamics and biology of cod (*Gadus morhua*) in the Irish Sea. PhD thesis, University of East Anglia, Norwich. Cited in- Hutchinson W.F, Carvalho G.R, Rogers S.I 2001 Marked genetic structuring in localised spawning populations of cod Gadus morhua in the North Sea and adjoining waters as revealed by microsatellites. *Mar. Ecol. Prog. Ser*. 223, pp. 251–260.

Burt, G.J. and Millner, R.S. 2008. Movements of sole in the southern North Sea and eastern English Channel from tagging studies (1955-2004). *Sci.Ser.Tech.Rep*. 44, Cefas, Lowestoft.

Cain, S.D. Boles, L.C. Wang, J.H. and Lohmann, K.J. 2005. Magnetic orientation and navigation in marine turtles, lobsters and molluscs: Concepts and conundrums. *Integrative and Comparative Biology* 45, pp. 539-546.

Camhi, M. Fowler, S. Musick, J. Brautigam A. and Fordham S. 1998. Sharks and their relatives: Ecology and Conservation. Occasional Paper of the IUCN Species Survival Commission Occas. Pap. No. 20.

Carlson, T. Hastings, M. and Popper, A. N. 2007. Memorandum – Update on Recommendations for Revised Interim Sound Exposure Criteria for Fish during Pile Driving Activities, sent to California Dept. of Trans and Washington Dept. of Trans.

Cefas. 2004. Offshore Wind Farms: Guidance Note for Environmental Impact Assessment in Respect of FEPA and CPA Requirements, June 2004.

Cefas. 2009. Strategic review of offshore wind farm monitoring data associated with FEPA licence conditions. Fish. Contract ME1117.

Chapman, C. J. and A. L. Rice 1971. Some direct observations on the ecology and behaviour of the Norway lobster Nephrops norvegicus. *Marine Biology* 10(4): 321-329.

Chapman, C.J. and Ballantyne, K.A. 1980. Some observations on the fecundity of Norway lobsters in Scottish waters.International Council for the Exploration of the Seas Council Meeting Papers, C.M.1980/K:25.

Chung-Davidson, Y. Bryan, M.B. Teeter, J. Bedore, C.N. and Li, W. 2008 Neuroendocrine and behavioural responses to weak electric fields in adult sea lampreys (*Petromyzon marinus*). *Hormones and Behaviour.* 54 (1), pp. 34-40.

Collins, K.J. Jensen, A.C. and Lockwood, A.P.M. 1992. Stability of a coal waste artificial reef. Chemical Ecology 6: 79-93. In:- Pickering, H. and Whitmarsh, D. 1997. Artificial reefs and fisheries exploitation: a review of the attraction versus production debate, the influence of design and its significance for policy. *Fisheries Research* 31, pp. 39-59.

Conway, D. V. P. Coombs, S. H. and Smith, C. 1997. Vertical distribution of fish eggs and larvae in the Irish Sea and southern North Sea. *ICES J. Mar. Sci.* 54(1), pp. 136-147.

Corten, A. 2001. Herring and Climate. Changes in the distribution of North Sea herring due to climate fluctuations. PhD Thesis. University of Groningen.

Coull, K. A., Johnstone, R., and Rogers, S.I. 1998. Fisheries Sensitivity Maps in British Waters. UKOOA Ltd.

Couperus, B. Winter, E. van Keeken, O. van Kooten, T. Tribuhl, S. and Burggraaf, D. 2010. Use of high resolution sonar for ner-turbine fish observations (DISSON) – We@Sea 2007-002. IMARES Report number C138/10.

De Groot, S.J. 1980. The consequences of marine gravel extraction on the spawning of herring, *Clupea harengus* Linné. *Journal of Fisheries Biology*, 16, pp. 605-611.

DATRAS 2013 Online database. Available at: http://datras.ices.dk (Accessed May 2013).

Department of Energy and Climate Change. 2011a. Overarching National Policy Statement for Energy (EN1). July 2011.

Department of Energy and Climate Change. 2011b. National Policy Statement for Renewable Energy (EN3). July 2011.

DEFRA. 2010 Eel Management plans for the United Kingdom. Overview for England and Wales. Available at: http://archive.defra.gov.uk/foodfarm/fisheries/documents/fisheries/emp/overview.pdf Accessed 11 September 2012.

DEFRA. 2007. Science and research projects. Determination of the size at maturity of the whelk *Buccinium undatum* in English waters Avaliable at http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=2&ProjectID=17916. Acessed 31 May 2013.

Dulvy, N.K. Notobartolo di Sciara, G. Serena, F. Tinti, F. Ungaro, N. Mancusi, C. and Ellis, J. 2006 *Dipturus batis*. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.2. Available at: (www.iucnredlist.org. Accessed 22 March 2012).

Eastwood, P. D. and Meaden, G. J. 2000. Spatial modelling of spawning habitat suitability for the sole (*Solea solea* L.) in the eastern English Channel and southern North Sea. ICES. Theme Session (N) on Spatial and Temporal Patterns in Recruitment Processes CM2000/N:05.

Eaton, D.R. Brown, J. Addison, J.T. Milligan, S.P. and Fernand, L.J. 2003. Edible crab (*Cancer pagurus*) larvae surveys off the east coast of England: implications for stock structure. *Fisheries Research* 65(1), pp.191-199.

Edwards, E. 1979. *The Edible Crab and its fishery in British Waters*. Fishing News Books Ltd. Farnham, Surrey, England.

Ellis, J.R.A. Cruz-Martinez, A. Rackham, B.D. and Rogers, S.I. 2005. The distribution of Chondrichthyan Fishes Around the British Isles and Implications for Conservation. *J. Northw. Atl. Fish. Sci*. 35, pp.195-223.

Ellis, J. Doran, S. Dunlin, G. Hetherington, S. Keable, J. and Skea, N. 2009. Programme 9: Spurdog in the Irish Sea. Final Report. Fisheries Science Partnership.

Ellis, J. R. Milligan, S. Readdy, L. South, A. Taylor, N. and Brown, M. 2010. Mapping spawning and nursery areas of species to be considered in Marine Protected Areas (Marine Conservation Zones). Cefas, Lowestoft.

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

Emu Limited. 2012. Dogger Bank Offshore Wind Farm (Tranche A, Cable route and Nearshore) Benthic Ecology Characterisation Survey. Report for Forewind, September 2012.

Engell-Sørensen, K. and Skyt, P.H. 2001. Evaluation of the Effect of Sediment Spill from Offshore Wind Farm Construction on Marine Fish. – Report to SEAS, Denmark, pp. 18.

Environment Agency, 2012. Provisional salmon and sea trout rod catch summary 2011. Available online at: www.environment-agency.gov.uk/static/documents/Lesiure/Rod_CR_Summary_2011_pdf Accessed on 22/6/2013

Environment Agency 2011. Facts and figures about eels. Available at: http://www.environmentagency.gov.uk/homeandleisure/recreation/fishing/38023.aspx. Accessed 22 August 2011.

Evans, P.G.H. Baines, M.E. and Coppock, J. 2011. Abundance and behaviour of cetaceans and basking sharks in the Pentland Firth and Orkney Waters. Report by Hebog Environmental Ltd & Sea Watch Foundation. Scottish Natural Heritage Commissioned Report no.419.

Folk, R.L. 1954. The distinction between grain size and mineral composition in sedimentary rocks. *Journal of Geology* 62, pp. 344-359.

Formicki, K. Sadowski, M. Tanski, A. Korzelecka-Orkisz, A. and Winnicki, A. 2004. Behaviour of trout (*Salmo trutta* L.) larvae and fry in a constant magnetic field. *Journal of Applied Ichthyology* 20, pp. 290-294.

Formicki, K. and Winnicki, A. 2009. Reactions of fish embryos and larvae to constant magnetic fields. *Italian Journal of Zoology*. 65, pp. 479-482.

Fox,C. Taylor, M. Dickey-Collas, M. Fossum, P. Kraus, G. Rohlf N. Munk, P. van Damme, C.J.G. Bolle, L.J. Maxwell, D.L and Wright, P.J. 2008. Mapping the spawning grounds of North Sea cod (Gadus morhua) by direct and indirect means. *Proc.R.Soc.B*. 275, pp. 1543-1548.

Franklin A. Pickett G. D. Connor P. M. 1980. *The Scallop and its fishery in England and Wales.* Laboratory leaflet No. 51.

Furness, R.W. 2002. Management implications of interactions between fisheries and sandeel-dependent seabirds and seals in the North Sea. *ICES Journal of Marine Science* 59, pp. 261-269.

Furness R. W.1999.Towards defining a sandeel biomass limit for successful breeding by seabirds. In P.J. Wright and F.M. Kennedy, 1999. Proceedings of a workshop held at FRS Marine Laboratory Aberedeen 22-24 February 1999. Fisheries Research Services Report No 12/99.

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

Gill, A.B. Gloyne-Phillips, I. Neal, K.J. and Kimber, J.A. 2005. The Potential Effects of Electromagnetic Fields generated by Sub-Sea Power Cables associated with Offshore Wind Farm Development on Electrically and Magnetically Sensitive Marine Organism- a Review. COWRI.E. 1.5 Electromagnetic Fields Review. Final Report. COWRIE-EM FIELD 2-06-2004.

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

Gill, A.B. & Taylor, H. 2001. The potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon elasmobranch fishes, Countryside Council for Wales, Contract Science Report 488.

Greenstreet, S.P.R. 2007. Variation in the abundance and distribution of sandeels and clupeids in the Wee Bankie/Marr Bank region of the north-western North Sea over the period 1997 to 2003. Fisheries Research Services Internal Report No: 25/07.

Greenstreet, S. Fraser, H. Piet, G. Robinson, L. Callaway, R. Reiss, H. Ehrich, S. Kroncke, I. Craeymeersh, J. Lancaster, J. Jorgensen, L. and Goffin, A. 2007. Species composition, diversity, biomass and production of the demersal fish community of the North Sea. Fisheries Research Services Collaborative Report NO.07/07.

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

Griffin, F.J. Sith, E. H. Vines, C.A. and Cherr, G.A. 2009. Impacts of suspended sediments on fertilization embryonic development, and early larval life stages of the Pacific herring, Clupea pallasi. *Biological Bulletin* 216, pp.175-187.

Hamerlynck, O. and Cattrijsse, A. 1994. The food of *Pomatochistus minutus* (Pisces, Gobiidae) in Belgian coast waters, and a comparison with the food of ists potential competitor P. Lozanoi. *Journal of Fish Biology* 44, pp. 753-771.

Hancock, D. 1967. Ministry of Agriculture, Fisheries and Food; Whelks. Laboratory Leaflet (new series) No. 15, Fisheries Laboratory, Burnham on Crouch, Essex, England.

Hanson, M. Karlsson, l. Westerberg, H. 1984 Magnetic material in European eel (*Anguilla anguillla* L.) Comparative Biochemistry and Physiology Part A. *Physiology* 77(2), pp. 221-224.

Hanson, M. and Walker, M.A. 1987 Magnetic particles in European eel (*Anguilla anguilla*) and carp (*Cyprinus carpio*). Magnetic susceptibility and remanence. *Journal of Magnetism and Magnetic Materials* 66(1), pp. 1-7.

Harding, D., Woolner, L., and Dann, J. 1986. The English groundfish surveys in the North Sea, 1977–85. ICES CM 1986/G:13. 8 pp. In- ICES, 2005. The North Sea fish community ICES FishMap.

Hassel, A. Knutsen, T. Dalen, J. Løkkeborg, S. Skaar, K.Østensen, Ø. Haugland, E. K. Fonn, M. Høines, A. and Misund, O. A. 2003. Reaction of sandeel to seismic shooting: a field experiment and fishery statistics study. Institute of Marine Research, Fisken og Havet 4, pp. 63.

Hassel, A. Knutsen, T. Dalen, J. Skaar, K. Løkkeborg, S. Misund, O.A. Oivind, O. Fonn, M. and Haugland, E.K. 2004. Influence of seismic shooting on the lesser sandeel (*Ammodytes marinus*), *ICES Journal of Marine Science* 61,pp.1165-1173.

Hastings, M.C. and Popper, A.N. 2005. Effects of sound on fish. Report to the California Department of Transportation Contract No. 43A0139. Task Order 1.

Heath, M.R. Rasmussen, J. Bailey, M.C. Dunn, J. Fraser, J. Gallego, A. Hay, S.J. Inglis, M. Robinson, S. 2011. Larval mortality rates and population dynamics of Lesser Sandeel (*Ammodytes marinus*) in the northwestern North Sea. *Journal of Marine Systems* 93, pp. 47-57.

Heessen, H.J.L 1993. The distribution of Cod (*Gadus morhua*) in the North Sea. *NAFO Sci. Counc. Studies* 18, pp.56-65.

Heessen, H.J.L. and Daan, N. 1996. Longterm trends in ten non-target North Sea fish species. *ICES Journal of Marine Science* 53, pp. 1063-1078.

Hinrichsen, H-H. Kraus, G. Voss, R. Stepputtis, D. and Baumann, H.2005. The general distribution pattern and mixing probability of Baltic sprat juvenile populations. *Journal of Marine Systems* 58, pp. 52 – 66.

Hislop, JR.G. Robb, A.P. Bell, M.A. and Armstrong, D.W. 1991 The diet and food consumption of whiting (*Merlangius merlangus*) in the North Sea. *ICES, J. Mar. Sci*. 48(2), pp.139-156.

Hobson, E.S. 1986. Predation on the Pacific sand lance, *A. hexapterus* (Pisces: Ammodytidae) during the transition between day and night in southeastern Alaska. *Copeia* 1, pp. 223–226.

Hoffman, E. Astrup, J. Larsen, F. and Munch-Petersen, S. 2000 Effects of marine windfarms on the distribution of fish, shellfish and marine mammals in the Horns Rev area. Baggrundsrapport nr 24 to ELSAMPROJEKT A/S: 42p.

Holden, M. J.1974. Problems in the rational exploitation of elasmobranch populations and some suggested solutions. Sea Fisheries Research (F. R. Harden Jones, ed). Elek: London, pp. 117-137.

Holland, G.J. Greenstreet, S.P.R. Gibb, I.M. Fraser, H.M. and Robertson, M.R. 2005. Identifying sandeel *Ammodytes marinus* sediment habitat preferences in the marine environment. *Mar. Ecol. Prog.Ser*. 303, pp. 269-282.

Holt, T.J. Rees, E.I.S. Hawkins, R. and Seed, R. 1998 Biogenic Reefs (Volume IX): An overview of dynamic and sensitivity characteristics for conservation of marine SACs. Scottish Association for Marine Science (UK Marine SACs Project), Available at:http://www.ukmarinesac.org.uk/pdfs/biogreef.pdf. [Accessed 19 December 2012]

Howard, F.G.1989. The Norway Lobster. Scottish Fisheries Information Pamphlet Number 7 1989 (Second Edition) ISSN 03099105.

Hunter, E. Buckley, A.A. Stewart, C. and Metcalfe, J.D. 2005. Repeated seasonal migration by a thornback ray in the southern North Sea. *Journal of Marine Biological Association of the UK*, 85, pp.1199-1200.

Hunter, E. Metcalfe, J.D. Reynolds, J. 2003. Migration route and spawning fidelity by North Sea plaice. *Proc. R. Soc. Lond*. B. 270, pp. 2097-2103.

Hvidt, C.B. Kaustrup, M. Leonhard, S.B. and Pedersen, J. 2005. Fish along the cable trace. Nysted Offshore Wind Farm. Final Report 2004.

ICES 2013a. Online data portal. Available at http://eggsandlarvae.ices.dk (Accessed May 2013).

ICES 2013b. Report of the Herring Assessment Group for the Area South of 620N, 12-21 March 2013. ICES CM.2013/ACOM:06.

ICES. 2012a. Report of the ICES Advisory Committee, 2012. ICES Advice, Book 6 North Sea.

ICES. 2012b. Report of the ICES Advisory Committee, 2012. ICES Advice, Book 5. The Celtic Sea and West of Scotland.

ICES Advice, 2012. Sandeel real-time monitoring assessment. Special request, Advice May 2012. Report of the ICES Advisory Committee, 2012. ICES Advice, Book 6 North Sea.

ICES. 2011a. Report of the ICES Advisory Committee, 2011. ICES Advice, Book 6 North Sea.

ICES. 2011b. Report of the Working Group on Elasmobranch Fishes (WGEF). Available at: http://www.ices.dk/reports/ACOM/2011/WGEF/wgef_Sect_02_Spurdog.pdf. [Accessed on 23 March 2012.

ICES. 2011c. Report of the ICES Advisory Committee, 2011. ICES Advice, Book 9.

ICES. 2010a. Report of the ICES Advisory Committee, 2010. ICES Advice, 2010. Books 6 North Sea.

ICES. 2010b. Report of the Herring Assessment Working Group for the Area South of 62n (HAWG), 15 - 23 March 2010, ICES Headquarters, Copenhagen, Denmark. 688 pp.

ICES. 2009. Report of the Working Group of Multispecies Assessment Methods (WGSAM), 5- 9 October 2009. ICES Headquarters, Copenhagen. ICES CM 2008/RMC:06.113 pp.

ICES. 2008a. North Sea-Ecosystems overview. ICES Advice 2008. Book 6.

ICES. 2008b. Report of the Working Group on Multispecies Assessment Methods (WGSAM), 6–10 October 2008, ICES Headquarters, Copenhagen. ICES CM 2008/RMC:06. 113 pp.

ICES .2007. Report of the Working Group on Elasmobranch Fishes (WGEF). 22-27 June Galway, Ireland. ICES CM 2007/ACFM:27. 318 pp.

ICES. 2005a. ICES FishMap. Available online at: http://www.ices.dk/marineworld/fishmap/ices/. Accessed 08/08/2012.

ICES. 2005b. Report of the Study Group of Multispecies Assessment ni the North Sea (SGMSNS), 5 -8 April 2005, ICES Headquarters. ICES CM 2005/D:06.163 pp.

ICES.2005c. Report of the Planning Group on North Sea Cod and Plaice Egg Surveys in the North Sea (PGEGGS), 10 -12 May 2005, Lowestoft, UK. ICES CM 2005/G:11. 85pp.

ICES. 2012. Report of the Working Group on the Assessment of Demersal Stocks in the North Sea and Skagerrak (WGNSSK), 27April -3 May 2012, ICES Headquarters, Copenhagen. ICES CM 2012/ACOM:13.1346 pp.

Institute for Ecology and Environmental Management (IEEM) (2010) Guidelines for ecological impact assessment in Britain and Ireland, Marine and coastal. Final Document – pp. 71.

Iglésias, S.P. Toulho at, L. and Sellos, D.Y. 2010. Taxonomic confusion and market mislabelling of threatened skates: important consequences for their conservation status. Aquatic Conservation: *Marine and Freshwater Ecosystems* 20, Pp. 319–333.

IHLS 2009 data : ICES HAWG, 2010. ICES Herring Assessment Working Group Report 2010.

IHLS 2010 data : ICES HAWG, 2011. ICES Herring Assessment Working Group Report 2011.

Jenkins, S.R. Lart, W. Vause, B.J. and Brand, A.R. 2003. Seasonal swimming behaviour in the queen scallop (*Aequipecten opercularis*) and its effect on dredge fisheries. *Journal of Experimental Marine Biology and Ecology* 289, pp. 163-179.

Jensen, A.C. Collins, K.L. Free, E.K. and Bannister, R.C.A.1994. Lobster (*Homarus gammarus*) movement on an artificial reef: the potential use of artificial reefs for stock enhancement. Proceedings of the Fourth International Workshop on Lobster Biology and Management, 1993. *Crustaceana* 67(2),.pp. 1994.

Jensen, A. C. Collins, K.L. Lockwood, A.P.M., and Mallinson, L.1992. Artificial reefs and lobsters: The Poole Bay Project. In: Proceedings of the 23rd Annual Shellfish Conference, 19-20 May 1992. The Shellfish Association of Great Britain, London, pp. 69-84. Cited In-

Jensen H. 2001. Settlement dynamics in the lesser sandeel *Ammodytes marinus* in the NorthSea. PhD Thesis, University of Aberdeen.

Jensen, H. and Christensen, A. 2008. RECLAIM. Resolving Climatic Impacts on fish stocks. Specific Targeted Research Project on: Modernisation and sustainability of fisheries, including aquaculture-based production systems. 1.6 Report of WP1. Chapter 18-Sandeel.

Jensen H. Rindorf A. Wright, P.J. and Mosegaard, H. 2011. Inferring the location and scale of mixing between habitat areas of lesser sandeel through information from the fishery. *ICES Journal of Marine Science* 68(1), pp. 43–51.

JNCC. 2011. Principal salmon and sea trout rivers in England and Wales . Available at: http://www.jncc.gov.uk. [Accessed on 31 May 2011].

JNCC. 2007. Joint Nature Conservation Committee. Second Report by the UK under Article 17 on the implementation of the Habitats Directive from January 2011 to December 2006. Peterborough. Available at: www.jncc.gov.uk/article17. [Accessed at 31 May 2011].

Johnsen, S. and Lohmann, K. J. 2005. The physics and neurobiology of magnetoreception. *Nature Reviews Neuroscience* 6, pp. 703-712.

Johnston, D.W. and Wildish, D.J. 1981. Avoidance of dredge spoil by herring (*Clupea harengus*). *Bulletin of Environmental Contamination and Toxicology*. 26, pp. 307-314. Cited in Engell-Sørensen 2001.

Johnston, D.W and Wildish, D.J. 1982. Affect of suspended sediment on feeding larval herring (*Clupea harengus harengus* L.). *Bulletin of Environmental Contamination and Toxicology* 29, pp. 261-267.

Judd, A. 2012. Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. Cefas contract report: ME5403-Module 15.

Kaiser, M.J. Collie, J.S. Hall, S.J. Jennings, S. and Poiner, I.R. 2003. Impacts of fishing gear on marine benthic habitats. In: *Responsible Fisheries in the Marine Ecosystem*. CABI Publishing, Wallingford, pp. 197-217.

Kalmijn, A.J. 1982. Electric and magnetic field detection in elasmobranch fishes. *Science* 218, pp. 916-918.

Karlsson, L. 1985. Behavioural responses of European silver eels (*Anguilla anguilla*) to the geomagnetic field. *Helgolander Meeresuntersuchungen* 39, pp. 71-8.

Kelly, F. L. and King, J. J. 2001. A review of the ecology and distribution of three lamprey species, *Lampetra fluviatilis* (L), *Lampetra planeri* (L.), and *Petromyzon marinus* (L.): a context for conservation and biodiversity considerations in Ireland. *Biology and Environment: Proceedings of the Royal Irish Academy*.101B(3), pp. 165-185.

Keltz, S and Bailey, N. 2012. Fish and shellfish stocks 2012. Marine Scotland science, the Scottish Government.Avialble at: http://www.scotland.gov.uk/Resource/0039/00392455.pdf. [Acessed 30 May 2013].

Kennedy, F.M. 1999. Proceedings of a workshop held at FRS Marine Laboratory Aberedeen 22-24 February 1999. Fisheries Research Services Report No 12/99.

Kimber, J.A. Sims, D.W. Bellamy, P.H. and Gill, A.B. 2011. The ability of a benthic elasmobranch to discriminate between biological and artificial electric fields*. Marine Biology* 158(1), pp. 1-8.

Langham, N.P.E. 1971.The distribution and abundance of larval sand-eels (*Ammodytidae*) in Scottish waters. *Journal of the Marine Biological Association of the United Kingdom* 51, pp. 697-707. Cited In: Jensen *et al*. 2003.

Langhamer, O. and Wihelmsson, D. 2009. Colonisation of fish and crabs of wave energy foundations and the effects of manufactured holes - a field experiment. *Marine Environmental Research* 68(4), pp. 151-157.

Laughton, R. and Burns, S. 2003. Assessment of sea lamprey distribution and abundance in the River Spey: Phase III. Scottish Natural Heritage Commissioned Report No. 043 (ROAME No. F02AC604).

Lawler, A. Firmin, C. Bell, E. 2006. Programme 14: Yorkshire Coast Crustacea, Fisheries Science Partnership: 2006/7, Cefas, Lowestoft

Leonhard, S.B. and Pedersen, J. 2006. Benthic communities at Horns Rev before, during and after Construction of Horn Rev Offshore Wind Farm Vattenfall Report Number: Final. Report/Annual report 2005, pp. 134.

Leonhard, S.B and Pedersen, J. 2005. Hard bottom substrate monitoring Horns Rev Offshore Wind Farm. Annual Status Report 2004.

Limpenny, S.E. Barrio Froján, C. Cotterill, C. Foster-Smith, R.L. Pearce, B. Tizzard, L. Limpenny, D.L. Long, D. Walmsley, S.Kirby, S. Baker, K. Meadows, W.J. Rees, J. Hill, J. Wilson, C. Leivers, M. Churchley, S. Russell, J. Birchenough, A.C. Green, S.L. and Law, R.J. 2011. The East Coast Regional Environmental Characterisation. Cefas Open report 08/04.pp. 287.

Lindeboom, H.J. Kouwenhoven, H.J. Bergman, M.J.N. Bouma, S. Brasseur, S. Daan, R.Fijn, R.C. de Haan, D. Dirksen, S. van Hal, R. Lambers, R.H.R. ter Hofsted, R. Krijgsveld, K.L. Leopold, M. and Scheidat, M. 2011. Short-term ecological effects of an Offshore Wind Farm in the Dutch coastal zone: a compilation. *Environ. Res. Lett.* 6.

Lockwood, S. J. 2005. A strategic environmental assessment of the fish and shellfish resources with respect to proposed offshore wind farms in the Eastern Irish Sea. Coastal Fisheries Conservation and Management Colwyn Bay.

Lohmann, K.J. Lohmann, M.F. and Putman, N.F.2007. Magnetic maps in animals: nature GPS's. *The Journal of Experimental Biology* 210, pp. 3697-3705.

Linley, E.A.S. Wilding, T.A. Hawkins, A. J.S. and Mangi, S. 2007. Review of the reef effects of offshore wind farm structures and their potential for enhancement and mitigation. Report from PML Applications Ltd and the Scottish Association for Marine Science to the Department for Business, Enterprise and Regulatory Reform (BERR), Contract No. RFA/005/0029P.

Lovell, J. M. Findlay, M.M. Moate, R.M. and Yan, H.Y. 2005. The Hearing Abilities of the Prawn Palaemon serratus. *Comparative Biochemistry and Physiology* Part A 140, pp. 89-100..

Macer, C.T. 1965. The distribution of larval sand eels (*Ammodytidae*) in the southern North Sea. Journal of the Marine Biological Association of the United Kingdom 45, pp. 187e207. Cited in Jensen *et al*. 2003.

MacMullen, P.H. 1983. The fishery of the velvet swimming crab- *Necora puber*. Seafish. MAFF Commission. Technical Report No SR218.

Maes, J. and Ollevier, F. 2002. Size structure and feeding dynamics in estuarine clupeid fish schools: field evidence for the school trap hypothesis. *Aquatic Living Resources* 15, pp.211-216.

Maitland, P. S. 2003a. Ecology of the River Brook and Sea Lamprey. Conserving Natura 2000 Rivers Ecology Series No. 5. English Nature, Peterborough

Maitland, P. S. 2003b. The status of smelt *Osmerus eperlanus* in England. Report no. 516. English Nature, Peterborough.

Maitland, P. S. and Hatton-Ellis, T. W. 2003. Ecology of the Allis and Twaite Shad. Conserving Natura 2000 Rivers Ecology Series No. 3. English Nature, Peterborough.

Maitland, P. S. and Lyle, A. A.1995. Shad and smelt in the Cree Estuary, SW Scotland. Report to Scottish Natural Heritage, Edinburgh.

Malcolm, I.A. Godfrey, J. and Youngson, A.F. 2010. Review of migratory routes and behaviour of Atlantic salmon, sea trout and European eel in Scotland's coastal environment: implications for the development of marine renewables. Environmental Research Institute, Thurso. Published by Marine Scotland Science. ISSN:2043-7722.

MarLIN, 2012. Available at: http://www.marlin.ac.uk/. [Accessed on 25 June 2012].

McCauley, R. D. Fewtrell, J. Duncan, A. J. Jenner, C. Jenner, M-N. Penrose, J. D. Prince, R. I. T. Adhitya, A. Murdoch, J. and McCabe, K. 2000. Marine seismic surveys – A study of environmental implications. *Appea Journal*, pp. 692-708.

McQuaid, N. Briggs, R.P. and Roberts, D. 2009. Fecundity of *Nephrops norvegicus* from the Irish Sea. *Journal of the Marine Biological Association of the United Kingdom*, vol 89 (6), no. 6, pp. 1181-1188

Méhault, S., Morandeau, F., Fifas, S. 2011. Discarded Nephrops survival after trawling. Working document for ICES Nephrops working group. IFREMER Report of project PRESPO, pp. 15.

Messieh, S. N. Wildish, D. J. and Peterson, R. H. 1981. Possible impact from dredging and soil disposal on the Miramichi Bay Herring Fishery. Can. Tech. Rep. Fish. Aquat. Sci. 1008, pp. 33. Cited in- Engell-Sørensen, K. and Skyt, P.H. 2001. Evaluation of the effect of sediment spill from offshore wind farm construction on marine fish. Report to SEAS, Denmark, pp. 18.

Meyer, C. G. Holland, K. N. and Papastamatiou, Y. P. 2005. Sharks can detect changes in the geomagnetic field. Journal of the Royal Society Interface 2, pp. 129-13.

Milligan, S. P. 1986. Recent studies on the spawning of sprat (*Sprattus sprattus* L.) in the English Channel. *Fisheries Research Technical Report* no. 83.

Mooney, T.A. Hanlon, R.T. Christensen-Dalsgaard, J. Madsen, P.T. Ketten, D.R. and Nachtigall, P.E. 2010. Sound detection by the longfin squid (*Loligo pealeii*) studied with auditory evoked potentials: Sensitivity to low-frequency particle motion and not pressure. *The Journal of Experimental Biology* 213, pp. 3748-3759.

Moore, A. Freake, S.M. and Thomas, I.M. 1990. Magnetic particles in the lateral line of the Atlantic Salmon (*Salmo salar* L.). *Philosophical Transactions: Biological Sciences* 329(1252), pp. 11-15.

Moore, A. and Riley, W.D. 2009. Magnetic particles associated with the lateral line of the European eel *Anguilla anguilla*. *Journal of Fish Biology* 74(7), pp. 1629-1634.

Moore, J. A. Hartel, K. E. Craddock, J. E. and Galbraith, J. K. 2003. An annotated list of deepwater fishes from off the New England region, with new area records. *Northeastern Naturalist* 10(2), pp.159–248.

Musick, J. A. 2005. Management techniques for elasmobranch fisheries. *FAO Fisheries Technical paper* 474. 2008.

Natural England. 2012. Seahorses and seagrass FAQ. Natural England. Available at: http://www.naturalengland.org.uk/regions/south_west/ourwork/seahorses.aspx#6 . [Accessed 15 June 2012].

Natural England. 2010. The Dee Estuary European Marine Site. Natural England & the Countryside Council for Wales‟ advice given under Regulation 33(2) of the Conservation (Natural Habitats &c.) Regulations 1994.

Navarro, J.M. and Widdows, J. 1997. Feeding physiology of *Cerastoderma edule* (L.) in response to a wide range of seston concentrations. *Marine Ecology Progress Series* 152, pp. 175-186.

Neal, K. and Wilson, E. 2008. *Cancer pagurus*. Edible crab. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]Plymouth: Marine Biological Association of the United Kingdom[cited 31/08/2012] Available at: http://www.marlin.ac.uk/speciesfullreview.php?speciesID=2872. [Accessed 31 May 2012].

Neal, K. 2008. Brown shrimp. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line] Plymouth: Marine Biological Association of the United Kingdom[cited 25/09/2012] Available at: http://www.marlin.ac.uk/taxonomyidentification.php?speciesID=3078. [Accessed 31 May 2012].

Nedwell, J. and Howell, D. 2004. A review of offshore wind related underwater noise sources. Report No. 544 R 0308. Report Commissioned by COWRIE.

Nedwell, J.R. Edwards, B. Turnpenny, A.W.H. and Gordon, J, 2004. Fish and marine mammal audiograms: A summary of available information. Subacoustech Report ref: 534R0214.

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

Newcombe, C. P. and J. O. T. Jensen. 1996. Channel suspended sediment and fisheries: a synthesis for quantitative assessment of risk and impact. *North American Journal of Fisheries Management* 16, pp. 693-727.

Nicholls, P. Hewitt, J. and Haliday, J. 2003. Effects of suspended sediment concentrations on suspension and deposit feeding marine macrofauna. NIWA Client Report ARC03267.

Nissling, A. Muller, A. Hinrichsen, H.-H. 2003. Specific gravity and vertical distribution of sprat (*Sprattus sprattus*) eggs in the Baltic Sea. *Fish Biol* 63, pp. 280–299.

Norman, C. P. and M. B. Jones (1993). Reproductive ecology of the velvet swimming crab, *Necora puber* (Brachyura: Portunidae), at Plymouth. *Journal of the Marine Biological Association of the United Kingdom,* 73, pp 379-389. doi:10.1017/S0025315400032938.

Normandeau, E., Tricas, T. and Gill, A. 2011. Effects of EMF from undersea power cables on elasmobranchs and other marine species. U.S. Depart. of the Interior, Bureau of Ocean Energy Management, Regulation and Enforcement, Pacific OCS Region, Camarillo, CA. OCS Study BOEMRE 2011-09.

Öhman, C. Sigray, P. and Westerberg, H. 2007. Offshore windmills and the effects of electromagnetic fields on fish Royal Swedish Academy of Science. *Ambio* 36(8), pp. 630-633.

OSPAR. 2008. Background document on potential problems associated with power cables other than those for oil and gas activities. OSPAR Commission. Biodiversity Series.

Parslow-Williams, P. Goodheir, C. Atkinson, R.J.A. and Taylor, A.C. 2002. Feeding energetics of the Norway lobster, *Nephrops norvegicus* in the Firth of Clyde, Scotland. *Ophelia* 56, pp. 101-120.

Patberg, W. de Leeuw, J. J. Winter, H. V. 2005. Verspreiding van rivierprik, zeeprik, fint en elft in Nederland na 1970. Nederlands Instituut voor Visserij Onderzoek (RIVO) BV. Rapport Nummer: C004/05.

Pawson, M. G. 1995. Biogeographical identification of English Channel fish and shellfish stocks. Fisheries Research technical report No 99.

Payne, M. R. Hatfield, E. M. C. Dickey-Collas, M. Falkenhaug, T. Gallego, A. Gröger, J. Licandro, P. Llope, M. Munk, P. Röckmann, C. Schmidt, J. O. and Nash, R. D. M. 2009. Recruitment in a changing environment: the 2000s North Sea herring recruitment failure. ICES Journal of Marine Science 66, pp. 272–277.

Pearson, W. H. Skalski, J. R. and Malme, C. I. 1992. Effects of sounds from a geophysical survey device on behaviour of captive rockfish (*Sebastes* spp.). *Can. J. Fish. Aquat. Sci*. 49, pp. 1343-1356.

Pickering, H. and Whitmarsh, D., (1997) Artificial reefs and fisheries exploitation: a review of the attraction versus production debate, the influence of design and its significance for policy. Fisheries Research 31, pp. 39-59.

Pinnegar, J.K. Stelzenmuller, V. Van der Kooij, J. Engelhard, G.H. Garrick-Maidment, N. and Righton, D.A. 2008. Occurrence of the short-snouted seahorse *Hippocampus hippocampus* in the central North Sea. Cybium 32(4), pp. 343-346.

Pizzolla, P. 2008. *Scyliorhinus canicula*. Small-spotted catshark. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=4319. [Accessed 22 March 2012].

Popper A. Carlson T. J. Hawkins, A. D. Southall B. D. and Gentry R. L. 2006. Interim Criteria for injury of Fish Exposed to a pile Driving Operation: A white Paper, available from http://www.wsdot.wa.gov/NR/rdonlyres/84A6313A-9297-42C9-BFA6-750A691E1DB3/0/BA_PileDrivingInterimCriteria.pdf, 200

Potter E. C. E. and Dare, P.J. 2003. Research on migratory salmonids, eel and freshwater fish stocks and fisheries. *Sci. Ser. Tech Rep*., Cefas Lowestoft, 119: 64pp.

Prins, T.C., van Beek J.K.L., Bolle, L.J. (2009) Modelschatting van de effecten van heien voor offshore windmolenparken op de aanvoer van vislarven naar Natura 2000. Deltares rapport Z4832

Proctor, N. V. 2005. Crustacean Stock Assessment at the Aldbrough Gas Storage Facility, Aldbrough. Report to Scottish & Southern Energy. Institute of Estuarine and Coastal Studies, University of Hull.

Rabaut, M., van de Morteel L., Vincx, M and Degraer, S. 2010. Biogenic reefs as structuring factor in *Pleuronectes platessa* (Plaice) nursery.*Journal of Sea Resarch* 64. 2010. 102-106

Reeve, A. 2007*. Solea solea*. Sole. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: www.marlin.ac.uk/speciesinformation.php?speciesID=4347. [Accessed 8 March 2012].

Reeve, A. 2008. *Lophius piscatorius*. Angler fish. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=3728. [Accessed 27 September 2012].

Riley, K. 2007. *Pomatoschistus minutus*. Sand goby. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesimportance.php?speciesID=4182. [Accessed 21 March 2012].

Robertson, M. J., Scunton, R.S., Gregory, R.S., Clarke, K.D., 2006. Effect of suspended sediment on freshwater fish and fish habitat. *Canadian Technical Report of fisheries and Aquatic Sciences*, 2644, pp. 37.

Rogers, S. and Stocks, R. 2001. North Sea Fish and Fisheries. *Technical Report* TR_003. Strategic Environmental Assessment-SEA2.

Rommel, S.A. and McCleave, J.D.1973. Prediction of Oceanic Electric Fields in relation to fish migration. *ICES Journal of Marine Science*. 35(1), pp. 27-31.

Rönbäck, P. and Westerberg, H. 1996. Sedimenteffekter på pelagiska fiskägg och gulesäckslarver. Fiskeriverket, Kustlaboratoriet, Frölunda, Sweden. Cited in Engell-

Sørensen, K. and Skyt, P.H., (2001) Evaluation of the effect of sediment spill from offshore wind farm construction on marine fish. Report to SEAS, Denmark: pp.18.

Rowley, S. 2008. *Molva molva*. Ling. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=3826. [Accessed 27 September 2012].

Rowley, S. and Wilding, C. 2008. *Ammodytes tobianus*. Lesser sandeel. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=2480. [Accessed 10 February 2012].

Ruiz, A. 2007a. *Pleuronectes platessa*. Plaice. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=4144. [Accessed on 08/03/2012].

Ruiz, A. 2007b. *Buglossidium luteum*. Solenette. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=2817. [Accessed 27 September 2012].

Ruiz, A. 2008c. *Limanda limanda*. Dab. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 28/08/2012]. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=3675

Ruiz, A. 2008d. *Pandalus montagui*. Pink shrimp. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 31/05/2013]. Available from: http://www.marlin.ac.uk/speciesinformation.php?speciesID=4034

Sadowski, M.A., Winnicki, A., Formicki, K., Sobocinski, A. and Tanski, A., (2007) The effect of Magnetic Field on permeability of egg shells of Salmonids Fishes. *Acta ichthyologica et piscatoria* 37, pp. 129-135.

Santos, M.B. and Pierce, G.J. 2003. The diet of Harbour porpoise (Phocoena phocoena) in the North East Atlantic. Oceanography and Marine Biology: An Annual Review 2003, 41, pp. 355-390.

Santos, M.B., Pierce, G.J., Learmonth, J.A., Reid, R.J., Ross, H.M., Patterson, I.A.P., Reid, D.G. and Beare, D.2004. Variability in the diet of h arbour porpoises (Phocoena phocoeana). *Marine Mammal Science*. 20(1), pp. 1-27.

Sayer, M. D. J., Magill, S., H., Pitcher, T. J., Morisette, L. and Ainsworth,C. 2005. Simulation-based investigations of fishery changes as affected by the scale and design of artificial habitats. *Journal of Fish Biology* 67 (Supplement B), pp. 218-243.

Schmidt, J. O., van Damme, C. J. G., Rockmann, C. and Dickey-Collas, M. 2009. Recolonisation of spawning grounds in a recovering fish stock: recent changes in North Sea herring. *Sci. Mar* 73(S1), pp.153-157.

Schmidt, J., Rohlf, N. and Groger, J. 2008. Report of the Herring Larvae Surveys in the North Sea in 2007/2008.

Seed, R. 1969 The ecology of *Mytilus edulis* on exposed rocky shores. *Oecologia* 3, pp. 317 - 350

Sell, A.F., Kroncke, I. and Ehrich, S. 2007. Linking the diversity of fish assemblages to habitat structure: A study on Dogger Bank (North Sea). ICES CM 2007/E:18.

Skaret, G., Axelsen, B.E., Nottestad, L., Ferno, A. and Johannessen, A.2005. The behaviour of spawning herring in relation to a survey vessel. *ICES Journal of Marine Science.* 62 (6), pp. 1061-1064.

Shark Trust, 2009. Common Skate Factsheet. Available at: http://www.sharktrust.org/content.asp?did=33255. [Accessed on 18/06/2012].

Shark Trust. 2010. An Illustrated Compendium of Sharks, Skates, Rays and Chimaera. Chapter 1: The British Isles and Northeast Atlantic. Part 2: Sharks.

Shelley, J. 2012. Habitats Regulations Assessment of the North East Coast Limitation of Net Licences Order 2012. Supporting Technical Report. Impact on Anadromous fishes: Atlantic Salmon (*Salmo salar*). Environment Agency

Smith I.P, Jensen A. C., Collins K.J. and Mattey E.L. 2001. Movement of wild European lobsters *Homarus gammarus* in natural habitat. Marine Ecology–Progress Series 222, pp. 177-186.

Stenberg, C., van Deurs, M., Stottrup, J., Mosegaard, H, Grome, T., Dinesen, G., Christensen, A., Jensen, H, Kaspersen, M., Berg, C.W., Leonhard, S.B., Skov, H., Pedersen, J., Hvidt, C.B. and Kaustrup, M. 2011. Effect of the Hors Rev 1 Offshore Wind Farm on Fish Communities. Follow-up Seven Years after Construction. DTU Aqua Report NO 246-2011.

Tanski, A., Formicki, k. Korzelecka-Orkisz, A. and Winnicki, A. 2005. Spatial orientation of fish embryos in magnetic field. Electronic Journal of Ichthyology 1, pp. 14.

Teal, L.R. 2011. The North Sea fish community: past, present and future. Background document for the 2011 National Nature Outlook. Wageningen, Wettelijke Onderzoekstaken Natuur & Milieu, WOtwerkdocument256. 64 p.

ter Hofstede, R. H., Winter, H. V. and Bos, O. G. 2008. Distribution of fish species for the generic Appropriate Assessment for the construction of offshore wind farms. IMARES Report C050/08.

Thompson, B.M. Lawler, A.R. and Bennett, D.B. 1995. Estimation of the spatial distribution of spawning crabs (Cancer pagurus) using larval surveys in the English Channel. ICES *Mar. Sci. Symp*., 199, pp. 139-150.

Thomsen, F. Ludemann, K. Kafemann, R and Piper, W. 2006 Effects of offshore wind farm noise on marine mammals and fish, Biola, Hamburg, Germany on behalf of COWRIE Ltd.

Tougaard, J. and Henriksen, O.D. 2009. Underwater noise from three types of oofshore wind turbines.: Estimation of impact zones for harbor porpoises and harbor seals. *J. Acoust. Soc. Am.*, 126, pp. 11-14.

Tricas, T.C. and Sisneros, J.A. 2004. Ecological functions and adaptations of the elasmobranch electrosense. In: The Senses of Fishes: Adaptations for the Reception ofNatural Stimuli (Ed. By von der Emde, G., Mogdans, J. & Kapoor, B.G.), pp. 308-329. New Delhi, India: Narosa Publishing House.

Tyler-Walters H, 2008. *Mytilus edulis*. Common mussel. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 22/05/2013]. Available at: http://www.marlin.ac.uk/speciesfullreview.php?speciesID=3848. [Acessed on 30/05/2013].

Ueno, S.P., Lovsund, P. and Ober, P.A.1986. Effect of time-varying magnetic fields on the action potential in lobster giant axon. Medical and Biological Engineering and Computing 24.

van Damme, C.J.G., Hoek, R., Beare, D., Bolle, L.J., Bakker, C., van Barneveld, E., Lohman, M., os-Koomen, E., Nijssen, P., Pennock, I. and Tribuhl, S. 2011. Shortlist Master plan Wind Monitoring fish eggs and larvae in the Southern North Sea; Final Report . Report number C098/11.

van Deurs, M., van Hal, R., Jensen, H., Tomczak, M.T. and Dolmer, P. 2008. A spatially and temporally explicit analysis of beam-trawling on sandeel fishing grounds in the North Sea. North Atlantic Case Study Appendix 1. A study part of the EU project INEXFISH financed by the RTD programme “Specific Support to Policies”, FP6 2004-SSP-4 “Integrating and Strengthening the European Research Area”.

van der Kooij, J., Scott, B.E. and Mackinson, S. 2008. The effects of environmental factors on daytime sandeel distribution and abundance on the Dogger Bank. *Journal of Sea Research* 60, pp. 201-209.

Vandendriessche, S., Derweduwen, J and Hostens, K. 2012. Chapter 5: Project Description- Monitoring the effects of offshore wind farms on the epifauna and demersal fish fauna of soft-bottom sediment. In-Degraer, S., Brabant, and Rumes.B. 2012. Offshore wind farms in the Belgian part of the North Sea: Heading for an understanding of environmental impacts. Royal Belgian Institute of Natural Science, Management Unit of the North Sea Mathematical Methods, Marine ecosystem management unit. 155pp. annexes.

Vriens, A.M. and Bretschneider, F.1979. The electrosensitivity of the lateral line of the European eels, *Anguillla anguillla* L. *Journal of Physiology*. 75 (4), pp. 341-342.

Wageningen Ur, (2012a). International Bottom Trawl surveys (IBTS) Results. 2010. Available online at: http://orca.wur.nl/surveys/survey_report_IBTS_2010/. [Accessed on 07/03/2012[.

Wageningen Ur, (2012b). Beam Trawl surveys (BTS) Results. 2010. Available online at: http://orca.wur.nl/surveys/survey_report_BTS_2010/. [Accessed on 07/03/2012].

Wahlberg, M. and Westerberg, H., (2005). Hearing in fish and their reactions to sounds from offshore wind farms. *Marine Ecology Progress Series*. 288, pp. 295-309.

Waldman, J., Grunwald, C. and Wirgin, I. 2008. Sea lamprey *Petromyzon marinus*: an exception to the rule of homing in anadromous fishes. *Biol. Lett*. 4, pp. 659–662.

Walters, H.T.2008. *Psetta maxima*. Turbot. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=4218. [Accessed 7 September 2012].

Walmsley S.A. and Pawson, M.G., 2007. The coastal fisheries of England and Wales, Part V: a review of their status 2005–6. *Sci. Ser. Tech Rep*., Cefas Lowestoft, 140, pp. 83.

Wanless, S., Wright, P.J., Harris, M.P. and Elston, D. A. 2005. Evidence for decrease in size of lesser sandeel *Ammodytes marinus* in a North Sea aggregation over a 30-yr period. *Mar Ecol Prog Ser* Vol. 279, pp. 237–246.

Wanless S., Harris M. and Rothery P.1999. Intra-and Inter-Seasonal Variation in Sandeel, *Ammodytes marinus* Consumption by Kittiwakes, *Rissa tridactyla* on the Isle of May and Long-term Changes in Numbers, Reproductive Output and Adult Survival. In: Wright, P.J. and Bailey, M. C. 1996.

Wanless, S., Harris, M. P., and Greenstreet, S. P. R.1998. Summer sandeel consumption by seabirds breeding in the Firth of Forth, south-east Scotland. – *ICES Journal of Marine Science* 55, pp. 1141–1151.

Warren, P.J and Sheldon R. W. 1967. Feeding and migration patterns of the pink shrimp *Pandalus montagui*, in the estuary of the River Crouch, Essex, England. *Journal of the Fisheries Research Board of Canada* 24 (3), pp. 569–580.

Weinert, M., Floeter, J, Kroncke, I. and Sell, A.F. 2010. The role of prey composition for the condition of grey gurnard (*Eutrigla gurnardus*). *Journal of Applied Ichthyology*. 26 (Supplement s1), pp. 78-84.

Westerberg, H. and Lagenfelt, I. 2008. Sub-Sea Power Cables and the Migration Behaviour of the European Eel. *Fisheries Management and Ecology* 15 (1-5), pp. 369-375.

Wheeler, A. 1978. Key to the fishes of Northern Europe. Frederik Warne (Publishers) Ltd, London.

Whitehead, P.J.P., Bauchot, M.-L., Hureau, J.-C., Neilsen, J., and Tortonese, E. 1986. Clupeidae. In Fishes of the North-eastern Atlantic and the Mediterranean Volume I. UNESCO, Paris, pp. 268-281.

Whitehead, P.J.P., Bauchot, M.-L., Hureau, J.-C., Neilsen, J., and Tortonese, E., (1986) Clupeidae. In Fishes of the North-eastern Atlantic and the Mediterranean Volume I. UNESCO, Paris, pp. 268-281.

Wilding., C. and Heard, J. 2004. *Gadus morhua*. Atlantic cod. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 21/03/2012]. Available from: http://www.marlin.ac.uk/speciesinformation.php?speciesID=3359. [Accessed 221 March 2012].

Wilhelmsson, D., Malm, T. Ohman, M.C. 2006. The influence of offshore windpower on demersal fish. ICES Journal of Marine Science 63(5), pp. 775-784.

Wilson, E. 2008. *Necora puber*. Velvet swimming crab. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]. Plymouth: Marine Biological Association of the United Kingdom. Available at: http://www.marlin.ac.uk/speciesinformation.php?speciesID=3858. [Accessed 14 September 2012].

Winter, HR., Aarts, G. and van Keeken, O.A. 2010. Residence time and behaviour of sole and cod in the Offshore Wind farm Egmond aan Zee (OWEZ). IMARES Report number OWEZ_R_265-TI_20100916.

Winslade, P.,R. 1971. *The Behavioural and Embryological Investigations of the lesser sandeel, Ammodytes marinus* Raitt. PhD Thesis. University of East Anglia.

Wood, S.A. 2001. Summary of harbour seal (*Phoca vitulina concolor*) food habits in Mid-coast Maine: Summer 2000. Report to MERI: 1-11. Marine Environ. Research Institute.

Wright, P.J., Jensen, H., and Tuck, I. 2000. The influence of sediment type on the distribution of the lesser sandeel *Ammodytes marinus*. *J.Sea.Res*. 44, pp. 243-256.

Wright, P.J. and Bailey, M. C. 1996. Timing of hatching in *Ammodytes marinus* from Shetland waters and its significance to early growth and survivorship. Marine Biology, 126, pp.143-152. Cited in Jensen *et al*. 2003.

