Supporting Risk-Based Fisheries Assessments for MPAs

Assessment of Beam Trawling Activity in North Norfolk Sandbanks and Saturn Reef SCI

National Federation of Fishermen's Organisations
December 2015

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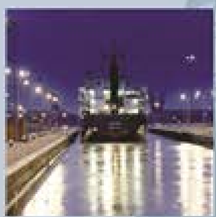



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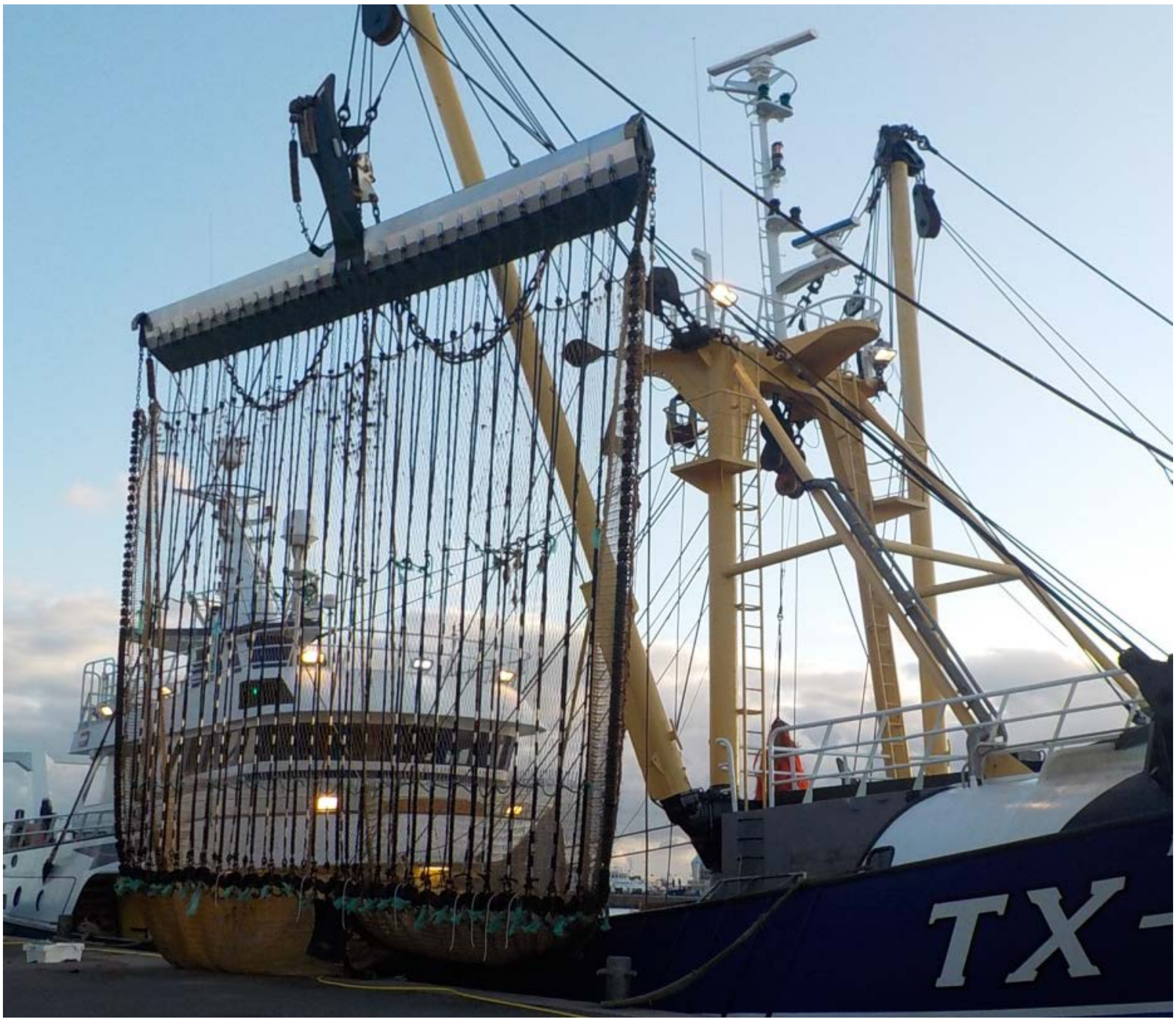

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Notice

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Executive Summary

This report provides a shadow, site-level assessment of beam trawling activity in North Norfolk Sandbanks and Saturn Reef Site of Community Importance (SCI). It has been drafted as part of a National Federation of Fishermen's Organisations' project, funded by the European Fisheries Fund and the Sea Fish Industry Authority entitled 'Supporting Risk-Based Fisheries Assessments for MPAs', undertaken by ABPmer and Ichthys Marine Ecological Consulting Ltd.

North Norfolk Sandbanks and Saturn Reef SCI is centred approximately 22 nm offshore of the north Norfolk coast. It has a surface area of 3,603 km^2 and comprises a series of ten main sandbanks and pockets of *Sabellaria spinulosa* biogenic reef. It is designated for the features 'subtidal sandbanks which are slightly covered by seawater all the time' and 'reefs'. The conservation objective is to 'restore'.

This shadow assessment reviews a range of information sources on fishing activity in the site, including ICES rectangle landings data, vessel monitoring system (VMS) data, sightings, the Marine Conservation Zones Fisheries Model and plotter data. The project also carried out a number of data gathering exercises, modelling, and analyses that have developed the evidence base in relation to fishing activities in the site.

Pressures

There are three potential pressure categories which may cause deterioration of the features and disturbance of species as a result of mobile benthic fishing within the North Norfolk Sandbanks and Saturn Reef SCI. These pressures are:

- Physical damage and disturbance through changes in suspended sediment concentration;
- Physical damage and disturbance through abrasion; and
- Biological disturbance through the selective extraction of species.

The majority of fishing effort in the site is by Dutch beam trawlers, most of which have switched from conventional beam trawling to electrical pulse trawling. This gear type produces electrical pulses near to the seabed,to stimulate the flatfish to rise up from the sediment and into the path of the net. Therefore the following pressure is included in relation to the use of pulse gear:

- Electromagnetic changes.

The pressures from beam and pulse trawling (such as the depth of penetration, resuspension of sediment contributing to changes in the levels of siltation, and levels of bycatch) have been based on existing evidence and modelling of the physical impacts of the individual gear components, based on the size, weight and towing speeds used by beam trawlers in the North Norfolk Sandbanks and Saturn Reef SCI.

Sensitivity

Using existing evidence, biological traits and expert opinion (ABPmer, 2013) the sensitivity of the features to the pressures from otter trawling has been assessed, based on tolerance and recoverability. Sensitivity was assessed for individual habitats, considering both the sensitivity of the habitat and its typical characterising species.

Modelling of physical impacts of the gears

Modelling of the physical impacts of the beam trawls and pulse trawls used in the site considered sediment mobilisation and depth of penetration of the different gear components. These models have been validated with experimental data from both laboratory and sea trials.

Natural disturbance modelling

Subtidal sand habitats such as those in the North Norfolk Sandbanks and Saturn Reef SCI are regularly disturbed, with species assemblages typical of wave-exposed conditions and adapted to high levels of disturbance. They are characterised by predominantly infaunal species, and able to recover rapidly from physical damage or disturbance. Areas of coarser and finer sediments, and areas in troughs between sandbanks are relatively more stable, but are still subject to regular natural disturbance and the faunal assemblages reflect this natural disturbance.

Natural disturbance modelling was carried out to consider the proportion of time, and the number of days in a year, that sediments are mobile, and that mobile bedforms of 2.5 cm height are present. This indicates that on the peaks of the sandbanks, active bedforms are present around 80–100% of the time. In the troughs between the sandbanks, sediments are still mobile 20–80% of the time, with active bedforms present around 10–20% of the time, or up to 80% for fine sand. In areas of coarse sediment, natural disturbance still plays a dominant role, with surface sediments mobile 20–30% of the time and mobile bedforms present 10–20% of the time (grain size 1000–2000 µm).

Exposure

Exposure levels to beam trawling were assessed under two scenarios: scenario 1 assumes all vessels are conventional beam trawlers; scenario 2 assumes the UK vessels are conventional beam trawlers and the non-UK vessels are pulse wing trawlers. Scenario 2 most closely reflects the current situation in 2015. The approaches used to assess exposure for over-15m vessels were:

- Swept area in relation to the area of each biotope;
- Seasonality of activity;
- Footprint of individual gear components from VMS data, assessed by creating tracks between consecutive 'fishing' pings and buffered to reflect the width of individual gear components; and
- Frequency of impact, assessed by counting the number of tracks between consecutive VMS fishing pings that cross a 250 m by 250 m grid cell. A further high-resolution frequency of impact analysis was conducted for the highest intensity areas, with a 25 m by 25 m grid cell.

Analysis of the frequency of impact from VMS data indicates that parts of the site are not fished at all, and large areas may be trawled less than once per year. There are areas where fishing activity appears to be more concentrated (the channels between the sandbanks). In these areas, trawl frequency is around three to four times per year, with more intensive areas increasing to seven to eight times per year, and the highest area is up to 12–16 times per year. However, this takes place over a very small area, and represents the number of passes of a 24m gear within a 250 m by 250 m grid cell. When the areas of highest intensity are analysed on a more detailed spatial scale, with a grid cell size equivalent to the width of the gear (25 m by 25 m), the number of repeated passes of the gear over the same area is indicated as two to three times (i.e. once every four to six months).

The exposure assessment in this study calculated the footprint of the area impacted by beam trawling over a five-year period as 1,422 km^2, with 1,176 km^2 from the ground gear and 246 km^2 from the beam shoes (conventional beam trawls), equating to 39% of the site. Assuming the non-UK vessels are all pulse wing trawls, the area impacted from these is 1,312 km^2, of which 43 km^2 is from the nose shoe (36% and 1% of the site, respectively).

Vulnerability

The vulnerability of each biotope to each pressure is assessed, based on the sensitivity of the biotope to the pressure, and the level of exposure. Based on the assessments of sensitivity and exposure of each habitat, in relation to the pressures exerted by individual gear components, it is assessed that those habitats with a low or moderate vulnerability to beam trawling impacts are:

- Under scenario 1:
  - Shallow and deep disturbance on all habitats — low vulnerability, except for deep disturbance on deep circalittoral sand which is assessed as moderate vulnerability;
  - Biological disturbance through removal of target and non-target species for all habitats — low vulnerability.

- Under scenario 2:
  - Shallow and deep disturbance on all habitats — low vulnerability.

Scenario 2 (assessing non-UK vessels as pulse wing trawls) results in lower vulnerability due to the lower benthic impacts of the pulse gear, and lower levels of bycatch of pulse trawls compared to conventional beam trawls. Scenario 2 most closely reflects the current situation of the fleet in 2015 (Dutch beam trawlers are predominantly using pulse gear).

It is understood that, as a 'red risk' interaction in the Matrix, the potential impact of beam trawling on *Sabellaria* reef will be addressed as a priority, and therefore this assessment has focussed on the sandbank habitats.

The sensitivity of all habitats has been assessed as 'not sensitive' to electromagnetic changes, resulting in an assessment of not vulnerable. However, there is insufficient information to make a full assessment of the *in-situ* effects of pulse trawling on characterising species. 'Trawl path mortality' studies are planned and/or underway by IMARES in the Netherlands, but results are not yet available.

For 'low' impacts, managers and Competent Authorities will need to decide whether these constitute an adverse effect on integrity (AEOI), particularly where these areas are subject to the high levels of natural disturbance observed in the site.

The assessments of vulnerability should be considered in relation to the conservation objective of the site which is to 'restore'. This indicates that the sandbank feature is not in favourable condition, although there is no direct evidence of the sandbanks being damaged or in deterioration. However, the area is subject to obstruction from infrastructure associated with oil and gas activities.

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1 Introduction

1.1 Need for an Assessment

The Habitats Regulations[1] implement the EC Habitats and Birds Directives in UK waters and require that an Appropriate Assessment (AA) should be undertaken by a competent authority where a plan or project is not directly connected with or necessary for the management of European site (Special Area of Conservation – SAC, or Special Protection Area – SPA) and where the possibility of a likely significant effect (LSE) on the site cannot be excluded, either alone or in combination with other plans or projects.

In 2012, the Department for Environment, Food and Rural Affairs (Defra) announced a revised approach to the management of commercial fisheries in European Marine Sites (EMS). The objective of this revised approach is to ensure that all existing and potential commercial fishing activities are managed in accordance with Article 6 of the Habitats Directive.

The revised approach is being implemented using an evidence-based, risk-prioritised, and phased basis. Risk prioritisation is informed by a matrix of the generic sensitivity of EMS sub-features to a suite of fishing activities, regardless of exposure. These sub-feature–activity combinations are categorised according to specific definitions, as red, amber, green or blue.

Activity–feature interactions identified as red risk within the matrix were given the highest priority, with the requirement that management measures were introduced for red-risk rated activities in inshore sites by the end of May 2014 at the latest in order to avoid the deterioration of Annex I features in line with obligations under Article 6(2) of the Habitats Directive (Defra 2013). Managing activities in sites outside of the 12 nm UK Territorial Limit requires legislative measures to be introduced by the European Commission, and so a deadline of 2016 was set for managing red-risk rated activities in offshore sites (Defra 2013).

Activity–feature interactions identified as amber risk within the matrix require a site-level assessment to determine whether management of an activity is required to conserve site features. Activity–feature interactions identified within the matrix as green also require a site-level assessment if there are 'in combination effects' with other plans or projects.

Site-level assessments are carried out in a manner that is consistent with the provisions of Article 6(3) of the Habitats Directive, to determine whether fishing activities are or are not having an adverse effect on the integrity of the site. This appraisal will help to inform a judgement on whether or not appropriate steps are required to avoid the deterioration of natural habitats and disturbances of the species for which the area has been designated, in order to ensure the conservation objectives are met. Any further measures deemed necessary are required to be introduced by the end of 2016 (MMO, 2015a).

This shadow, site-level assessment has been drafted as part of a National Federation of Fishermen's Organisations-sponsored project entitled 'Supporting Risk-Based Fisheries Assessments for MPAs', undertaken by ABPmer and Ichthys Marine Ecological Consulting Ltd. The assessment has two

[1] Conservation of Habitats and Species Regulations, 2010; The Offshore Marine Conservation (Natural Habitats, & c.) Regulations 2007 (as amended); The Conservation (Natural Habitats, & c.) Regulations (GB: 1994 as amended in 2007).

objectives; the first is to determine whether or not beam trawling within the North Norfolk Sandbanks and Saturn Reef Site of Community Importance (SCI) alone or in combination with other plans or projects has a likely significant effect on the interest feature 'Sandbanks which are slightly covered by seawater all the time' of the site; the second is to determine whether beam trawling has an adverse effect on the integrity (AEOI) of this EMS. The results of this shadow, site-level assessment are not official or binding in any way.

1.2 Information Reviewed to Inform this Assessment

The key documents reviewed for this assessment were:

- JNCC, 2010. Offshore Special Area of Conservation: North Norfolk Sandbanks and Saturn Reef. SAC Selection Assessment. Version 5.0 (20 August 2010);
- JNCC, 2012. Offshore Special Area of Conservation: North Norfolk Sandbanks and Saturn Reef. Conservation Objectives and Advice on Operations. Version 6.0 (September 2012);
- Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O., and Reker, J.B. 2004. The Marine Habitat Classification for Britain and Ireland Version 04.05 (in JNCC, 2015);
- Draft Generic Supplementary Advice Table (SAT) for habitats (supplied by Natural England, August 2015);
- Draft Advice on Operations for Margate and Long Sands (supplied by Natural England, August 2015);
- ABPmer, 2013. Tools for Appropriate Assessment of Fishing and Aquaculture Activities in Marine and Coastal Natura 2000 Sites. Reports II, III and V. R. 2070. Report for Marine Institute;
- Natura 2000 Fisheries management options paper: Southern North Sea, Haisborough, Hammond and Winterton SCI, Inner Dowsing, Race Bank and North Ridge SCI, North Norfolk Sandbanks and Saturn Reef SCI, Margate and Long Sands SCI, Outer Thames Estuary SPA;
- Natural England's Fisheries Impacts Evidence Database;
- Key relevant peer-reviewed literature (included in the reference list).

Data sources informing the assessment (described in more detail in Section 3) were:

- UKSeaMap habitat map of the site;
- International Council for the Exploration of the Seas (ICES) rectangle landings data for all UK vessels;
- Vessel Monitoring System (VMS) data for UK and non-UK over-15m vessels;
- FisherMap and the MCZ Fisheries Model data for UK under-15m vessels;
- Sightings data for all vessels;
- Interviews conducted with Dutch skippers;
- Modelling of physical impacts of the gears; and
- Modelling of natural disturbance at the site.

2 Information about the European Marine Site

2.1 Overview and Qualifying Features

The North Norfolk Sandbanks and Saturn Reef Site was proposed as a Site of Community Importance (SCI) in August 2010. SCIs are Special Areas of Conservation (SAC) sites that have been adopted by the European Commission but are not yet formally designated by the government of each country.

The site is located approximately 22 nm offshore of the North Norfolk coast (Figure 2.1), has a surface area of 3,603 km^2 and comprises a series of ten main sandbanks with a number of smaller sandbanks and pockets of *Sabellaria spinulosa* biogenic reef.

The qualifying features for the North Norfolk Sandbanks and Saturn Reef SCI are:

- Subtidal sandbanks which are slightly covered by seawater all the time (1110); and
- Reefs (1170).

The sandbanks at the site are non-vegetated, sublittoral, open shelf ridge tidal current sandbanks (JNCC, 2010) and are described as the best example of tidal linear sandbanks in the UK. The ten sandbanks have a north-west to south-east orientation and are thought to be slowly elongating in a north-easterly direction (Cooper *et al.,* 2008). The sandbanks are present from about 22 nm off the north-east coast of Norfolk out to approximately 60 nm (Collins *et al*., 1995). The banks within the SCI are Leman, Ower, Inner, Well, Broken, Swarte, and four banks collectively called the Indefatigables.

The sandbanks comprise 66% of the volume of the 'Norfolk Banks' which equates to a volume of 4,100 million m^3 (Cooper *et al*., 2008). The banks are over 50 km in length, up to 1.7 km wide and a maximum of 38 m high (Cooper *et al*., 2008). The banks are described in the site documents (JNCC, 2010) as the area of sandy sediments in less than 20m of water. JNCC (2010) considers the flanks and troughs of the banks which extend into deeper water to be integral to the structure and function of the banks.

The SCI is in an area of moderate energy (JNCC, 2012). There are sandwaves present on the sandbanks which are synonymous with surface sediments being regularly mobilised by tidal currents (JNCC, 2010). In addition, the sandbanks are described as being sand sinks by Cooper *et al*. (2008). The higher energy parts of the site are characterised by communities able to withstand more dynamic conditions.

The definition for sandbanks has recently changed according to a revised interpretation by CEC (2007); the time of site designation dictates the definition used. For the sandbanks within the North Norfolk Sandbanks and Saturn Reef SCI, the revised definition is used. To accompany the new definition, JNCC has produced new Annex 1 habitat layers, in order to produce a more accurate picture of the extent of sandbanks within the UK. The layers were created using bathymetric slope, depth and aspect combined with sediment data (referred to as the 'sandbank slope analysis method'). This data layer has been laid over the EUNIS habitat data layer (see Figure 2.2). The identified sandbanks broadly coincide with the areas of infralittoral sediment.

The EUNIS level 4 habitats that are present in the site are:

- Atlantic and Mediterranean moderate energy infralittoral rock;
- Infralittoral coarse sediment;
- Circalittoral coarse sediment;
- Deep circalittoral coarse sediment;
- Infralittoral fine sand or infralittoral muddy sand;
- Circalittoral fine sand or circalittoral muddy sand;
- Deep circalittoral sand.

Overlaying the EUNIS level 4 habitat data layer with the bathymetry data layer indicates that the peaks of the sandbanks (less than 20 m of water) are associated with infralittoral fine sands and muddy sand. This is in line with the fauna present on the peaks of the sandbanks at the site being described by JNCC (2012) as typical of the biotope 'infralittoral mobile clean sand with sparse fauna' (JNCC, 2012). This species-poor biotope is characteristic of a higher energy environment and mobile sediments (JNCC, 2010, 2012). Infralittoral fine sands are typically characterised by fauna such as amphipods (*Bathyporeia*), bivalves (*Fabulina fabula*) and polychaetes (*Nephthys cirrosa, Spiophanes bonbyx* and *Lanice conchilega*) (ABPmer, 2013). Infralittoral habitats are the designated feature in the site as determined by JNCC site documents (JNCC, 2012).

A study looking at the benthos and fish species present in the region (Ellis *et al*., 2010), also found that at the crest of the sandbanks epifaunal and infaunal communities were species-poor. Species typical of this habitat include mobile species such as lesser weever (*Echiichthys vipera*) and brown shrimp (*Crangon crangon)* (Ellis *et al*., 2010) and deep-burrowing and deposit-feeding species (MarLIN website; Ellis *et al*., 2010), such as the polychaete *Nephtys cirrosa* and the isopod *Eurydice pulchra* (Connor *et al*., 2004). These characteristics make them favour naturally-disturbed habitats and as such, they are more adapted to being able to withstand disturbance (Diesing *et al*., 2013) such as that associated with beam trawling.

The troughs are primarily associated with circalittoral fine sands or muddy sands (Figure 2.2). There is no direct reference to the circalittoral habitats within the documentation produced by JNCC. It is therefore assumed that the fauna associated with this habitat is as described in Ellis *et al*. (2010) and Connor *et al*. (2004) whereby circalittoral fine sands and muddy sands are characterised by a wide range of echinoderms, including in some areas the pea urchin, *Echinocyamus pusillus* and *Amphiura* spp and *Ophiura* spp., polychaetes and bivalves such as *Abra alba* and *Nucula nitidosa* (ABPmer, 2013). Ellis *et al*. (2010) also found that species diversity increased in the troughs which run parallel with the sandbanks. The only genus that does not have increased species diversity in the troughs is nematodes which were more diverse on the sandbanks (Ellis *et al*., 2010).

The site documentation produced by JNCC does not mention the circalittoral habitats and associated biological community as part of the designated feature. However, because the documentation states that the troughs are integral to the structure and function of the banks, the circalittoral habitats and associated species have been included as part of this assessment. While the physical processes operating within the troughs are clearly linked to the form of the banks, the linkages between the structure and function of the benthic habitats in the troughs with those on the banks is less clear.

The *Sabellaria spinulosa* biogenic reef feature was first found in 2002 and represented a well-developed biogenic reef structure. Although *S. spinulosa* is a common species around the UK and Europe, there are very few examples of known, well-developed reefs. The formation of the reef structure is important — individuals of the species *S. spinulosa* are not protected; it is the reef formation alone that is a designated feature under the biogenic reef category in Annex I of the EC Habitats Directive.

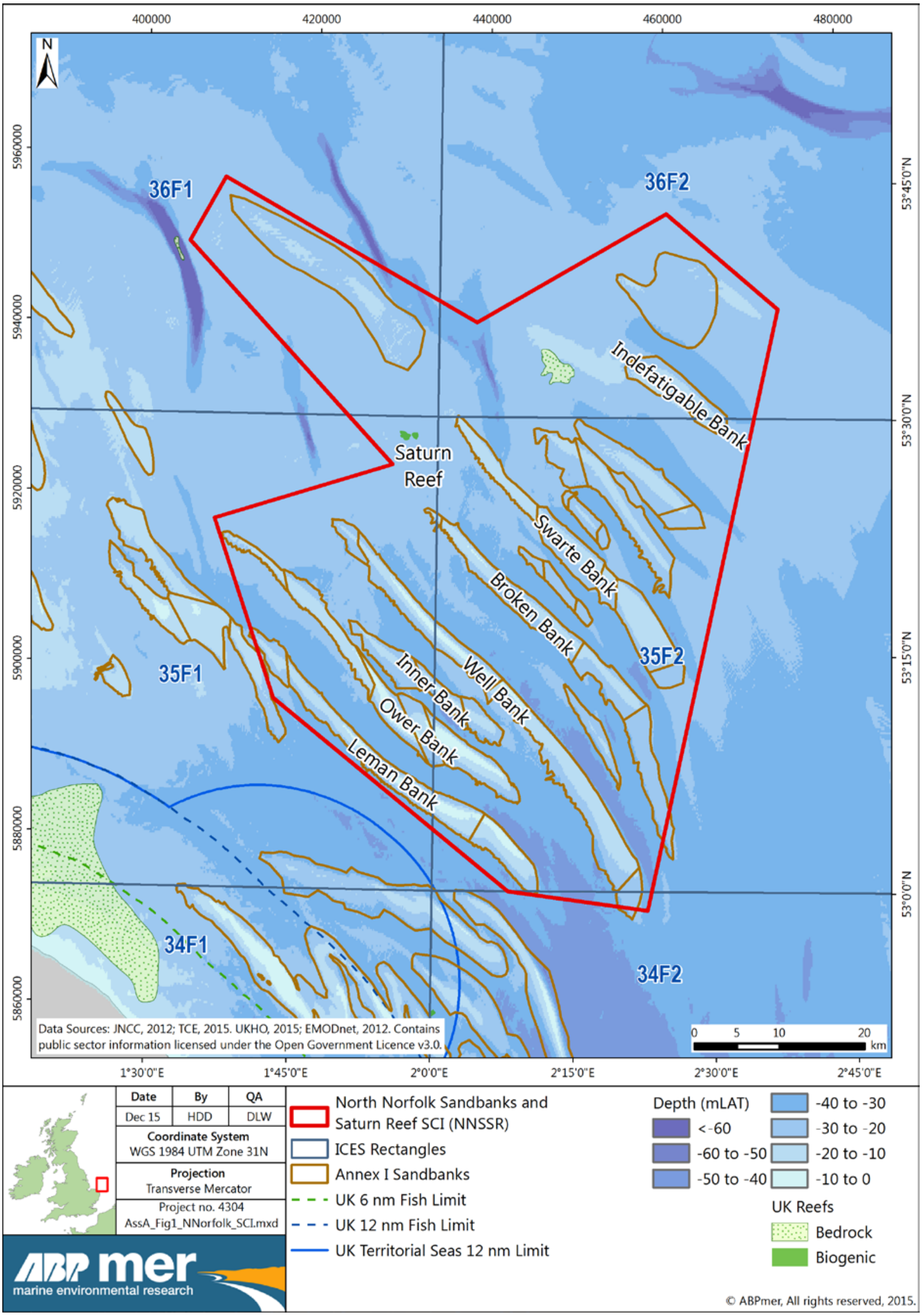
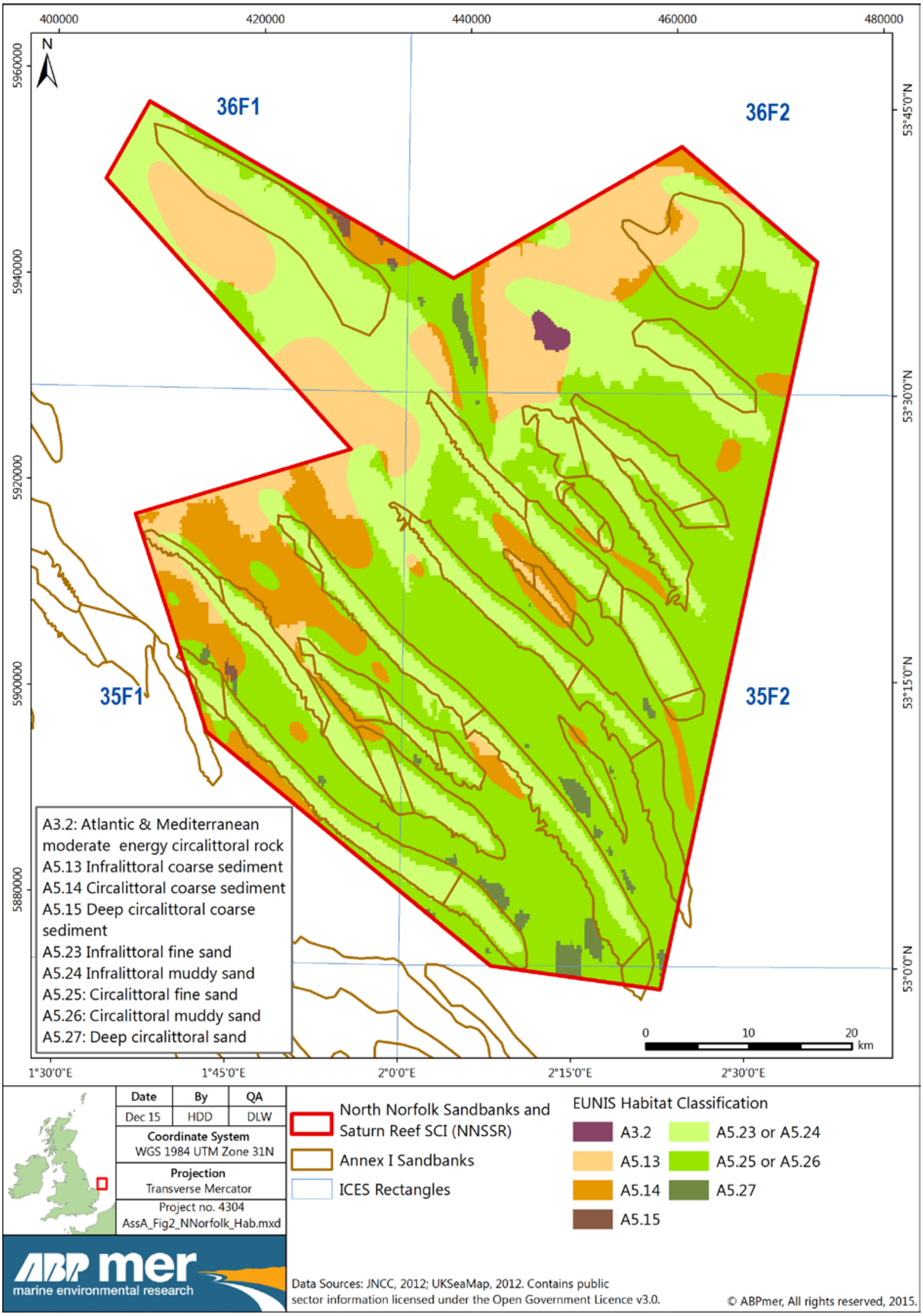


Figure 2.1 Location of North Norfolk Sandbanks and Saturn Reef SCI



Source: UKSeaMap 2012

Figure 2.2 Habitat map of North Norfolk Sandbanks and Saturn Reef SCI

In 2002, BMT Cordah, recorded a *S. spinulosa* reef structure which rose above the seabed about 10 cm and densely covered an area of 750 m by 500 m (BMT Cordah, 2003). However, subsequent surveys at the site failed to find such structures. It is not known if the disappearance of the structure was due to it being naturally short-lived, or whether the disappearance is due to damage through anthropogenic activities. The presence of a substantial reef area in 2002 indicates that this area is favourable for the development of reefs (JNCC, 2012).

JNCC and Cefas undertook a survey at the site in November 2013 and have since undertaken further analysis of the data on biological communities within the site. These were undergoing external peer review and were unavailable to the project prior to being fully signed off. However, JNCC (no date) indicates:

> *"…that the biological communities associated with the individual modelled banks occur across the MPA, including adjacent sandy areas where the seabed is much deeper. Sand is the dominant sediment type across the MPA, with patches of coarser and mixed sediment, which may then also be associated in places with Sabellaria spinulosa reef. These results confirm JNCC's earlier view set out in the SAC Selection Assessment Document, that the whole MPA should be considered as a representative functioning example of the Annex I sandbank feature."*

The survey found five aggregations of *S. spinulosa* worm tubes within the boundary of the SCI. Whether these aggregations are considered to constitute reef structure(s), and the actual location of these formations, has not yet been made publically available (JNCC, 2013).

2.2 Habitat Data

The habitat data used for this assessment are from EUNIS. The habitats present in the site according to these data are shown in Figure 2.2. Table 1 presents further information on these habitats.

EUNIS data were generated using habitat maps created from subtidal field survey data combined with a broad-scale subtidal predictive habitat map (EUSeaMap) (JNCC, 2014a) which was created by overlaying classified oceanographic models with a classified substrate map (JNCC, 2014a). As well as the EUNIS habitat layers the Annex 1 Sandbanks map produced by JNCC has been considered.

Table 1. Subtidal sandbanks sub-features and the associated habitats

Feature	Sub-Feature / EUNIS Level 4 Habitat	EUNIS and JNCC Codes	Description (From JNCC)
Subtidal sandbanks	Atlantic and Mediterranean moderate energy infralittoral rock	A3.2 IR.MIR	This habitat complex occurs on predominantly moderately wave-exposed bedrock and boulders, subject to moderately strong to weak tidal streams. On the bedrock and stable boulders there is typically a narrow band of kelp *Laminaria digitata* in the sublittoral fringe which lies above a *Laminaria hyperborea* forest and park.
	Infralittoral coarse sediment	A5.13 SS.SCS.ICS	Moderately exposed habitats with coarse sand, gravelly sand, shingle and gravel in the infralittoral, are subject to disturbance by tidal steams and wave action. Such habitats found on the open coast or in tide-swept marine inlets are characterised by a robust fauna of infaunal polychaetes such as *Chaetozone setosa* and *Lanice conchilega*, cumacean crustacea such as *Iphinoe trispinosa* and *Diastylis bradyi,* and venerid bivalves.
	Circalittoral coarse sediment	A5.14 SS.SCS.CCS	Tide-swept circalittoral coarse sands, gravel and shingle generally in depths of over 15-20m. This habitat may be found in tidal channels of marine inlets, along exposed coasts and offshore. This habitat, as with shallower coarse sediments, may be characterised by robust infaunal polychaetes, mobile crustacea and bivalves. Certain species of sea cucumber (e.g. *Neopentadactyla*) may also be prevalent in these areas along with the lancelet *Branchiostoma lanceolatum*.
	Deep circalittoral coarse sediment	A5.15 SS.SCS.OCS	Offshore (deep) circalittoral habitats with coarse sands and gravel or shell. This habitat may cover large areas of the offshore continental shelf although there is relatively little quantitative data available. Such habitats are quite diverse compared to shallower versions of this habitat and generally characterised by robust infaunal polychaete and bivalve species.
	Infralittoral fine sand or infralittoral muddy sand	A5.23 or A5.24 SS.SSa.IFiSa or SS.SSa.IMuSa	Clean sands which occur in shallow water, either on the open coast or in tide-swept channels of marine inlets. The habitat typically lacks a significant seaweed component and is characterised by robust fauna, particularly amphipods (*Bathyporeia*) and robust polychaetes including *Nephtys cirrosa* and *Lanice conchilega*. Or Non-cohesive muddy sand (with 5% to 20% silt/clay) in the infralittoral zone, extending from the extreme lower shore down to more stable circalittoral zone at about 15-20 m. The habitat supports a variety of animal-dominated communities, particularly polychaetes (*Magelona mirabilis*, *Spiophanes bombyx* and *Chaetozone setosa*), bivalves (*Fabulina fibula* and *Chamelea gallina*) and the urchin *Echinocardium cordatum*.
	Circalittoral fine sand or circalittoral muddy sand	A5.25 or A5.26 SS.SSa.CFiSa or SS.SSa.CMuSa	Clean fine sands with less than 5% silt/clay in deeper water, either on the open coast or in tide-swept channels of marine inlets in depths of over 15-20m. The habitat may also extend offshore and is characterised by a wide range of echinoderms (in some areas including the pea

Feature	Sub-Feature / EUNIS Level 4 Habitat	EUNIS and JNCC Codes	Description (From JNCC)
			urchin *Echinocyamus pusillus*), polychaetes and bivalves. This habitat is generally more stable than shallower, infralittoral sands and consequently supports a more diverse community. Or Circalittoral non-cohesive muddy sands with the silt content of the substratum typically ranging from 5% to 20%. This habitat is generally found in water depths of over 15-20m and supports animal-dominated communities characterised by a wide variety of polychaetes, bivalves such as *Abra alba* and *Nucula nitidosa*, and echinoderms such as *Amphiura* spp and *Ophiura* spp., and *Astropecten* irregularis. These circalittoral habitats tend to be more stable than their infralittoral counterparts and as such support a richer infaunal community.
	Deep circalittoral sand	A5.27 SS.SSa.OSa	Offshore (deep) circalittoral habitats with fine sands or non-cohesive muddy sands. Very little data is available on these habitats however they are likely to be more stable than their shallower counterparts and characterised by a diverse range of polychaetes, amphipods, bivalves and echinoderms.
Reef	Sublittoral polychaete worm reefs on sediment	A5.61 (NB not present in UKSeaMap data)	Sublittoral reefs of polychaete worms in mixed sediments found in a variety of hydrographic conditions. Such habitats may range from extensive structures of considerable size to loose agglomerations of tubes. Such communities often play an important role in the structural composition or stability of the seabed and provide a wide range of niches for other species to inhabit. Consequently polychaete worm reefs often support a diverse flora and fauna.

2.3 Conservation Objectives

The conservation objective for North Norfolk Sandbanks and Saturn Reef SCI Annex I *Sandbanks which are slightly covered by seawater all the time*, and Annex I *reef*, provided by JNCC (2012) is:

> *"Subject to natural change, **restore** the sandbanks which are slightly covered by seawater all the time and reefs to favourable condition, such that:*
>
> - *the natural environmental quality, natural environmental processes and extent are maintained*
> - *the physical structure, diversity, community structure and typical species, representative of sandbanks which are slightly covered by seawater all the time and reefs in the Southern North Sea are restored".*

The UK conservation agencies use the term 'Favourable Condition' to represent the concept of 'Favourable Conservation Status' for the interest features of an individual SAC (Davies *et al*., 2001). For an Annex I habitat, such as sandbanks, 'Favourable Conservation Status' under the Habitats Directive occurs when:

i. its natural range and area it covers within that range are stable or increasing; and
ii. the specific structure and functions, which are necessary for its long-term maintenance, exist and are likely to continue to exist for the foreseeable future; and
iii. the conservation status of its typical species is favourable (JNCC, 2012).

The sandbank and reef features both have the conservation objective to *restore*. This implies that the features are damaged or degraded in some way. In the marine environment, 'restore' refers to natural recovery to favourable condition through the reduction or removal of adverse pressures. As such, when 'restore' is the conservation objective, information on the current condition of the features and the potential activities which may cause damage to the feature are needed.

There is currently no condition table for these features within the SCI and so it is not possible to outline the existing condition of the sandbanks or reefs. Nor has the target condition of the interest features been defined (JNCC, 2012; JNCC, 2015). In addition, there is no direct evidence of the sandbanks being damaged or in deterioration. However, because the conservation objectives are to 'restore' the assumption has been taken in this assessment that the features are currently in an unfavourable condition. In addition, as stated in the Conservation Objectives document by JNCC (2012), although there is no direct evidence of the sandbanks being damaged or in deterioration, the area is subject to "*unprecedented levels of obstruction from infrastructure associated with oil and gas activities*" and there is uncertainty concerning the level of abrasion pressure from beam trawling. These pressures could be the reason why the feature is not in a favourable condition.

2.4 Fisheries in EMS Matrix Categorisation of Risk

A Matrix considering the relationship and reviewing the evidence review of fisheries and European Marine Site features, prepared by Natural England and reviewed by Cefas, has categorised the interaction of towed trawls and reef features as a 'red risk'. A red risk is defined as being where it is clear that the conservation objectives for the feature will not be achieved because of its sensitivity to that type of fishing irrespective of feature condition, level of pressure, or background environmental conditions in all sites where that feature occurs.

For red risk categories it is expected that 'suitable management measures will be identified and introduced as a priority to protect those features from that fishing activity or activities (MMO, 2014)'. As reef features are identified as a red risk, and management measures will therefore be introduced for the reef feature, this assessment does not consider the reef feature further.

Beam trawls on subtidal sandbank features is categorised as an 'amber risk'. An amber risk is defined as being '*where there is doubt as to whether conservation objectives for a feature (or sub-feature) will be achieved because of its sensitivity to a type of fishing, in all EMS's where that feature occurs, the effect of that activity or activities on such features will need to be assessed in details at a site specific level. Appropriate management action should then be taken based on that assessment*' (MMO, 2014).

2.5 Overview of Existing Management Measures

Around the coast of England, management of fishing activities is based on the EU Common Fisheries Policy, but additional measures may be introduced by Government to cover UK-registered vessels, and the IFCAs can implement local regulations within the 6 nm limit (Mardle *et al.*, 2002). As the North Norfolk Sandbanks and Saturn Reef SCI lies beyond 12 nm, management of fishing activity falls under the Common Fisheries Policy, and any management measures must be implemented through EU legislation. A procedure is in place whereby Member States can request the European Commission to implement management measures for fishing activity in European Marine Sites. This involves presenting information on 11 questions to the European Commission. The process does not require a formal Habitats Regulations Assessment (HRA), but our understanding is that the requirement for management measures should be based on the outcomes of such an assessment.

At this time it is understood that there are no formal management measures in place for the North Norfolk Sandbanks and Saturn Reef SCI (GOV.UK website, 2015).

Under European legislation (Art 30(1), EC No 850/98), there is a limit on the size of beam trawls, which cannot exceed 24 m length overall for each vessel (i.e. two 12 m beams). The fisheries that take place in the site (beam trawling for flatfish) are regulated by Total Allowable Catches set by the Council of the European Union.

3 Fishing Activities within the Site

The following key data sources were used to inform this assessment on the distribution and intensity of fishing activity in the site, and its impacts:

- International Council for the Exploration of the Seas (ICES) rectangle landing data for all UK vessels;
- Vessel Monitoring System (VMS) data for UK and non-UK over-15m vessels;
- FisherMap and the MCZ Fisheries Model data for UK under-15m vessels;
- Sightings data for all vessels;
- Plotter data;
- Interviews conducted with Dutch skippers;
- Modelling of physical impacts of the gears;
- Modelling of natural disturbance at the site.

Each data source is outlined below, and informs a picture of the overall fishing activity in the site. Specific data sources are then further analysed to inform the assessment of exposure to fishing in the shadow assessment (see Sections 5.2.2 and 5.4).

3.1 Overview

The North Norfolk Sandbanks and Saturn Reef SCI lies beyond 12 nm. Available information indicates that the predominant fishing activity within the site is beam trawling for flatfish. The maps of bottom fishing intensity using VMS data produced by ICES in response to an OSPAR special request also confirm that the predominant benthic fishing activity in the vicinity of the site is beam trawling (OSPAR, 2014).

ICES rectangle data (Section 3.2), sightings data (Section 3.4), FisherMap and the MCZ Fisheries Model (3.5), indicate that the level of activity in the SCI by smaller vessels (under-10m or under-15m) is low. The SCI is situated 22 nm from the UK coast, which limits its accessibility for smaller vessels. VMS data are therefore considered to provide a good representation of fishing activity in the site.

VMS data (Section 3.4) indicate that 7 UK over-15m beam trawlers and 18 of unknown gear type, and 70 non-UK over-15m vessels of beam trawl or 'unknown' gear fished in the SCI over the period 2009–2013 (Section 3.3). During interviews, fishermen indicated that effort has shifted from the North Norfolk Sandbanks area to the Dogger Bank in recent years.

3.2 ICES Rectangle Landings Data

Landings data from ICES rectangles represent UK landings only and are representative of the rectangle as a whole. The SCI falls within the boundaries of ICES rectangles 35F1, 35F2, 36F1 and 35F2 (there is a very small area within 34F2). However, the area which the site covers is only a proportion of each rectangle. As such, caution must be taken when interpreting the data as it is not possible to confidently conclude what proportion of the landings from each rectangle derive from the North Norfolk Sandbank and Saturn Reef SCI.

UK landings data from 2009–2013 from these rectangles are shown in Figure 3.1.

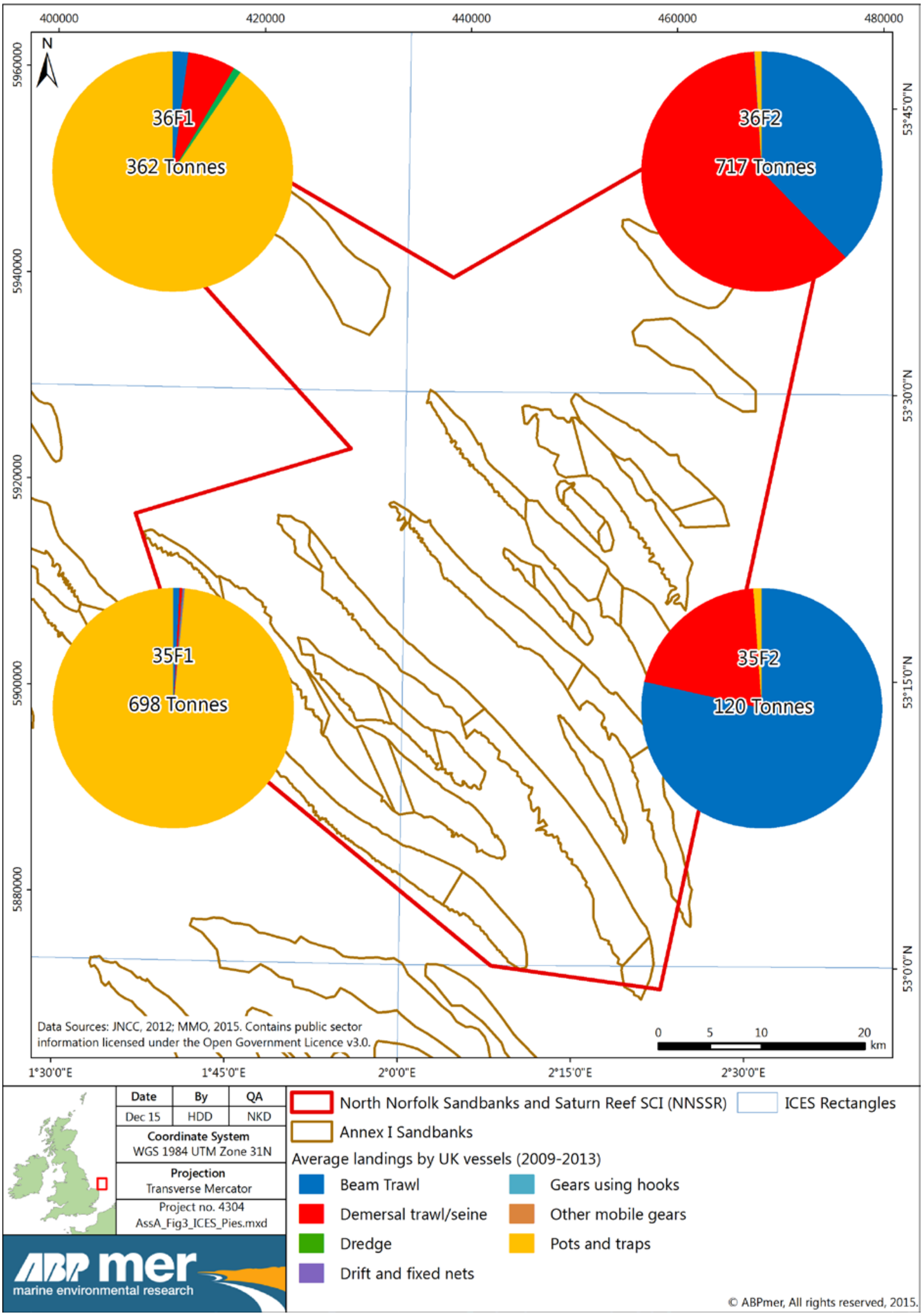


Figure 3.1 **Live weight of landings by ICES rectangle for all UK vessels, annual average 2009-2013**

For rectangles 35F1 and 36F1 (the two most westerly areas), the proportion of catch from beam trawling was very low, 0.8% and 2% respectively. The majority of UK landings from these areas is from pots and traps. ICES rectangles 35F2 and 36F2 had a higher proportion of live weight landings from beam trawling: 35F2 79%; and 36F2 38%. However, based on the evidence from the VMS data, fishing effort is much greater to the north and south of these rectangles, outside the boundary of the SCI. Also, fishing effort by other nationalities (mainly Dutch) is much greater than UK effort.

According to the ICES rectangle data, UK under-10m vessels did not land any fish from beam trawling; all beam trawling by UK vessels in the ICES rectangles is carried out by vessels more than 10m in length. The MCS Fisheries Model data did identify a low level of activity from vessels under 15m length, and so it is assumed that a small percentage of the fishing done at the site by UK vessels is carried out by vessels between 10m and 15m in length.

Table 2 presents the live weight landings from all gears by length group (UK vessels only), from ICES rectangles that overlap the SCI (ICES rectangle 34F2 also overlaps, but the area of the site within this rectangle is so small that it has not been included here). Landings are dominated by over-10m vessels, of which a large amount of their landings in the two ICES rectangles closest to shore (35F1 and 36F1) derive from pots and traps. Bema trawl and demersal trawl and seine represent a significant proportion of landings from the two ICES rectangles furthest from shore (35F2 and 36F2).

Table 2. Live weight (tonnes) landed from all gears, by length group, from ICES rectangles 35F1, 35F2, 36F1 and 36F2, UK vessels only, from 2009–2013

Length group and Gear	35F1	35F2	36F1	36F2	Total
10m and Under					
Demersal trawl/seine	<1				<1
Drift and fixed nets	3				3
Gears using hooks	2		<1		2
Pots and traps	558		55		613
Sub-total	***563***		***55***		***618***
Over-10m					
Beam trawl	29	471	38	1353	1,890
Demersal trawl/seine	13	122	116	2196	2,446
Dredge	2		18		20
Drift and fixed nets	4			3	7
Gears using hooks	<1	<1			<1
Other mobile gears	2				2
Pots and traps	2,878	7	1,582	35	4,502
Sub-total	***2,927***	***599***	***1,755***	***3586***	***8,867***
Grand Total	**3,491**	**599**	**1,810**	**3586**	**9,486**
Average per Year	**698**	**120**	**362**	**717**	**1,897**

Table 3 presents the live weight in tonnes caught by UK beam trawlers in ICES rectangles that overlap with the site (excluding 34F2). Landings are predominantly of plaice (by weight), although the high market value of sole mean that it accounts for a greater landing value than plaice. The other main species landed are other flatfish (turbot, dabs, brill), followed by a range of rays, demersal fish and crustaceans, although in very small quantities. All landings by UK beam trawls are from over-10m vessels.

Table 3. Live weight (tonnes) landed from ICES rectangles which overlap the North Norfolk Sandbanks and Saturn Reef SCI from UK beam trawls (2009–2013)

Species	35F1	35F2	36F1	36F2	Total
Plaice	7	330	20	940	1,297
Sole	10	69	8	138	225
Turbot	1	19	0	45	65
Dabs	0	9	2	30	42
Brill	1	8	1	32	41
Other	10	36	7	167	219
Total	**29**	**470**	**38**	**1,353**	**1,890**

3.3 Vessel Monitoring System Data

Satellite-based Vessel Monitoring Systems (VMS) are used to track the location of fishing vessels. VMS has been required for vessels over 15m in length since 2005, and since 2013 has applied to over-12m vessels. VMS data for 12-15m vessels were not available to this project. Under the EU Regulations, every two hours the VMS system must send a 'ping' to the relevant national Fisheries Monitoring Centre, indicating the vessel's identification, date, time, location (latitude and longitude), speed and heading. Vessel identification can then be linked to other data sources to identify vessel nationality, size, gear types and landings.

For this project, the MMO provided VMS ping data for over-15m UK vessels for 2009–2013 (Figure 3.2). Gear type was identified from logbook data where vessel identification, date and ICES rectangle matched. In the original dataset provided to the project, 84% of UK pings in the site had no information on gear type. Where a vessel had some pings with gear type identified, that gear type was then applied across the remaining pings for that vessel. After this procedure, 50% of the UK pings still had no gear type identified.

The MMO also provided VMS ping data for over-15m non-UK vessels for 2009–2013 (Figure 3.3). Gear type was identified by matching the vessel identification to the European Union Community Fleet Register (CFR). The primary and secondary gear types in the CFR indicate what the vessel owner intended at the time of registration of the vessels, but may not reflect the gear used at the time of the ping.

The VMS data show that the gear used within the site is predominantly beam trawls (EU gear code TBB) (77% of all pings in the site) (Table 4). There are also some bottom otter trawls (5%); unknown gear type accounted for 11% of pings in the site.

Dutch vessels represent the majority of effort in the site, accounting for 82% of the VMS pings for beam trawl or unknown gear types between 2009 and 2013 (Table 5). There is also some Belgian and German beam trawling. There is a small number of pings from Norwegian vessels but these are of unknown gear type, as their vessels are not included on the CFR.

Between 2009 and 2013, 95 vessels fished the site using beam trawls or unknown gear type. Pings with no gear type associated have been assumed to be beam trawlers in order to undertake a precautionary assessment of impact, as it is not possible to determine that their gear type is not beam trawl. The 95 vessels comprised: 48 Dutch vessels; 25 UK vessels (of which 7 were identified as beam trawlers, and 18 were of unknown gear type), 18 Belgian vessels; 2 German vessels; and 2 Norwegian vessels.

Table 4. Number of VMS pings by gear type recorded within the site for UK and non-UK over-15m vessels, 2009–2013

Gear Type	UK	Non-UK	Percentage of Pings
Beam trawls	382	15,421	77%
Dredges	1	2	0%
Gillnets (not specified)	128		1%
Gillnets (set)	1	26	0%
Longlines	289		1%
Nephrops trawls	3		0%
Otter trawls (bottom)	562	462	5%
Otter trawls (midwater)	2	88	0%
Otter trawls (not specified)	194		1%
Otter twin trawls / multi-rig	11	1	0%
Pair trawls (bottom)	321		2%
Pair trawls (midwater)	13	9	0%
Purse seine	0	2	0%
Pots	389		2%
Seine (Scottish, anchored, pair or fly shooting)	2	3	0%
Blank	2283	22	11%
Total	**4581**	**16036**	**100%**

Table 5. Number of VMS pings by nationality within the site for over-15m vessels (beam trawl and unknown gear types), 2009–2013

Country	Number of Pings	Percentage of Pings
UK	2,665	15%
Belgium	443	2%
Germany	57	<1%
Netherlands	14,935	82%
Norway	8	<1%
Total	**18,789**	**100%**

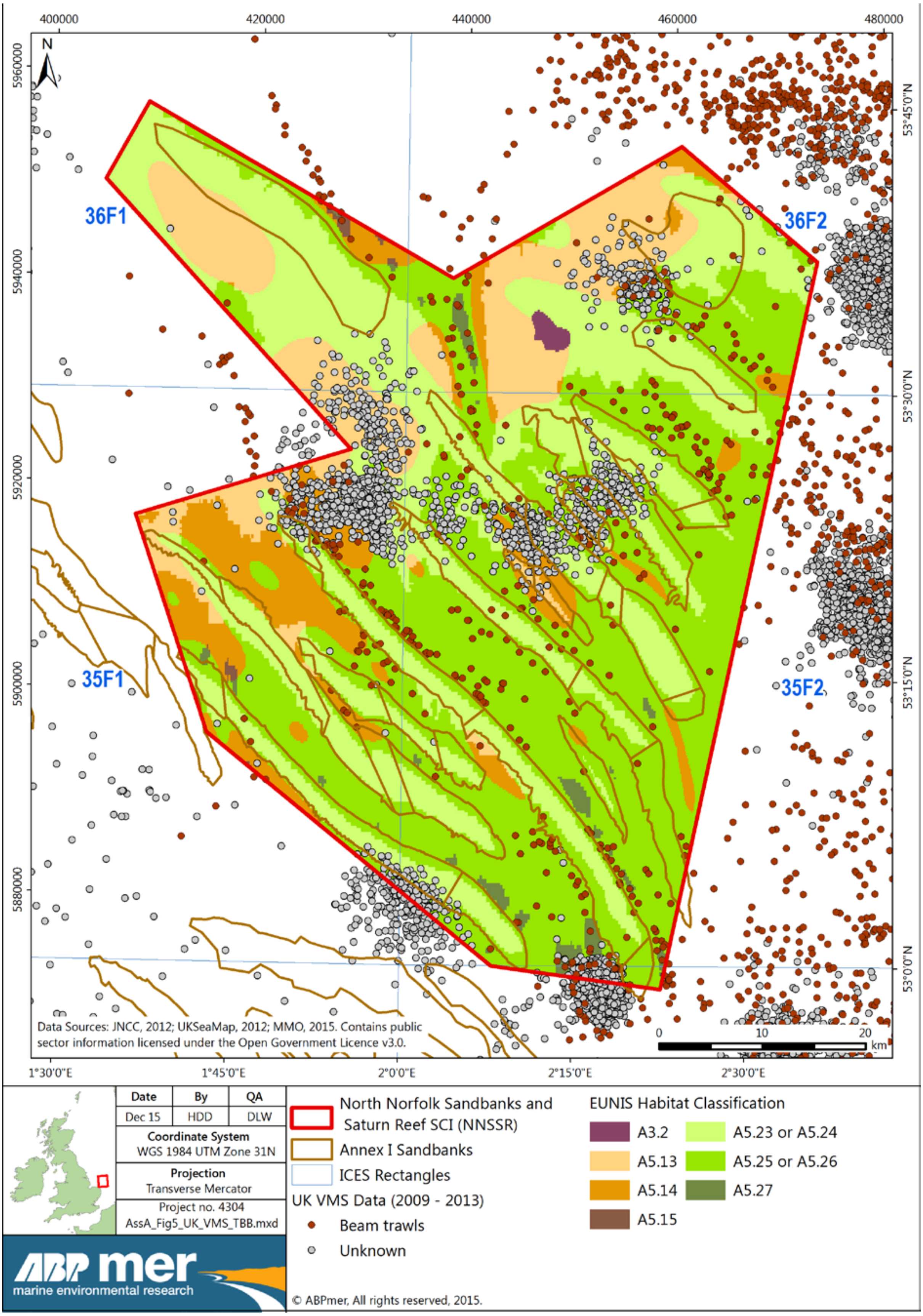


Figure 3.2 VMS pings for UK over-15m beam trawl vessels, 2009–2015

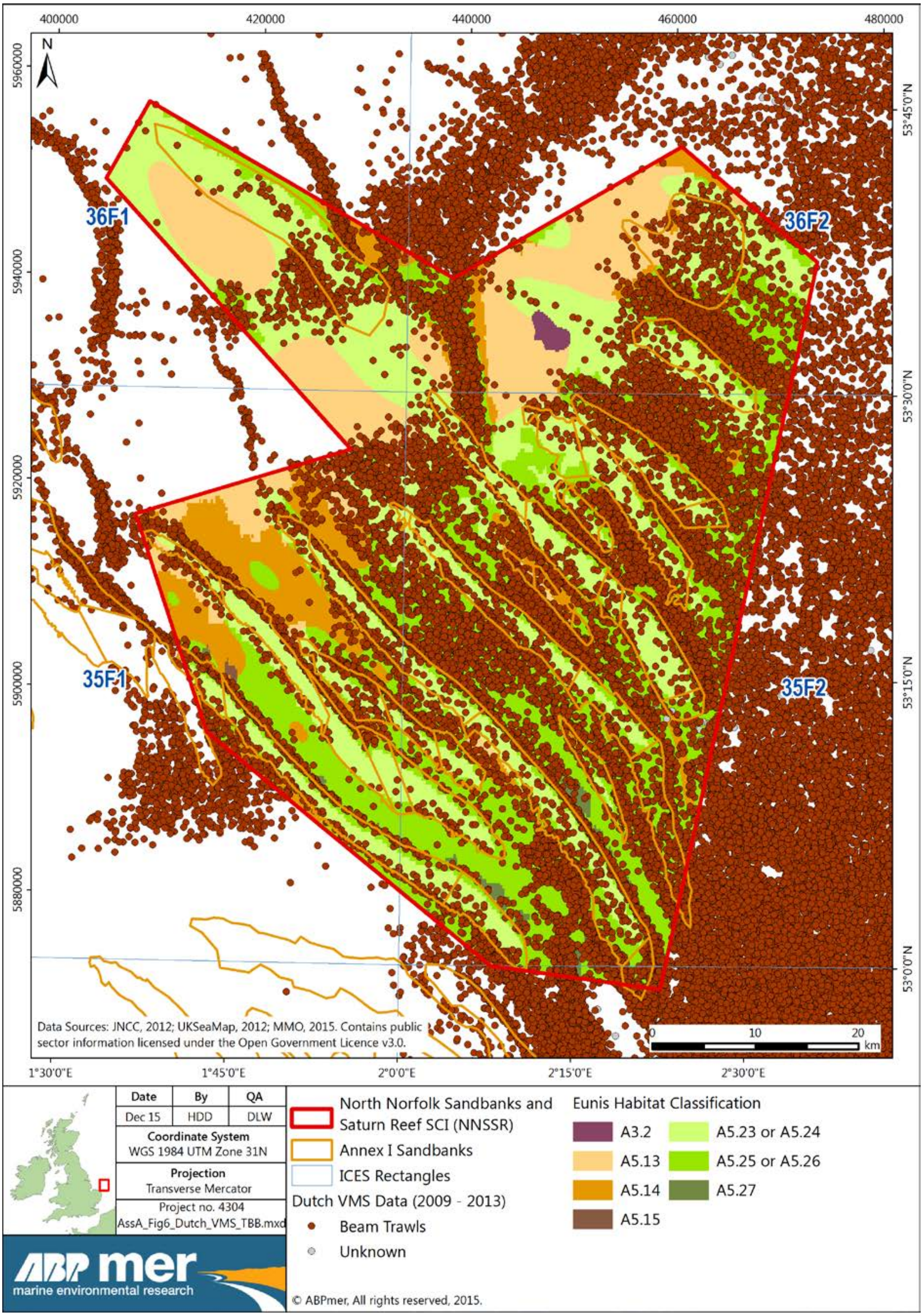


Figure 3.3 VMS pings for Dutch over-15m beam trawl vessels, 2009–2013

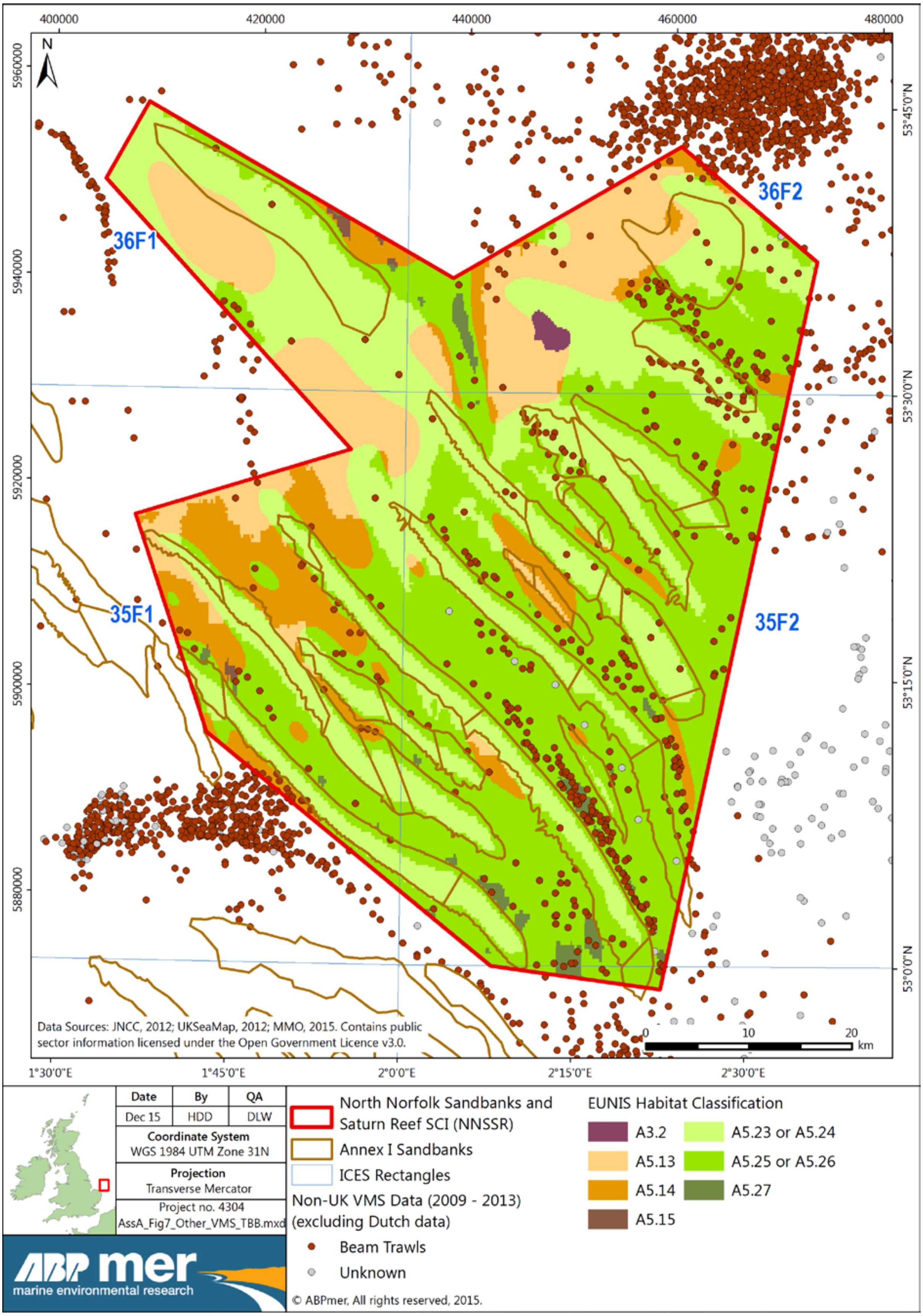


Figure 3.4 VMS pings for other non-UK over-15m beam trawl vessels, 2009–2013

3.4 Sightings Data

Sightings data on fishing activity are collected through air, sea and land surveillance activities (MMO, 2015b). Information recorded is vessel type (for example, otter trawler, bottom seiner), activity (i.e. whether or not the vessel was fishing), and vessel nationality, length category, location (ICES rectangle and latitude and longitude), speed, course, date and time.

In the period 2009–2013 a total of 76 active fishing sightings were recorded within the SCI (Figure 3.5), all of which were vessels over 15m in length, and 73 which were beam trawlers. Therefore the sightings data, coupled with the data from the ICES rectangles, provide strong evidence that the majority of the vessels active in the site are over-15 m, and that the VMS data are therefore representative of the fishing activity in the site.

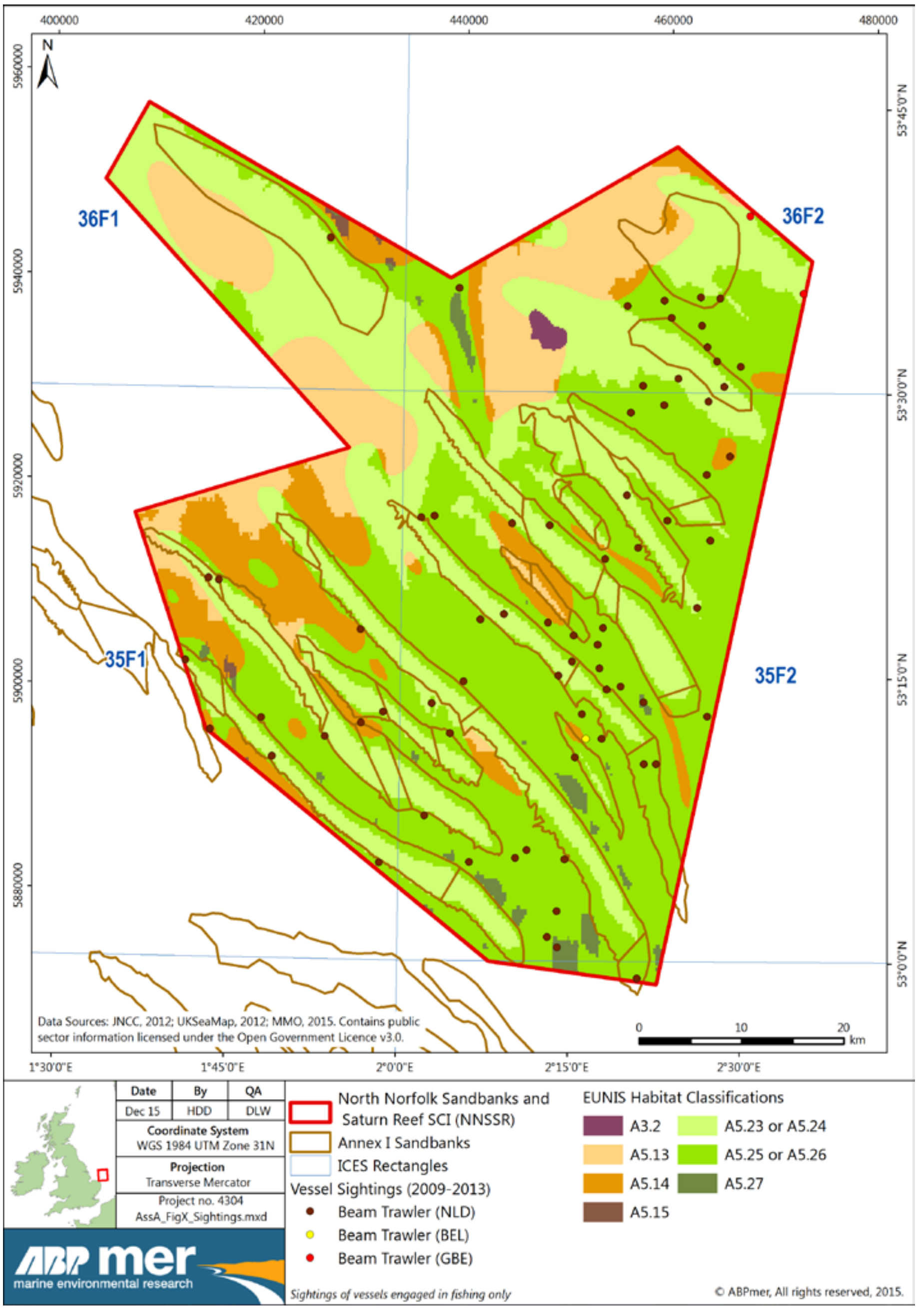


Figure 3.5 Sightings data

3.5 MCZ Fisheries Model

The Marine Conservation Zone (MCZ) fisheries model was created based on the spatial distribution of UK value of landings by broad-scale gear types for vessels under 15m in length. The model distributes the value of landings from a particular ICES rectangle using information on the spatial distribution of fishing effort within that rectangle from FisherMap. FisherMap data come from surveys of fishers which were conducted by the regional MCZ projects. Information gathered included target species, gear type and date, covering the period between 2004 and 2010. The MCZ fisheries model provides an indication of the distribution of the value of landings caught from within an area at a resolution of 1/200th of an ICES rectangle (approximately 5.5km by 3.5km). This is not sufficient to identify fishing on individual features or habitats depending on their scale.

The MCZ Fisheries Model data confirm that UK vessels under 15m in length use the site at very low levels and indicates that the mean value of landings is £28 per year per 1/200th of an ICES rectangle (Figure 3.6).

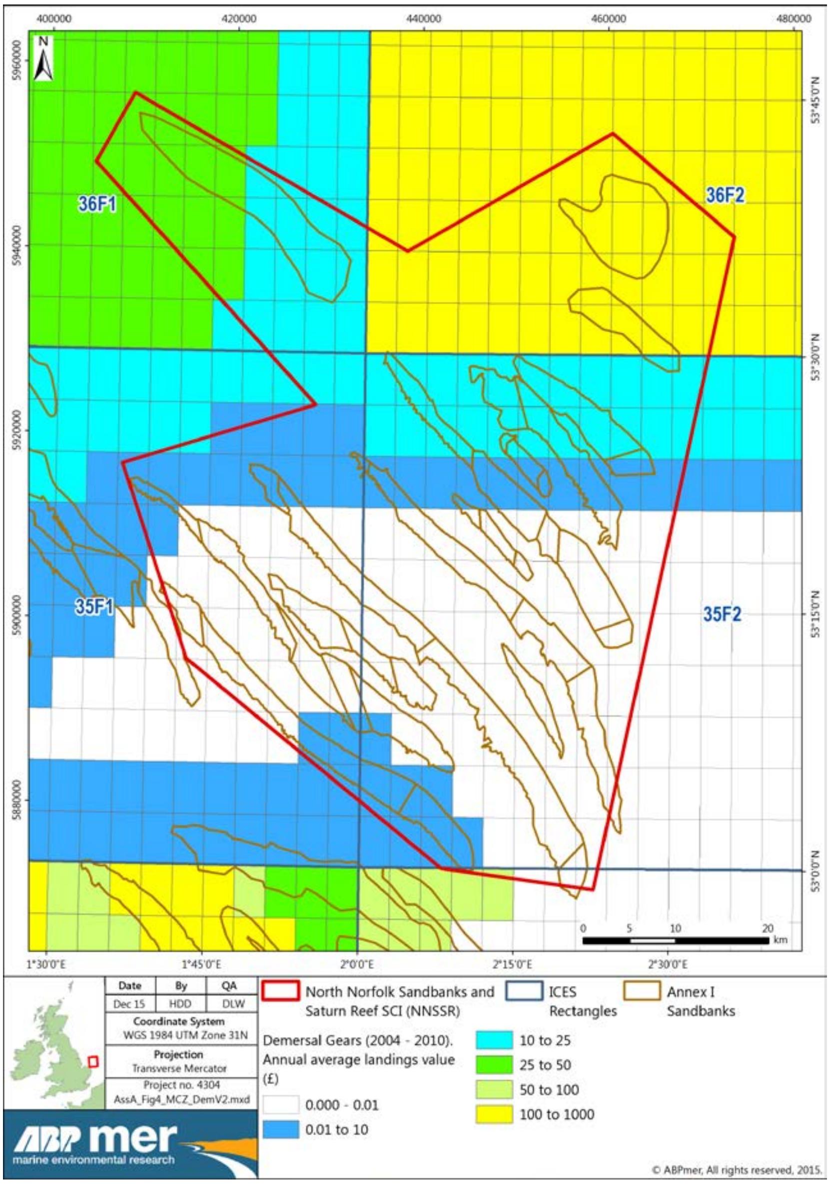


Figure 3.6 **MCZ Fisheries Model for UK under-15m demersal gear vessels, modelled landings value, 2004–2010)**

3.6 Plotter Data

Plotter data has been compiled by The Crown Estate and National Federation of Fishermen's Organisation's UK Fishermen's Information Mapping (UKFIM) project. The plotter data held for Margate and Long Sands SCI were considered in relation to this assessment. The data show a large number of tracks for beam trawls, predominantly following the lines of the sandbanks (along the flanks or within the troughs) some for dredges and unknown gear.

The data for UKFIM was provided voluntarily by participating fishermen, and therefore some areas have better coverage than others, according to the willingness of individual fishermen to provide their data. In the vicinity of the site, the majority of vessels that provided data were beam trawls. Drawing conclusions from the data must be done with care, as it is not always clear what the plotter marks represent (e.g. fishing lines to navigate to preferred fishing grounds; actual tow lines representing fishing activity; fasts which are avoided for fishing as gear may become snagged), or the timescale associated with the tracks. Additionally, plotters and plotter information may be shared between fishermen, and therefore the information stored on an individual plotter may relate to the activity of different vessels.

In summary, it was considered that the UKFIM plotter data for beam trawls do not add any additional information to the shadow assessment, over and above that provided by the VMS data.

Plotter data were received from an individual Dutch over-15m vessel from this site, for 2009–2014. The data show tracks along specific lines, similar to the VMS data. The data indicate that some areas are targeted during several years, and other areas are only targeted in one or a few years.

3.7 Interviews

Interviews were carried out during July and August 2015 with Dutch skippers of beam trawl vessels that fish in the North Norfolk Sandbanks and Saturn Reef SCI, to gather information on vessel size, gear dimensions and configurations, and levels of effort. The interview proforma is provided in Appendix A, ABPmer & Ichthys Marine, 2015.

Eight interviews were carried out with skippers of vessels based at the following ports in the Netherlands:

- Texel (4);
- Harlingen (3) (two of which were UK-flagged vessels);
- Urk (1).

The interviews gathered information on the dimensions, configurations and weights of the gear in use by the vessels, which were used in the modelling of the physical impacts of the gears (see Section 0), including whether they used conventional beam trawls with tickler chains or electrical pulse trawls. Information on fishing patterns (length of tow, number of tows per day, speed of tows) was also collected. Information on fishing areas was not collected, since the activity of these vessels is represented in the VMS data.

Consultations with the skippers and representatives of Producer Organisations and fishermen's associations provided a picture of the overall number of Dutch-owned vessels from different ports that may fish in the North Norfolk Sandbanks and Saturn Reef SCI, together with the type of beam trawl gear that they operate as of August 2015 (Table 6, below).

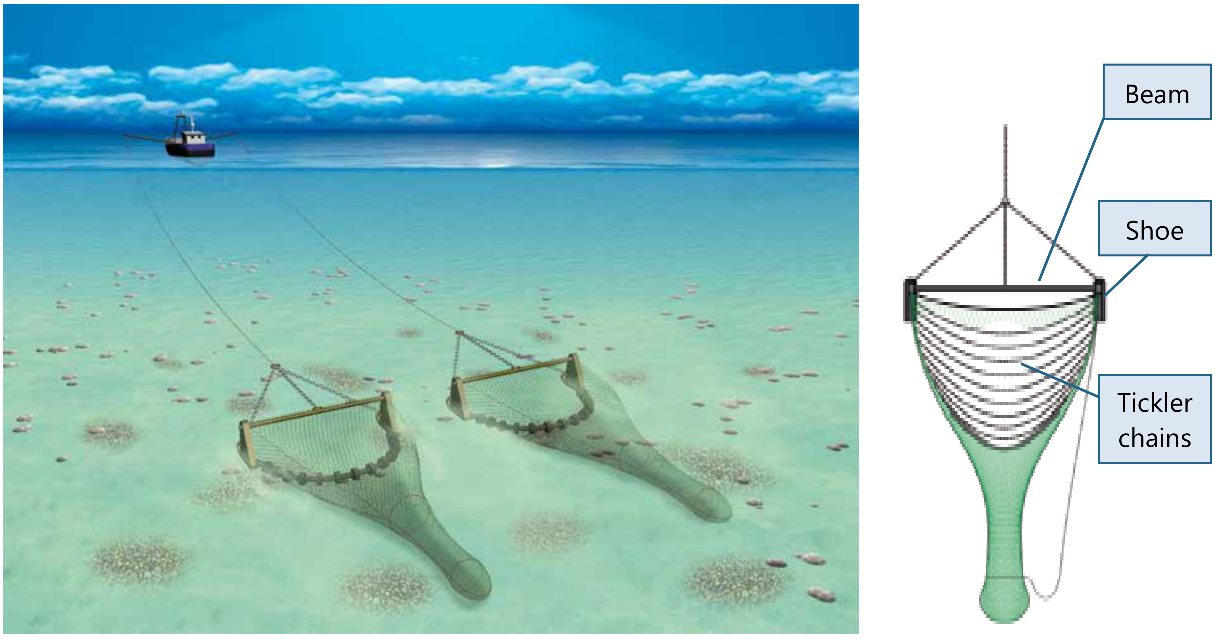
3.8 Gear Details

Interviews with fishermen demonstrate that beam trawl vessels fishing in the North Norfolk Sandbanks and Saturn Reef SCI use either conventional beam trawls with tickler chains (Figure 3.7), or increasingly, electrical pulse trawls.

3.8.1 Conventional beam trawls

Beam trawls are formed from a steel pipe, supported on 'shoes' at each end, which opens the net horizontally. The beam does not come into contact with the seafloor (Figure 3.7). A series of 'tickler' chains is hung from the beam and is designed to contact the seabed and disturb fish located on or just under the sediment surface, such that they are caught in the following net. In areas of rougher ground, a chain mat may be used instead of tickler chains, but this is not the case in the North Norfolk Sandbanks and Saturn Reef SCI. The number of tickler chains (usually between seven and nine) is adjusted according to ground conditions and towing speed, so that the gear maintains contact with the seabed. In recent years, Dutch fishers have been using wider shoes on the trawls to reduce the depth to which the shoes penetrate the seabed (fisherman, pers. comm.).

Vessels tow two beams, one on each side of the vessel from outrigger booms. Each beam is 12 m long (the limit allowed under EU legislation), giving an overall gear width of 24 m. Various design features may be used to help reduce bycatch of debris and undesirable species, including benthic release panels in the floor of the net or square mesh panels, and the mesh of the cod end is 80 mm to allow small fish to escape.



Source: Grieve *et al.*, 2014

Figure 3.7 A vessel towing two beam trawls (left). Diagram (right) showing gear components of a beam trawl with tickler chains

3.8.2 Pulse trawls

The majority of the Dutch beam trawl fleet targeting sole has adopted electrical pulse trawling. This has happened in response to public and governmental pressure to reduce the seabed impacts of beam trawling with tickler chains (industry representative, *pers. comm.*).

Pulse trawls replace the mechanical stimulation of the tickler chains with electrical stimulation, resulting in reduced bottom contact and seabed impact, lower fuel costs and discards (Soetart *et al.*, 2013). A series of electrodes extend from the beam to the opening of the net, in parallel to the direction of travel of the gear (rather than perpendicularly as for the tickler chains). The electrodes consist of 6–12 different copper conductors (diameter 26–33 mm, length 125–180 mm), alternated with isolators, and are approximately 6 m long overall.

A dedicated power cable from the vessel to the trawl transmits the electric current to the electrodes. The electrodes then send a mild electric pulse into the seabed to stimulate the fish to rise up and be caught by the trawl, with minimum sea bed disturbance (SeaFish, 2015).

Pulse trawls can be used either with a beam (e.g. the Delmeco beam, a modified hydrodynamically shaped beam, with beam shoes at each end), or with a hydrofoil 'wing' (the HFK SumWing) with a single central 'nose shoe' (Figure 3.9). At each end of the wing is a small wear plate (referred to in this report as 'wing end'). This does not maintain contact with the seabed, but serves to stabilise the gear if one end comes into contact with the seabed.

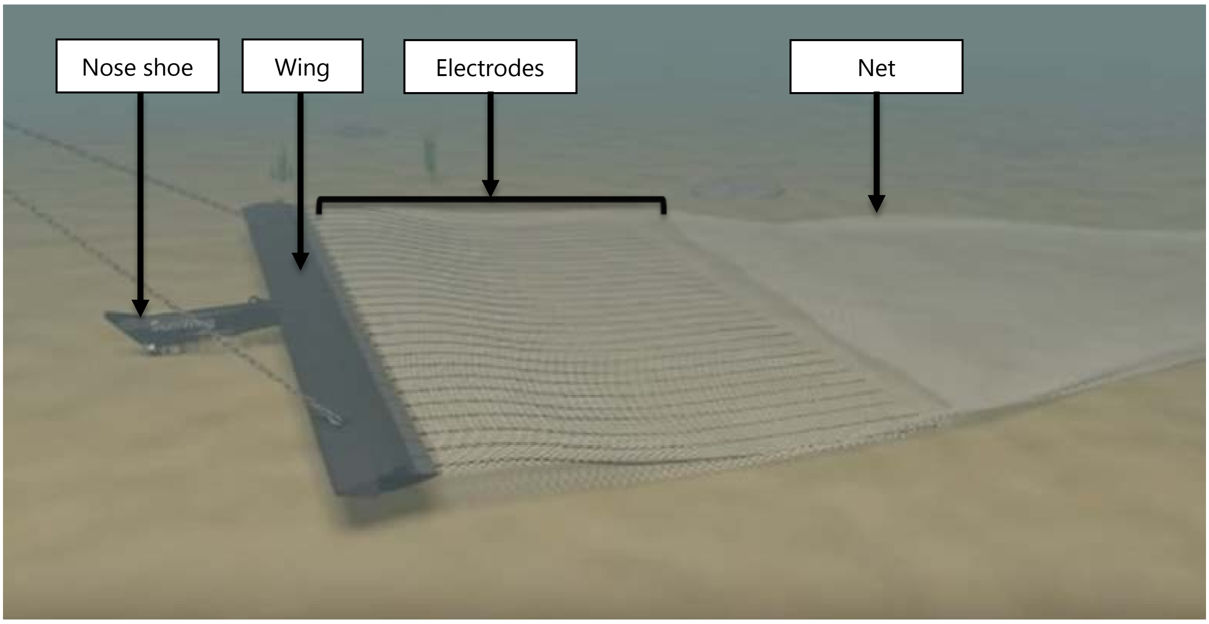


Figure 3.8 Diagram of HFK SumWing electrical pulse trawl configuration

Source: Adapted from youtu.be/NNtA1e2Ww-8.

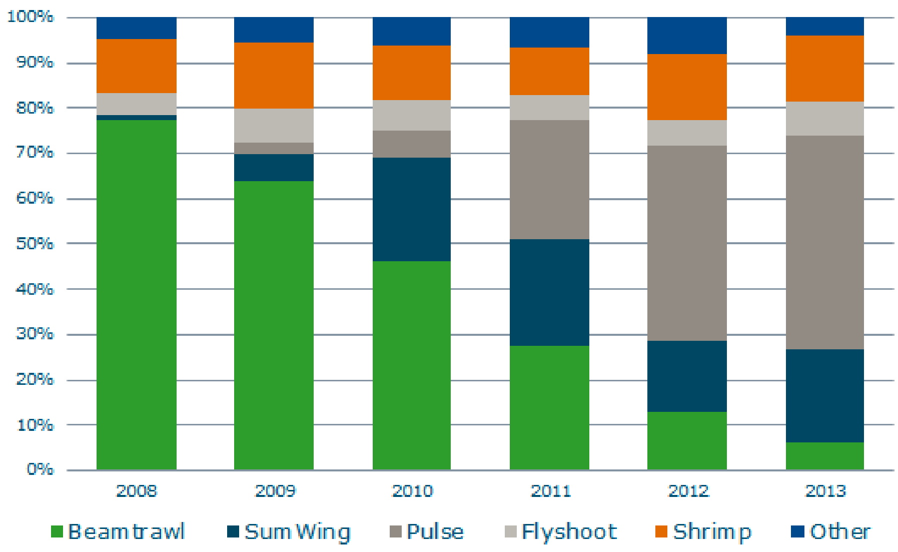
The SumWing works on the principle of a hydrofoil cross section to get the gear down and to maintain its position just above the seabed, with the trawl and electrodes behind. This reduces the bottom pressure on the seabed. The wing is filled with air, and therefore weighs a lot less in water (1,644 kg in water) than in in air (3,094 kg) (HFK Engineering BV, 2010). It is in the region of 25% the weight of a standard beam trawl (SeaFish, 2015).

The SumWing can be used either with tickler chains, or with electrical pulse gear. The combination of the SumWing and pulse gear reduces fuel usage by about 40%, due to reducing drag and the slower towing speed that is used with the pulse wing gear.

Photos by: S.F.Walmsley

Figure 3.9 Photos showing pulse wing trawl (HFK SumWing) (left) and pulse beam trawl (Delmeco) (right)

The Dutch pulse trawl vessels operate under a derogation to the general EU ban on the use of electricity in fishing (EC No 850/98, Art 31), issued in December 2006. This derogation allowed no more than 5% of the beam trawl fleet of each Member State to use the electric pulse trawl in part of the ICES divisions IVc and IVb (southern North Sea). In May 2009, the first licenced Dutch trawlers started using pulse gear, and by October 2010, this equated to 22 vessels (5% of the fleet). In 2011, 20 more licences were attributed to the Dutch fleet in relation to scientific investigations, which were all active by 2012. In 2014, 42 more licences were provided under a pilot project (under Art 14 of the CFP), increasing the amount of Dutch trawlers allowed to operate pulse trawls to 10% of the fleet (Quirijns *et al.*, 2015). This brought the total number of Dutch vessels permitted to use pulse trawls to 84 (NSAC, 2015). There are also now fishing vessels flagged in the UK, Germany and Belgium that also have derogations to the EU ban on electrical fishing (Verschueren, 2015).



Source: Turenhout, 2015

Figure 3.10 Percentage of effort in the Dutch demersal fleet, 2008–2013

The shift from conventional beam trawling to pulse trawling in the Dutch fleet is also shown by Turenhout (2015). In 2008, 77% of Dutch demersal fishing effort was conventional beam trawling, with 1% SumWing and 0% pulse fishing. In 2013, only 6% of effort was conventional beam trawling, with 21% SumWing and 47% pulse fishing (Figure 3.10). Since 2013, further vessels have converted to pulse trawling.

3.8.3 Proportion of the fleet using pulse trawls

There are a number of different possible configurations of gear — conventional beam trawl with tickler chains, SumWing with ticklers, SumWing with pulse, and Delmeco beam with pulse. Table 7 shows the number of vessels using different types of configuration in Dutch ports that fish in the North Norfolk Sandbanks and Saturn Reef area. Over 70% use pulse trawls, the majority of which use the HFK SumWing design. Some vessels fish on the banks within the North Norfolk Sandbanks and Saturn Reef SCI over 50% of the time, but the majority of vessels fish there only occasionally (Wouter Broekhaven, VisNed, *pers. comm.*). Some of the vessels based in Dutch ports are flagged in other Member States. Of the twenty Dutch-flagged vessels in Table 6, only three use tickler chain gear; 85% use pulse gear. It is not clear what proportion of effort in the North Norfolk Sandbanks and Saturn Reef SCI is from pulse trawls vs conventional beam trawls; it may be around 85% of the Dutch effort, or it may be that the pulse trawl vessels are responsible for a larger proportion of the actual fishing in the site, meaning that nearly all the beam trawl effort in the site is now pulse trawling.

Verschueren (2015) indicates that of the 83 pulse trawlers (across all Member States, but the majority (77) being Dutch), 70 are using the HFK SumWing and 13 are using the Delmeco beam. This indicates that the most common gear now in use for targeting sole on the North Norfolk Sandbanks is the HFK SumWing with pulse.

Table 6. Number of vessels that may be active in the North Norfolk Sandbanks and Saturn Reef SCI using different types of beam trawl gear, by Dutch port (2015)

Port	Beam Trawl		Pulse Trawl			Total
	Traditional Beam Trawl	SumWing with Tickler	HFK	Delmeco	Not Specified	
Katwijk	2	0	0	0	3[a]	5
Stellendam	0	0	6	1	0	7
Arnemuiden	0	0	4	0	0	4
Urk	4[b]	2[a]	0	0	5[c]	11
Total	**6**	**2**	**10**	**1**	**8**	**27**
Percentage	**22%**	**7%**	**37%**	**4%**	**30%**	**100%**
	29%		**71%**			

a. Includes one UK-flagged vessel
b. UK-flagged vessels
c. Includes one German-flagged vessel

Source: consultations with Dutch fishing industry representatives.

3.8.4 Gear dimensions

The typical dimensions of the traditional beam trawl and pulse trawl gears used by Dutch vessels in the North Norfolk Sandbanks SCI are presented in Table 7. The information on gear dimensions from industry allows the assessment to use values that closely resemble those in use in the site.

The overall swept area between the traditional beam trawl and the pulse trawl gears used by the Dutch vessels are similar, but there are differences when we consider the individual gear components.

The beam trawl shoes make up approximately 12% of the swept area of the conventional beam trawl, whereas the nose shoe on the HFK SumWing pulse trawl is 2% of the swept area. The tickler chains on the traditional beam trawl extend laterally across the swept area of the gear. The electrodes on the pulse gear run parallel to the direction of towing of the gear, and therefore do not make contact with the seabed across the whole width of the gear. The ground gears or footrope are made up of steel wire or chain with rubber discs. On the pulse trawls, a straight foot rope is used (rather than one that forms a curve between the beam shoes), which means the discs are more likely to roll over the seabed rather than be dragged due to the angle of attack.

The gears differ in weight, with the conventional beam trawl with ground gear weighing ~4,500 kg in air, the Delmeco trawl with electrodes weighing ~4,500 kg in air, and the pulse wing trawl with electrodes weighing ~3,000 kg in air (1,644 kg in water).

There are also differences in the towing speeds at which the gears are towed - the traditional beam trawl is towed at 6–7 knots and the pulse trawls are towed at a slower speed, approximately 4.5 knots. This has implications for the physical impacts, as slower towing speeds result in less hydrodynamic drag, and less sediment resuspension, and a smaller overall swept area for the same fishing time.

Table 7. Typical dimensions and weights of the beam trawl gears used in North Norfolk Sandbanks and Saturn Reef SCI

Vessel Type	Gear Type	Vessel Length (m)	Vessel Power (kW)	Beam Length (m)	Ground Gear	Bobbin Diameter (cm)	Tickler Chains Used?	Beam, Weight (kg)	Contact Width of Nose Shoe or Beam Shoes (m)	Net Material	Towing Speed (Knots)	n
Dutch	HFK Pulse Wing	42	1327	2 x 12	Steel wire with rubber discs and bobbins, with pulse gear	12–30	No	3000 (inc. electrode)	0.25 (one per beam)	3mm dyneema or nylon	4.6	5
Dutch	Delmeco pulse beam	41	1120	2 x 12	Chain with rubber discs and bobbins, with pulse gear	22	No	4500 (inc. electrode)	0.6 (two per beam)	4mm nylon	4.5	1
Dutch or UK	SumWing trawl	44	1490	2 x 12	Chain with rubber discs and bobbins. Footrope is 36 m	32 in centre, down to 17	Yes 7 tickler chains, 24 mm, estimated 1000 - 2000 kg	3000	0.25 (one per beam)	3mm polyester	6.3	1
Dutch or UK	Traditional beam trawl	40	1324	2 x 12	Steel wire with rubber discs and bobbins, 36m footrope	32 in centre, down to 18.	Yes 7-8 chains of 24mm, est. 1000kg	3500	0.7 (two per beam)	3.5mm polyester	6.2	1

3.9 Modelling of Physical Impacts of the Gears

Modelling of the physical impacts of the beam and pulse trawls used by Dutch vessels was carried out by Dr. Barry O'Neill from Marine Scotland Science. Typical gear weights and dimensions, as derived from the interviews, were used for the modelling of physical impacts of the gear (see Section 3.7 and 3.8.4).

Sediment mobilisation is predicted from the empirical model of O'Neill and Summerbell (2011), which is updated by O'Neill and Ivanović (2015). This model uses sediment concentration data collected behind gear components in contact with the seabed on a range of sediment types, to relate the quantity of sediment put into the water column to the hydrodynamic drag and the proportional silt fraction of the sediment (% of sediment < 63 µm).

The geotechnical models of Esmaeili and Ivanović (2014) and Ivanović and O'Neill (2015) are used to predict the penetration depth into the sediment. These types of models have been widely used in solving geomechanical problems for sediments in undrained conditions and can predict the penetration depth, soil displacement and drag force associated with towing individual gear components across the seabed. They have been validated with experimental data from both laboratory and sea trials (Ivanović *et al*., 2011). For full details, see Appendix B, ABPmer & Ichthys Marine (2015).

3.9.1 Sediment mobilised

The modelling results (Table 8) show that the amount of sediment mobilised behind the conventional beam trawl gear is 65 kg per metre towed (for sediment with a 2% silt fraction), rising to 185 kg per metre towed (for sediment with a 20% silt fraction) (the total quantity of sediment mobilised by the gear takes into account the number of each gear component). These values equate to a depth of sediment mobilised of 3.4 mm and 9.7 mm, respectively (the 'total' for the depth of sediment mobilised represent an average across the gear width). The gear components that mobilise the greatest amount of sediment are the net followed by the ground gear.

For the pulse wing trawl, the amount of sediment mobilised behind the gear is 29 kg per metre towed (2% silt fraction), rising to 85 kg per metre towed (20% silt fraction), equating to a depth of sediment mobilised of 1.5 mm and 4.4 mm, respectively. The gear components that mobilise the greatest amount of sediment are the net, followed by the ground gear (which includes the electrodes). The values for the pulse wing trawl are lower than the conventional beam trawl due to the slower speed at which it is towed, lighter weight, and different configuration.

Table 8. Sediment mobilised behind each gear component in contact with the seabed of conventional beam trawls and pulse wing trawls, for sediments with different levels of silt content

Gear Component	Number of Compo-nents	2% Silt Fraction		5% Silt Fraction		10% Silt Fraction		20% Silt Fraction	
		Sediment Mobilised (kg/m)	Depth of Sediment (mm)	Sediment Mobilised (kg/m)	Depth of Sediment (mm)	Sediment Mobilised (kg/m)	Depth of Sediment (mm)	Sediment Mobilised (kg/m)	Depth of Sediment (mm)
Conventional beam trawl @ 6.2 knots									
Ground gear	1	9.6	0.5	12.9	0.7	18.5	1.0	29.7	1.6
Net	1	32.1	1.7	41.6	2.2	57.3	3.0	88.7	4.7
Shoes	2	3.0	2.7	3.8	3.4	5.2	4.7	8.1	7.3
Chains	8	2.2	0.9	2.9	1.2	4.0	1.7	6.3	2.6
Total		**65**	**3.4**	**85**	**4.5**	**118**	**6.2**	**185**	**9.7**
Pulse wing trawl @ 4.6 knots									
Ground gear	1	6.4	0.3	8.8	0.5	13.0	0.7	21.3	1.1
Net	1	21.4	1.1	27.9	1.5	38.8	2.0	60.5	3.2
Nose shoe	1	1.1	2.7	1.4	3.4	1.9	4.7	2.9	7.3
Total		**29**	**1.5**	**38**	**2.0**	**54**	**2.8**	**85**	**4.4**
Note: The total amount of sediment mobilised by the gear takes into account the number of each gear component present. The 'total' for the equivalent depth of sediment mobilised represents an average across the swept path of the gear.									

Source: ABPmer & Ichthys Marine, 2015

3.9.2 Penetration depth

The magnitude of gear penetration on any given sediment type is dependent on the pressure force, which in turn is a function of both the weight and the surface area of the gear (Ivanović & O'Neill, 2015). A smaller gear component will affect a smaller area of seabed, but may penetrate to a greater depth than a heavier component with a larger surface area.

Numerical simulations have demonstrated that the penetration depth of successive elements is not cumulative (Depestele *et al.*, 2015). Therefore, the penetration depth across the path of each gear is assumed to be that of the element that penetrated the most along a particular track.

The modelling results (Table 9) show that the penetration depth of the different gear components varies considerably, with the ground gear, tickler chains and electrodes penetrating less than 1 cm into the sediment, and the beam shoes penetrating up to 9 cm in sand. These figures are consistent with other experimental results from sea trials and numerical results from simulation modelling (Ivanović *et al.,* 2011; Esmaeili and Ivanović, 2014; Depestele *et al.,* 2015; Ivanović & O'Neill, 2015). Importantly, penetration from the beam shoes and nose shoe is the deepest, but this occurs over a very small proportion (approximately 5–12%) of the overall gear footprint.

The penetration of the nose shoe of the pulse wing is assumed to be the same as the conventional beam trawl shoes, as a worst-case scenario. The pressure that the nose shoe exerts on the seabed, and therefore the penetration depth, cannot be determined solely from its weight, as lift forces act on the wing when it is being towed which, in effect, lighten its apparent weight on the seabed.

Penetration depths reported here relate to one-off events. However, the regular mobilisation of sediments by natural processes (see section 3.10) indicates that any tracks or furrows made will be rapidly infilled.

Table 9. Penetration depth of individual gear components in contact with the seabed of conventional beam trawls and pulse wing trawls in sand

Gear Component	Swept Width (m)	Penetration depth (mm)
Conventional beam trawl (per beam)		
Ground gear	1 x 12	5.2
Shoes	2 x 0.7	90
Chains	2 x 12	2.5
Average across whole gear		**15**
Pulse wing trawl (per wing)		
Ground gear	1 x 12	2.7
Nose shoe	1 x 0.7	90
Electrodes	28 x 0.25	1.5
Average across whole gear		**7.8**

Source: ABPmer & Ichthys Marine, 2015

The following is noted:

- The greatest physical impact comes from the penetration of the beam shoes and pulse nose shoe into the sediment, which is up to 9 cm depth on sand (likely to be less for the pulse nose shoe), however, this occurs over a very small proportion of the overall swept area of the gear (approximately 0.5–2.8 m of a 24 m gear footprint).
- The penetration depth of the tickler chains and of the electrodes is calculated to be less than 2 mm.

- The amount of sediment mobilised equates to a sediment depth of 6.2 mm (average across the gear, 10% silt fraction) for conventional beam trawls, and 2.8 mm for pulse wing trawls, with a maximum not greater than 4.7 mm for any individual component.

3.10 Modelling of Natural Disturbance

Modelling was carried out to determine the spatially varying frequency of seabed disturbance from natural processes within the site, with the aim of placing fishing disturbance in the context of natural disturbance. Natural seabed disturbance was inferred from the proportion of time that certain threshold conditions are exceeded. Two different thresholds were tested, based on standard empirical formulae (Soulsby, 1997), namely:

- the threshold of sediment motion; and
- the presence of dynamic ripple bed features with a minimum height.

The proportion of time that sediments are mobile encompasses a range of possible conditions from the slight movement of individual sediment grains at the sediment surface, to much higher rates of transport of sediment as bedload and (at higher levels) in suspension. The 'mobile bed' condition broadly describes conditions where sediment grains are potentially or actually in motion locally. Depending on the magnitude of sediment mobility, this condition may result in related effects, such as locally increased local suspended concentration, the abrasion of exposed surfaces, or fluidisation and morphological change of the seabed (e.g. scouring of sediment near local obstacles or infilling of burrows).

Sediment ripple bed features are a natural result of sediment transport. The typically relatively small height (a few centimetres) and length (tens of centimetres) of these features means that migration of the ripple crest can be rapid, leading to potentially frequent changes in the overlying thickness of sediment relative to a fixed, shallow buried location in the seabed. The dimensions (height and length) of ripple features formed by tidal currents are largely controlled by the seabed sediment grain size; ripple features caused by wave action are also dependent on the characteristic wave height and period, and the local water depth. The height of the ripple bedform is broadly indicative of the thickness of sediment that is being strongly disturbed, and the thickness of any burial/exposure risk.

In general, current-induced disturbance is more likely to be more frequent, uniform and persistent, and of a relatively lower magnitude. Wave-induced disturbance is more likely to be episodic, seasonal and with short term fluctuations in magnitude and direction (between individual waves and wave groups), and (especially in shallower water) may be of a relatively higher magnitude.

Natural disturbance was quantified using data on:

- Bathymetry (water depth, from EMODnet, UKHO and GEBCO, resolution ~150 m by ~220 m, sufficient to resolve the sandbank features present in the sites);
- Seabed type (broadly indicative of grain size distribution, from a composite of EMODnet, British Geological Survey and Defra's 'hard substrates' layers, categorised zone boundaries);
- Tidal current speed (frequency distribution of depth mean tidal current speed, Atlas of UK Marine Renewable Energy Resources, resolution ~1.6 km by 1.8 km);
- Wave height frequency distribution (ABPmer SEASTATES wave hindcast database, 31 years of hourly hindcast data, approximately 5 km resolution).

The modelling of natural disturbance was carried out using Matlab. The spatial resolution of the analysis and the results are the same as that of the water depth data (~150 m x 220 m). The extent of the analysis is the SAC site boundary, plus a surrounding buffer to include areas within one tidal excursion of the site (the distance to which water might move out of and back to the site within one typical spring tide). The source input data for waves and currents are at a coarser resolution (1.8 km and 5 km respectively). The tidal current frequency data were spatially interpolated firstly to a higher frequency resolution, and then spatially to each location. The wave height frequency data were available at a suitably high frequency resolution at source; wave statistics for local calculations were assigned from the nearest available data point. In the model, these inputs are applied to a series of empirical relationships provided in Soulsby (1997) in order to estimate the proportion of time that sediment is locally mobile and the height of associated dynamic bedforms. Full details are provided in Appendix G, ABPmer & Ichthys Marine (2015).

The outputs provide:

- an estimate of the proportion of time that:
  - sediments are disturbed by currents, by waves, and by currents or waves;
  - mobile bedforms of 2.5 cm height or more are present in each model cell;
- an estimate of the average number of days per year that:
  - sediments are disturbed by currents, by waves, and by currents or waves;
  - mobile bedforms of 2.5 cm height or more are present in each model cell;

The proportion of time that sediments are mobile provides an indication of the level of disturbance in the site. At a certain level of disturbance, mobile bedforms such as sand ripples form, and move rapidly (e.g. tens of metres per day). The presence of these mobile bedforms indicates that the top layer of sediment is being continually reworked to a depth equivalent to at least the ripple height. The simultaneous presence of fauna indicates that they are both adapted and dependent on such conditions; the community composition will reflect the influence of these natural environmental conditions. The level of natural disturbance can also be expressed as the average number of days during which sediments are mobile or mobile bedforms occur. This can be compared to the number of passes of fishing gear in a month or in a year to provide an indication of relative levels of fishing and natural disturbance, although it is recognised that fishing can cause impacts that natural disturbance of sediments does not (e.g. penetration into the sediment causing crushing of infauna).

Figure 3.11 shows the outputs of the natural disturbance modelling, indicating the proportion of time that sediments are mobile (middle row) and that mobile bedforms are present (bottom row). Figure 3.12 shows the outputs of the natural disturbance modelling for the average number of days per year that sediments are mobile (middle row) and that mobile bedforms are present (bottom row).

These figures show that the sediments in the North Norfolk Sandbanks and Saturn Reef SCI are highly mobile, with mobile bedforms present on the tops of the sandbanks 85–95% of the time. In the deeper areas between the sandbanks, where the majority of trawling takes place (see Figure 3.2, Figure 3.3 and Figure 3.4), sediments are also mobile and active bedforms are present for around 50–70 % of the time. Even in the eastern part of the site where currents are less strong, mobile bedforms are present around 20% of the time. Wave and current conditions are such that active bedforms are present for at least some period each day every day of the year across most of the site.

Both these figures show the results assuming a uniform sediment grain size of 250 μm is present, characteristic of fine sand. The sediments in the site are predominantly fine sand, but can also include other muddy sand and coarse sediments in varying proportions. Further modelling outputs for different grain sizes, and for particular spatial distributions of other (uniform) grain sizes indicated by EMODnet habitat types, and monthly outputs, are provided in Appendix G of ABPmer and Ichthys Marine (2015).

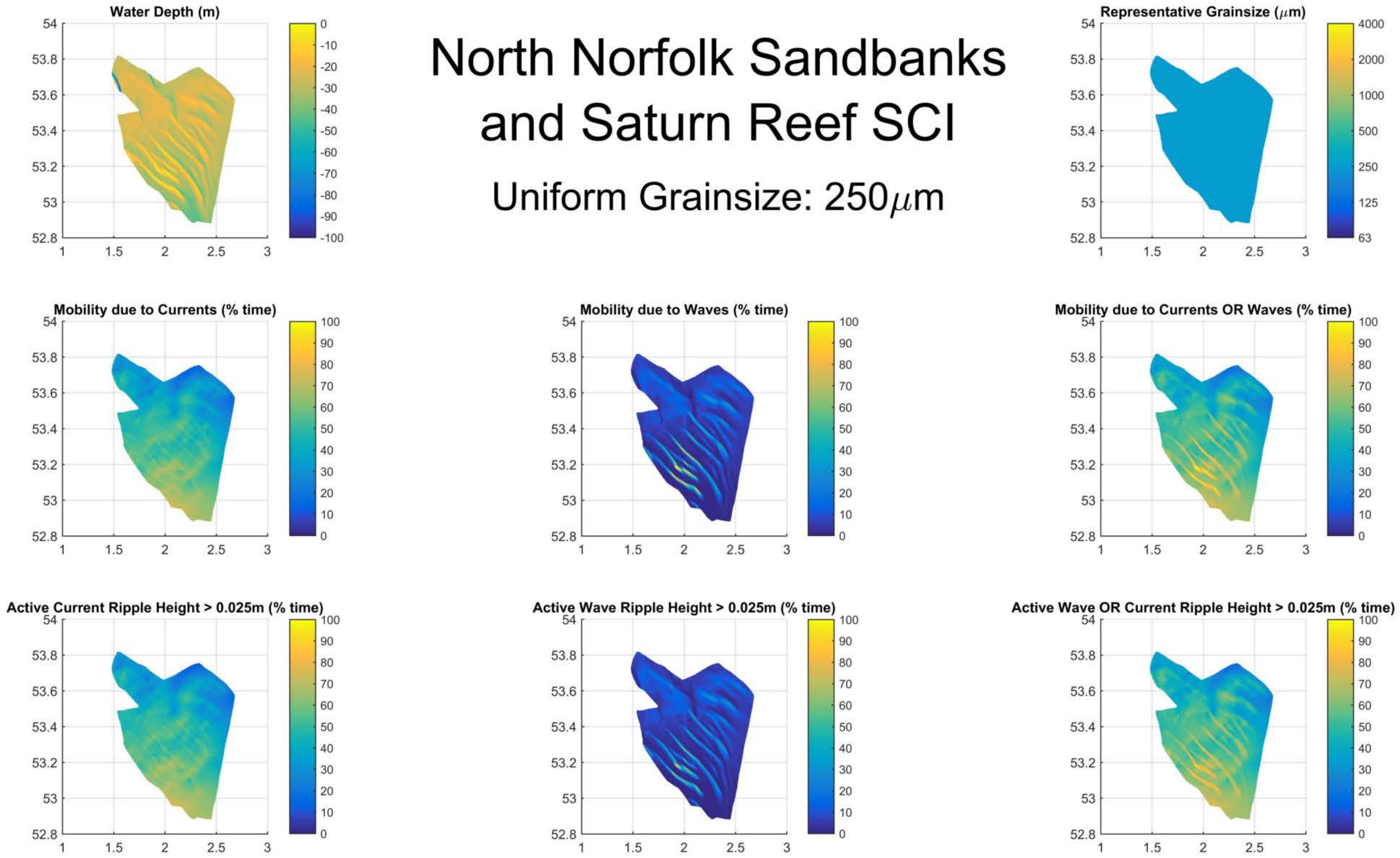


Figure 3.11 **Natural disturbance modelling outputs for North Norfolk Sandbanks and Saturn Reef SCI, showing percentage of time that sediments are mobile and that active bedforms are present due to waves or currents for a uniform grainsize of 250 μm**

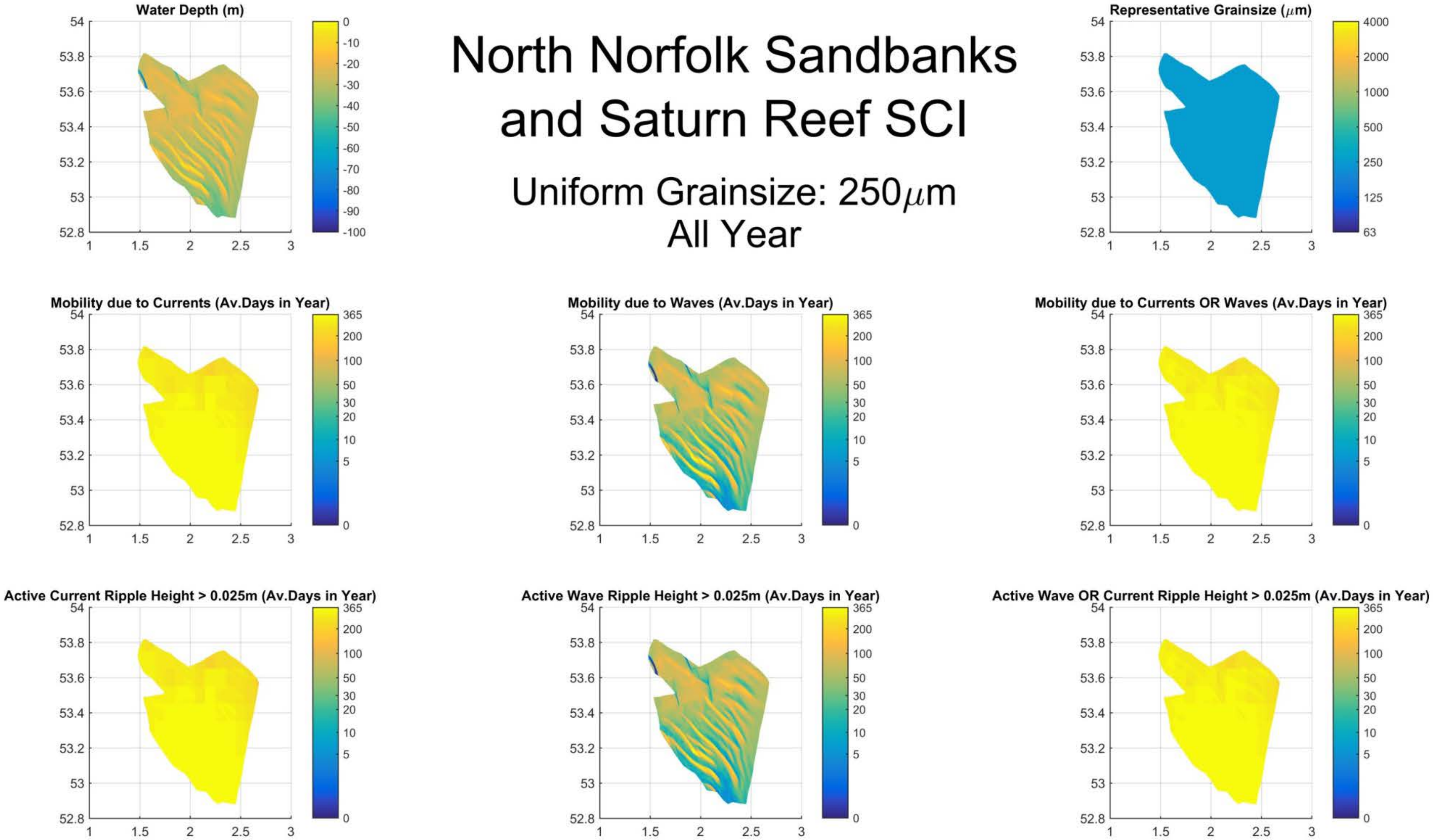


Figure 3.12 Natural disturbance modelling outputs for North Norfolk Sandbanks and Saturn Reef SCI, showing number of days per year that sediments are mobile, and that active bedforms are present due to waves or currents, for uniform grain size of 250 µm

3.11 Literature on the Impact of Fishing Activity on Designated Features

3.11.1 Conventional beam trawls

The physical effects of beam trawls are expected to be high due to the close contact that the gear maintains with the seabed (Suuronen *et al.,* 2012) and the infaunal benthic impact it causes (e.g. Lindeboom & de Groot, 1998; Kaiser *et al.,* 2006). Beam trawls cause direct physical disruption of the seabed, such as scraping, ploughing or resuspension of the sediment (Lindeboom & De Groot, 1998). This can render disturbed and damaged invertebrates susceptible to predation, and dislodge colonies that are rooted in the sand (Rabault *et al.,* 2007). The passage of the trawl over the seabed can also cause small-scale changes in bathymetry, such as the smoothing-off of ripples (Fonteyne, 1994).

The penetration depth of a beam trawl depends on the sediment characteristics. Paschen *et al.* (2000) reported that the penetration depth of tickler chain beam trawls varies between 10 and 80 mm, depending on the type of gear and substrate. On coarse and mixed sediments, beam trawl shoes leave marks up to 10 cm deep (Eigaard *et al.,* 2015). Multiple passes of a tickler chain beam was measured to cause changes of 2–2.5 cm to seabed bathymetry (12 hours after trawling, mean value) (Depestele *et al.,* 2015), but modelling of the physical impacts of the gears used in the site on sand (the predominant substrate) (Section 0), indicates that the tickler chains are likely to penetrate 1.8 mm.

The duration that beam trawl marks remain visible will depend on the upper sediment layer and on the hydrographic conditions. On the seabed consisting of medium to coarse sand, tracks have been observed to remain visible for up to 6 days. On sediments with mainly finer particles a corresponding figure of 37 hours was recorded (FAO, 2015).

3.11.2 Pulse trawls

Pulse trawls are lighter in weight than conventional beam trawls, and are towed at a slower speed. This results in a smaller swept area per hour trawled compared to conventional beam trawling (van Marlen *et al.,* 2014), while also reducing the depth that the gear penetrates in to the seabed (Depestele *et al.*, 2015). This has the added benefit of reducing fuel consumption and therefore the cost of fishing in comparison to conventional beam trawls. Economic performance in Dutch pulse trawl fisheries for sole is significantly better than that of the traditional Dutch beam trawl fishery.

Seabed impact

Pulse trawls have been shown to have a lower penetration depth than conventional beam trawls due to the lower penetration of the electrodes in the sediment compared to the tickler chains. Depestele *et al.* (2015) carried out modelling and experimental work to measure and assess the physical impacts of beam trawling in a shallow coastal zone area of the North Sea, to the south-west of the Netherlands in an area of sandy sediments (fine sand or muddy sand in the EUNIS classification). Multiple passes of a pulse beam trawl had a lower impact on seabed bathymetry than multiple passes of a tickler chain beam trawl. For the tickler chain beam trawl (trawling intensity 1.4), the mean alteration to seabed bathymetry was 2.6 cm, with a maximum of 12.8 cm. The mean alteration to seabed bathymetry from the pulse trawl (at trawling intensity 2.4, i.e. higher intensity than the tickler chain beam trawl) was 1.5 cm, with a maximum of 5.8 cm. It should be noted that the pulse trawl gear used in these experiments was the Delmeco pulse beam, with a beam design more similar to that of conventional beam trawl gear, and therefore would be expected to have greater seabed impacts than the pulse wing trawls that are now more common amongst the Dutch fleet.

The tracks from the tickler chain gear did not change much between 12 and 44 hours after trawling, whereas the trawl marks of the pulse trawl faded somewhat more between 55 and 107 hours after trawling, but trawl marks remained detectable up to at least four days after trawling. The persistence of trawl marks and a continuously changing seabed bathymetry affect benthic community structure and biogeochemical processes (Guichard and Bourget, 1998; Cutter *et al.*, 2003; Handley *et al.,* 2014, all cited in Depestele *et al.,* 2015).

In soft sediment environments, the depth of the sediment mixed layer is strongly related to the biological community and the amount of bioturbation. Large burrowing infauna draw oxygen deep into the sediment leading to a deeper mixed layer. The sediment biogeochemistry reflects the ecosystem function of the sediment. Biogeochemical cycling rates are much higher in the oxidised part of the sediment that overlies darker sediment indicating a reducing environment. Where the oxidised part of the sediment (the mixed layer) extends deeper, the sediment function in terms of nutrient recycling back into the water column is higher than in areas with a shallow mixed layer (Teal *et al.*, 2010).

Under the EU BENTHIS research project, sediment profiling imaging was carried out in 2014 experimental trials on the Frisian Front (in muddy sediments) to investigate the difference in impact between conventional beam trawling and pulse trawling. The research is not yet published, and results are pending final image analysis, but the main conclusions are reported in ABPmer & Ichthys Marine (2015). Prior to trawling, in the conventional beam trawl area, the mixed layer was around 3 cm deep, indicating a biological community lacking large bioturbations. Immediately after trawling, a layer around 3 cm thick of what appeared to be loose sediment was present on the sediment surface, with the mixed layer still visible beneath. 24 hours after trawling, the mixed layer appeared shallower than prior to trawling, likely caused by an increase in oxygen use. In the pulse trawl area, immediately after trawling, a layer of loose sediment appeared which was less compared to the conventional beam trawl area (~1 cm), with the mixed layer visible beneath. 24 hours after trawling, the loose layer had disappeared and there appeared to be no consistent decrease in the depth of the mixed layer from prior to trawling.

Some research has also been carried out into trawl path mortality using a benthic sledge, investigating the abundance of overall densities of benthic fauna before and after trawling. However, there was no consistent pattern between the conventional beam trawl, pulse trawl and reference areas that could be attributed to the effects of trawling (Teal *et al.,* 2014).

Catch and bycatch

Catches of sole and plaice are lower per hour trawled in pulse trawls than in conventional beam trawl fisheries, but due to the lower fuel costs, overall profitability is higher. For pulse trawls, more sole are landed from a smaller swept area compared to conventional beam trawls, but fewer plaice (NSAC, 2015).

Pulse trawls demonstrate a reduction in unwanted bycatch (of undersized fish and benthos) compared to conventional beam trawls, although this is dependent on the technical specification of the gear and the fishing grounds. Van Marlen *et al.* (2014) carried out experimental catch comparisons of a conventional beam trawl, a pulse beam trawl and a pulse wing trawl. Total discards from the pulse trawls were 33% of those from the conventional beam trawl. Fish discards in the pulse trawls were 44% of those from the conventional beam trawl, and benthos discards were 62% (Table 10). There were also reduced catches of undersized plaice (significant) and sole and cod (not significant) in terms of catch per unit area.

The majority of bycatches of benthic invertebrates in both conventional beam trawls and pulse trawls were of epifauna (e.g. crustaceans and echinoderms), with only approximately 10% being made up of infauna (e.g. bivalves, crustaceans, echinoderms). However, the amount of infauna caught by the pulse trawls, although a small amount, was higher than in the conventional beam trawls (van Marlen *et al.*, 2013).

Table 10. Comparison of catches and bycatches from conventional beam trawl and pulse trawls

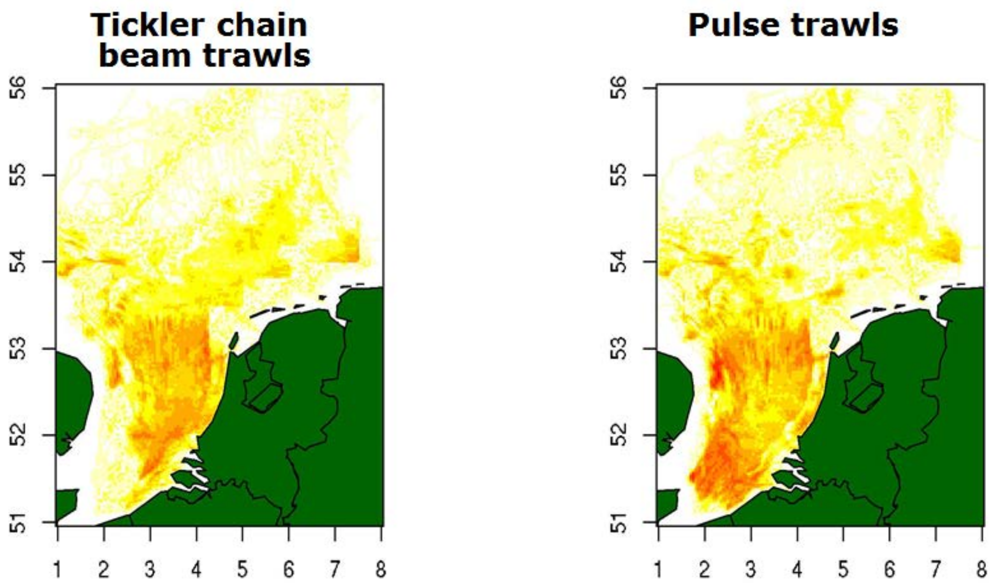
Measure	Unit	Beam Trawl	Pulse Trawl	Pulse as % of Beam	P
Total catch	Baskets per hour	19.74	7.34	37%	<0.001
Landings	Baskets per hour	2.81	1.75	62%	<0.001
Discards	Baskets per hour	16.94	5.59	33%	<0.001
- Fish discards	Weight / fishing hr	3132	1376	44%	<0.001
- Benthos	n per hour	5125	3155	62%	<0.001
Plaice landings	Kg per hour	38.62	27.89	72%	0.0016
Sole landings	Kg per hour	17.07	13.46	79%	<0.001

Source: van Marlen *et al.,* 2014

Teal *et al.* (2014) studies the effects of beam and pulse trawling on the benthic ecosystem in a shallow sandy habitat (fine sand or muddy sand) of 15–22 m depth in an area in the south-west of the Netherlands. There was a large variability in benthic species before and after trawling, and no effect was detected from fishing in terms of a reduction in abundance between the trawled and reference areas.

Spatial pattern of effort

The development of pulse trawling has reduced the weight of the gear and seabed impact, and has allowed the expansion of trawling in areas that were previously of limited importance to conventional beam trawling. Figure 3.13 shows the spatial distribution of effort for conventional beam trawlers and for pulse trawls, showing an increase of effort in the southern North Sea and closer in towards the Thames Estuary. The timescales relating to the two figures are not specified.



Source: Rijnsdorp, 2015.

Figure 3.13 Spatial distribution of effort for conventional beam trawlers (left) and pulse trawlers (right)

Impact of electricity

Van Marlen *et al.* (2014) reported that the effect of pulse stimulation varies by species. Some benthic species exhibit a jerky or jumping response (e.g. ragworm, common prawn, European green crab, Atlantic razor clam), while others exhibit no detectable response (e.g. subtruncate surf clam, common starfish).

In contrast, a study on benthic invertebrates (19 species of molluscs, echinoderms, crustaceans and polychaetes) found that they showed minor or negligible reactions during exposure to electrical pulses (of a higher amplitude and longer exposure than that used on commercial fishing vessels), and survival after three weeks did not deviate from the control group (Smaal & Brummelhuis, 2005, cited in Soetart *et al.,* 2013). ICES (2009) concluded that the results of experiments showed a low level of impact on the complete range of benthic invertebrate species tested, which were considered representative of those encountered in the beam trawl fisheries.

Electrical stimulation causes muscle contractions, and haemorrhages and bone fractures have been observed in some fish species. For example, in the experimental trawls by van Marlen *et al.* (2014), frequent haemorrhages were observed in cod from a pulse trawl, and only one out of 47 cod from a comparable beam trawl. Fractures in the spine of cod were observed in four out of 45 cod from the pulse trawl (9%), and none from the beam trawl. In contrast, no injuries have been detected in sole, dogfish (which use electroreceptors to locate their prey), dab, shrimp or ragworm. However, shrimp exposed to 200 V/m later revealed a higher severity of a virus infection (Rijnsdorp, 2015). The derogation for the use of the pulse trawl in Council Regulation (EC) No 43/2009 defines the maximum electrical power in kW (kW = V*A) for each beam trawl as no more than the length in metre of the beam multiplied by 1.25 (i.e. 18kW per beam), with the effective voltage between the electrodes as no more than 15 V.

In laboratory experiments, cod were affected by an electrical pulse, but only if they were less than 20 cm from the electrode (Soetaert *et al.,* 2013). Twenty percent died shortly after; 30% died by 14 days after exposure; 45% had injuries. No lesions were found in fish exposed at a distance of greater than 20 cm from the electrode. Fish exposed at 20–30 cm from the electrodes displayed mild contractions but did not suffer injury (no lesions) and responded well to feeding cycles. However, cod that were 40 cm from the electrodes did not react to the exposure and exhibited normal feeding behaviour. This indicates that the area within which cod are exposed to potentially damaging levels of electrical stimulation is limited to a restricted area close to the gear.

The effect of electrical stimulation varies with the size of the organism. The strength of the electric field experienced by an individual depends on the potential difference across its body, which increases with increasing body size (Figure 3.14). Therefore larger individuals will be affected more than smaller individuals by the same current. This results in lower levels of catch of undersized individuals, and minimises potentially negative effects on juveniles.

Laboratory studies on cod found that small juvenile fish (12–16 cm) exposed to high field strengths of 250–300 V m^{-1} were not affected. Subsequent post-mortem examinations did not reveal any vertebral injury or haemorrhage (De Haan *et al.*, 2011, cited in Soetart *et al.,* 2013). Large cod (41–55 cm) exposed to lower field strengths (40–100 V m^{-1}) showed vertebral injuries in 50–70% of individuals.

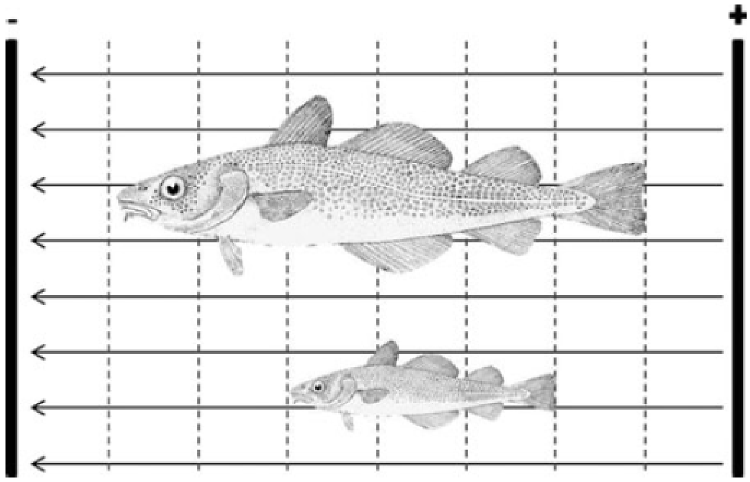


Figure 1 Draw of cod in a homogenous electric field. The heavy vertical lines represent 2 electrodes. The horizontal lines are the field lines, representing the current flow between the 2 electrodes. The dashed vertical lines are equipotentials, zones with the same potential. The larger the difference between 2 extremities of a fish (here: between head and tail), the higher the potential difference over its body and the stronger it is experiencing the electric field. For example, suppose an applied potential difference over the electrodes of 80 V that results in a potential difference between each equipotential of 10 V. In this case, the large fish will feel 60 V, whereas the small one will only feel 30 V. Note that the orientation of the fish has a marked influence on the potential difference over his body.

Source: Soetart *et al.*, 2013

Figure 3.14 Effect of electrical stimulation on animals of different sizes

Evidence gaps

Research has been carried out into the differences in catches and bycatches of conventional beam trawls and pulse trawls. However, there is a lack of research on the fate of the organisms that may be affected by the gear but are not caught in it. ICES (2009) highlighted that "[t]here are indications that the gear could inflict increased mortality on target and non-target species that contact the gear but are not retained"; this evidence gap has not yet been addressed. Additionally, further testing is required of the effects of electrical pulse at the maximum levels (and with pulse characteristics in terms of power, amplitude, duration and frequency) permitted in the pulse trawl gear.

A number of research needs are highlighted by NSAC (2015) and others:

- The fate of organisms impacted by the gear that are not caught or bycaught within it;
- The potential for different effects on fish of all stages of development;
- Potential detrimental long-term effects to the ecological role of the seafloor, including the biogeochemical functioning and the microbial loop;
- The frequency, voltage and duration of pulse that maximises catch and minimises negative effects on other organisms;
- Longer-term effects on different species, including on electrosensitive species and possible effects on their electrosensitive organs from repeated exposure.

Rijnsdorp (2015) highlights a number of research studies that are planned: to investigate trawl path mortality; effect on electroreceptor organs of electrosensitive fish; thresholds of short- and long-term effects; long-term effects on populations; effect on substrate and chemistry; changes in spatial deployment; as well as technological, economic and governance aspects.

4 Assessment of Likely Significant Effect

Table 11 provides the shadow test of likely significant effect (LSE) for beam trawling on sandbanks in the North Norfolk Sandbanks and Saturn Reef SCI.

Table 11. Assessment of LSE

<table>
<tr><th>Question</th><th colspan="2">Response</th></tr>
<tr><td>1. Is the activity/activities directly connected with or necessary to the management of the site for nature conservation?</td><td colspan="2">No.</td></tr>
<tr><td>2. What pressures (such as abrasion, disturbance) are potentially exerted by the gear type(s)?</td><td colspan="2">Physical damage through changes in suspended sediment and disturbance or abrasion; and
Biological disturbance through the selective extraction of species.</td></tr>
<tr><td>3. Is the feature potentially exposed to the pressure(s)?[1]</td><td colspan="2">Yes. Sandbanks and associated features have the potential to be exposed to the pressures to some degree.</td></tr>
<tr><td>4. What are the potential effects/impacts of the pressure(s) on the feature[2], taking into account the exposure level?

(Reference to conservation objectives)</td><td colspan="2">There is potential for a change in physical structure, diversity, community structure and typical species representative of the sandbanks. A change to these attributes could hamper the ability of the site to 'restore' to a favourable condition, as stated in the Conservation Objectives.</td></tr>
<tr><td>5. Is the potential scale or magnitude of any effect likely to be significant?[3]</td><td>Alone

Cannot be excluded.

Pressure overlaps sand bank feature.</td><td>Alone

Cannot be excluded.

Pressure overlaps sand bank feature.</td></tr>
<tr><td>6. Have NE been consulted on this LSE test?
If yes, what was NE's advice?</td><td colspan="2">N/A. This project constitutes a shadow assessment and therefore NE has not been consulted.</td></tr>
<tr><td colspan="3">1. Provide overview of activity levels, including current management measures that reduce/remove the feature's exposure to the activity.
2 Consider the sensitivity of the feature to that pressure (where available).
3 Yes: completion of AA required. If no: LSE required only.
4 If conclusion of LSE alone an in-combination assessment is not required.</td></tr>
</table>

5 Information for Appropriate Assessment

This assessment considers the vulnerability of the subtidal sandbanks feature within North Norfolk Sandbanks and Saturn Reef SCI to beam trawling. This is based on the feature's sensitivity to pressures that might arise from beam trawling (Section 5.1), and its exposure to the activity, and therefore to the pressures identified. The aim of this is to ensure that the integrity of the subtidal sandbank feature is not adversely affected.

The methodology used to assess sensitivity and exposure is provided in Section 5.2. The assessment of sensitivity is provided in Section 5.3, and the assessment of exposure in Section 5.4.

5.1 Potential Pressures

Habitat elements of the feature can be affected by, or considered 'at risk' from a pressure which changes the habitat type and the time taken to recover. The faunal assessments consider whether the biological community is likely to change as a result of the pressure. Biological communities are often inherently linked to the substrate type, therefore pressures that are expected to change sediment type would be likely to change the species assemblage (ABPmer, 2013).

The subtidal sandbanks feature of the North Norfolk Sandbanks and Saturn Reef SCI is currently not in a favourable condition (conservation objective to 'restore'). However, there was no condition table for these features nor target condition defined (JNCC, 2012; JNCC, 2015). Although there is no direct evidence of the sandbanks being damaged or in deterioration, the area is subject to "*unprecedented levels of obstruction from infrastructure associated with oil and gas activities*" and there is uncertainty concerning the level of abrasion pressure from beam trawling (JNCC, 2012).

JNCC (2012) provides two pressure categories which may cause deterioration of natural habitats and disturbance of species as a result of mobile benthic fishing. These pressures are:

- Physical damage and disturbance through changes in suspended sediment concentration;
- Physical damage and disturbance through abrasion; and
- Biological disturbance through the selective extraction of species.

In addition, pulse wing trawls introduce electrical impulses into the ecosystem, to stimulate the flatfish to rise up from the sediment and into the path of the net. Therefore the following pressure is included in relation to the use of pulse gear:

- Electromagnetic changes.

5.1.1 Physical damage and disturbance through changes in suspended sediment concentration

As the beam trawl fishing gear is towed along the seafloor, fine material is pushed into suspension, resulting in a short-term increase in suspended sediment concentration (SSC). This has the potential reduce levels of light penetration, and when it resettles, to smother and damage the physical structure of the sandbanks and the associated epifauna resulting in a physical effect from the addition of fine sediments. Therefore, for changes in suspended sediment concentration, the average depth of sediment mobilised across the overall gear width is considered.

In higher energy locations, such as the SCI, the associated fauna tend to be well-adapted to disturbance and changes to SSC. As a result, the fauna is more tolerant of fishing-related disturbance (JNCC, no date(b); Dernie *et al*., 2003; Hiddink *et al*., 2003).

Siltation does occur naturally at the site as it is described as a sand sink (Cooper *et al*., 2008). Any material entering into suspension as a result of trawling will originate from within the system and therefore it is expected that having sediment in suspension within the site and the subsequent siltation is within the limits of natural variability, and will not alter the character and classification of the feature.

5.1.2 Physical damage and disturbance through abrasion

Trawling has the potential to reduce benthic habitat complexity and increase homogeneity of the sediment topography (Linnane *et al*., 2000). This may occur through the removal of physical structures (e.g., Auster *et al.,* 1996) or the sorting of surficial sediments (e.g., Schwinghamer *et al.,* 1996), and through reducing the abundance of species that play an 'ecosystem engineering' role by creating habitat features, or by facilitating the flow of oxygen or nutrients within sediments (e.g. Thrush and Dayton, 2002 and references therein). However, the effects of trawling are habitat-dependent, and in mobile sediments the effects are minimised because the habitat is dynamic and the species living there are adapted to regular perturbation (e.g., Kaiser *et al*., 1998; Thrush and Dayton, 2002).

While trawling has been found to cause long-term changes to sediment structure in sheltered sites (e.g., Jennings *et al*., 2002), other studies reported that on mobile sand habitats, no effects were detectable from beam trawling in terms of changes in the mean density of individuals, number of species or diversity indices (Kaiser *et al*., 1998), and the impact of trawling on shallow sand habitats was not detectable within a few hours to a few days of intensive fishing occurring (e.g. Depestele *et al*., 2015). It is noted that the majority of the North Norfolk Sandbanks and Saturn Reef SCI is made up of sediments which are mobilised regularly (see Section 3.10).

The magnitude of gear penetration on any given sediment type is dependent on the pressure force, which in turn is a function of both the weight and the surface area of the gear (Ivanović & O'Neill, 2015), as described in detail in Section 3.9. Penetration is therefore considered for individual gear components.

5.1.3 Biological disturbance through selective extraction of species

There is potential for impacts to the biological communities through the selective extraction of species during a trawl event. Infralittoral fine sand and circalittoral sand, muddy sand and coarse sediment are not considered to be dependent upon any species, and so are not sensitive to their removal (ABPmer, 2013). However, the removal of non-target species which characterise the biotopes may result in changes to the biological community which in turn, may change the classification of the given assemblage.

5.1.4 Electromagnetic changes

Pulse trawlers use electrical current to stimulate the fish to swim upwards and into the net. The aim of this technology is to reduce the benthic impact of the gear from tickler chains which penetrate the sediment in order to stimulate the fish to swim into the net. This reduces the bycatch of undersized fish and of non-target species, as well as reduces the physical disturbance to the benthic environment. In general replacing the tickler chains with electrical probes is seen as an alternative for diminishing environmental effects of beam trawling (van Marlen *et al*., 2014). Species' reactions to electrical stimulation varies between species as described in Section 3.8.2 and van Marlen *et al.* 2014.

5.2 Assessment Methodology

5.2.1 Sensitivity

The assessment of sensitivity provided below is based on the 'Sensitivity Matrix' created by ABPmer for the Marine Institute (ABPmer, 2013), building on Tillin *et al.* (2010). These matrices report on the sensitivity of benthic habitats and associated species to a range of pressures from fishing and aquaculture activities. Evidence tables also provide an assessment of the likely risk to features. This is further supplemented by information on the susceptibility of species to trawling according to their biological traits, based on the work of Bolam *et al.* (2014). Appendix E of the Final Project Report (ABPmer & Ichthys Marine, 2015) provides details of the biological traits assessed; this was further supplemented by additional literature. The Natural England Fisheries Impacts Evidence Database (FIED) (Natural England, 2015) was also used to identify relevant evidence sources on impacts of beam trawling.

Sensitivity has been described in the UK Review of Marine Nature Conservation (Defra, 2004) as dependent on the intolerance of a species or habitat to damage from an external factor and the time taken for its subsequent recovery. It is therefore a measure of the likelihood of change when a pressure is applied to a feature, as a function of that feature's capacity to tolerate the change and its subsequent ability to recover.

In order to assess the sandbanks' sensitivity, the tolerance and recovery of relevant components have therefore been considered. Sensitivity is assessed for individual habitats at EUNIS Level 4, the level to which they are specified in the available habitat data. Typical characterising species of these habitats have been considered in the assessment of sensitivity.

The scales of tolerance and recoverability identified in ABPmer (2013) have been used. These scales have been informed by other sensitivity assessment approaches as described within ABPmer (2013), and are based on the MB0102 Defra project (Tillin *et al.*, 2010), which has been used extensively by regulators to support decisions on UK MPA planning and management. The tolerance scale is shown in Table 12.

Table 12. Tolerance scale

Tolerance	Description
None	Key structural or characterising species severely in decline and/or physico-chemical parameters are also affected e.g. removal of habitat causing change in habitat type. A severe decline/reduction relates to the loss of >75% of the extent, density or abundance of the assessed species or habitat element e.g. loss of > 75% substratum (where this can be sensibly applied).
Low	Significant mortality of key and characterising species with some effects on physico-chemical character of habitat. A significant decline/reduction relates to the loss of 25%-75% of the extent, density or abundance of the selected species or habitat element e.g. loss of 25-75% substratum.
Medium	Some mortality of species or loss of habitat elements e.g. the loss of <25% of the species or element, (can be significant 25-75%, where these are not keystone structural and characterising species) without change to habitat type.
High	No significant effects to the physico-chemical character of habitat and no significant effect on population viability of key/characterising species, but may be some detrimental effects on individuals, including rates of feeding, respiration and gamete production.

Source: ABPmer, 2013.

The recovery category is based on the time scale needed for full recovery (Table 13). As described in ABPmer (2013), 'full recovery' is envisaged as a return to the state of the habitat that existed prior to impact. However, in order to fully assess recovery, the baseline against which the pressure is being assessed must be known. In effect, this is a return to a recognisable habitat and its associated community. However, this does not necessarily mean that every component species has returned to its prior condition, abundance and extent, but that the relevant functional components are present and the habitat is structurally and functionally recognisable as the habitat of conservation concern.

Table 13. Recovery categories and descriptions

Recovery Category	Description
Low	Full recovery 6+ years
Medium	Full recovery within 3-5 years
High	Full recovery within ≤ 2 years
Very High	Full recovery within 6 months

Source: ABPmer, 2013.

To assess sensitivity the tolerance and recovery times are combined as shown in Table 14.

Table 14. Sensitivity, based on tolerance and recoverability

Recovery	Tolerance			
	None	Low	Medium	High
Low	Very High	High	Low	Not Sensitive
Medium	High	Medium	Low	Not Sensitive
High	Medium	Medium	Low	Not Sensitive
Very High	Low	Low	Low	Not Sensitive

Source: ABPmer, 2013.

The terms 'not sensitive', and low, medium, high and very high sensitivity, are described as follows:

Not Sensitive: An assessment of 'not sensitive' is based on the ability of a feature to tolerate impacts. An assessment of not sensitive indicates that the assessed pressure is not expected to lead to significant effects on structural habitat elements or characterising species. Where tolerance is assessed as high, any rate of recovery will result in a 'not sensitive' assessment, as there are no significant impacts for the feature to recover from. Increased pressure intensity, frequency or duration may however lead to greater impacts and a different sensitivity assessment.

Low Sensitivity: 'Low sensitivity' is defined on the basis of tolerance and recovery. A feature is assessed as having low sensitivity to a given pressure level where tolerance is assessed as medium so that there is no significant impact but recovery may take between 6 months to more than 6 years. Alternatively the tolerance threshold may be none, or low, however, recovery is rapid (within 6 months).

Medium Sensitivity: Features assessed as expressing 'medium sensitivity' to a pressure benchmark are those where tolerance is categorised as none but where recovery takes place within two years, or those where tolerance is low (the pressure leads to a significant effect) and recovery is predicted to occur within >2 -5 years (medium to high recovery).

High Sensitivity: Features assessed as being of 'high sensitivity' experience significant impacts following the pressure (no to low tolerance) with full recovery requiring at least three years. The feature may not be recovered after six years.

Very High Sensitivity: Features assessed as having 'very high sensitivity' are those that are predicted to have no tolerance to the pressure (75% decline of assessed elements), and where full recovery is predicted to take more than 6 years.

5.2.2 Exposure

Exposure is assessed for VMS (over-15m) vessels only, because the level of exposure to non-VMS (under-15m) beam trawl vessels is minimal or nil. The VMS data do not distinguish between the use of conventional beam trawls and the use of pulse wing trawls. The analyses are therefore carried out for two scenarios:

- Assuming all beam trawl pings are conventional beam trawls;
- Assuming all UK pings are conventional beam trawls, and all non-UK beam trawl pings are pulse wing trawls.

The former provides a 'worst case' scenario. The latter provides a scenario that is closer to the current situation, with a large proportion of the Dutch fleet having adopted pulse trawling, and with most of those vessels using the HFK SumWing rather than the Delmeco hydrodynamic beam. It is recognised that there are uncertainties in this (there are some UK vessels that use pulse trawls, not all the Dutch fleet use pulse trawls, but it is likely that those representing the majority of effort in the site do, and the shift to pulse trawling has taken place over the time period analysed, i.e. there was more conventional beam trawling at the beginning of the time period, and more pulse trawling at the end of the time period). However, the two scenarios provide examples of the two extremes; the actual situation is likely to lie within these bounds.

For over-15m vessels, three different approaches were used: swept area, VMS footprint and frequency of impact.

To calculate swept area on each habitat, the VMS 'fishing' pings were intersected with the habitats in ArcGIS. For non-UK pings (which had time associated), the time associated with the pings was summed to obtain the time fishing on each habitat. For UK pings, each ping was assumed to represent two hours' fishing (information on the minutes associated with each ping was not available in the UK VMS dataset received). The time was summed to obtain the time fishing on each biotope. The towing speed for conventional beam trawls was taken as 6 knots[2], and for pulse wing trawls was 4.5 knots[3] (indicated from VMS data, interviews, and literature, see Section 3.8) and gear width of 24 m, the swept area was calculated as:

$$\textit{Swept area } (km^2) = \textit{Time fishing (in hours) x Tow speed (in km/hr) x Gear width (in km)}$$

This was then pro-rated to the area affected by each gear component, according to the width of the individual components (based on information of gear configurations from interviews) to obtain the area of habitat impacted by each component. Figure 5.1 shows the widths used for the individual gear components.

2 The average towing speed from the VMS data for beam trawls (across all nationalities) in 2009 (when most beam trawls were still conventional beam trawls) was 5.3 knots. However, this was felt to be an under-estimate, since the VMS data were for 'fishing' pings only (taken as 1–6 knots), and therefore may have excluded pings at a higher speed that were also related to fishing activity. Eigaard *et al.* (2015) indicate the average towing speed for flatfish beam trawls to be 5.2 ±1.3 knots.

3 The average towing speed from the VMS data for Dutch beam trawls in 2013 (when a large proportion of the Dutch fleet were using pulse wing trawls) was 4.8 knots.

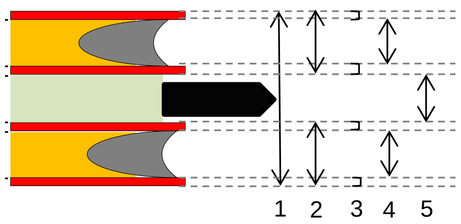
Because pings may be sent out more frequently than every two hours, it is likely that the number of hours trawled by UK vessels is over-represented, although as UK pings are a small proportion of the total number of beam trawl pings in the site, this will not cause a significant over-estimation of swept area. In addition, the pings with no gear type have been used in the calculation which may also cause the number of hours recorded to be over-represented.

To calculate the VMS 'footprint', tracks were created in the 'Points to Line' tool from the Data Management toolbox within ArcGIS to link consecutive fishing pings from individual vessels (using 2009–2013 data). The tracks were then sequentially buffered to reflect the width of the individual gear components of over-15m beam trawlers (Figure 5.1).

A polygon was then created for each gear component by joining together the respective individual tracks, and overlain on the habitat map. Where polygons for different gear components overlapped, the component with greater impact (beam shoes > tickler chains or ground gear and nose shoe > ground gear) was used, with overlapping areas subtracted from the polygons of less-impacting gear components. The polygons were clipped to the SAC area, and the area of each habitat and biotope impacted by the individual gear components was calculated in GIS.

The tracks created between sequential VMS pings may not represent the actual path of the fishing vessel, and there are alternative methods for interpolating tracks between VMS pings. However, comparison of plotter tracks and VMS pings (Lee, 2012), showed that there can be a good correspondence between the pings and the actual vessel track. Furthermore, the analysis compiles five years of data, and therefore provide a good approximation of the overall footprint of fishing activity, as it reflects fishing patterns over a number of years and therefore incorporates interannual variability.

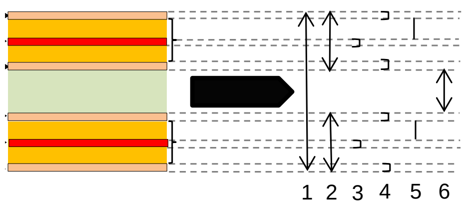
Conventional beam trawl



Key

1. Full gear width to outer edges of beams = 32.5m
2. Full width of each beam = 12m
3. Beam shoes on inner and outer edges of gear = 0.7m
4. Ground rope and tickler chains = 10.6m
5. No impact (vessel width to inner edges of beams) = 8.5m

Pulse wing trawl



Key

1. Full gear width to outer edges of beams = 32.5m
2. Full width of each beam = 12m
3. Nose shoe in middle of each beam = 0.25
4. Wing ends on inner and outer edges of each beam = 0.1m
5. Electrodes = 5.58 m

6: No impact (vessel width to inner edges of beams) = 8.5m

Figure 5.1 Widths of individual gear components used to buffer VMS tracks for UK and non-UK over-15m beam trawl and pulse trawl vessels

To assess the number of times that an area is impacted, the VMS tracks were converted into gridded data, and the number of tracks that crossed each grid cell was calculated. Grid cell size was 250 m by 250 m. This is ten times larger than the width of the gear, therefore more than one track per cell does not necessarily mean that the same area of seabed is impacted multiple times. A higher resolution grid (for example, that equates with the swept width of the gear) was unmanageable for the whole site in terms of data processing. However, a higher-resolution grid (25 m by 25 m, reflecting the width of the gear) was applied to two small areas, which encompass the highest level of intensity of fishing activity within the site.

The exposure was assessed on the basis of individual gear components, so that the sensitivity of the habitats to the pressures exerted by those individual gear components (e.g. based on penetration depth) can be assessed. Furthermore, the assessment considered seasonal exposure, to be able to consider the impact of fishing activity in the context of any known seasonal differences in sensitivity of the habitats and species, and in the context of differing levels of natural disturbance within the year.

The assessment of exposure to each pressure is based on the proportion of the area of the habitat affected by the pressure (from the relevant gear component), on the following scale:

- Low: 0–10%;
- Moderate: 11–75%;
- High: 75–150%;
- Very high: >150%.

The results of the exposure assessment are provided in Section 5.4.

5.2.3 Vulnerability

Based on sensitivity and exposure the vulnerability of the assessed features can be described generically as set out in Table 15. Vulnerability is a measure of the degree to which a feature is sensitive to a pressure and exposed to that pressure. Vulnerability can be considered to be an expression of the likely significance of effects; where features have high vulnerability they are more likely to be changed by the activity-related pressures under consideration.

Table 15. Vulnerability, based on sensitivity and exposure

Exposure	Sensitivity			
	None	Low	Medium	High
Low	Not Vulnerable	Not Vulnerable	Low	Moderate
Moderate	Not Vulnerable	Low	Moderate	High
High	Not Vulnerable	Moderate	Moderate	High
Very High	Not Vulnerable	Moderate	High	High

Source: ABPmer, 2013.

5.3 Sensitivity Assessment

Impacts to the sandbanks from beam trawling could result from physical damage to the sandbanks through changes in suspended sediment levels and through abrasion, causing changes to the physical structure (such as sediment particle size distribution), diversity, community structure and typical species representative of sandbanks which are indicators for the conservation objectives. Impacts could also result from biological disturbance through the selective extraction of species. These impacts are considered for each habitat in turn below. For each biotope, a summary table of its sensitivity to each pressure is provided, together with summary text describing the tolerance and recovery of both the habitat and its characterising species. Full details can be found in the Habitat Sensitivity Assessment in Appendix A.

5.3.1 Infralittoral coarse sediment

Infralittoral coarse sediment is a moderately-exposed habitat with coarse sand, gravelly sand, shingle and gravel in the infralittoral, subject to disturbance by tidal steams and wave action. Such habitats found on the open coast or in tide-swept marine inlets are characterised by a robust fauna of infaunal polychaetes such as *Nephtys cirrosa* and *Bathyporeia* spp, *Chaetozone setosa* and *Lanice conchilega*, *cumacean crustacea* such as *Iphinoe trispinosa* and *Diastylis bradyi,* and venerid bivalves. The sensitivity of the biotope *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand has been incorporated into the assessment for this habitat as this is the biotope JNCC (2010) used for their assessments of sandbanks within the Conservation Objectives and Advice on Operations document.

A summary of the sensitivity of this habitat to each pressure is provided below. See Section A.1 for the full sensitivity assessment for this habitat to demersal beam trawl gears, including tolerance and recoverability of both the habitat and characterising species.

Table 16. Sensitivity summary for infralittoral coarse sediment (SS.SCS.ICS)

Impact Pathway	Impact/ Pressure Resulting From	Sensitivity Used in Assessment
Physical damage (surface abrasion)	Ground gear coming into contact with seabed	Not sensitive
Physical damage (shallow disturbance)	Electrodes or tickler chains coming into contact with seabed	Low
Physical damage (deep disturbance)	Beam shoes or nose shoe coming into contact with seabed	Low–Medium
Changes in suspended sediment	Sediment mobilised in the wake of the gear	Not Sensitive
Electromagnetic changes	Electromagnetic pulses from gear (pulse gears only)	Not Sensitive
Biological disturbance	Removal of target and non-target species	Low

Surface Abrasion: This habitat is not sensitive to surface abrasion as this pressure is unlikely to alter the habitat type and there would be a fast recovery from any changes. In addition, as described in detail in Appendix G of ABPmer & Ichthys Marine (2015), using the natural disturbance model for grain size 1000 µm, in the area where this habitat is present, surface sediments are mobilised by waves or currents between 20%–30% of the time. The characterising species (such as *N. cirrosa* and *Bathyporeia*) are also not sensitive to surface abrasion as they live infaunally and their biological traits make them adapted to high energy environments.

Shallow Disturbance: The biotope is assessed as having a low sensitivity to shallow disturbance. Shallow disturbance has the potential to cause changes in the topography of the habitat, which may cause the formation of pits and trenches. Infralittoral coarse sands have a medium tolerance and a high recovery to shallow disturbance, as shallow disturbance will not change the habitat type, and any furrows will be rapidly filled in. As described in Section 3.10 and in detail in Appendix G of ABPmer & Ichthys Marine (2015), the top sediment layer is regularly mobilised by natural processes (currents) 20%–30% of the time with active ripple bedforms (2.5 cm) present 10%–20% of the time. Although it is acknowledged that natural disturbance is not directly comparable to the pressure caused by shallow disturbance as a result of beam trawling, it does provide an insight to the natural processes occurring at the site and whether or not the site does experience any disturbance, and as such, whether or not the habitat is able to tolerate disturbance.

Shallow disturbance has the potential to cause physical damage and mortality to organisms. *Bathyporeia* spp. have a medium tolerance to shallow disturbance as they are mobile and due to its small size is unlikely to be retained in a trawl. Mortality has been recorded to occur, but their abundance recovers very rapidly, therefore they have a low sensitivity to shallow disturbance. *N. cirrosa* lives infaunally (below the depth expected to be affected by the beam shoes), is adapted to naturally-disturbed environments, and is mobile and has a high recruitment rate; it has therefore been assessed that this species is not sensitive to shallow disturbance. Overall, this habitat has a low sensitivity to shallow disturbance.

Deep Disturbance: The types of impacts are the same as stated in shallow disturbance, but more severe. The topography may change and so tolerance is assessed as medium for the habitat and low to high for the characterising species as the species present are not described within the habitat data available. The site is a dynamic environment (see Section 3.10). Natural disturbance modelling for 1000 µm grain size indicates that surface sediments in the area of this habitat are mobile 20%–30% of the time, predominantly due to currents, with active ripple bedforms (2.5 cm height) present 10%–20% of the time. Therefore any trenches or pits formed as a result of beam trawling would be expected to be infilled during periods of high current speed e.g. on a daily basis during peak tidal flows or at least twice monthly during spring tides). *Bathyporeia* spp. have a medium tolerance to deep disturbance as they are mobile and can move out of the path of a trawl, but mortality has been recorded to occur. However, their abundance recovers very rapidly, therefore they have a low sensitivity to deep disturbance. *N. cirrosa* lives infaunally (at 5 cm – 15 cm depth) so there is potential for this species to be impacted by beam trawling, but it has a high recruitment rate. Therefore tolerance has been assessed as medium and recovery as high, giving a low sensitivity to deep disturbance. Therefore given the sensitivity of the habitat and any species that may be present within the habitat, overall sensitivity is assessed as low to medium.

Changes in Suspended Sediment: Increases in suspended sediment and changes in turbidity would not alter the character of the habitat and so tolerance is assessed as high and recovery is assessed as very high, therefore the habitat is considered to be not sensitive. Fauna associated with the biotope are adapted to a high energy environmental where the levels of suspended sediments is greater than more sheltered environments. In addition the biota are generally infaunal and not photosynthetic and so are considered as having a high tolerance, very high recovery and are therefore considered not sensitive to the levels of suspended sediment expected at the site as a result of beam trawling.

Electromagnetic Changes: The habitat and characterising species are assessed as not sensitive as it is expected that they have a high tolerance to electromagnetic changes.

Biological Disturbance: This habitat is assessed as not sensitive to removal of species as the infralittoral coarse sand habitat will not be altered as a result. However the fauna associated with the habitat does have the potential to be affected. Pulse wing trawls have less bycatch compared to conventional beam trawls and so this will have reduced in the site relative to the effort since the introduction of pulse trawling. However species associated with the habitat may be a potential food source for the target species (plaice and sole). As such, tolerance is assessed as medium and recovery as very high. Therefore it is concluded that this habitat and its characterising species have a low sensitivity to biological disturbance.

5.3.2 Circalittoral coarse sediment

Circalittoral coarse sands, gravel and shingle are normally at depths of 15–20m (JNCC, 2015) and are found in tidal channels. This habitat is characterised by robust infaunal polychaetes, mobile crustacea and bivalves (JNCC, 2015). The sensitivity of the biotope *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand has been incorporated into the assessment for this habitat as this is the biotope

JNCC (2010) used for their assessments of sandbanks within the Conservation Objectives and Advice on Operations document.

A summary of the sensitivity of this habitat to each pressure is provided below. See Section A.2 for the full sensitivity assessment for this habitat to demersal beam trawl gears, including tolerance and recoverability of both the habitat and characterising species.

Table 17. Sensitivity summary for circalittoral coarse sediment (SS.SCS.CCS)

Impact Pathway	Impact/ Pressure Resulting From	Sensitivity Used in Assessment
Physical damage (surface abrasion)	Ground gear coming into contact with seabed	Not sensitive
Physical damage (shallow disturbance)	Electrodes or tickler chains coming into contact with seabed	Low
Physical damage (deep disturbance)	Beam shoes or nose shoe coming into contact with seabed	Low–Medium
Changes in suspended sediment	Sediment mobilised in the wake of the gear	Not Sensitive
Electromagnetic changes	Electromagnetic pulses from gear (pulse gears only)	Not Sensitive
Biological disturbance	Removal of target and non-target species	Low

This habitat has the same sensitivity assessment as infralittoral coarse sediment above in Section 5.3.1.

5.3.3 Deep circalittoral coarse sediment

Offshore (deep) circalittoral habitats have coarse sands and gravel or shell. This habitat may cover large areas of the offshore continental shelf although there is relatively little quantitative data available. The habitat is generally characterised by robust infaunal polychaetes and bivalve species (EUNIS Habitat Classification 2007). A summary of the sensitivity of this habitat to each pressure is provided below. See Section A.3 for the full sensitivity assessment for this habitat to demersal beam trawl gears, including tolerance and recoverability of both the habitat and characterising species.

Table 18. Sensitivity summary for deep circalittoral coarse sediment (SS.SCS.OCS)

Impact Pathway	Impact/Pressure Resulting From	Sensitivity Used in Assessment
Physical damage (surface abrasion)	Ground gear coming into contact with seabed	Not Sensitive
Physical damage (shallow disturbance)	Electrodes or tickler chains coming into contact with seabed	Low
Physical damage (deep disturbance)	Beam shoes or nose shoe coming into contact with seabed	Low–Medium
Changes in suspended sediment	Sediment mobilised in the wake of the gear	Not Sensitive
Electromagnetic changes	Electromagnetic pulses from gear (pulse gears only)	Not Sensitive
Biological disturbance	Removal of target and non-target species	Low

This habitat has the same sensitivity assessment as infralittoral coarse sand above in Section 5.3.1. The habitat is deeper and so may not be in as higher energy environment as the shallower habitats. The percentage of time this habitat is mobile due to currents is greater. Using the natural disturbance modelled for 1000–2000 µm grain sizes (as described in Appendix G of ABPmer & Ichthys Marine, 2015), the top layer of sediment is regularly mobilised by currents 20%–30% of the time, with active ripple bedforms (2.5 cm height) present around 10% of the time.

tolerance and recovery times are expected to be within the bracket of the benchmarks used for this assessment (see Section 5.2).

5.3.4 Infralittoral fine sand or infralittoral muddy sand

This is a well-sorted habitat typical of tidal swept channels (JNCC, 2015). A summary of the sensitivity of this habitat to each pressure is provided below. See Section 0 for the full sensitivity assessment for this habitat to demersal beam trawl gears, including tolerance and recoverability of both the habitat and characterising species. The sensitivity of the biotope *Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand has been incorporated into the assessment for this habitat as this is the biotope JNCC (2010) used for their assessments of sandbanks within the Conservation Objectives and Advice on Operations document.

Table 19. Sensitivity summary for infralittoral fine sand or infralittoral muddy sand (SS.SSa.IFiSa)

Impact Pathway	Impact/Pressure Resulting From	Sensitivity Used in Assessment
Physical damage (surface abrasion)	Ground gear coming into contact with seabed	Not Sensitive
Physical damage (shallow disturbance)	Electrodes or tickler chains coming into contact with seabed	Low
Physical damage (deep disturbance)	Beam shoes or nose shoe coming into contact with seabed	Low–Medium
Changes in suspended sediment	Sediment mobilised in the wake of the gear	Not Sensitive
Electromagnetic changes	Electromagnetic pulses from gear (pulse gears only)	Not Sensitive
Biological disturbance	Removal of target and non-target species	Low

This habitat has the same sensitivity assessment conclusion as infralittoral coarse sand above in Section 5.3.1. The sediment is finer and the percentage of time this habitat is mobile due to currents is greater. Using the natural disturbance modelled for 250 µm grain size (as described in Appendix G of ABPmer & Ichthys Marine, 2015), the top layer of sediment is mobilised by currents or waves and active ripple bedforms (2.5 cm) present 40–100% of the time. For muddier sediments (e.g. 63 µm grain size, active ripple bedforms are expected to be present 20–60% of the time on the tops of the banks only. The natural levels of suspended sediment may be greater than for infralittoral coarse sand, but tolerance and recovery times are expected to be within the bracket of the benchmarks used for this assessment (see Section 5.2).

5.3.5 Circalittoral fine sand or circalittoral muddy sand

This habitat is made up of fine clean sands in tide-swept areas. A summary of the sensitivity of this habitat to each pressure is provided below. The sensitivity of the biotope *Nephtys cirrosa* and Bathyporeia spp. in infralittoral sand has been incorporated into the assessment for this habitat as this is the biotope JNCC (2010) used for their assessments of sandbanks within the Conservation

Objectives and Advice on Operations document. See Section A.5 for the full sensitivity assessment for this habitat to demersal beam trawl gears, including tolerance and recoverability of both the habitat and its characterising species.

Table 20. Sensitivity summary for circalittoral fine sand or circalittoral muddy sand (SS.SSa.CFiSa)

Impact Pathway	Impact/Pressure Resulting From	Sensitivity Used in Assessment
Physical damage (surface abrasion)	Ground gear coming into contact with seabed	Not sensitive
Physical damage (shallow disturbance)	Electrodes or tickler chains coming into contact with seabed	Low
Physical damage (deep disturbance)	Beam shoes or nose shoe coming into contact with seabed	Low–Medium
Changes in suspended sediment	Sediment mobilised in the wake of the gear	Not Sensitive
Electromagnetic changes	Electromagnetic pulses from gear (pulse gears only)	Not Sensitive
Biological disturbance	Removal of target and non-target species	Low

This habitat has the same sensitivity assessment as infralittoral coarse sand in Section 5.3.1. The sediment is finer and so the percentage of time this habitat is mobile due to currents is greater. Using the natural disturbance modelled for 63 µm and 250 µm grain sizes (as described in Appendix G of ABPmer & Ichthys Marine, 2015), the top layer of sediment is regularly mobilised by currents or waves 20–80% of the time in the areas where this habitat occurs, with active ripple bedforms (2.5 cm height) present 10–80% of the time for 250 µm grain size, and 0–20% of the time for 63 µm grain size. The levels of suspended sediments may also be greater than in the infralittoral coarse sand habitat, but tolerance and recovery times are expected to be within the bracket of the benchmarks used for this assessment (see Section 5.2).

5.3.6 Deep circalittoral sand

There is not a lot of data on this habitat but it is likely to be characterised by a range of polychaetes, amphipods, bivalves and echinoderms. A summary of the sensitivity of this habitat to each pressure is provided below. See Section A.6 for the full sensitivity assessment for this habitat to demersal beam trawl gears, including tolerance and recoverability of both the habitat.

Table 21. Sensitivity summary for deep circalittoral sand (SS.SSa.OSa)

Impact Pathway	Impact/Pressure Resulting From	Sensitivity Used in Assessment
Physical damage (surface abrasion)	Ground gear coming into contact with seabed	Not Sensitive
Physical damage (shallow disturbance)	Electrodes or tickler chains coming into contact with seabed	Low
Physical damage (deep disturbance)	Beam shoes or nose shoe coming into contact with seabed	Low–Medium
Changes in suspended sediment	Sediment mobilised in the wake of the gear	Not Sensitive
Electromagnetic changes	Electromagnetic pulses from gear (pulse gears only)	Not Sensitive
Biological disturbance	Removal of target and non-target species	Low

This habitat has the same sensitivity assessment conclusion as infralittoral coarse sand in Section 5.3.1. The sediment is finer and the percentage of time this habitat is mobile due to currents is greater. Using the natural disturbance modelled for 250 µm grain size (as described in Appendix G of ABPmer & Ichthys Marine, 2015), the top layer of sediment is regularly mobilised by currents or with active ripple bedforms (2.5 cm) 60%–70% of the time. In addition, the levels of suspended sediment may be greater, but the tolerance and recovery times are expected to be within the bracket of the benchmarks used for this assessment (see Section 5.2).

5.4 Exposure Assessment

This assessment considers the exposure of the individual habitats to beam trawling. The assessment is presented for two scenarios:

- Scenario 1: All UK and non-UK beam trawlers are using conventional beam trawl gear with tickler chains;
- Scenario 2: All UK beam trawlers are using conventional beam trawl gear with tickler chains, and all non-UK beam trawlers are using pulse wing trawls.

5.4.1 Physical damage – abrasion and changes in suspended sediment concentration

The exposure to physical damage from abrasion and changes in suspended sediment concentration is assessed in relation to the area of individual habitats impacted from beam trawling. This is considered in relation to the swept area, VMS footprint polygons, and frequency of disturbance.

Beam trawling by over-15m vessels predominantly occurs parallel to and running along the outer edges of the sandbanks in water depths of 30–40m (circalittoral), with very low levels of fishing occurring on and at the peaks of the sandbanks. Fishing mainly occurs on the fine sediment, with large areas of coarse sediment in the northern part of the site not exposed to fishing pressure (Figure 3.2, Figure 3.3 and Figure 3.4).

Swept area

The average area trawled per year (the 'swept area') has been calculated from the VMS data. Table 22 presents, for scenario 1, the area of each habitat and the annual average swept area from beam trawling between 2009 and 2013 that each of the habitats within the site boundary is exposed to, based on VMS 'fishing' pings for UK and non-UK vessels over-15m in length. Table 23 presents, for scenario 2, the area of each habitat and the annual average swept area from conventional beam trawling and pulse wing trawling between 2009 and 2013 that each of the habitats within the site boundary is exposed to, based on VMS 'fishing' pings for UK and non-UK vessels over-15m in length. These results are also shown in Figure 5.2.

Under scenario 1, the overall swept area is 1,551 km^2, equivalent to 43% of the area of the site. The habitat where the majority of fishing takes place is 'circalittoral fine sand or circalittoral muddy sand', with a swept area of 970 km^2 per year, an area equivalent to 60% of the area of the habitat. When the footprint of the individual gear components is taken into account, the swept area from the beam shoes is equivalent to 7% of the habitat area, and the area from the ground gear is equivalent to 53% of the area of the habitat. However, fishing may be concentrated in certain parts of the habitat, leaving other parts unimpacted by trawling. The habitats with the largest swept area in relation to the area of the habitat are deep circalittoral sand (swept area equivalent to 142% of the area of the habitat) and deep circalittoral coarse sediment (swept area equivalent to 109% of the area of the habitat). This is primarily a function of the relatively small areas of these habitats in the site, meaning that any pings that fall within them result in a high swept area compared to the size of the habitat (compare with the results of the VMS footprint analysis below).

Under scenario 2, the swept area is 1,387 km^2 per year, equivalent to 38% of the area of the site. The swept areas on the individual habitats are also correspondingly lower, due to the slower towing speed for pulse wing trawls. The habitat where the majority of fishing effort occurs is circalittoral fine sand or circalittoral muddy sand, with a swept area of 857 km^2, equivalent to 53% of the area of the habitat area. When the footprint of the individual gear components is taken into account, 46% is from the pulse wing trawl ground gear, 5% from the conventional beam trawl ground gear, and 1% from each of the beam shoes, pulse trawl nose shoe and wing ends.

Table 22. Average swept area of each habitat from beam trawling per year for scenario 1, based on VMS data (over-15 m vessels, TBB and 'unknown' gear types), UK and non-UK combined (2009–2013)

Habitat	Habitat Area (km^2)	Swept Area (Annual Average) (km^2)	Swept Area as % of Habitat Area	Swept Area as % of Habitat Area, by Gear Component	
			Overall	Beam Shoes	Ground Gear
Moderate energy infralittoral rock	9.1	0	0%	0%	0%
Infralittoral coarse sediment	459.6	83	18%	2%	16%
Circalittoral coarse sediment	332.0	128	39%	5%	34%
Deep circalittoral coarse sediment	6.3	7	109%	13%	96%
Infralittoral fine sand or Infralittoral muddy sand	1142.0	300	26%	3%	23%
Circalittoral fine sand or Circalittoral muddy sand	1609.1	970	60%	7%	53%
Deep circalittoral sand	45.4	64	142%	17%	125%
Total	**3603.4**	**1,551**	**43%**	**5%**	**38%**

Table 23. Average swept area of each habitat from beam trawling per year, for scenario 2, based on VMS data (over-15 m vessels, TBB and 'unknown' gear types), UK and non-UK combined (2009–2013)

Habitat	Habitat Area (km²)	Swept Area (Annual Average) (km²)	Swept Area as % of Habitat Area					
			Overall	Conventional Beam Trawl		Pulse Wing Trawl		
				Beam Shoes	Ground Gear	Nose Shoe	Ground Gear	Wing Ends
Moderate energy infralittoral rock	9.1	0	0%	0%	0%	0%	0%	0%
Infralittoral coarse sediment	459.6	78	17%	1%	9%	0%	7%	0%
Circalittoral coarse sediment	332.0	116	35%	1%	7%	1%	25%	0%
Deep circalittoral coarse sediment	6.3	6	95%	0%	1%	2%	90%	2%
Infralittoral fine sand or Infralittoral muddy sand	1142.0	274	24%	1%	7%	0%	15%	0%
Circalittoral fine sand or Circalittoral muddy sand	1609.1	857	53%	1%	5%	1%	46%	1%
Deep circalittoral sand	45.4	57	125%	1%	10%	2%	110%	2%
Total	**3603.4**	**1,387**	**38%**	**1%**	**6%**	**1%**	**30%**	**1%**

These figures are likely to overestimate the actual area exposed to conventional beam trawling and pulse wing trawling because fishing is likely to be concentrated in particular areas. Additionally, the inclusion of pings where the gear type is blank or 'unknown' (86% of the UK pings, and <1% of the non-UK pings, 13% combined) means that these swept area estimates are likely to over-estimate beam trawling impact.

Figure 5.3 shows the swept area on each habitat per year from 2009 to 2013, assuming all vessels were using conventional beam trawl. Fishing is fairly consistent from year to year. There was a general decline over the period 2009–2012, and an increase in 2013.

Figure 5.4 shows the average swept area on each habitat per year from 2009 to 2013, assuming all UK vessels were using conventional beam trawl, and all non-UK vessels were using pulse wing trawl. Due to the slower towing speed of the pulse wing trawl, the overall swept area is less than in Figure 5.3, falling from an average of 1,551 km^2 per year to 1,387 km^2 per year.

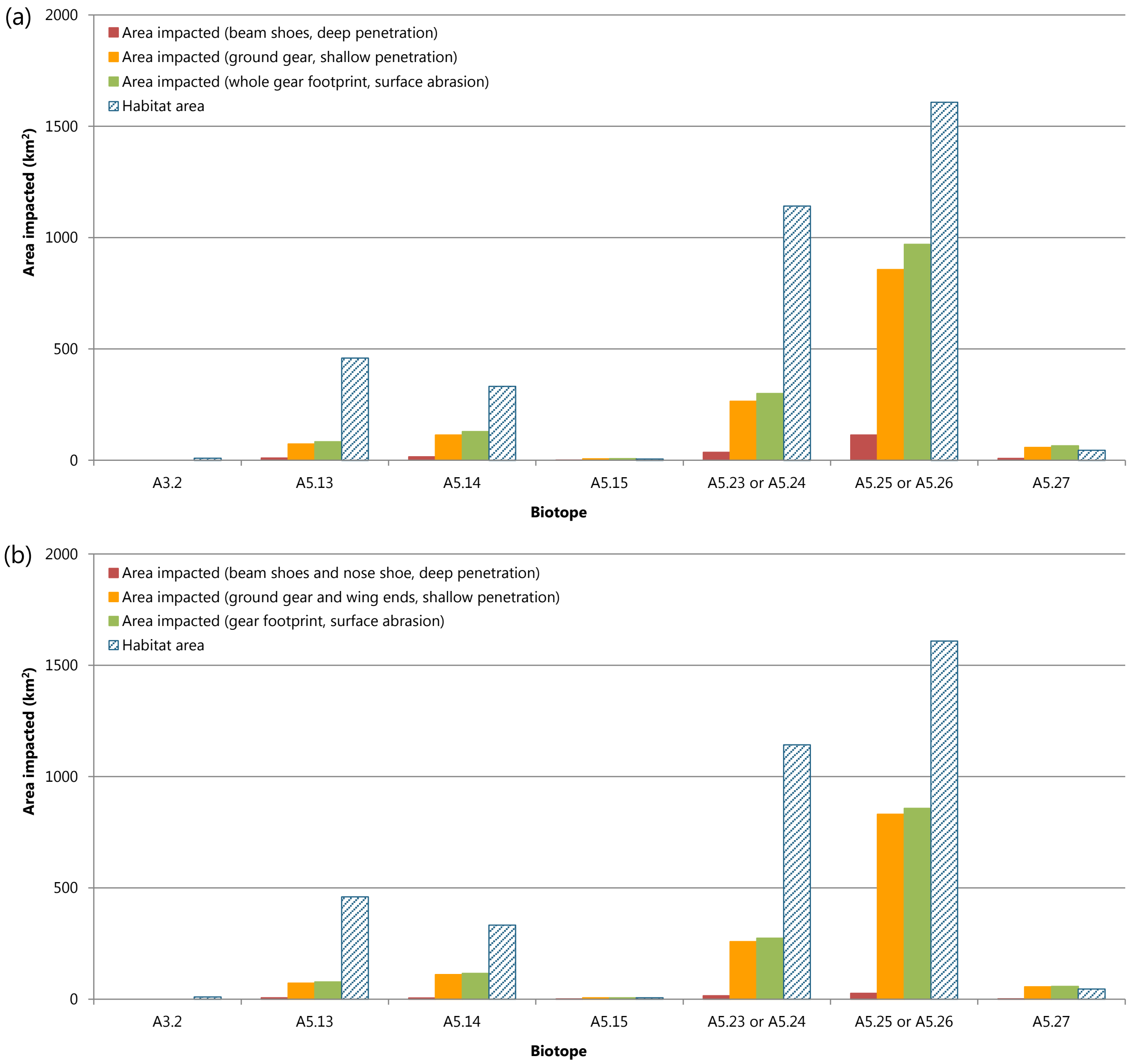


Figure 5.2 **Swept area by gear component (annual average) in relation to biotope area, for over-15m vessels, UK and non-UK combined (a) for scenario 1 (b) for scenario 2**

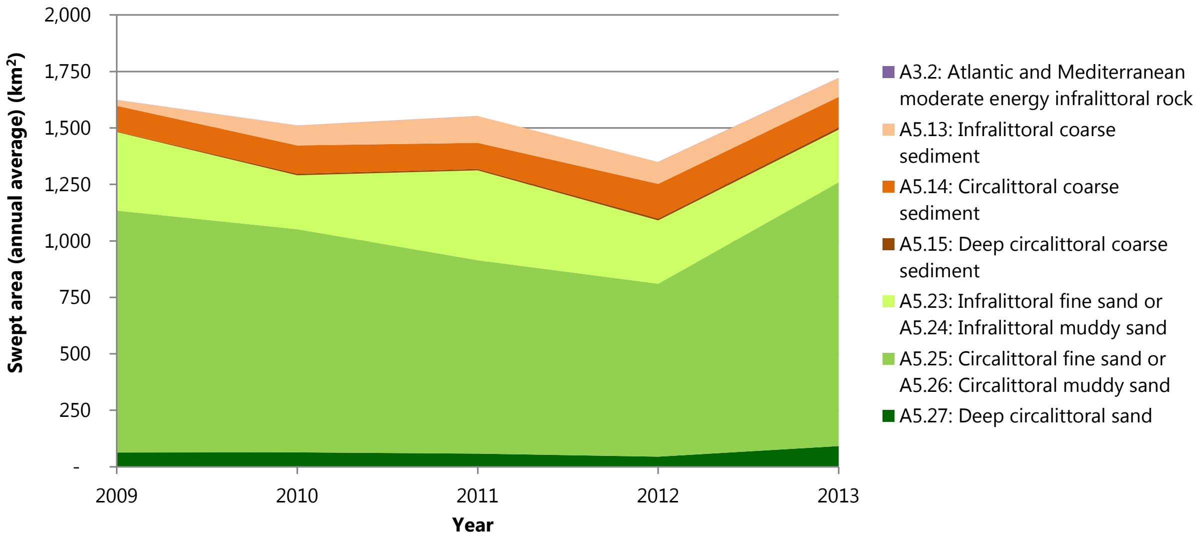


Figure 5.3 **Annual average swept area by habitat type for UK and non-UK vessels (TBB and 'unknown' gear types), assuming conventional beam trawl gear (km^2) (2009–2013)**

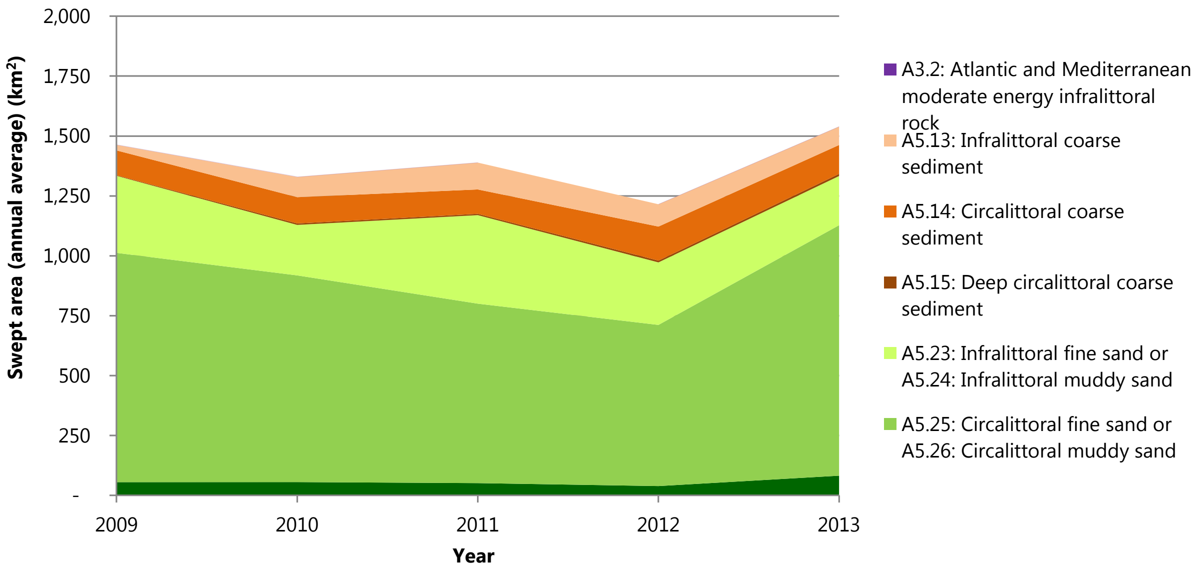


Figure 5.4 **Annual average swept area by habitat type for UK and non-UK vessels (TBB and 'unknown' gear types), assuming conventional beam trawl gear for UK vessels, and pulse wing trawl for non-UK vessels (km^2) (2009–2013)**

Seasonality

Figure 5.5 illustrates the average number of hours fished monthly by UK and non-UK beam trawl vessels between 2009 and 2013 in the site. The effort in terms of hours shows a peak in March and April, and a low in December and January.

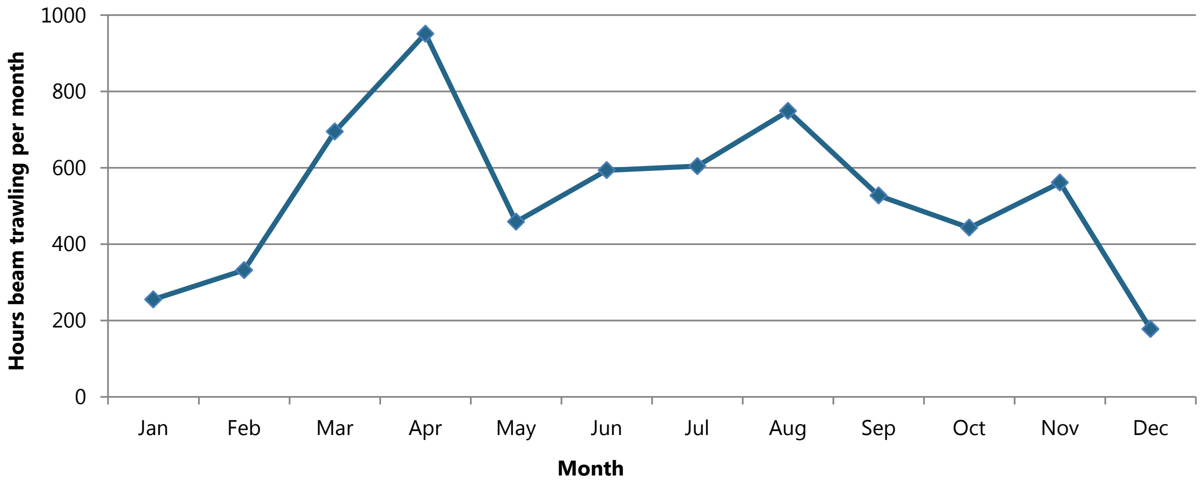


Figure 5.5 Hours trawling by beam trawls per month, over-15m vessels (UK and non-UK, TBB and 'unknown' gears) (average, 2009–2013)

Area impacted by individual gear components, from VMS

The analysis of buffered tracks from VMS ping data for over-15m vessels (see Section 5.2.2) shows that only 39% of the North Norfolk Sandbanks and Saturn Reef SCI habitat area is impacted by over-15m beam trawls over a five-year period, with only 7% being impacted by the beam shoes (Table 24). The impact areas from beam shoes and from ground gear including tickler chains, created from the tracks between VMS fishing pings, are shown in Figure 5.6 (UK vessels) and Figure 5.7 (non-UK vessels).

These figures show the cumulative fishing effort over a five-year period (2009–2013) and show that fishing appears to be concentrated in particular parts of the site, namely the channels between the sandbanks. The buffered VMS tracks that reflect the width of individual gear components show the scale of the fishing activity in relation to the size of the site — it is difficult to see the impact areas from the beam shoes, because the width of the components is so small.

An area of 1,422 km^2 was impacted by the footprint of the beam trawls over the five-year period 2009–2013 (Table 24). This represents 39% of the area of the site. Conversely, 61% of the site was not impacted by beam trawling over the five-year period.

The habitat that was impacted over the largest area was 'circalittoral fine sand or circalittoral muddy sand' (A5.25 or A5.26) (840 km^2 over a five-year period by UK and non-UK vessels combined, or 52% of the habitat area). The habitat 'infralittoral fine sand or infralittoral muddy sand' (A5.23 or A5.24) was impacted over an area of 328 km^2 over the five-year period (31% of the habitat area) (Table 24).

The habitat that was impacted over the largest proportion of its area was 'circalittoral fine sand or circalittoral muddy sand' (see above). 'Deep circalittoral coarse sediment' (A5.15) was impacted over 49% of its area (Table 24).

This indicates that, over a five-year period, 48% of the circalittoral fine sand or circalittoral muddy sand, and 51% of the deep circalittoral sediment, was **not** impacted by beam trawling. Larger proportions of the other biotopes were not impacted over the five-year period (typically 70–85%).

These percentages represent the proportion of each habitat area impacted by the full width of the gear over the five-year period (2009–2013). They do not take account of multiple passes of the gear, i.e. it does not represent the overall swept area by the gear. This is considered in the swept area calculations above, and frequency of impact figures below.

Table 24. Area of each habitat impacted by high and medium impact gear components of over-15m conventional beam trawls (UK and non-UK) in North Norfolk Sandbanks and Saturn Reef SCI from VMS footprint polygons (scenario 1) (2009–2013)

Biotope	Habitat Area (km^2)	Area Impacted					
		Total		Beam Shoes		Ground Gear	
		Area Impacted (km^2)	% Habitat Area	Area Impacted (km^2)	% Habitat Area	Area Impacted (km^2)	% Habitat Area
Moderate energy infralittoral rock	9	0	2%	0	0%	0	1%
Infralittoral coarse sediment	460	82	18%	11	3%	70	15%
Circalittoral coarse sediment	332	110	33%	18	5%	92	28%
Deep circalittoral coarse sediment	6	3	49%	1	9%	2	40%
Infralittoral fine sand or muddy sand	1,142	358	31%	53	5%	306	27%
Circalittoral fine sand or muddy sand	1,609	840	52%	156	10%	683	42%
Deep circalittoral sand	45	30	65%	7	15%	23	50%
Total	**3,603**	**1,422**	**39%**	**246**	**7%**	**1,176**	**33%**

Table 25. Area of each habitat impacted by high and medium impact gear components of over-15m conventional beam trawls (UK) and pulse wing trawls (non-UK) in North Norfolk Sandbanks and Saturn Reef SCI from VMS footprint polygons (scenario 2) (2009–2013)

Biotope	Habitat Area (km^2)	Area Impacted									
		Conventional Beam Trawls				Pulse Wing Trawls					
		Beam Shoes		Ground Gear		Nose Shoe		Ground Gear		Wing Ends	
		Area Impacted (km^2)	% habiTat Area	Area Impacted (km^2)	% Habitat Area	Area Impacted (km^2)	% Habitat Area	Area Impacted (km^2)	% Habitat Area	Area Impacted (km^2)	% Habitat Area
Moderate energy infralittoral rock	9	0	0%	0	0%	0	<0.1%	0.1	2%	0	<0.1%
Infralittoral coarse sediment	460	4	<1%	25	5%	1	<1%	54	12%	1	<1%
Circalittoral coarse sediment	332	2	<1%	13	4%	3	1%	94	28%	1	<1%
Deep circalittoral coarse sediment	6	<1	<1%	<1	2%	<1	2%	3	45%	0	<1%
Infralittoral fine sand or muddy sand	1,142	6	<1%	42	4%	9	1%	310	27%	4	<1%
Circalittoral fine sand or muddy sand	1,609	8	<1%	56	3%	28	2%	767	48%	8	<1%
Deep circalittoral sand	45	<1	<1%	2	5%	1	3%	27	59%	<1	<1%
Total	**3,603**	**20**	**<1%**	**139**	**4%**	**43**	**1%**	**1,256**	**35%**	**14**	**<1%**

Note: Overlaps between the UK conventional beam trawl polygons and the non-UK pulse wing trawl polygons have not been taken into account. The total area impacted is therefore not a sum of the two gear types; the actual area will be less (see Table 24). Within a gear type (conventional beam trawls, or pulse wing trawls), the area impacted by the individual components can be summed to provide the total area for that gear.

When the use of pulse wing trawls is taken into account, the overall distribution of impact across the habitats remains the same (Table 25). The footprint is now predominantly attributable to the ground gear of the pulse wing trawls (35% of the area of the site), with 4% impacted by the conventional beam ground gear, 1% by the pulse wing nose shoe, and less than 1% by the conventional beam shoes and the wing ends. The footprint of the gears on the individual habitats shows a similar shift; the majority of the area impacted relates to the ground gear of the pulse trawls, with small areas attributable to the beam shoes, nose shoe, and the conventional beam trawl ground gear (i.e. tickler chains).

The linking of consecutive VMS pings, which are two hours apart, do not necessarily represent the actual fishing path taken by vessels, and therefore the actual area impacted may be more or less than calculated here. However, the analysis provides a useful measure that more clearly represents the actual area impacted (and consequently, the area not impacted) by the gears. It should be noted that the pings analysed include beam trawl and unknown gear types. Of these, 10% were unknown, and therefore it is possible that the areas have been over-estimated slightly due to the inclusion of unknown gears.

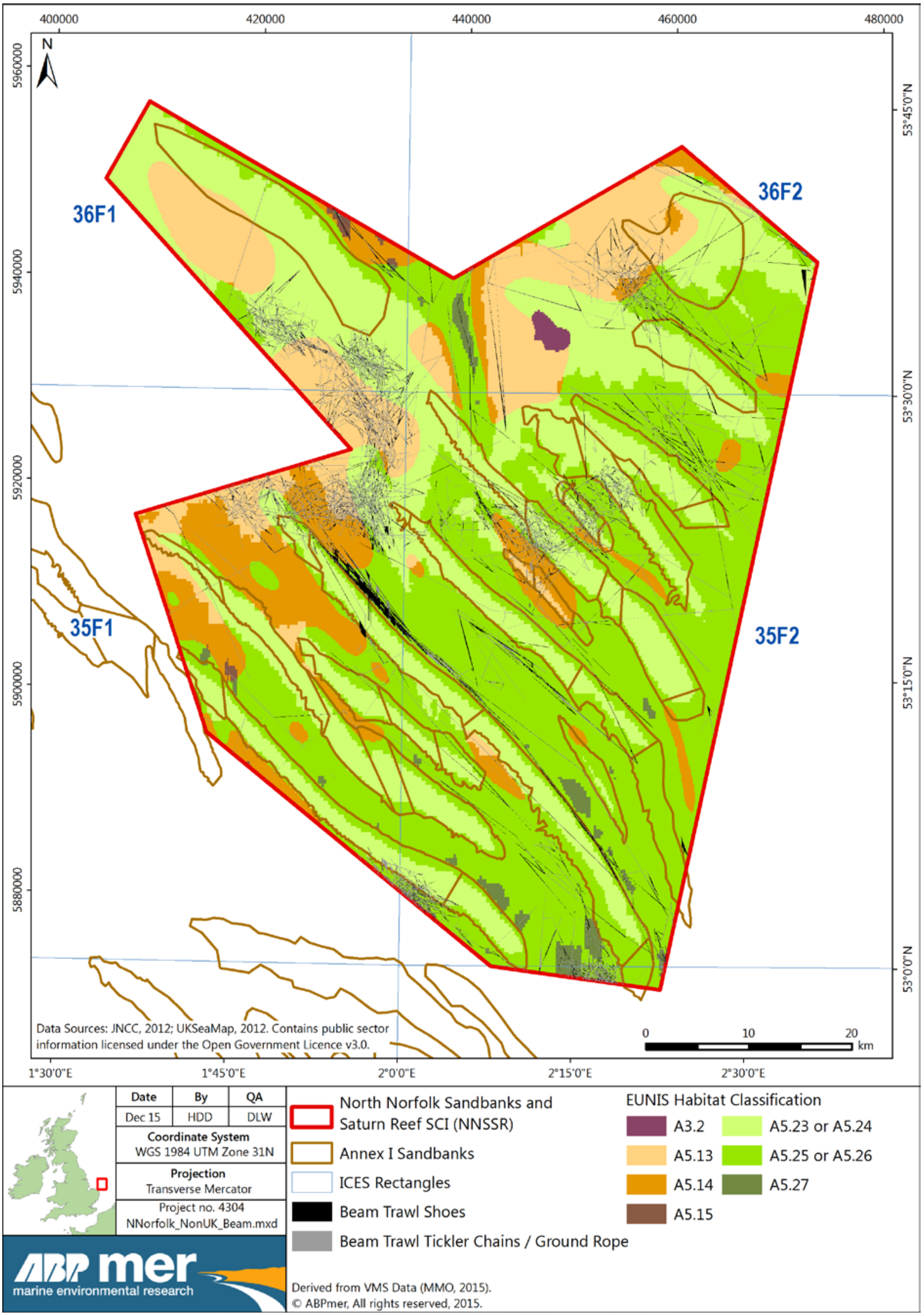


Figure 5.6 VMS footprint polygons of from beam shoes and ground gear by UK beam trawlers in North Norfolk Sandbanks SCI (combining fishing pings from TBB and 'unknown' gear types)

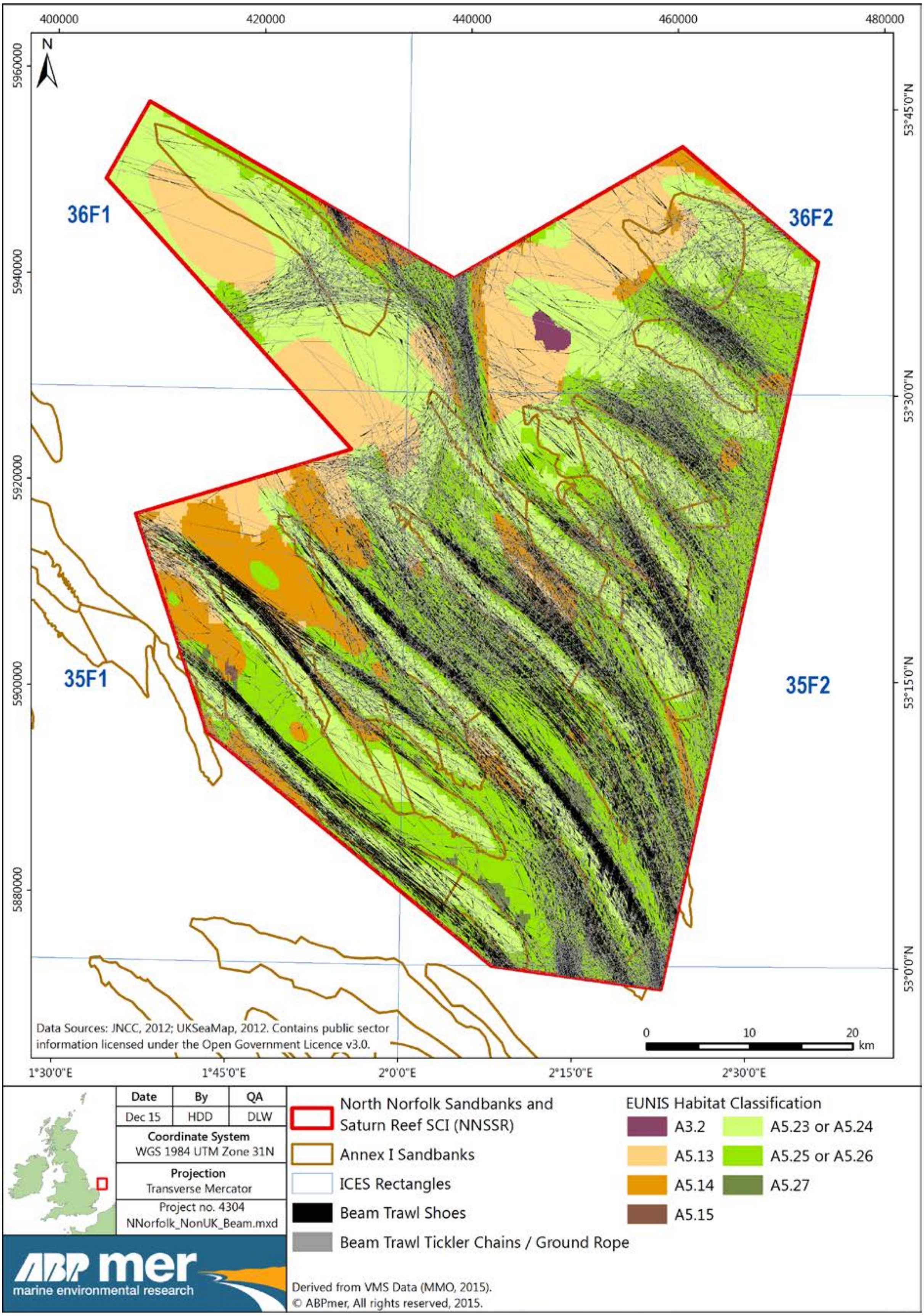


Figure 5.7 VMS footprint polygons from beam shoes and ground gear by non-UK beam trawls in North Norfolk Sandbanks SCI (combining fishing pings from TBB and 'unknown' gear types) (2009–2013)

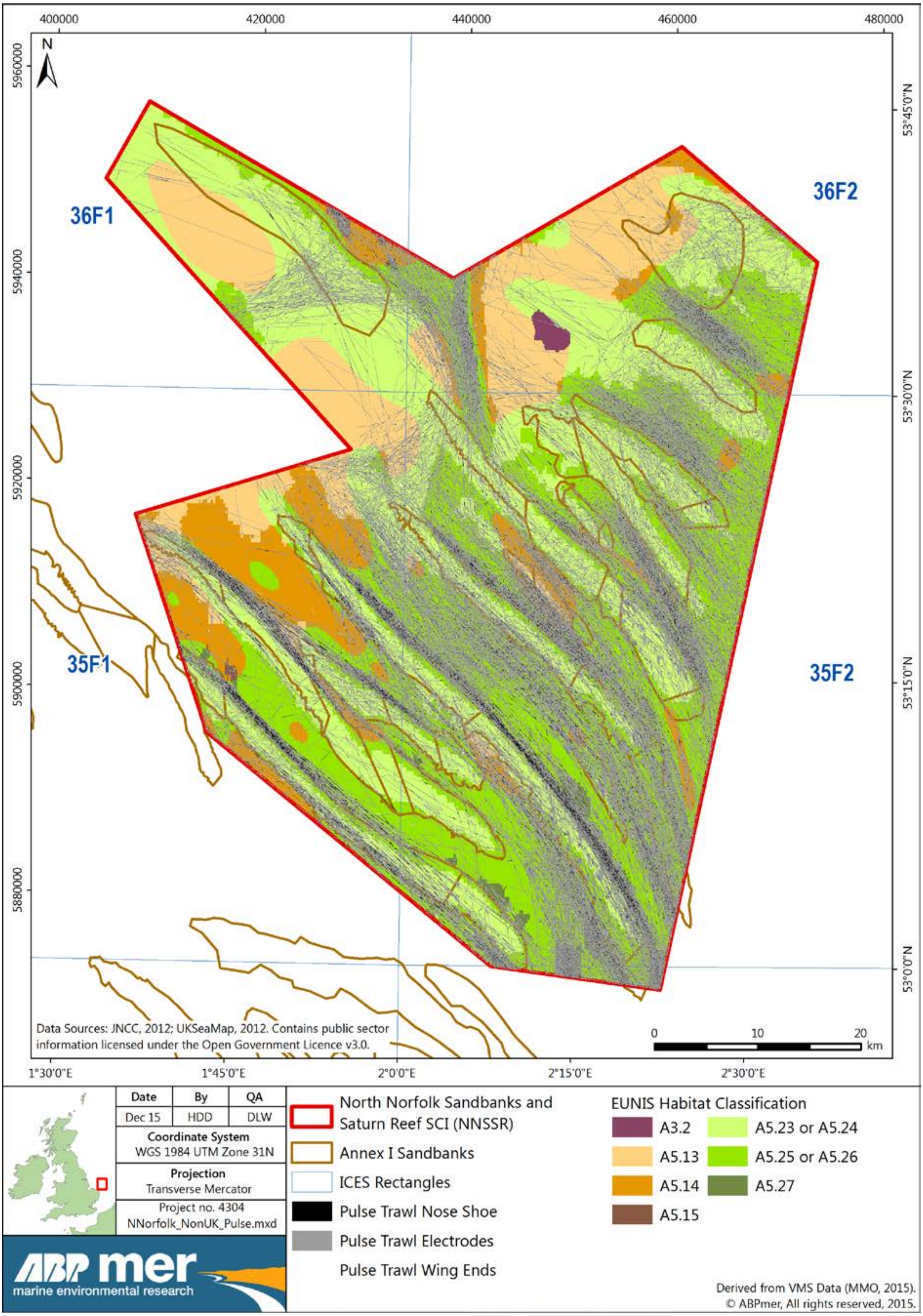


Figure 5.8 **VMS footprint polygons of from nose shoe, and ground gear (electrodes) and wing ends by non-UK pulse wing trawls in North Norfolk Sandbanks SCI (combining fishing pings from TBB and 'unknown' gear types)**

Frequency of impact

The frequency with which certain areas are impacted by beam trawling is shown in Figure 5.9. This shows that parts of the site are not fished at all, and large areas may be trawled less than once per year. There are areas where fishing activity appears to be more concentrated (the channels between the sandbanks). In these areas, trawl frequency is around three to four times per year, with more intensive areas increasing to seven to eight times per year, and the highest area is up to 12–16 times per year. However, this takes place over a very small area.

The seasonal density grids (Figure 5.10) show most activity occurs during March to May, with the least activity from December to February.

To better elucidate the actual frequency of impact, and in response to a comment made at the final project workshop, two small areas of the highest intensity of fishing were picked out for further analysis at a higher spatial resolution. A 25 m by 25 m grid was used, to equate to the swept width of the gear. The results are shown in Figure 5.11 and Figure 5.12. This demonstrates that even for the most intensely fished areas (12–16 trawl passes per year in a 250 m by 250 m grid), the actual frequency of repeated passes of the gear over the same area is likely to be closer to two to three times per year, or once every four to six months.

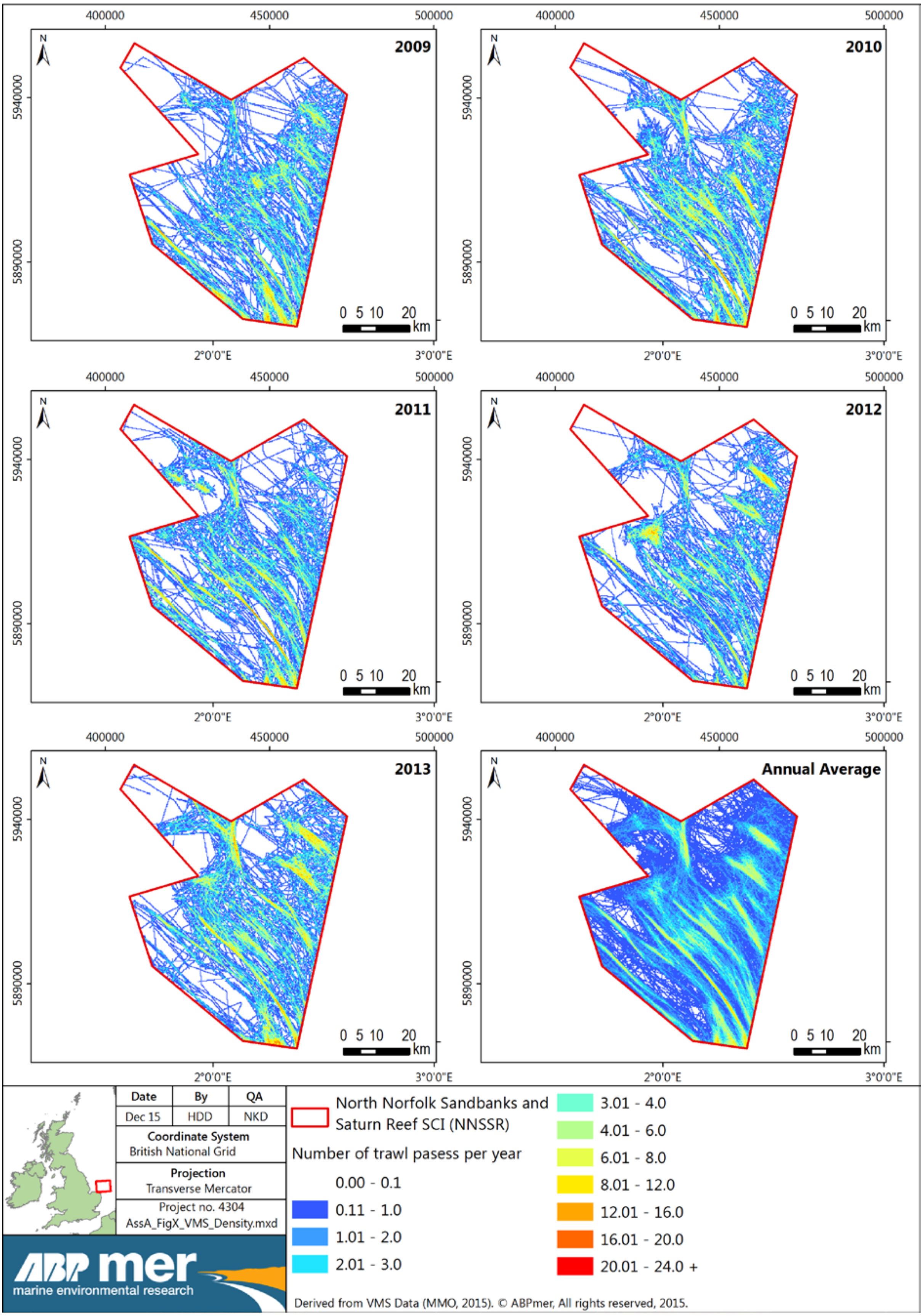


Figure 5.9 **Density grids showing frequency of beam trawl passes, 250 m by 250 m grid (annual, and annual average) (2009–2013)**

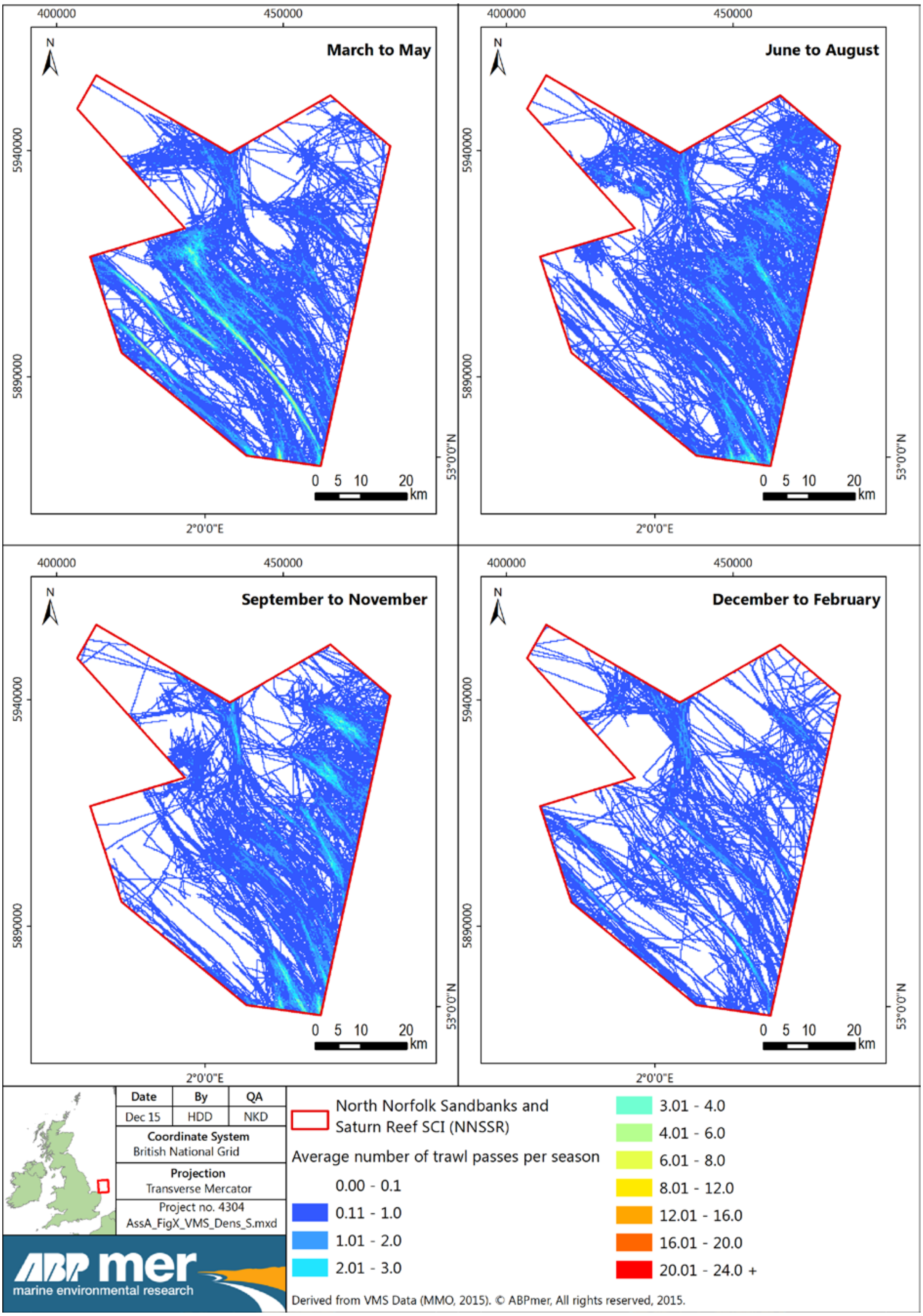


Figure 5.10 Density grids showing frequency of beam trawl passes on a seasonal basis (average number of passes for each three-month period), 250 m by 250 m grid (2009–2013)

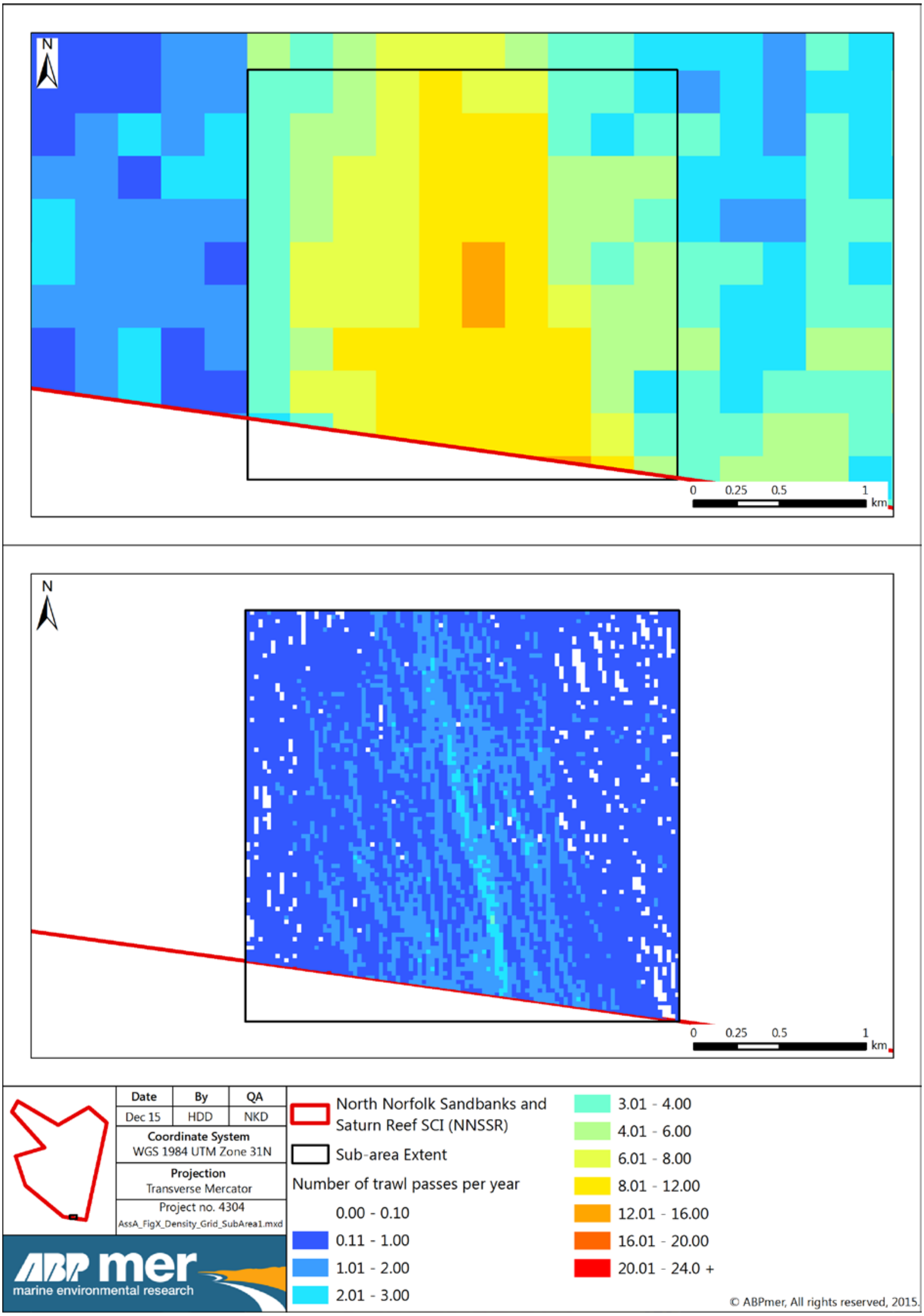


Figure 5.11 **High resolution density grid showing frequency of beam trawl passes, 25 m by 25 m grid (lower), compared to the original 250 m by 250 m grid (upper) (annual average) (2009–2013)**

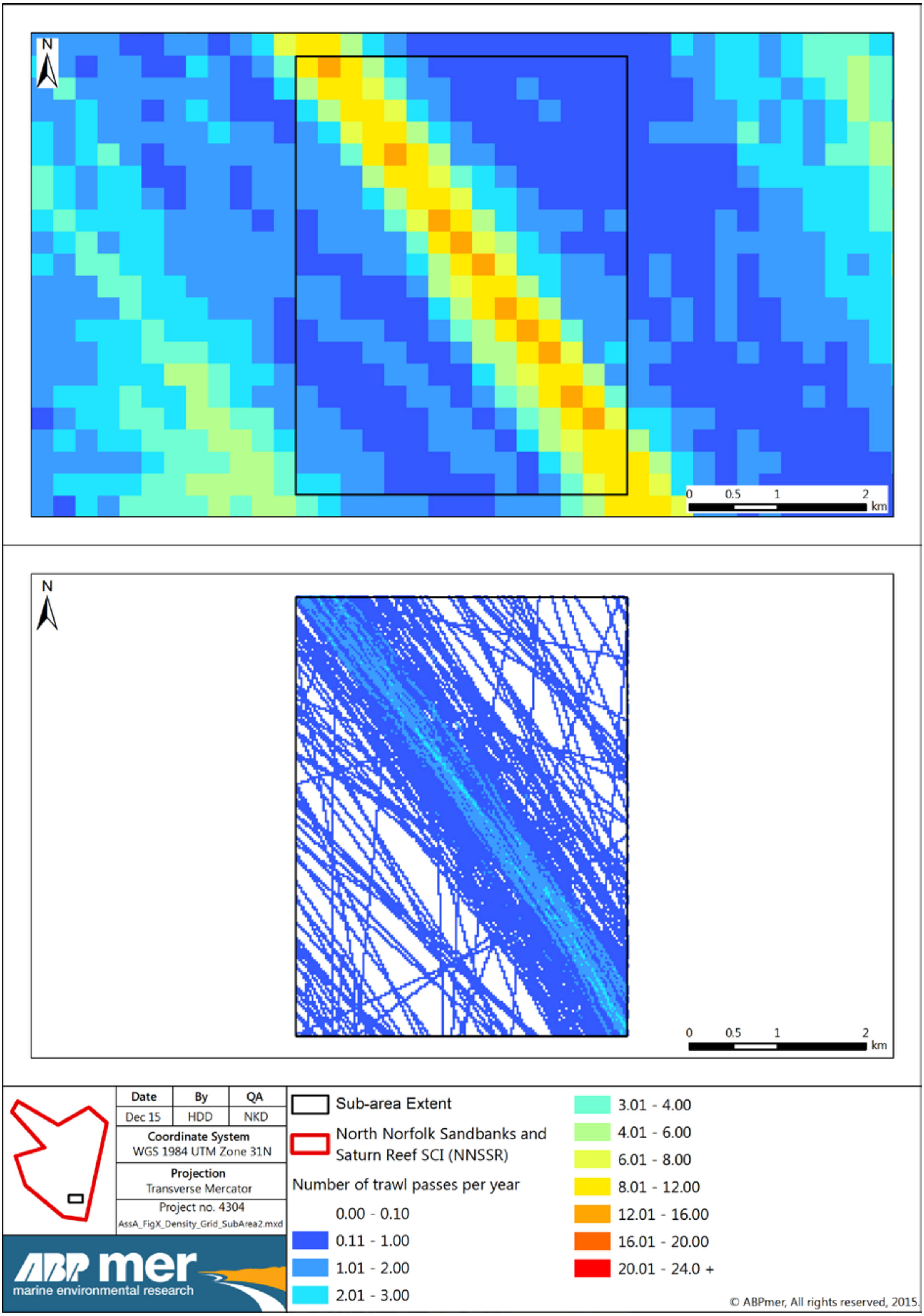


Figure 5.12 High resolution density grid showing frequency of beam trawl passes, 25 m by 25 m grid (lower), compared to the original 250 m by 250 m grid (upper) (annual average) (2009–2013)

5.4.2 Biological disturbance through the selective extraction of species

Exposure to bycatch is assessed by analysing catch from each trawl. There are no studies of bycatch levels from within the site, so it is not possible to fully understand the extraction levels that the sandbanks feature is exposed to. The level of bycatch will depend on the number of hours and area trawled, and therefore the assessment is related to the assessment of surface abrasion, which takes into account the full width of the gear. For conventional beam trawls, the same level of exposure has been given as for surface abrasion, across the gear footprint.

A number of recent studies have analysed levels of bycatch from conventional beam trawls and pulse trawls; these are summarised in Section 3.11. Pulse trawls demonstrate a reduction in unwanted bycatch (of undersized fish and benthos) compared to conventional beam trawls, although this is dependent on the technical specification of the gear and the fishing grounds. Total discards from the experimental pulse trawls were 33% of those from the conventional beam trawl; fish discards in the pulse trawls were 44% of those from the conventional beam trawl; and benthos discards were 62% (van Marlen *et al.*, 2014). There were also reduced catches of undersized plaice (significant) and sole and cod (not significant) in terms of catch per unit area.

Both conventional beam trawls and pulse trawls caught more epifauna than infauna, but the pulse trawls caught relatively more infauna than the beam trawls (Table 26).

Table 26. Catch per unit effort of discards from conventional beam trawling and pulse trawling

Discard Category	Beam Trawl	Pulse Trawl	Pulse as % of Beam	p-Value
Fish	**3,132**	**1,376**	**44**	**<0.001**
- benthic fish	2,837	1,229	43	<0.001
- demersal fish	273	145	53	<0.001
- pelagic fish	22	2	10	0.0069
Benthos	**5,125**	**1,875**	**62**	**<0.001**
- epifauna	5,066	2,921	58	<0.001
- infauna	59	234	397	<0.001

Source: van Marlen *et al.*, 2014.

Therefore the assessment of exposure for pulse trawls is given as less than the exposure to surface abrasion across the gear footprint.

5.4.3 Overall assessment

The exposure assessment in this study has calculated the footprint of the area impacted by beam trawling over a five-year period as 1,422 km^2, with 1,176 km^2 from the ground gear and 246 km^2 from the beam shoes (conventional beam trawls), equating to 39% of the site. Assuming the non-UK vessels are all pulse wing trawls (this more accurately reflects the reality), the area impacted from these is 1,312 km^2, of which 43 km^2 is from the nose shoe (36% and 1% of the site, respectively).

The assessment of the level of exposure of each habitat to each pressure, for scenario 1 and 2, is provided in Table 27.

Table 27. Summary of exposure assessment for each habitat and pressure, for scenarios 1 and 2

Habitat	Pressure	Scenario 1	Exposure	Scenario 2	Exposure
Moderate energy infralittoral rock	Surface abrasion (across gear footprint)	Swept area: not exposed. Footprint 2% of biotope area. **Apparent VMS footprint likely to be an artefact of creation of tracks between pings**	None	Swept area: not exposed. Footprint 2% of biotope area. **Apparent VMS footprint likely to be an artefact of creation of tracks between pings**	None
	Physical damage – shallow disturbance (beam trawl and pulse trawl ground gear)	Swept area: not exposed. Footprint 1% of biotope area. **Apparent VMS footprint likely to be an artefact of creation of tracks between pings**	None	Swept area: not exposed. Footprint 2% of biotope area. **Apparent VMS footprint likely to be an artefact of creation of tracks between pings**	None
	Physical damage – deep disturbance (beam shoes or pulse trawl nose shoe)	Swept area: not exposed. Footprint <1% of biotope area. **Apparent VMS footprint likely to be an artefact of creation of tracks between pings**	None	Swept area: not exposed. Footprint <0.1% of biotope area. **Apparent VMS footprint likely to be an artefact of creation of tracks between pings**	None
	Siltation	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	None	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	None
	Biological extraction of species	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels can be high, therefore the exposure is given as the same as the surface abrasion exposure.	None	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels in pulse trawls is lower than beam trawls, therefore the exposure is given as less than the surface abrasion exposure.	None
	Electromagnetic changes	N/a for conventional beam trawls	None	Exposure is a function of the amount of fishing, therefore same level of exposure as shallow disturbance (the footprint of the electrode ground gear)	None
Infralittoral coarse sediment	Surface abrasion (across gear footprint)	Swept area 18% of biotope area. Footprint 18% of biotope area. Frequency of disturbance 0–1 times per year (in a 250m by 250m area).	Moderate	Swept area 17% of biotope area. Footprint 19% of biotope area. Frequency of disturbance 0–1 times per year (in a 250m by 250m area).	Moderate
	Physical damage – shallow disturbance (beam trawl and pulse trawl ground gear)	Swept area 16% of biotope area. Footprint 15% of biotope area.	Moderate	Swept area 17% of biotope area. Footprint 17% of biotope area.	Moderate
	Physical damage – deep disturbance (beam shoes or pulse trawl nose shoe)	Swept area is 2% of biotope area. Footprint is 3% of biotope area.	Low	Swept area 1% of biotope area. Footprint 1% of biotope area.	Low
	Siltation	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate

Habitat	Pressure	Scenario 1	Exposure	Scenario 2	Exposure
	Biological extraction of species	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels can be high, therefore the exposure is given as the same as the surface abrasion exposure.	Moderate	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels in pulse trawls is lower than beam trawls, therefore the exposure is given as less than the surface abrasion exposure.	Low
	Electromagnetic changes	N/a for conventional beam trawls	None	Exposure is a function of the amount of fishing, therefore same level of exposure as shallow disturbance (the footprint of the electrode ground gear)	Moderate
Circalittoral coarse sediment	Surface abrasion (across gear footprint)	Swept area 39% of biotope area. Footprint 33% of biotope area. Frequency of disturbance 0–2 times per year(in a 250m by 250m area).	Moderate	Swept area 35% of biotope area. Footprint 34% of biotope area. Frequency of disturbance 0–2 times per year (in a 250m by 250m area).	Moderate
	Physical damage – shallow disturbance (beam trawl and pulse trawl ground gear)	Swept area 34% of biotope area. Footprint 28% of biotope area.	Moderate	Swept area 33% of biotope area. Footprint 33% of biotope area.	Moderate
	Physical damage – deep disturbance (beam shoes or pulse trawl nose shoe)	Swept area is 5% of biotope area. Footprint is 5% of biotope area.	Low	Swept area 2% of biotope area. Footprint 1% of biotope area.	Low
	Siltation	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate
	Biological extraction of species	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels can be high, therefore the exposure is given as the same as the surface abrasion exposure.	Moderate	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels in pulse trawls is lower than beam trawls, therefore the exposure is given as less than the surface abrasion exposure.	Low
	Electromagnetic changes	N/a for conventional beam trawls	None	Exposure is a function of the amount of fishing, therefore same level of exposure as shallow disturbance (the footprint of the electrode ground gear)	Moderate
Deep circalittoral coarse sediment	Surface abrasion (across gear footprint)	Swept area 109% of biotope area. Footprint 49% of biotope area. Frequency of disturbance 2–3 times per year (in a 250m by 250m area). Swept area is high but footprint is considerably less, therefore exposure is moderate.	Moderate	Swept area 95% of biotope area. Footprint 50% of biotope area. Frequency of disturbance 2–3 times per year (in a 250m by 250m area). Swept area is high but footprint is considerably less, therefore exposure is moderate.	Moderate

Habitat	Pressure	Scenario 1	Exposure	Scenario 2	Exposure
	Physical damage – shallow disturbance (beam trawl and pulse trawl ground gear)	Swept area 96% of biotope area. Footprint 40% of biotope area. Swept area is high but footprint is considerably less, therefore exposure is moderate.	Moderate	Swept area 93% of biotope area. Footprint 48% of biotope area. Swept area is high but footprint is considerably less, therefore exposure is moderate.	Moderate
	Physical damage – deep disturbance (beam shoes or pulse trawl nose shoe)	Swept area is 13% of biotope area. Footprint is 9% of biotope area.	Low	Swept area 2% of biotope area. Footprint 2% of biotope area.	Low
	Siltation	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate
	Biological extraction of species	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels can be high, therefore the exposure is given as the same as the surface abrasion exposure.	Moderate	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels in pulse trawls is lower than beam trawls, therefore the exposure is given as less than the surface abrasion exposure.	Low
	Electromagnetic changes	N/a for conventional beam trawls	None	Exposure is a function of the amount of fishing, therefore same level of exposure as shallow disturbance (the footprint of the electrode ground gear)	Moderate
Infralittoral fine sand or Infralittoral muddy sand	Surface abrasion (across gear footprint)	Swept area 26% of biotope area. Footprint 31% of biotope area. Frequency of disturbance mostly 0–1 times per year, some areas up to 3 times per year (in a 250m by 250m area).	Moderate	Swept area 24% of biotope area. Footprint 32% of biotope area. Frequency of disturbance mostly 0–1 times per year, some areas up to 3 times per year (in a 250m by 250m area).	Moderate
	Physical damage – shallow disturbance (beam trawl and pulse trawl ground gear)	Swept area 23% of biotope area. Footprint 27% of biotope area.	Moderate	Swept area 23% of biotope area. Footprint 31% of biotope area.	Moderate
	Physical damage – deep disturbance (beam shoes or pulse trawl nose shoe)	Swept area is 3% of biotope area. Footprint is 5% of biotope area.	Low	Swept area 1% of biotope area. Footprint 1% of biotope area.	Low
	Siltation	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate
	Biological extraction of species	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels can be high, therefore the exposure is given as the same as the surface abrasion exposure.	Moderate	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels in pulse trawls is lower than beam trawls, therefore the exposure is given as less than the surface abrasion exposure.	Low

Habitat	Pressure	Scenario 1	Exposure	Scenario 2	Exposure
	Electromagnetic changes	N/a for conventional beam trawls	None	Exposure is a function of the amount of fishing, therefore same level of exposure as shallow disturbance (the footprint of the electrode ground gear)	Moderate
Circalittoral fine sand or Circalittoral muddy sand	Surface abrasion (across gear footprint)	Swept area 60% of biotope area. Footprint 52% of biotope area. Frequency of disturbance varies; many areas not impacted or impacted only once per year, more regularly fished areas around three times per year, small areas up to 16 times per year (passes of a 24m gear within a 250m by 250m area), or 2–3 times per year in a 25m by 25m area.	Moderate	Swept area 53% of biotope area. Footprint 54% of biotope area. Frequency of disturbance varies; many areas not impacted or impacted only once per year, more regularly fished areas around three times per year, small areas up to 16 times per year (passes of a 24m gear within a 250m by 250marea), or 2–3 times per year in a 25m by 25m area.	Moderate
	Physical damage – shallow disturbance (beam trawl and pulse trawl ground gear)	Swept area 53% of biotope area. Footprint 42% of biotope area.	Moderate	Swept area 52% of biotope area. Footprint 52% of biotope area.	Moderate
	Physical damage – deep disturbance (beam shoes or pulse trawl nose shoe)	Swept area is 7% of biotope area. Footprint is 10% of biotope area.	Low	Swept area 2% of biotope area. Footprint 2% of biotope area.	Low
	Siltation	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate
	Biological extraction of species	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels can be high, therefore the exposure is given as the same as the surface abrasion exposure.	Moderate	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels in pulse trawls is lower than beam trawls, therefore the exposure is given as less than the surface abrasion exposure.	Low
	Electromagnetic changes	N/a for conventional beam trawls	None	Exposure is a function of the amount of fishing, therefore same level of exposure as shallow disturbance (the footprint of the electrode ground gear)	Moderate
Deep circalittoral sand	Surface abrasion (across gear footprint)	Swept area 142% of biotope area. Footprint 65% of biotope area. Frequency of disturbance varies from zero to 12-16 times per year (in a 250m by 250m area), or 2–3 times per year in a 25m by 25m area. Swept area is high but footprint is considerably less, therefore exposure is moderate.	Moderate	Swept area 125% of biotope area. Footprint 68% of biotope area. Frequency of disturbance varies from zero to 12-16 times per year (in a 250m by 250m area), or 2–3 times per year in a 25m by 25m area. Swept area is high but footprint is considerably less, therefore exposure is moderate.	Moderate

Habitat	Pressure	Scenario 1	Exposure	Scenario 2	Exposure
	Physical damage – shallow disturbance (beam trawl and pulse trawl ground gear)	Swept area 125% of biotope area. Footprint 50% of biotope area. Swept area is high but footprint is considerably less, therefore exposure is moderate.	Moderate	Swept area 121% of biotope area. Footprint 65% of biotope area. Swept area is high but footprint is considerably less, therefore exposure is moderate.	Moderate
	Physical damage – deep disturbance (beam shoes or pulse trawl nose shoe)	Swept area is 17% of biotope area. Footprint is 15% of biotope area.	Moderate	Swept area 4% of biotope area. Footprint 4% of biotope area.	Low
	Siltation	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate	The amount of siltation will be a function of the amount of fishing and is therefore given the same level of exposure as surface abrasion.	Moderate
	Biological extraction of species	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels can be high, therefore the exposure is given as the same as the surface abrasion exposure.	Moderate	Removal of non-target species is a function of the level of bycatch per haul, and the amount of fishing. Bycatch levels in pulse trawls is lower than beam trawls, therefore the exposure is given as less than the surface abrasion exposure.	Low
	Electromagnetic changes	N/a for conventional beam trawls.	None	Exposure is a function of the amount of fishing, therefore same level of exposure as shallow disturbance (the footprint of the electrode ground gear).	Moderate

5.5 Vulnerability and Overall Assessment

Based on the assessments of sensitivity and exposure of each habitat, in relation to the pressures exerted by individual gear components, it is assessed that those habitats with a low or moderate vulnerability to beam trawling impacts are:

- Under scenario 1 (Table 28):
  - Shallow and deep disturbance on all habitats — low vulnerability, except for deep disturbance on deep circalittoral sand which is assessed as moderate vulnerability;
  - Biological disturbance through removal of target and non-target species for all habitats — low vulnerability.

- Under scenario 2 (Table 29):
  - Shallow and deep disturbance on all habitats — low vulnerability.

Scenario 2 (assessing non-UK vessels as pulse wing trawls) results in lower vulnerability due to the lower benthic impacts of the pulse gear, and lower levels of bycatch of pulse trawls compared to conventional beam trawls.

It is understood that, as a 'red risk' interaction in the Matrix, the potential impact of beam trawling on *Sabellaria* reef will be addressed as a priority, and therefore this assessment has focussed on the sandbank habitats.

The sensitivity of all habitats has been assessed as 'not sensitive' to electromagnetic changes, resulting in an assessment of not vulnerable. However, there is insufficient information to make a full assessment of the *in-situ* effects of pulse trawling. 'Trawl path mortality' studies are planned and/or underway by IMARES in the Netherlands, but results are not yet available.

A summary is provided in Table 30.

Table 28. Summary of sensitivity, exposure and vulnerability – Scenario 1

Biotope	Impact Pathway	Sensitivity	Exposure	Vulnerability
Infralittoral coarse sediment	Surface abrasion	Not sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Low	Low
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	None	Not vulnerable
	Removal of target and non-target species	Low	Moderate	Low
Circalittoral coarse sediment	Surface abrasion	Not sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Low	Low
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	None	Not vulnerable
	Removal of target and non-target species	Low	Moderate	Low
Deep circalittoral coarse sediment	Surface abrasion	Not Sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Low	Low
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	None	Not vulnerable
	Removal of target and non-target species	Low	Moderate	Low
Infralittoral fine sand or infralittoral muddy sand	Surface abrasion	Not Sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Low	Low
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	None	Not vulnerable
	Removal of target and non-target species	Low	Moderate	Low
Circalittoral fine sand or circalittoral muddy sand	Surface abrasion	Not sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Low	Low
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	None	Not vulnerable
	Removal of target and non-target species	Low	Moderate	Low
Deep circalittoral sand	Surface abrasion	Not Sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Moderate	Moderate
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	None	Not vulnerable
	Removal of target and non-target species	Low	Moderate	Low

Table 29. Summary of sensitivity, exposure and vulnerability – Scenario 2

Biotope	Impact Pathway	Sensitivity	Exposure	Vulnerability
Infralittoral coarse sediment	Surface abrasion	Not sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Low	Low
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	Moderate	Not vulnerable
	Removal of target and non-target species	Low	Low	Not vulnerable
Circalittoral coarse sediment	Surface abrasion	Not sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Low	Low
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	Moderate	Not vulnerable
	Removal of target and non-target species	Low	Low	Not vulnerable
Deep circalittoral coarse sediment	Surface abrasion	Not Sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Low	Low
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	Moderate	Not vulnerable
	Removal of target and non-target species	Low	Low	Not vulnerable
Infralittoral fine sand or infralittoral muddy sand	Surface abrasion	Not Sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Low	Low
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	Moderate	Not vulnerable
	Removal of target and non-target species	Low	Low	Not vulnerable
Circalittoral fine sand or circalittoral muddy sand	Surface abrasion	Not sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Low	Low
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	Moderate	Not vulnerable
	Removal of target and non-target species	Low	Low	Not vulnerable
Deep circalittoral sand	Surface abrasion	Not Sensitive	Moderate	Not vulnerable
	Shallow disturbance	Low	Moderate	Low
	Deep disturbance	Not sensitive – Medium	Low	Low
	Changes in suspended sediment	Not Sensitive	Moderate	Not vulnerable
	Electromagnetic changes	Not Sensitive	Moderate	Not vulnerable
	Removal of target and non-target species	Low	Low	Not vulnerable

Table 30. Summary of impacts

Feature/Sub Feature(s)	Conser-vation Objective	Potential Pressure (Such as Abrasion, Disturbance) Exerted by Beam Trawling	Potential Ecological Impacts of Pressure Exerted by the Activity/Activities on the Feature	Sensitivity	Level of Exposure of Feature to Pressure	Vulnerability Assessment	Mitigation Measures
Subtidal sandbanks: coarse sediment (infralittoral, circalittoral and deep)	Restore	Physical damage – surface abrasion (from ground gear of trawls)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Habitats are not sensitive to surface abrasion. Species are often infaunal. They are characteristic of high-energy, wave-disturbed environments, and have high recovery rates.	Exposure is moderate under both scenarios.	Not vulnerable under both scenarios.	Not required as not vulnerable.
		Physical damage – shallow disturbance (from ground gear and electrodes)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Habitats have low sensitivity to shallow disturbance. The high levels of natural disturbance in the site mean any topographic changes will be rapidly infilled. Species are adapted to living in wave-disturbed environments and have high recovery rates.	Exposure is moderate under both scenarios.	Low vulnerability under both scenarios.	Unlikely to be necessary due to low vulnerability and high levels of natural disturbance. Mitigation options include: ▪ Do nothing; ▪ Reduce/limit pressure; and/or ▪ Remove/avoid pressure. Reducing or limiting the pressure could be achieved by reducing beam trawling activity across the site; closing some areas to beam trawling; or implementing gear modifications that further reduce benthic impacts, however, much has already been achieved through for example increasing the surface area of beam shoes to reduce penetration, adopting the SumWing gear to reduce benthic impacts.
		Physical damage – deep disturbance (from beam shoes and nose shoe)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Habitats have low to medium sensitivity to deep disturbance. High levels of natural disturbance; species adapted to living in wave-disturbed environments and have high recovery rates. As the species are not described a	Exposure is low under both scenarios.	Low vulnerability under both scenarios.	Unlikely to be necessary due to low vulnerability and high levels of natural disturbance. Mitigation options include: ▪ Do nothing; ▪ Reduce/limit pressure; and/or ▪ Remove/avoid pressure. Reducing or limiting the pressure could be achieved by reducing beam trawling activity across the site; closing some areas to beam trawling; or implementing gear modifications

Feature/Sub Feature(s)	Conser-vation Objective	Potential Pressure (Such as Abrasion, Disturbance) Exerted by Beam Trawling	Potential Ecological Impacts of Pressure Exerted by the Activity/Activities on the Feature	Sensitivity	Level of Exposure of Feature to Pressure	Vulnerability Assessment	Mitigation Measures
				precautionary sensitivity assessment of low to medium is given.			that further reduce benthic impacts, however, much has already been achieved through for example increasing the surface area of beam shoes to reduce penetration, adopting the SumWing gear to reduce benthic impacts.
		Changes in suspended sediment (from sediment resuspended by hydrodynamic forces from passage of gear)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Not sensitive to changes in suspended sediment concentrations. Species are adapted to high energy, wave-disturbed environments and are adapted to regular burial by sediments.	Exposure is moderate under both scenarios.	Not vulnerable under both scenarios.	Not required as not vulnerable.
		Electromagnetic changes (from electrical pulse, pulse gear only)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Assessed as not sensitive to electromagnetic changes. Characterising species are small and infaunal and therefore will not be subject to high field strengths. However, there is uncertainty in the effects of repeated exposure and of the fate of organisms in the trawl path.	Not exposed under scenario 1; moderate exposure under scenario 2.	Not vulnerable under scenario 1 (due to not exposed). Not vulnerable under scenario 2 (due to not sensitive), but uncertainty over *in situ* effects and repeated exposure.	Under scenario 2 (most closely relates to current situation), further research is needed on whether electrical pulse gear may be causing a negative impact or not. Mitigation options include: ▪ Do nothing; ▪ Reduce/limit pressure; and/or ▪ Remove/avoid pressure. Reducing or limiting the pressure could be achieved by reducing pulse trawling activity across the site; closing some areas to pulse trawling; or restricting the voltage and frequency of pulse that can be used in the site. Restricting the use of pulse trawling may result in a return to higher levels of conventional beam trawling, with higher physical benthic impacts.
		Removal of target and non-target species (from catch and bycatch of organisms in the trawl net)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Low sensitivity, species associated with the habitat may be a potential food source for the target species.	Exposure is moderate under scenario 1, and low under scenario 2 due to the	Low vulnerability for scenario 1. Not vulnerable for scenario 2.	Not required under scenario 2 as not vulnerable.

Feature/Sub Feature(s)	Conser-vation Objective	Potential Pressure (Such as Abrasion, Disturbance) Exerted by Beam Trawling	Potential Ecological Impacts of Pressure Exerted by the Activity/Activities on the Feature	Sensitivity	Level of Exposure of Feature to Pressure	Vulnerability Assessment	Mitigation Measures
					lower levels of bycatch from pulse trawls.		
Subtidal sandbanks: infralittoral fine sand or muddy sand	Restore	Physical damage – surface abrasion (from ground gear of trawls)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Habitats are not sensitive to surface abrasion. Species are often infaunal. They are characteristic of high energy, wave-disturbed environments, and have high recovery rates.	Moderate under both scenarios.	Not vulnerable under both scenarios.	Not required as not vulnerable.
		Physical damage – shallow disturbance (from ground gear and electrodes)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Habitats have low sensitivity to shallow disturbance. The high levels of natural disturbance in the site mean any topographic changes will be rapidly infilled. Species are adapted to living in wave-disturbed environments and have high recovery rates.	Moderate under both scenarios.	Low under both scenarios.	Not required as not vulnerable.
		Physical damage – deep disturbance (from beam shoes and nose shoe)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Habitats have low to medium sensitivity to deep disturbance. High levels of natural disturbance; species adapted to living in wave-disturbed environments and have high recovery rates. As the species are not described a precautionary sensitivity assessment of low to medium is given.	Low under both scenarios.	Low under both scenarios.	Unlikely to be necessary due to low vulnerability and high levels of natural disturbance. See mitigation measures options for deep disturbance for sublittoral coarse sediments.

Feature/Sub Feature(s)	Conser-vation Objective	Potential Pressure (Such as Abrasion, Disturbance) Exerted by Beam Trawling	Potential Ecological Impacts of Pressure Exerted by the Activity/Activities on the Feature	Sensitivity	Level of Exposure of Feature to Pressure	Vulnerability Assessment	Mitigation Measures
		Changes in suspended sediment (from sediment resuspended by hydrodynamic forces from passage of gear)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Habitats are not sensitive to changes in suspended sediment concentrations. Species are adapted to high energy, wave-disturbed environments and are adapted to regular burial by sediments.	Moderate under both scenarios.	Not vulnerable under both scenarios.	Not required as not vulnerable.
		Electromagnetic changes (from electrical pulse, pulse gear only)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Assessed as not sensitive to electromagnetic changes. Characterising species are small and infaunal and therefore will not be subject to high field strengths. However, there is uncertainty in the effects of repeated exposure and of the fate of organisms in the trawl path.	None under scenario 1; moderate under scenario 2.	Not vulnerable under both scenarios.	Further research is needed on whether electrical pulse gear may be causing a negative impact or not. See mitigation measures for electromagnetic changes for sublittoral coarse sediment.
		Removal of target and non-target species (from catch and bycatch of organisms in the trawl net)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Low sensitivity, species associated with the habitat may be a potential food source for the target species.	Moderate under scenario1; Low under scenario 2.	Low under scenario 1; not vulnerable under scenario 2.	Not required under scenario 2 (most similar to current situation) as not vulnerable.
Subtidal sandbanks: circalittoral fine sand or muddy sand (including deep)	Restore	Physical damage – surface abrasion (from ground gear of trawls)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Habitats are not sensitive to surface abrasion. Species are often infaunal. They are characteristic of high-energy, wave-disturbed environments, and have high recovery rates.	Moderate under both scenarios.	Not vulnerable under both scenarios.	Not required as not vulnerable.

Feature/Sub Feature(s)	Conser-vation Objective	Potential Pressure (Such as Abrasion, Disturbance) Exerted by Beam Trawling	Potential Ecological Impacts of Pressure Exerted by the Activity/Activities on the Feature	Sensitivity	Level of Exposure of Feature to Pressure	Vulnerability Assessment	Mitigation Measures
		Physical damage – shallow disturbance (from ground gear and electrodes)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Habitats have low sensitivity to shallow disturbance. The high levels of natural disturbance in the site mean any topographic changes will be rapidly infilled. Species are adapted to living in wave-disturbed environments and have high recovery rates.	Moderate under both scenarios.	Low under both scenarios.	Unlikely to be necessary due to low vulnerability and high levels of natural disturbance. See mitigation measures options for shallow disturbance for sublittoral coarse sediments.
		Physical damage – deep disturbance (from beam shoes and nose shoe)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Habitats have low to medium sensitivity to deep disturbance. High levels of natural disturbance; species adapted to living in wave-disturbed environments and have high recovery rates. As the species are not described a precautionary sensitivity assessment of low to medium is given.	Low (moderate for deep circalittoral sand under scenario 1 only)	Moderate under scenario 1. Low under scenario 2.	Scenario 2 best reflects current fishing practices in the sites. Unlikely to be necessary due to low vulnerability and high levels of natural disturbance. See mitigation measures options for deep disturbance for sublittoral coarse sediments.
		Changes in suspended sediment (from sediment resuspended by hydrodynamic forces from passage of gear)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Habitats are not sensitive to changes in suspended sediment concentrations. Species are adapted to high energy, wave-disturbed environments and are adapted to regular burial by sediments.	Moderate under both scenarios.	Not vulnerable under both scenarios.	Not required as not vulnerable.

Feature/Sub Feature(s)	Conser-vation Objective	Potential Pressure (Such as Abrasion, Disturbance) Exerted by Beam Trawling	Potential Ecological Impacts of Pressure Exerted by the Activity/Activities on the Feature	Sensitivity	Level of Exposure of Feature to Pressure	Vulnerability Assessment	Mitigation Measures
		Electromagnetic changes (from electrical pulse, pulse gear only)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Assessed as not sensitive to electromagnetic Moderate changes. Characterising species are small and infaunal and therefore will not be subject to high field strengths. However, there is uncertainty in the effects of repeated exposure and of the fate of organisms in the trawl path.	None under scenario 1; moderate under scenario 2.	Not vulnerable under both scenarios.	Further research is needed on whether electrical pulse gear may be causing a negative impact or not. See mitigation measures for electromagnetic changes for sublittoral coarse sediment.
		Removal of target and non-target species (from catch and bycatch of organisms in the trawl net)	Potential changes to physical structure, diversity, community structure and typical species representative of the habitat	Low sensitivity, species associated with the habitat may be a potential food source for the target species.	Low under both scenarios.	Low vulnerability under scenario 1; not vulnerable under scenario 2.	Not required under scenario 2 (most similar to current situation) as not vulnerable.

6 Conclusion

There are three potential pressure categories which may cause deterioration of the features and disturbance of species as a result of beam trawling within the North Norfolk Sandbanks and Saturn Reef SCI. These pressures are:

- Physical damage and disturbance through changes in suspended sediment concentration;
- Physical damage and disturbance through abrasion; and
- Biological disturbance through the selective extraction of species.

Due to the recent expansion of pulse trawling, particularly by the Dutch fleet, an additional pressure is added:

- Electromagnetic changes.

Based on existing evidence, biological traits and expert opinion (ABPmer, 2013) the sensitivity of the features from beam trawling has been assessed. The pressures from beam trawling (such as the depth of penetration, resuspension of sediment contributing to changes in the levels of siltation, and levels of bycatch) have been based on existing evidence and modelling of the physical impacts of the individual gear components, based on the size, weight and towing speeds used by conventional beam trawlers and pulse wing trawlers in North Norfolk Sandbanks and Saturn Reef SCI.

The infralittoral and circalittoral habitats are located in an area of moderate energy and characterised by fauna which are tolerant to disturbance and able to recover rapidly from disturbance caused by beam trawling. The habitat data available only provide detail to EUNIS level 4, and therefore the sensitivity assessment has also considered typical characterising species of these habitats, in particular *Nephtys cirrosa* and *Bathyporeia,* which are highlighted by JNCC (2010) in relation to the sandbank feature. The habitats and characterising species are not sensitive to surface abrasion, changes in suspended sediments and electromagnetic changes. They have low sensitivity to shallow disturbance and low-medium sensitivity to deep disturbance, as these pressures have the potential to cause changes in the topography of the habitat, although infilling of any furrows will be rapid due to the levels of natural disturbance at the site. Characterising species may suffer some mortality from the passage of a trawl, but have high recruitment rates and their abundance recovers very rapidly. The habitats have low sensitivity to biological disturbance from the removal of target and non-target species, as the habitat itself will not be affected but the associated fauna may be affected.

Natural disturbance modelling been carried out to consider the proportion of time, and the number of days in a year, that sediments are mobile, and that mobile bedforms of 2.5 cm height are present in the site. This indicates that sediments are highly mobile, with mobile bedforms present on the tops of the sandbanks 85–95% of the time, and in the deeper areas between the sandbanks for around 10–80% of the time for 250 µm grain size, and 0–20% for 63 µm grain size. Even in the eastern part of the site where currents are less strong, mobile bedforms are present around 20% of the time.

Exposure levels to beam trawling have been assessed under two scenarios: scenario 1 assumes all vessels are conventional beam trawlers; scenario 2 assumes the UK vessels are conventional beam trawlers and the non-UK vessels are pulse wing trawlers. Scenario 2 most closely reflects the current situation in 2015. The level of exposure for each habitat is based on evidence from VMS data for over-15m vessels (there are no under-15m beam trawlers active in the site), analysed to provide swept area, VMS footprint and frequency of impact. Data from VMS records show that between 2009 and

2013 on average, the swept area by the over-15m vessels was 1,551 km^2 (scenario 1), equivalent to 43% of the area of the SCI area, or 1,387 km^2 (scenario 2), equivalent to 38% of the area of the site. However, the actual footprint of the fishing activity, based on VMS footprint polygons was 1,422 km^2 (39% of the site) over a five-year period, with only 7% being impacted by the beam shoes. This indicates that 61% of the site was not impacted by beam trawling over the five-year period.

Exposure to beam trawling has been assessed as none (for moderate energy infralittoral rock) to moderate. Exposure to surface abrasion and shallow disturbance is moderate across all habitats and both scenarios. This is based on the footprint and swept area of beam (or pulse) trawling on each habitat type in relation to the overall area of each habitat type. Large parts of the site have very low levels of activity, where the habitats will be minimally affected by beam trawling; small areas are more intensively fished. Exposure to deep disturbance is low across both scenarios for all habitats except deep circalittoral sand, which is moderate (due to the smaller overall area of this habitat). Exposure to changes in suspended sediment is the same as for surface abrasion (moderate), and exposure to electromagnetic changes is none in scenario 1 and moderate in scenario 2. Exposure to removal of target and non-target species is moderate in scenario 1 and low in scenario 2 due to the lower levels of bycatch in pulse trawls.

Analysis of the frequency of impact from VMS data indicates that parts of the site are not fished at all, and large areas may be trawled less than once per year. There are areas where fishing activity appears to be more concentrated (the channels between the sandbanks). In these areas, trawl frequency is around three to four times per year, with more intensive areas increasing to seven to eight times per year, and the highest area is up to 12–16 times per year. However, this takes place over a very small area, and represents the number of passes of a 24m gear within a 250 m by 250 m grid cell. When the areas of highest intensity are analysed on a more detailed spatial scale, with a grid cell size equivalent to the width of the gear (25 m by 25 m), the number of repeated passes of the gear over the same area is indicated as two to three times (i.e. once every four to six months).

The vulnerability of the 'reef' feature has not been assessed

Based on the assessments of sensitivity and exposure of each habitat, in relation to the pressures exerted by individual gear components, it is assessed that those habitats with a low or moderate vulnerability to beam trawling impacts are:

- Under scenario 1:
  - Shallow and deep disturbance on all habitats — low vulnerability, except for deep disturbance on deep circalittoral sand which is assessed as moderate vulnerability;
  - Biological disturbance through removal of target and non-target species for all habitats — low vulnerability.
- Under scenario 2:
  - Shallow and deep disturbance on all habitats — low vulnerability.

It is understood that, as a 'red risk' interaction in the Matrix, the potential impact of beam trawling on *Sabellaria* reef will be addressed as a priority, and therefore this assessment has focussed on the sandbanks habitats.

For 'low' impacts, managers and Competent Authorities will need to decide whether these constitute an AEOI, particularly where these areas are subject to the high levels of natural disturbance observed in the site.

Scenario 2 (assessing non-UK vessels as pulse wing trawls) results in lower vulnerability due to the lower benthic impacts of the pulse gear, and lower levels of bycatch of pulse trawls compared to conventional beam trawls.

The sensitivity of all habitats has been assessed as 'not sensitive' to electromagnetic changes, resulting in an assessment of not vulnerable. However, there is insufficient information to make a full assessment of the *in-situ* effects of pulse trawling. Further research is needed on whether electrical pulse gear may be causing a negative impact or not, particularly in the longer term and as a result of repeated exposure. Trawl path mortality' studies are planned and/or underway by IMARES in the Netherlands, but results are not yet available.

The assessments of vulnerability should be considered in relation to the conservation objective of the site (see Section 2.3) which is to 'restore'. This indicates that the sandbank feature is not in favourable condition, although there is no direct evidence of the sandbanks being damaged or in deterioration. However, JNCC (2012) highlights that the area is subject to "*unprecedented levels of obstruction from infrastructure associated with oil and gas activities*" and there is uncertainty concerning the level of abrasion pressure from beam trawling.

If it is considered that the low vulnerability pathways need to be addressed, vulnerability could be reduced through the implementation of mitigation options. Mitigation options include:

- Do nothing;
- Reduce/limit pressure; and/or
- Remove/avoid pressure.

Options for reducing physical damage include reducing activity across the site; closing some areas to beam trawling; or implementing gear modifications that further reduce benthic impacts, however, much has already been achieved through for example increasing the surface area of beam shoes to reduce penetration, or adopting the SumWing gear to reduce benthic impacts.

There are a number of uncertainties in the data used for the assessment. These are explored in Table 31.

Table 31. Summary of available evidence and gaps

Issue	Availability of Data and Information	Gaps In Evidence	Confidence in Assessment	Recommendations
Interest Feature *Sandbanks which are slightly covered by seawater all of the time*	The Site Selection Assessment Document (JNCC, 2010) Annex I Sandbanks 'sandbank slope analysis method' (JNCC, 2014b)	It is not clear whether or not the fauna of the deeper circalittoral habitats should be included as part of the assessment of sandbanks. In the Site Selection document it states that: '*The boundary [of the site] presented includes both 'sandy sediments in less than 20m water depth' and the flanks and troughs of these banks which are also part of the sandbank feature but extend into deeper waters*'. '*The parts of the banks in deeper waters are considered integral to the structure and functions of the banks and an integral part of the sandbanks feature conservation interest, although their precise extent is not defined*' There is no reference to the biological communities associated with the circalittoral habitats and their relation to the infralittoral habitat near the peaks of the banks. It is not clear whether any functional linkages between the troughs and the crests of the sandbanks should be considered in relation to the sensitivity of the infralittoral habitats.	**Low** It is unclear what habitats and associated species are included as part of the interest feature. Using the precautionary approach this assessment has considered the infralittoral and circalittoral habitats and associated species.	JNCC is currently updating its conservation advice for the site and this should provide clearer information regarding the sub-features and attributes associated with the features.
	UKSeaMap EUNIS habitats	EUSeaMap is a predictive seabed habitat map. The confidence in the data in the area of the North Norfolk Sandbanks and Saturn Reef (NNSSR) site is between 25% and 50%. The actual habitat types present at the site may differ from those represented in UKSeaMap.	**Low**	JNCC and Cefas have carried out further survey work in the site, which should help clarify the habitats and biotopes present.
Condition of sandbank feature	Normally provided in Regulations 33 Advice document from Natural England or JNCC	NNSSR site does not have a Regulations 33 advice document. Within the literature, there are no favourable condition tables. The conservation objective is to 'restore'. However, there is no clear reference to what is damaged or in deterioration at the site which leads to the feature being in an unfavourable condition.	**Low**	JNCC to provide clear condition status of the feature and reasons for unfavourable condition status, if appropriate.
Interest feature: *Reefs* (Saturn Reef)	Site documents	Saturn Reef was found in 2002 but subsequent surveys have failed to find it. The presence of a reef in 2002 indicates that the area is favourable for the development of reef. This assessment has not considered the reef feature but assumed that it will be addressed as a 'red-risk' matrix interaction.	**Low**	JNCC and Cefas have carried out further survey work in the site, which should help clarify the presence and extent of any *Sabellaria* reef.
Fishing area and	ICES rectangle landings	Very coarse resolution. From the ICES rectangles it is not	**Medium – High**	The method used by MMO to link

Issue	Availability of Data and Information	Gaps In Evidence	Confidence in Assessment	Recommendations
intensity for over-15m vessels	data	possible to identify what data is from within the SCI boundary and what data is from outside.	VMS ping data provide a reasonable picture of the distribution of fishing effort. Assumptions were made whereby it was assumed that any VMS ping with unknown gear type was beam trawling, but this was a small proportion of the overall number of pings.	VMS and logbook data should be based on the vessel and dates of fishing trips rather than the vessel, date and ICES rectangle. The speed rule used to identify 'fishing' pings should be tailored to the gear type or fishing métier.
	Sightings data	Limited survey records are available. These are heavily biased dependent upon survey effort.		
	VMS data	VMS pings are sent out every two hours, therefore they do not capture all activity. Identification of 'fishing' activity is based on a speed rule and this may result in the misclassification of pings. VMS (UK): Fishing gear is unknown for 86% of assessed pings. VMS (non-UK): Fishing gear was identified from the main gear type recorded in the Community Fleet Register, which may not reflect the gear used during the fishing operation. Less than 1% of assessed pings were of unknown gear type. Overall, 13% of assessed pings had unknown gear type. Estimates of swept area have been improved through the use of information on towing speed (from VMS and from interviews with skippers), gear type (conventional beam trawl or pulse wing trawl) and gear configuration (from interviews with skippers). Estimates of actual footprint have been improved through the analysis of VMS tracks between pings, buffered to reflect width of individual gear components.		
Fishing area and intensity for under-15m vessels	ICES rectangle landings data — provide comprehensive landings data for UK vessels	Data are not at a sufficient resolution to assess the fishing impact on particular interest features or habitats, or even within the site. Data are for UK vessels only; non-UK vessels are not included. There is no VMS information for vessels under 15m in length. VMS has been in place for vessels 12–15m since 2013, but MMO have not yet released these data. Spatial patterns of fishing intensity for vessels under-12m will still remain.	**Medium** There is little information available about fishing patterns and intensity for under-15m vessels, but ICES rectangle data indicate that under-15m activity in the area is low, and none for beam trawls.	Because the beam trawling effort in the NNSSR site is by larger vessels, this is not a priority for this site.
	Sightings data	Sightings data provide information on vessels that have been seen in the area, but they are dependent on the frequency of surveillance, and are not comprehensive.		
	MCZ Fisheries Model — provides information on fishing patterns for under-15m vessels to a resolution of 1/200th of an ICES rectangle.	Not at a sufficient resolution to be able to analyse clearly the fishing impact on particular interest features or habitats. Information on fishing areas were collected in 2008–2010 and may not reflect current fishing patterns or intensity. Confidence in the data is dependent on the participation rate of fishermen in the MCZ process.		
Gear type and operation	VMS data ICES rectangle landings	In the EU gear codes, all beam trawls are identified as TBB. The specific type of beam trawl is not known, for example, pulse trawling, use of tickler chains etc. Recent developments in	**Medium** The type of the beam trawl will affect the area exposed to fishing	Higher spatial resolution information on the actual footprint of fishing activity, rather than

Issue	Availability of Data and Information	Gaps In Evidence	Confidence in Assessment	Recommendations
	data Publically-available literature	electronic pulse trawls used by the Dutch fleet mean that the impacts could be different. Further information has been collected on the gear type and dimensions through interviews with skippers. Recent research and literature on impacts of pulse trawls has been accessed and reviewed.	(under swept area calculations, due to specific towing speeds) and impacts of the gear.	assessment of footprint from 2-hourly VMS pings, which do not resolve individual tows and may over- or under-estimate exposure.
Impacts of gears and sensitivity of habitats and communities	Peer-reviewed and grey literature on the impacts of fishing — large quantities of information and studies have been carried out. A good assessment tool for the impact of fishing and aquaculture on benthic habitats has been developed by ABPmer (2013).	Lack of long-term *in-situ* studies looking at the long-term impacts of fishing. Although the short-term effects of fishing may be well known, the long-term efforts are not. It may be more important to understand long-term tolerance and recovery rates as these are instrumental to understanding a feature's vulnerability to a pressure and so, the overall long-term condition. Not all habitats are included within the key literature resources such as ABPmer (2013).	**Medium** There is a good understanding of the short-term effects of beam trawling and studies are emerging which are looking at the long-term effects. There is less information available regarding the effects of pulse trawling, due to the relatively recent development of this gear. Modelling of sediment resuspension and penetration of individual gear components provides gear-specific pressure levels.	Further research into actual impacts of the gears in the site, and further research into impacts of pulse trawling, including longer-term impacts and effects of repeated exposure.
	Modelling of gear impacts	Modelling of gear impacts has provided specific pressure levels for the gears in use in the site, but empirical evidence is lacking.		
Uncertainty on biological extraction	Levels and composition of bycatch in beam trawls and pulse trawls	The lack of bycatch data specific to the site makes it hard to analyse extraction rate of non-target species.	**Medium** There is a lack of information regarding extraction and bycatch rates. Rates will be gear specific and literature on levels of bycatch from beam and pulse trawls has been used in the assessment.	Further studies on level and composition of bycatch from the site.
Levels of natural disturbance at the site	Natural disturbance modelling	Lack of information of sediment grain size in areas of the site, which affects the assessment of mobility.	**Medium** Natural disturbance modelling provides a good indication of the frequency of disturbance of the top layers of sediment at the site. However, fishing gears will cause some impacts (penetration, causing crushing of organisms) that differ from the effects of natural disturbance (this has been assessed).	

7 In-combination Assessment

The Habitat Regulations require that, in determining whether a plan or project is likely to have a significant effect on a European site, its effects should be considered both alone and in-combination with other plans or projects. Therefore, to inform such an in-combination assessment for this shadow assessment of beam trawling at the North Norfolk Sandbanks and Saturn Reef SCI, a review of existing and relevant plans and projects that may potentially affect the same interest features of the European sites has been undertaken. A list of the relevant projects and plans is provided below.

The potential sources of in-combination effects to the North Norfolk Sandbanks and Saturn Reef SCI include the following relevant projects, plans and activities (the plans and projects which spatially overlap the SCI are shown in Figure 7.1, and oil and gas pipelines that are present in the site are shown in Figure 7.2):

- Other demersal fishing activity (otter trawling, seining);
- Pelagic fishing activity;
- Dudgeon offshore windfarm (OWF);
- Sheringham Shoal OWF;
- East Anglia ONE, THREE and FOUR OWFs;
- Anglia gas field;
- Oil fields at the Indefatigable and Leman sandbanks ;
- Sizewell C New Nuclear Power Station;
- Shipping: widespread throughout the region, the density and spatial extent is linked with the shipping density plots;
- Cables and pipelines; and
- Hanson Aggregate Licence Areas.

In-combination effects could occur to the interest features as a result of any of the plans and projects listed above in addition to the physical damage and disturbance and biological disturbance already identified. Consideration of whether in-combination effects are likely to occur with beam trawling, is provided in Table 32, based on the potential in-combination effect pathway.

Table 32. Plans or projects with potential in-combination effects at the site

Plan or Project	In-combination Effect Pathway
Fishing activity (demersal)	Demersal otter trawling and demersal seining interact with the benthic habitats and therefore have the potential for an in-combination effect. However, VMS ping data shows a very small proportion of pings from these gear types (7%), and therefore there is no potential for significant in-combination effects.
Fishing activity (pelagic)	This activity does not interact directly with the benthic habitats, therefore there is no direct in-combination effect.
Offshore wind farms: Dudgeon, Sheringham Shoal and East Anglia ONE, THREE and FOUR	The windfarms do not directly overlap with the SCI, therefore no direct impact. Given the distance from the site there is no potential for indirect effects caused by potential changes in the hydrodynamic nature of the region which could lead to changes in sediment transport processes.
Anglia Gas and Oil fields	There are a considerable number of oil and gas developments

Plan or Project	In-combination Effect Pathway
	which overlap with the SCI. It is acknowledged by JNCC that the SCI's interest features are highly or moderately vulnerable to physical loss through obstruction from high levels of oil and gas infrastructure and so this is considered to pose a moderate risk of damage to the interest features (JNCC, 2012). Sandbanks features are not vulnerable to physical loss through beam trawling activities and so there is no potential for in-combination effects.
Sizewell C New Nuclear Power Station	No potential for in-combination effects
Shipping	This activity does not interact directly with the benthic habitats, therefore no direct in-combination effect.
Cables and pipelines	There is spatial overlap with active and disused telecom cables, and oil and gas pipelines. Therefore there is potential for in-combination effects as a result of physical disturbance from abrasion. JNCC has assessed the habitat as having a low vulnerability to this pressure. Beam trawling will not result in the removal of sediment from the feature, and exposure to abrasion from the cable and pipelines is low, therefore there is no potential for significant in-combination effects.
Aggregate extraction	Physical damage and disturbance to habitats and associated fauna. There is spatial overlap with some application and option areas with the SCI. These are in areas of low fishing activity. Whether there is the potential for in-combination effects depends on the current status of these areas.

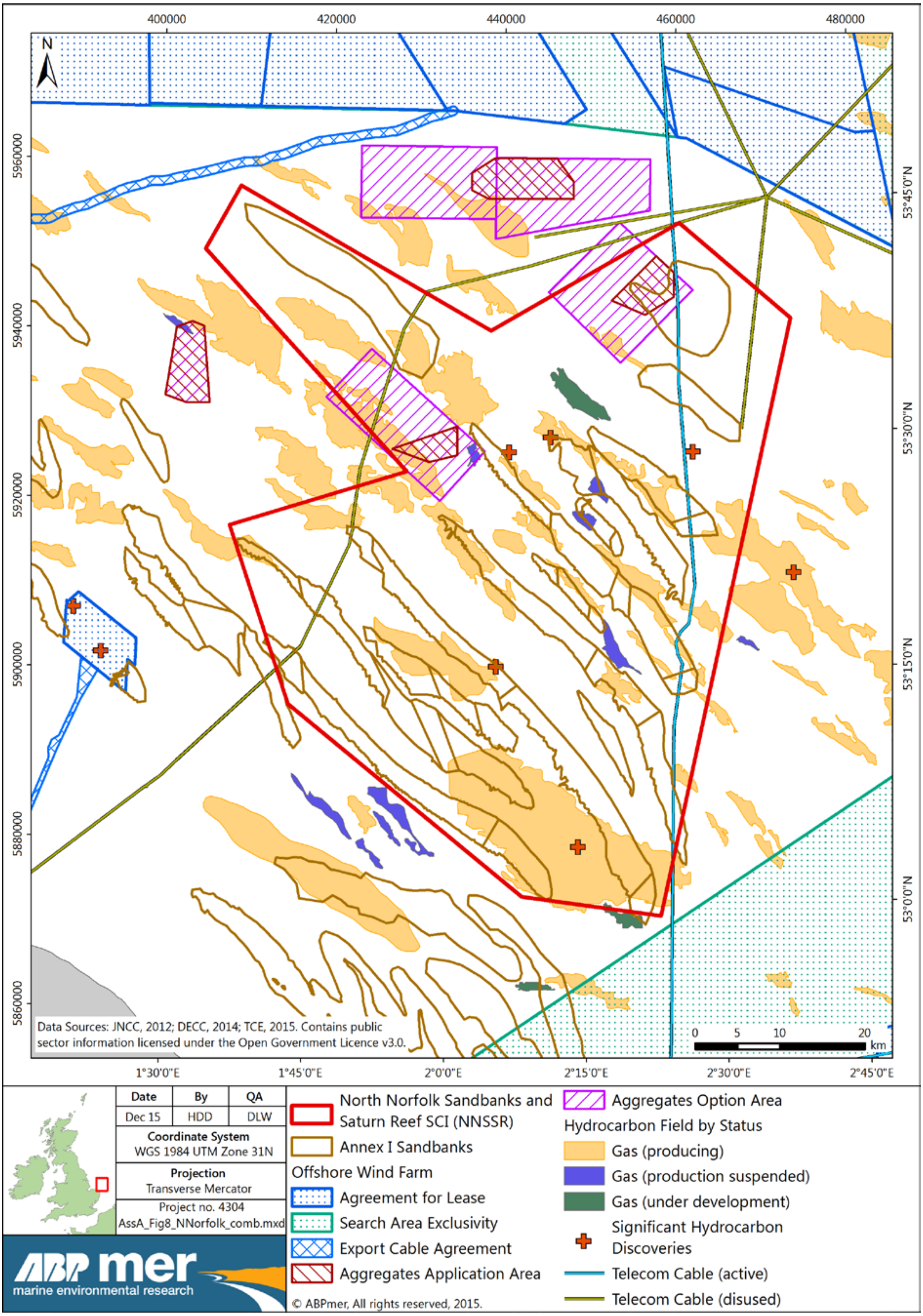
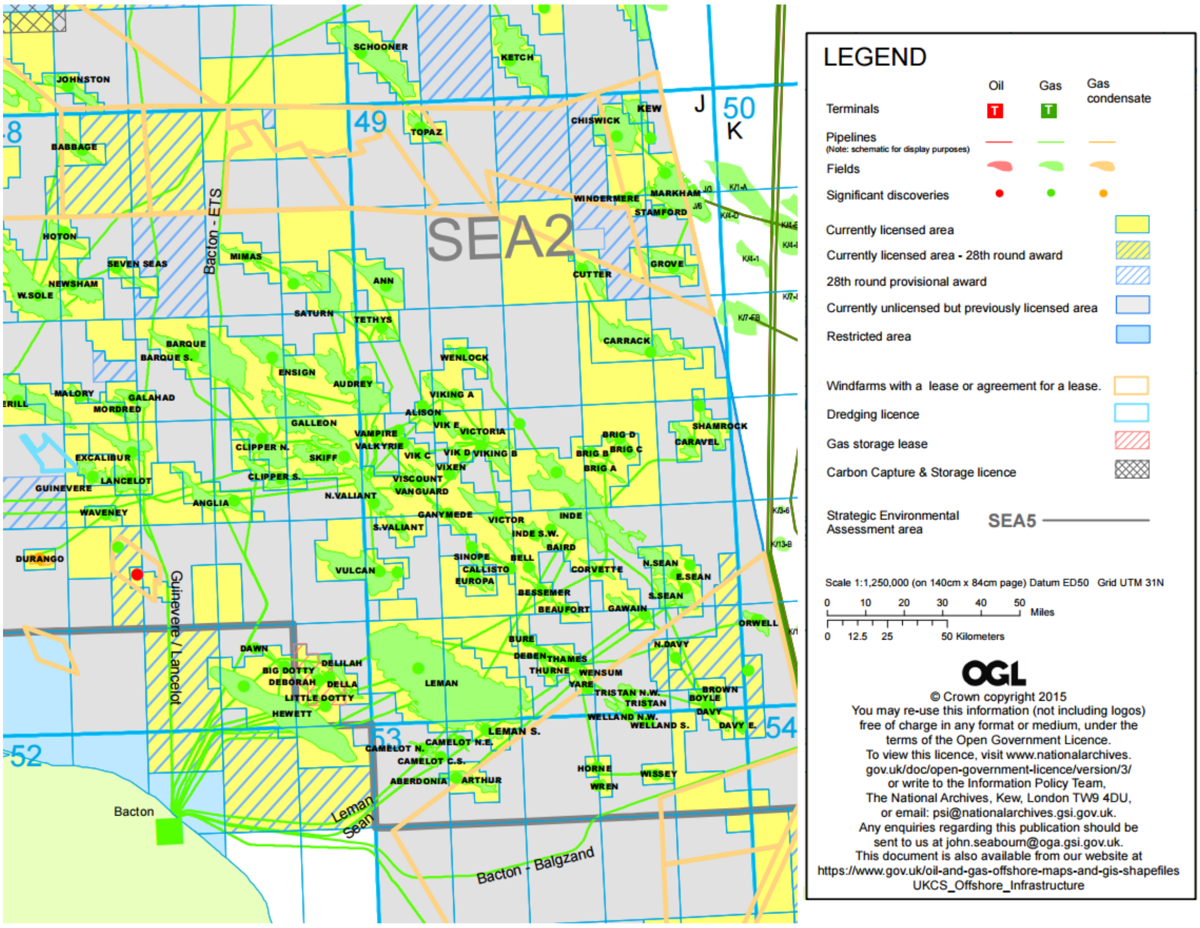


Figure 7.1 **North Norfolk Sandbanks and Saturn Reef SCI in-combination activities**



Source: www.gov.uk/government/uploads/system/uploads/attachment_data/file/473031/UKCS_Offshore_Infrastructure.pdf

Figure 7.2 UK Continental Shelf offshore infrastructure

8 Integrity Test

Based on the assessments of sensitivity and exposure of each habitat, in relation to the pressures exerted by individual gear components, habitats that have been identified as having a low vulnerability to beam trawling impacts are:

- Under scenario 1 (all beam trawlers are conventional beam trawlers):
  - Shallow and deep disturbance on all habitats;
  - Biological disturbance through removal of target and non-target species for all habitats.
- Under scenario 2 (all UK beam trawlers are conventional beam trawlers and all non-UK beam trawlers are pulse wing trawlers):
  - Shallow and deep disturbance on all habitats except deep disturbance on deep circalittoral sand, due to low exposure.

It is uncertain whether this low vulnerability might constitute an adverse effect on the integrity of the site. Disturbance from fishing activity is low relative to levels of natural disturbance in the site. The faunal assemblages present are already adapted to the high levels of natural disturbance.

The significance of these effects will depend on the baseline against which achievement of the conservation objectives is assessed, particularly whether this baseline includes existing levels of fishing activity.

The assessments of vulnerability should be considered in relation to the conservation objective of the site (see Section 2.3) which is to 'restore'. This indicates that the sandbank feature is not in favourable condition, although there is no direct evidence of the sandbanks being damaged or in deterioration. However, JNCC (2012) highlights that the area is subject to "*unprecedented levels of obstruction from infrastructure associated with oil and gas activities*" and there is uncertainty concerning the level of abrasion pressure from beam trawling.

Mitigation options, should they be deemed necessary, are outlined in Table 30.

There are some caveats to this conclusion. In particular, clarification of the Conservation Objectives and Advice documents is required in relation to:

- The extent to which demersal fishing is considered to cause failure of Conservation Objectives;
- The lack of targets for attributes.

Confidence in the assessment and a list of key issues and gaps in evidence are summarised in Table 31. This provides an overview of the information and data gaps, which reduce the confidence in the conclusions of the assessment.

9 Reference List

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10 Abbreviations

AA	Appropriate Assessment
ABPmer	ABP Marine Environmental Research Ltd
AEOI	Adverse effect on integrity
cSAC	Candidate Special Area of Conservation
Cefas	Centre for Fisheries, Environment and Aquaculture Science
CFR	Community Fleet Register
EMS	European Marine Site
EU	European Union
EUNIS	European Nature Information System
HRA	Habitats Regulations Assessment
ICES	International Commission for the Exploration of the Sea
IFCA	Inshore Fisheries and Conservation Authority
JNCC	Joint Nature Conservation Committee
LSE	Likely Significant Effect
MarLIN	The Marine Life Information Network
MCZ	Marine Conservation Zone
MESH	Mapping European Seabed Habitats
MLS	Margate and Long Sands
MMO	Marine Management Organisation
MPA	Marine Protected Area
NAEOI	No Adverse Effect on Integrity
NNSSR	North Norfolk Sandbanks and Saturn Reef
NSAC	North Sea Advisory Council
OSPAR	Oslo-Paris Convention
OTB	Bottom otter trawl
OWF	Offshore Wind Farm
SAC	Special Area of Conservation
SCI	Site of Community Importance
SSC	Suspended sediment concentration
spp.	Species
TBB	Twin beam trawl
UK	United Kingdom
VMS	Vessel Monitoring System

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

Appendices

A Habitat Sensitivity Assessments

A.1 Infralittoral coarse sediment

Infralittoral coarse sediment habitats are moderately exposed habitats with coarse sand, gravelly sand, shingle and gravel in the infralittoral, which are subject to disturbance by tidal steams and wave action. Such habitats are found on the open coast or in tide-swept marine inlets and are characterised by a robust fauna of infaunal polychaetes such as *Chaetozone setosa* and *Lanice conchilega*, *cumacean crustacea*, *trispinosa* and *Diastylis bradyi*, and venerid bivalves. The sensitivity of the biotope *Nephtys cirrosa* and *Bathyporeia spp*. in infralittoral sand has been incorporated into the assessment for this habitat as this is the biotope JNCC (2010) used for their assessments of sandbanks within the Conservation Objectives and Advice on Operations document. The sensitivity assessment for this habitat is provided in Table A.1.

Table A.1 Sensitivity for Infralittoral coarse sediment (SS.SCS)

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
Physical damage resulting from abrasion and/or selective extraction Surface Abrasion	Infralittoral coarse sediment	**High** Surface abrasion can re-suspend sediments and reduce habitat complexity (Depestele *et al*, 2015 and references therein) by smoothing out structures and displacing and overturning any larger cobbles or boulders present as well as flattening biogenic structures (ABPmer, 2013). However surface abrasion is unlikely to alter habitat type (ABPmer, 2013) and so tolerance is assessed as High. In addition, as described in detail in Appendix G of ABPmer & Ichthys Marine (2015), using the natural disturbance model for grain size 1000 µm, the area where this habitat is present, surface sediments are mobilised by currents between 20%-30% of the time (for 2000 µm grain size, relevant values are 5–20%).	**Very High** The site is a highly dynamic area (JNCC, 2012) and the North Norfolk Sandbank is formed by strong tidal currents and it is therefore considered that the sandbank could recover rapidly between disturbance events.	**Not Sensitive** The habitat is considered to have high tolerance to surface abrasion as it is unlikely to alter the habitat type. Recovery is considered to be very high and the habitat feature is therefore considered to be Not Sensitive to surface abrasion, particularly in view of the levels of natural disturbance at the site. As stated in Section 3.10 the top sediment layer is regularly mobilised by natural processes (currents and waves) and often forms mobile bedforms (ripples) and so, surface disturbance is considered within the limits of natural variability at the site.
	Characterising species	**High** This biotope is generally characterised by the presence of an infaunal benthic community, which, due to the position in the sediment or under stones, are relatively protected from	**Very High** The species present within this biotope at this site will have the ability of recovering rapidly following surface disturbance. As described in detail in Section 3.10 the top	**Not Sensitive** The characterising species are considered to have high tolerance to surface disturbance and very high recovery therefore considered to be Not

Impact Pathway	Feature	**Tolerance**	**Recoverability**	**Sensitivity**
		temporary surface disturbance. However any polychaetes such as *L. conchilega* are robust (ABPmer, 2013) sessile, soft bodied tube-dwelling polychaetes as described in ABPmer & Ichthys Marine,2015. The tube is tough and flexible and so is able to provide *L. conchilega* some protection from physical damage as the polychaete is able to retreat in the long tube (ABPmer, 2013). According to several studies, macrobenthic communities from high-energy environments (characterised by clean sediments) tend to be less affected by fishing as they are subject to natural sediment disturbance (e.g. Currie and Parry, 1996; Kaiser *et al*. 1996; Zajac and Whitlatch, 2003). Therefore tolerance of characterising species is assessed as high.	sediment layer is regularly mobilised by natural processes (currents and waves) and often forms mobile bedforms (ripples) and so, surface disturbance is considered within the limits of natural variability at the site. Although surface abrasion has the potential to damage species or parts of species that are found at the surface, many organisms may be adapted to predation damage e.g. siphon removal by fish during immersion periods.	Sensitive to surface abrasion.
Shallow disturbance Ground gear, chains and electrodes <25mm disturbance	Infralittoral coarse sediment	**Medium** Shallow disturbance will result in the formation of tracks and pits as well as the surface disturbance effects outlined above. Fishing for demersal species will disturb the shallow layer of sediment and any protruding or shallow burrowing species. Trawling on infralittoral coarse habitats can result in tracks in the sediment, smoothing of sea floor, sediment re-suspension, removal of fine sediment fractions and displaced/overturned gravel, stones and boulders (Roberts *et al,* 2010) resulting in an altering of habitat topography. As described in Section 3.10 and in detail in Appendix G of ABPmer & Ichthys Marine (2015), the top sediment layer is regularly mobilised by natural processes (currents) 20%-30% of the time with active ripple bedforms (2.5 cm) present 10%-20% of the time. Although it is acknowledged that natural disturbance is not directly comparable to the pressure caused by shallow disturbance as a result of beam	**High** In general any tracks or pits resulting from surface damage would be likely to infill within 6 months and normal hydrodynamic and mixing and sorting processes are expected to have restored sediments within 6 months to 2 years. As the natural disturbance modelling suggests, (Appendix G of ABPmer & Ichthys Marine, 2015), surface sediments are mobilised by currents 20%–30% of the time. Therefore it is considered that the habitat could recover rapidly between disturbance events. Tickler beam trawl penetrates deeper than pulse wing trawls, both of which fade over time, but the pulse trawls have been shown to fade quicker (Depestele *et al.* 2015 and Teal, 2015).	**Low** Based on the potential impact of physical damage by shallow disturbance on the habitat and associated biota, this feature has been assessed to have a medium tolerance. Recoverability will be high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		trawling, it does provide an insight to the natural processes occurring at the site and whether or not the site does experience any disturbance, and as such, whether or not the habitat is able to tolerate and recover from disturbance. Therefore tolerance is assessed as medium as the habitat still remains and alterations are confined to surficial layers.		
	Characterising Species	**High–Medium**	**High**	**Low**
		Shallow disturbance has the potential to result in similar impacts as the surface abrasion, but there is greater potential that the infaunal species will also be disturbed. Species that occupy a shallower (within the first 2.5 cm) position within the sediment will be affected. Biological traits such as mobility and being small as described in Appendix E of ABPmer and Ichthys Marine , 2015 and Bolam (2014) protect infaunal from trawling impacts. For example *Bathyporeia* spp. is a small mobile species capable of moving out of the path of fishing gear (Appendix E, ABPmer & Ichthys Marine, 2015). It is a burrow-dwelling amphipod and therefore is unlikely to be impacted by surface abrasion and has a high tolerance. *N. cirrosa* is able to burrow or swim away from disturbance. When in the sediment it is found between 5–15 cm depth (Appendix E, ABPmer & Ichthys Marine, 2015), therefore has high tolerance as it will not be affected by surface abrasion. However given that some species present such as such bivalves are more fragile, tolerance is assessed as high - medium.	The ability of the species present at the site to recover is linked to biological traits such as whether they or not they are 'R-selected species', their recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). The species present have the ability to recover rapidly following physical disturbance. As described in detail in Section 3.10 and above, the top sediment layer is regularly mobilised by natural processes (currents and waves). Further, polychaetes such as *N. cirrosa* may even benefit from disturbance. The amount of available food for predator/scavenger species may increase due to the number of injured and killed organisms (Frid *et al.,* 2000). Species such as *L. conchilega* have been categorised by Gittenberger and van Loon (2011) through literature and expert review, as AMBI fisheries Group IV — a second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed (ABPmer, 2013). However, their populations are able to recover quickly and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger & van Loon, 2011; ABPmer, 2013). Therefore, shallow disturbance is	Based on the potential impact of physical damage by shallow disturbance on the characterising species, this feature has been assessed to have a medium tolerance. Recoverability will be high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
			considered within the limits of natural variability at the site. In addition, some of the species present are ephemeral, therefore recovery is assessed as high.	
Deep disturbance Trawl Shoes >25mm disturbance	Infralittoral coarse sediment	**Medium** Deep disturbance will result in the surface and shallow disturbance effects outlined above, but to a more severe degree. Habitat tolerance is assessed as 'medium' as changes will occur but the habitat will remain intact (ABPmer, 2013).	**High** The site is formed by strong tidal currents and surface sediments are mobilised 20–30% of the time in the area of coarse sediment (1000–2000 µm grain size). It is therefore considered that the habitat could recover relatively rapidly between disturbance events. Tracks or furrows resulting from deep disturbance would be likely to infill within 6 months – 2 years and normal hydrodynamic and mixing and sorting processes are expected to have been restored	**Low** Based on the potential impact of physical damage by deep disturbance on the habitat it has been assessed to have a medium tolerance. Although changes and alterations to the seabed topography will be made they are unlikely to significantly change the habitat itself and the services it provides. Recoverability will be high to very high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.
	Characterising Species	**Low–High** The impacts of deep disturbance will be the same as surface and shallow but more severe. The tolerance of the species will be dependent upon their position within the sediment and biological traits such as their size and mobility (Appendix E, ABPmer & Ichthys Marine, 2015) and so tolerance will vary between taxa from low to high (ABPmer, 2013).	**High** As described above, the ability of the species present at the site to recover is linked to biological traits such as whether they or not they are 'R- selected species', their recolonisation rate and/or re-recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). Therefore it is assessed that recovery will be high.	**Not Sensitive–Medium** The sensitivity of the characterising species to deep disturbance ranges from not sensitive to medium sensitivity. Deep disturbance has the potential to cause directly mortality and consequently alter species composition. However, the impacts of this pressure are dependent upon the biological traits of the individual taxa.
Physical damage and disturbance from changes in suspended sediment levels Tickler beam trawls 0.62 cm equivalent sediment layer across swept area (Appendix B, ABPmer & Ichthys Marine , 2015) Pulse wing trawl 0.28 cm equivalent sediment layer across swept area (Appendix B, ABPmer & Ichthys Marine , 2015)	Infralittoral coarse sediment	**High** As the gear moves over the sediment, sediment will be mobilised into the water column. This can cause smothering of suspension feeding fauna through the re-suspension of sediment by the fishing gears (Jennings and Kaiser, 1998). The quantity of sediment re-suspended by trawling depends on the sediment grain size and the degree of compaction, which is lower on coarse sand (Jennings and Kaiser, 1998). As discussed in detail in Appendix G ABPmer & Ichthys Marine (2015) only small amounts of material	**Very High** Recovery will depend on the rate of sediment mixing or removal of the overburden, either naturally or through human activities and recovery to a recognisable form of the original biotope will not take place until this has happened. In areas where the local hydrodynamic conditions are unaffected, fine particles will be removed by wave action moderating the impact of this pressure. The rate of habitat restoration would be site-specific and would be	**Not Sensitive** Suspended sediment from trawling activities is likely to occur although it will not cause significant changes to the habitat or mortality to the species. Natural disturbances from wave, current and storm actions although with the settling out of sediment would result in the rapid recovery of the feature. It is therefore assessed that this habitat is not sensitive to the low levels of increased suspended sediments expected at the site.

Impact Pathway	Feature	**Tolerance**	**Recoverability**	**Sensitivity**
		is expected to be mobilised at the site as a result of beam and pulse wing trawling. As described within Section 3.10 sediment is regularly mobilised and so it is not expected to impact the composition of the sediment type. In addition, an expert workshop convened to assess the sensitivity of marine features to support MCZ planning assessed shallow tide swept coarse sands as having no sensitivity to changes in siltation (low), based on a benchmark of 5cm of fine material added to the seabed in a single event (ABPmer, 2013). Therefore tolernce is assessed as high.	influenced by the type of siltation and rate. Due to the naturally high hydrodynamic mixing suspended sediments and siltation from fishing gear is unlikely to surpass naturally occurring levels and so recovery is assessed as very high.	
	Characterising Species	**High**	**Very High**	**Not-Sensitive**
		Animals associated with this biotope are generally infaunal and not photosynthetic and so are considered as having a high tolerance to the changes in suspended sediments expected at the site.	Bivalves and other benthic infauna are generally able to escape from burial of more than 10cm. Bivalves are able to clear gills so would be expected to reposition in sediment and avoid gill clogging (Grant & Thorpe 1991). Cockles buried under 5cm of sediment have been able to re-establish siphon contact with surface in less than 24 hours (Chang & Levings 1978). Also give the high tolerence recovery is assessed as very high.	Characterising species are not sensitive.
Electromagnetic changes	Infralittoral coarse sediment	**High**	**Very High**	**Not Sensitive**
		There are no expected impacts to the habitat as a result of the electronic fields and pulses created by the gear.	No impact therefore nothing to recover from and recovery is assessed as very high	There are no expected impacts to the habitat as a result of the electronic fields and pulses created by the gear.
	Characterising Species	**High**	**Very High**	**Not Sensitive**
		Electronic pulses have been observed to potentially cause cod spinal damage (van Marlen *et al* 2014) and this only occurred if fish were within 20 cm of the electrode. Dogfish have been observed as not being affected (de Haan *et al.* 2009 in Soetaert *et al.*, 2013). Tank experiments concluded that any effects to invertebrates were not	Very high recovery due to high recruitment rates and population growth rates.	Characterising species are assessed as not sensitive as it is expected that they have a high tolerance to electromagnetic changes and very high recovery from disturbance.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		significant (ICES, 2010, 2011, 2012). van Marlen *et al.* (2013) highlights the fact that pulse stimulation on benthic species varies between the taxa and the smaller the species, the less likely it is the get an effect of electrical stimulation. Although more evidence is required, for the characterising species considered here, tolerance is assessed as being high.		
Biological disturbance through the selective extraction of species Bottom towed gear may have direct impacts on seabed and produce significant amounts of re-suspension which may trigger off considerable productivity pulses due to the rate of dissolved and particulate nutrient releases from seabed disturbance.	Infralittoral coarse sediment	**High** The feature is not considered to be functionally dependent on targeted or non-targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal.	**Very High** There is minimal impact from which to recover.	**Not Sensitive** The removal of target or non-target species would have no significant effect on the physio-chemical character of the habitat. Tolerance is high, and so sensitivity has been assessed as 'Not Sensitive'.
	Characterising Species	**Medium** The characterising species are not directly dependent on other species to provide habitat (although there may be numerous indirect interactions). A study by van Marlen *et al.*, 2014 showed discard was much reduced (57% for fish and 80% for benthic species) for pulse trawls compared to conventional beam trawls. Far fewer undersized plaice were caught as well. However there is still potential for the characterising species to be removed which may result in changes to the biological community and hence the classification of the assemblage type. In addition, a large proportion of the species present at the site are infaunal and occupy the sediment at a depth below the depth of penetration of the ground gear and chains and/or electrodes. In addition, the target species (plaice and sole) feed on bottom living organisms such as worms, crustaceans and shellfish (Ruiz,	**High** Many of the species present at the site are infaunal and so are not expected to be removed in significant numbers. In addition, the species present are expected to be able to resettle and recolonise following a disturbance event (ABPmer, 2013). Therefore recovery is assessed as high.	**Low** The characterising species are assessed as having a low sensitivity to biological disturbance given their medium tolerance and high recoverability.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		2007). Therefore the removal of these target species does have the potential to alter the biological community which may in turn change the classification of the given assemblage. Therefore, tolerance is assessed as medium.		

A.2 Circalittoral coarse sediment

The sensitivity assessment for this habitat is provided in Table A.2.

Table A.2 Sensitivity for circalittoral coarse sediment

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
Physical damage resulting from abrasion and/or selective extraction Surface Abrasion	Circalittoral coarse sediment	**High** The tolerance to surface abrasion is considered unlikely to alter habitat type as described in Infralittoral coarse sediment Infralittoral coarse sediment habitats are moderately exposed habitats with coarse sand, gravelly sand, shingle and gravel in the infralittoral, which are subject to disturbance by tidal steams and wave action. Such habitats are found on the open coast or in tide-swept marine inlets and are characterised by a robust fauna of infaunal polychaetes such as *Chaetozone setosa* and *Lanice conchilega*, *cumacean crustacea*, *trispinosa* and *Diastylis bradyi,* and venerid bivalves. The sensitivity of the biotope *Nephtys cirrosa* and *Bathyporeia spp.* in infralittoral sand has been incorporated into the assessment for this habitat as this is the biotope JNCC (2010) used for their assessments of sandbanks within the Conservation Objectives and Advice on Operations document. The sensitivity assessment for this habitat is provided in Table A.1. Table A.1 for infralittoral coarse sediment. In addition, as described in detail in Appendix G of ABPmer & Ichthys Marine	**Very High** The site is a highly dynamic area (JNCC, 2012) and the North Norfolk Sandbank is formed by strong tidal currents and it is therefore considered that the sandbank could recover rapidly between disturbance events. As the natural disturbance modelling suggests, (Appendix G of ABPmer & Ichthys Marine, 2015), surface sediments are mobilised by currents 20% -340% of the time.	**Not Sensitive** The habitat is considered to have a high tolerance to surface disturbance as it is unlikely to alter the habitat type. Recovery is considered to be very high therefore it is considered to be Not Sensitive to surface abrasion.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		(2015), using the natural disturbance model for grain size 1000 µm, the area where this habitat is present, surface sediments are mobilised by currents between 20%-30% of the time (for 2000 µm grain size, relevant values are 5–20%).		
	Characterising Species	**High** This habitat is characterised by robust infaunal organisms and so their position in the sediment protects them from surface abrasion. As such, tolerance is assessed as high.	**Very High** There is no impact expected from this pressure and so recovery is assessed as very high.	**Not Sensitive** Species are infaunal and so have a high tolerance and very high recovery. Therefore it is concluded that the characterising species are not sensitive to surface abrasion.
Shallow disturbance Ground gear, chains and electrodes <25mm disturbance	Circalittoral coarse sediment	**Medium** Shallow disturbance will result in the surface disturbance effects outlined in Infralittoral coarse sediment Infralittoral coarse sediment habitats are moderately exposed habitats with coarse sand, gravelly sand, shingle and gravel in the infralittoral, which are subject to disturbance by tidal steams and wave action. Such habitats are found on the open coast or in tide-swept marine inlets and are characterised by a robust fauna of infaunal polychaetes such as *Chaetozone setosa* and *Lanice conchilega*, *cumacean crustacea*, *trispinosa* and *Diastylis bradyi,* and venerid bivalves. The sensitivity of the biotope *Nephtys cirrosa* and *Bathyporeia spp.* in infralittoral sand has been incorporated into the assessment for this habitat as this is the biotope JNCC (2010) used for their assessments of sandbanks within the Conservation Objectives and Advice on Operations document. The sensitivity assessment for this habitat is provided in Table A.1.	**High** As the natural disturbance modelling suggests, (Appendix G of ABPmer & Ichthys Marine, 2015), surface sediments are mobilised by currents 20% - 30% of the time. Due to this degree of mobility, in general any tracks or pits resulting from surface damage would be likely to infill within 2 years and normal hydrodynamic and mixing and sorting processes are expected to have been restored.	**Low** Based on the potential impact of physical damage by shallow disturbance on the habitat this feature has been assessed to have a medium tolerance. Recoverability will be high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		Table A.1. In general, fishing activities that penetrate the substratum to a greater extent will potentially damage these habitats to a greater degree than fishing activities using lighter gear (Hall *et al.* 2008). . As described in Section 3.10 and in detail in Appendix G of ABPmer & Ichthys Marine (2015), the top sediment layer is regularly mobilised by natural processes (currents) 20%-30% of the time with active ripple bedforms (2.5 cm) present 10%-20% of the time. Although it is acknowledged that natural disturbance is not directly comparable to the pressure caused by shallow disturbance as a result of beam trawling, it does provide an insight to the natural processes occurring at the site and whether or not the site does experience any disturbance, and as such, whether or not the habitat is able to tolerate and recover from disturbance. Therefore tolerance is assessed as medium.		
	Characterising Species	**High–Medium**	**High**	**Low**
		According to several studies, macrobenthic communities from high-energy environments (characterised by clean sediments) tend to be less affected by fishing as they are subject to natural sediment disturbance (e.g. Currie and Parry, 1996; Kaiser *et al.* 1996; Zajac and Whitlatch, 2003). Nevertheless, in a moderately disturbed environment, Morello *et al.* (2006) found that fishing impacts on benthic community structure were still distinguishable from those resulting from natural variation. The tolerance of the various taxa will vary depending upon their biological traits (Appendix E ABPmer & Ichthys Marine,	The ability of the species present at the site to recover is linked to biological traits such as whether they or not they are 'R- selected species', their recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). The species present have the ability to recover rapidly following physical disturbance. Further, polychaetes such as *N. cirrosa* may even benefit from disturbance. The amount of available food for predator/scavenger species may increase due to the number of injured and killed organisms (Frid *et al.*, 2000). Species such as L. *conchilega* have been categorised by Gittenberger and van Loon (2011) through literature and expert	Based on the potential impact of physical damage by shallow disturbance on the characterising species, this feature has been assessed to have a medium tolerance. Recoverability will be high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		2015) and the species present are descibred as robust and infaunal. For example Bathyporeia spp. is a small mobile species capable of moving out of the path of fishing gear (Appendix E , ABPmer & Ichthys Marine, 2015). It is a burrow-dwelling amphipod and therefore is unlikely to be impacted by surface abrasion and has a high tolerance. *N. cirrosa* is able to burrow or swim away from disturbance. When in the sediment it is found between 5–15 cm depth (Appendix E , ABPmer & Ichthys Marine, 2015), therefore will not be affected by surface abrasion and has high tolerance. Therefore tolerance is assessed as high-medium	review, as AMBI fisheries Group IV — a second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed (ABPmer, 2013). However, their populations are able to recover relatively quickly and benefit from the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger & van Loon, 2011; ABPmer, 2013).	
Deep disturbance Trawl Shoes >25mm disturbance	Circalittoral coarse sediment	**Medium** Deep disturbance will result in the surface and shallow disturbance effects outlined above, but to a more severe degree. Habitat tolerance is assessed as 'medium' as changes will occur but the habitat will remain intact (ABPmer, 2013).	**High** In general any tracks or furrows resulting from deep disturbance would be likely to infill rapidly and normal hydrodynamic and mixing and sorting processes are expected to have been restored. Surface sediments are mobilised 20–30% of the time in the area of coarse sediment (1000–2000 µm grain size). It is therefore considered that the habitat could recover rapidly between disturbance events. Because this is a deeper and therefore slightly more stable habitat than the infralittoral sediment, tracks or furrows resulting from deep disturbance may take longer to recover, but would be likely to infilled and normal hydrodynamic and mixing and sorting processes restored within 2 years. Due to this degree of mobility recovery is assessed as high.	**Low** Based on the potential impact of physical damage by deep disturbance on the habitat it has been assessed to have a medium tolerance. Although changes and alterations to the seabed topography will be made they are unlikely to significantly change the habitat itself and the services it provides. Recoverability will be high high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.
	Characterising Species	**Low–High** The impacts of deep disturbance will be	**High** As described above, the ability of the species	**Not Sensitive–Medium** The sensitivity of the characterising

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		the same as surface and shallow but more severe. The tolerance of the species will be dependent upon their position within the sediment and biological traits such as their size and mobility (Appendix E , ABPmer & Ichthys Marine , 2015) and so tolerance will vary between taxa from low to high (ABPmer, 2013).	present at the site to recover is linked to biological traits such as whether they or not they are 'R- selected species', their recolonisation rate and/or re- recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). Therefore it is assessed that recovery will be high.	species to deep disturbance ranges from not sensitive to medium sensitivity. Deep disturbance has the potential to cause directly mortality and consequently alter species composition. However, the impacts of this pressure is dependent upon the biological traits of the individual taxa.
Physical damage and disturbance from changes in suspended sediment levels An average equivalent sediment layer across the whole swept area is 6.2mm for a tickler beam trawl and 2.8mm for a pulse wing trawl (assuming 10% silt fraction).	Circalittoral coarse sediment	**High** As the gear moves over the sediment, sediment will be mobilised into the water column. This can cause smothering of suspension feeding fauna through the re-suspension of sediment by the fishing gears (Jennings and Kaiser, 1998). The quantity of sediment re-suspended by trawling depends on the sediment grain size and the degree of compaction, which is lower on coarse sand (Jennings and Kaiser, 1998). As discussed in detail in Appendix G, ABPmer & Ichthys Marine (2015) only small amounts of material is expected to be mobilised at the site as a result of beam and pulse wing trawling. As described within Section 3.10, sediment is regularly mobilised and so it is not expected to impact the composition of the sediment type. Therefore tolernce is assessed as high.	**Very High** Recovery will depend on the rate of sediment mixing or removal of the overburden, either naturally or through human activities and recovery to a recognisable form of the original biotope will not take place until this has happened. In areas where the local hydrodynamic conditions are unaffected, fine particles will be removed by wave action moderating the impact of this pressure. The rate of habitat restoration would be site-specific and would be influenced by the type of siltation and rate. Due to the naturally high hydrodynamic mixing suspended sediments and siltation from fishing gear is unlikely to surpass naturally occurring levels and so recovery is assessed as very high.	**Not Sensitive** Suspended sediment from trawling activities is likely to occur although it will not cause significant changes to the habitat or mortality to the species. Natural disturbances from wave, current and storm actions although with the settling out of sediment would result in the rapid recovery of the feature. It is therefore assessed that this habitat is not sensitive to the low levels of increased suspended sediments expected at the site.
	Characterising Species	**High** Animals associated with this biotope are generally infaunal and not photosynthetic and as such are considered as having a high tolerance to the changes in suspended sediments expected at the site.	**Very High** Bivalves and other benthic infauna are generally able to escape from burial of more than 10cm. Bivalves are able to clear gills so would be expected to reposition in sediment and avoid gill clogging (Grant & Thorpe 1991). Cockles buried under 5cm of sediment have been able to re-establish siphon contact with surface in less than 24 hours (Chang & Levings 1978). Recovery is assessed as very high.	**Not Sensitive** Characterising species are not sensitive.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
Electromagnetic changes Pulse gear only	Circalittoral coarse sediment	**High** There are no expected impacts to the habitat as a result of the electronic fields and pulses created by the gear.	**Very High** Very high recovery due to high recruitment rates and population growth rates.	**Not Sensitive** There are no expected impacts to the habitat as a result of the electronic fields and pulses created by the gear.
	Characterising Species	**High** Electronic pulses have been observed to potentially cause cod spinal damage (van Marlen *et al* 2014) and this only occurred if fish were within 20 cm of the electrode. Dogfish have been observed as not being affected (de Haan *et al.* 2009 in Soetaert *et al.*, 2013). Tank experiments concluded that any effects to invertebrates were not significant (ICES, 2010, 2011, 2012). van Marlen *et al.* (2013) highlights the fact that pulse stimulation on benthic species varies between the taxa and the smaller the species, the less likely it is the get an effect of electrical stimulation. Although more evidence is required, for the characterising species considered here, tolerance is assessed as being high.	**Very High** Very high recovery due to high recruitment rates and population growth rates.	**Not Sensitive** Characterising species are assessed as not sensitive as it is expected that they have a high tolerance and very high recovery from electromagnetic changes.
Biological disturbance through the selective extraction of species Bottom towed gear may have direct impacts on seabed and produce significant amounts of re-suspension which may trigger off considerable productivity pulses due to the rate of dissolved and particulate nutrient releases from seabed disturbance.	Circalittoral coarse sediment	**High** The feature is not considered to be functionally dependent on targeted or non-targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal.	**Very High** There is minimal impact from which to recover.	**Not Sensitive** The removal of target or non-target species would have no significant effect on the physio-chemical character of the habitat. Tolerance is high, and so sensitivity has been assessed as 'Not Sensitive'.
	Characterising Species	**Medium** The characterising species are not directly dependent on other species to provide habitat (although there may be numerous indirect interactions). A study by van Marlen *et al.*, 2014 showed discard was much reduced (57% for fish and 80% for benthic species) for pulse trawls compared to conventional beam trawls. Far fewer undersized plaice were	**High** Many of the species present at the site are infaunal and so are not expected to be removed in significant numbers. In addition, the species present are expected to be able to resettle and recolonise following a disturbance event (ABPmer, 2013). Therefore recovery is assessed as high.	**Low** The characterising species are assessed as having a low sensitivity to biological disturbance given their medium tolerance and high recoverability.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		caught as well. However there is still potential for the characterising species to be removed which may result in changes to the biological community and hence the classification of the assemblage type. In addition, a large proportion of the species present at the site are infaunal and occupy the sediment at a depth below the depth of penetration of the ground gear and chains and/or electrodes. In addition, the target species (plaice and sole) feed on bottom living organisms such as worms, crustaceans and shellfish (Ruiz, 2007). Therefore the removal of these target species does have the potential to alter the biological community which may in turn change the classification of the given assemblage. Therefore, tolerance is assessed as medium.		

A.3 Deep circalittoral coarse sediment

The sensitivity assessment for this habitat is provided in Table A.3.

Table A.3 Sensitivity for deep circalittoral coarse sediment

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
Physical damage resulting from abrasion and/or selective extraction Surface Abrasion	Deep circalittoral coarse sediment	**High** The tolerance to surface abrasion is considered unlikely to alter habitat type as described in Table A.1for infralittoral coarse sediment. In addition, as described in detail in Appendix G of ABPmer & Ichthys Marine (2015), using the natural disturbance model for grain size 1000 µm, the area where this habitat is present, surface sediments are mobilised by currents between 20%-30% of the time.	**Very High** The site is a highly dynamic area (JNCC, 2012) and the North Norfolk Sandbank is formed by strong tidal currents and it is therefore considered that the sandbank could replenish and recover relatively rapidly between disturbance activities. Therefore it is expected that any changes to the habitat would be recovered from within 6 months.	**Not Sensitive** The habitat is considered to have a high tolerance to surface disturbance as it is unlikely to alter the habitat type. Recovery is considered to be very high therefore it is considered to be not sensitive to surface abrasion.
	Characterising Species	**High** This habitat is characterised by robust infaunal organisms and so their position in the sediment protects them from surface abrasion. As such, tolerance is assessed as high.	**Very High** There is no impact expected from this pressure and so recovery is assessed as very high.	**Not Sensitive** Species are infaunal and so have a high tolerance and very high recovery. Therefore it is concluded that the characterising species are not sensitive to surface abrasion.
Shallow disturbance Ground gear, chains and electrodes <25mm disturbance	Deep circalittoral coarse sediment	**Medium** Shallow disturbance will result in the surface disturbance effects outlined in Table A.1. In general, fishing activities that penetrate the substratum to a greater extent will potentially damage these habitats to a greater degree than fishing activities using lighter gear (Hall *et al.* 2008). As described in Appendix G of ABPmer & Ichthys Marine, 2015, the top sediment layer is regularly mobilised by natural processes (currents) 20%-30% of the time with active ripple bedforms (2.5 cm) present around 10% of the time.. Therefore tolerance is assessed as medium.	**High** Using the natural disturbance model for grain size 1000 µm, the area where this habitat is present, surface sediments are mobilised by currents between 20%-30% of the time . As such, in general any tracks or furrows resulting from surface damage would be likely to infill within 2 years and normal hydrodynamic and mixing and sorting processes are expected to have been restored.	**Low** Based on the potential impact of physical damage by shallow disturbance on the habitat this feature has been assessed to have a medium tolerance. Recoverability will be high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
	Characterising Species	**Medium** In a moderately disturbed environment, Morello *et al.* (2006) found that fishing impacts on benthic community structure were still distinguishable from those resulting from natural variation. The tolerance of the various taxa will vary depending upon their biological traits (Appendix E , ABPmer & Ichthys Marine , 2015) and the species present are described as robust and infaunal. Therefore tolerance is assessed as medium	**Very High** The ability of the species present at the site to recover is linked to biological traits such as whether they or not they are 'R-selected species', their recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). The species present have the ability to recover rapidly following physical disturbance.	**Low** Based on the potential impact of physical damage by shallow disturbance on the characterising species, this feature has been assessed to have a medium tolerance. Recoverability will be high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.
Deep disturbance Trawl Shoes >25mm disturbance	Deep circalittoral coarse sediment	**Medium** Deep disturbance will result in the surface and shallow disturbance effects outlined above, but to a more severe degree. Habitat tolerance is assessed as 'Medium' as changes will occur but the habitat will remain intact (ABPmer, 2013).	**High** Using the natural disturbance model for grain size 1000–2000 µm, the area where this habitat is present, surface sediments are mobilised by currents between 20%-30% of the time. As such, in general any tracks or furrows resulting from surface damage would be likely to infill within 6 months and normal hydrodynamic and mixing and sorting processes are expected to have restored sediments within 2 years. Recovery is assessed as high.	**Low** Based on the potential impact of physical damage by deep disturbance on the habitat it has been assessed to have a medium tolerance. Although changes and alterations to the seabed topography will be made they are unlikely to significantly change the habitat itself and the services it provides. Recoverability will be high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.
	Characterising Species	**Low–High** The impacts of deep disturbance will be the same as surface and shallow but more severe. The tolerance of the species will be dependent upon their position within the sediment and biological traits such as their size and mobility (Appendix E , ABPmer & Ichthys Marine , 2015) and so tolerance will vary between taxa from low to high (ABPmer, 2013).	**High** As described above, the ability of the species present at the site to recover is linked to biological traits such as whether they or not they are 'R- selected species', their recolonisation rate and/or re-recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). Therefore it is assessed that recovery will be high.	**Not Sensitive–Medium** The sensitivity of the characterising species to deep disturbance ranges from not sensitive to medium sensitivity. Deep disturbance has the potential to cause directly mortality and consequently alter species composition. However, the impacts of this pressure is dependent upon the biological traits of the individual taxa.
Physical damage and disturbance from changes in suspended sediment levels An average equivalent sediment layer across the whole swept area is	Deep circalittoral coarse sediment	**High** As the gear moves over the sediment, sediment will be mobilised into the water column. This can cause smothering of suspension feeding fauna through the re-suspension of sediment by the fishing gears	**Very High** Recovery will depend on the rate of sediment mixing or removal of the overburden, either naturally or through human activities and recovery to a recognisable form of the original biotope	**Not Sensitive** Suspended sediment from trawling activities is likely to occur although it will not cause significant changes to the habitat or mortality to the species. Natural disturbances from wave, current and storm

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
6.2mm for a tickler beam trawl and 2.8mm for a pulse wing trawl (assuming 10% silt fraction).		(Jennings and Kaiser, 1998). The quantity of sediment re-suspended by trawling depends on the sediment grain size and the degree of compaction, which is lower on coarse sand (Jennings and Kaiser, 1998). As discussed in detail in Appendix G, ABPmer & Ichtys Marine (2015) only small amounts of material is expected to be mobilised at the site as a result of beam and pulse wing trawling. As described within Section 3.10, sediment is regularly mobilised and so it is not expected to impact the composition of the sediment type. Therefore tolerence is assessed as High.	will not take place until this has happened. In areas where the local hydrodynamic conditions are unaffected, fine particles will be removed by wave action moderating the impact of this pressure. The rate of habitat restoration would be site-specific and would be influenced by the type of siltation and rate. Due to the naturally high hydrodynamic mixing suspended sediments and siltation from fishing gear is unlikely to surpass naturally occurring levels and so recovery is assessed as very high.	actions although with the settling out of sediment would result in the rapid recovery of the feature. It is therefore assessed that this habitat is not sensitive to the low levels of increased suspended sediments expected at the site.
	Characterising Species	**High**	**Very High**	**Not Sensitive**
		Animals associated with this biotope are generally infaunal so are considered as having a high tolerance to the changes in suspended sediments expected at the site.	Bivalves and other benthic infauna are generally able to escape from burial of more than 10cm. Bivalves are able to clear gills so would be expected to reposition in sediment and avoid gill clogging (Grant & Thorpe 1991). Cockles buried under 5cm of sediment have been able to re-establish siphon contact with surface in less than 24 hours (Chang & Levings 1978). Also give the high tolerence recovery is assessed as very high.	Characterising species are not sensitive
Electromagnetic changes Pulse gear only	Deep circalittoral coarse sediment	**High**	**Very High**	**Not Sensitive**
		There are no expected impact to the habitat as a result of the electronic fields and pulses created by the gear.	-	There are no expected impact to the habitat as a result of the electronic fields and pulses created by the gear.
	Characterising Species	**High**	**Very High**	**Not Sensitive**
		Electronic pulses have been observed to potentially cause cod spinal damage (van Marlen *et al* 2014) and this only occurred if fish were within 20 cm of the electrode. Dogfish have been observed as not being affected (de Haan *et al.* 2009 in Soetaert *et al.*, 2013). Tank experiments concluded that any effects to invertebrates were not significant (ICES, 2010, 2011, 2012). van	Very high recovery due to high recruitment rates and population growth rates.	Characterising species are assessed as not sensitive as it is expected that they have a high tolerance and very high recovery from disturbance.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		Marlen *et al.* (2013) highlights the fact that pulse stimulation on benthic species varies between the taxa and the smaller the species, the less likely it is the get an effect of electrical stimulation. Although more evidence is required, for the characterising species considered here, tolerance is assessed as being high.		
Biological disturbance through the selective extraction of species Bottom towed gear may have direct impacts on seabed and produce significant amounts of re-suspension which may trigger off considerable productivity pulses due to the rate of dissolved and particulate nutrient releases from seabed disturbance.	Deep circalittoral coarse sediment	**High** The feature is not considered to be functionally dependent on targeted or non-targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal.	**Very High** There is minimal impact from which to recover.	**Not Sensitive** The removal of target or non-target species would have no significant effect on the physio-chemical character of the habitat. Tolerance is high, and so sensitivity has been assessed as 'Not Sensitive'.
	Characterising Species	**Medium** The characterising species are not directly dependent on other species to provide habitat (although there may be numerous indirect interactions). A study by van Marlen *et al.*, 2014 showed discard was much reduced (57% for fish and 80% for benthic species) for pulse trawls compared to conventional beam trawls. Far fewer undersized plaice were caught as well. However there is still potential for the characterising species to be removed which may result in changes to the biological community and hence the classification of the assemblage type. In addition, a large proportion of the species present at the site are infaunal and occupy the sediment at a depth below the depth of penetration of the ground gear and chains and/or electrodes. In addition, the target species (plaice and sole) feed on bottom living organisms such as worms, crustaceans and shellfish (Ruiz, 2007). Therefore the removal of these target species does have the potential to alter the	**High** Many of the species present at the site are infaunal and so are not expected to be removed in significant numbers. In addition, the species present are expected to be able to resettle and recolonise following a disturbance event (ABPmer, 2013). Therefore recovery is assessed as high.	**Low** The characterising species are assessed as having a low sensitivity to biological disturbance given their medium tolerance and high recoverability.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		biological community which may in turn change the classification of the given assemblage. Therefore, tolerance is assessed as medium.		

A.4 Infralittoral fine sand or infralittoral muddy sand

The sensitivity assessment for this habitat is provided in Table A.4.

Table A.4 Sensitivity for infralittoral fine sand or infralittoral muddy sand

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
Physical damage resulting from abrasion and/or selective extraction Surface Abrasion	Infralittoral fine sand or infralittoral muddy sand	**High** The tolerance to surface abrasion is considered unlikely to alter habitat type as described in Table A.1 for infralittoral coarse sediment. In addition, as described in detail in Appendix G of ABPmer & Ichthys Marine (2015), using the natural disturbance model for grain size 250 µm, the area where this habitat is present, surface sediments are mobilised by currents or waves 40–100%of the time. For muddier sediments (e.g. 63 µm grain size, values for natural disturbance are the same. The highest levels of mobility are on the tops of the sandbanks.	**Very High** The site is a highly dynamic area (JNCC, 2012) and the North Norfolk Sandbank is formed by strong tidal currents and it is therefore considered that the sandbank could replenish and recover relatively rapidly between disturbance activities. Therefore it is expected that any changes to the habitat would be recovered from within 6months.	**Not Sensitive** The habitat is considered to have a high tolerance to surface abrasion as it is unlikely to alter the habitat type. Recovery is considered to be very high therefore it is considered to be not sensitive to surface abrasion.
	Characterising Species	**High** This habitat supports infaunal organisms, such as polychaetes and bivalves, and so their position in the sediment protects them from surface abrasion. As such, tolerance is assessed as high.	**Very High** Very high recovery due to high recruitment rates and population growth rates.	**Not Sensitive** Species are infaunal and so have a high tolerance and very high recovery. Therefore it is concluded that the characterising species are not sensitive to surface abrasion.
Shallow disturbance Ground gear, chains and electrodes <25mm disturbance	Infralittoral fine sand or infralittoral muddy sand	**Medium** Shallow disturbance will result in the surface disturbance effects outlined in Table A.1. In general, fishing activities that penetrate the substratum to a greater extent will potentially damage these habitats to a greater degree than fishing activities using lighter gear (Hall *et al.* 2008). As described in Appendix G of ABPmer & Ichthys Marine, 2015, the bedform is disturbed with active ripple	**Very High** Using the natural disturbance model for grain sizes 63–250 µm, the area where this habitat is present, surface sediments are mobilised by currents 40–100%of the time. In general any tracks or furrows resulting from surface damage would be likely to infill rapidly and normal hydrodynamic and mixing and sorting processes are expected to have been restored.	**Low** Based on the potential impact of physical damage by shallow disturbance on the habitat this feature has been assessed to have a medium tolerance. Recoverability will be very high due to the high levels of natural disturbance by wave, current, and storm action in the areas of this habitat. As a result, sensitivity has been assessed as low.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		bedforms present 40–100% of the time. For muddier sediments (e.g. 63 µm grain size, active ripple bedforms are expected to be present 20–60% of the time on the tops of the banks only. Although it is acknowledged that natural disturbance is not directly comparable to the pressure caused by shallow disturbance as a result of beam trawling, it does provide an insight to the natural processes occurring at the site and whether or not the site does experience any disturbance, and as such, whether or not the habitat is able to tolerate disturbance. Therefore tolerance is assessed as medium.		
	Characterising Species	**High–Medium**	**Very High**	**Low**
		According to several studies, macrobenthic communities from high-energy environments (characterised by clean sediments) tend to be less affected by fishing as they are subject to natural sediment disturbance (e.g. Currie and Parry, 1996; Kaiser *et al*. 1996; Zajac and Whitlatch, 2003). Nevertheless, in a moderately disturbed environment, Morello *et al*. (2006) found that fishing impacts on benthic community structure were still distinguishable from those resulting from natural variation. The tolerance of the various taxa will vary depending upon their biological traits (Appendix E, ABPmer & Ichthys Marine , 2015). For example *Bathyporeia* spp. is a small mobile species capable of moving out of the path of fishing gear (Appendix E, ABPmer & Ichthys Marine, 2015). It is a burrow-dwelling amphipod and therefore is unlikely to be impacted by surface abrasion and has a high tolerance. *N. cirrosa* is able to burrow or swim away	The ability of the species present at the site to recover is linked to biological traits such as whether they or not they are 'R-selected species', their recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). Because this is a high energy environment it is expected that the species present will have the ability of recovering rapidly following physical disturbance. Further, Polychaetes such as *N. cirrosa* may even benefit from disturbance. The amount of available food for predator/scavenger species may increase due to the number of injured and killed organisms (Frid *et al*., 2000). Species such as *L. conchilega* have been categorised by Gittenberger and van Loon (2011) through literature and expert review, as AMBI fisheries Group IV — a second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed (ABPmer, 2013). However, their populations are able to recover relatively quickly and benefit from	Based on the potential impact of physical damage by shallow disturbance on the characterising species, this feature has been assessed to have a medium tolerance. Recoverability will be high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		from disturbance. When in the sediment it is found between 5–15 cm depth (Appendix E, ABPmer & Ichthys Marine, 2015), therefore will not be affected by surface abrasion and has high tolerance. As such the species present are described as robust and infaunal. Therefore tolerance is assessed as high to medium	the disturbance, causing their population sizes to increase significantly in areas with intense fisheries (Gittenberger & van Loon, 2011; ABPmer, 2013).	
Deep disturbance Trawl Shoes >25mm disturbance	Infralittoral fine sand or infralittoral muddy sand	**Medium** Deep disturbance will result in the surface and shallow disturbance effects outlined above, but to a more severe degree. Habitat tolerance is assessed as 'medium' as changes will occur but the habitat will remain intact (ABPmer, 2013).	**Very High** In general any tracks or furrows resulting from surface damage would be likely to infill very rapidly due to the levels of natural disturbance in the areas where this habitat occurs, and normal hydrodynamic and mixing and sorting processes will be rapidly restored. North Norfolk Sandbanks are formed by strong tidal currents and it is therefore considered that the habitat and recover relatively rapidly between disturbance events. Because this is a deeper and therefore slightly more stable habitat than the infralittoral sediment, tracks or furrows resulting from deep disturbance would be likely to infilled and normal hydrodynamic and mixing and sorting processes are expected to have been restored within 2 years. And so recovery is assessed as high.	**Low** Based on the potential impact of physical damage by deep disturbance on the habitat it has been assessed to have a medium tolerance. Although changes and alterations to the seabed topography will be made they are unlikely to significantly change the habitat itself and the services it provides. Recoverability will be very high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.
	Characterising Species	**Low–High** The impacts of deep disturbance will be the same as surface and shallow but more severe. The tolerance of the species will be dependent upon their position within the sediment and biological traits such as their size and mobility (ABPmer & Ichthys Marine , 2015). And so tolerance will vary between taxa from low to high (ABPmer, 2013).	**High** As described above, the ability of the species present at the site to recover is linked to biological traits such as whether they or not they are 'R- selected species', their recolonisation rate and/or re-recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). Therefore it is assessed that recovery will be high.	**Not Sensitive–Medium** The sensitivity of the characterising species to deep disturbance ranges from not sensitive to medium sensitivity. Deep disturbance has the potential to cause directly mortality and consequently alter species composition. However, the impacts of this pressure are dependent upon the biological traits of the individual taxa.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
Physical damage and disturbance from changes in suspended sediment levels An average equivalent sediment layer across the whole swept area is 9.7mm for a tickler beam trawl and 4.4mm for a pulse wing trawl (assuming 20% silt fraction).	Infralittoral fine sand or infralittoral muddy sand	**High** As the gear moves over the sediment, sediment will be mobilised into the water column. This can cause smothering of suspension feeding fauna through the re-suspension of sediment by the fishing gears (Jennings and Kaiser, 1998). The quantity of sediment re-suspended by trawling depends on the sediment grain size and the degree of compaction, which is lower on coarse sand (Jennings and Kaiser, 1998). As discussed in detail in Appendix G, ABPmer & Ichthys Marine (2015) only small amounts of material is expected to be mobilised at the site as a result of beam and pulse wing trawling. As this is a high energy environment as described within Section 3.10, sediment is regularly mobilised and so it is not expected to impact the composition of the sediment type. Therefore tolernce is assessed as high.	**Very High** Recovery will depend on the rate of sediment mixing or removal of the overburden, either naturally or through human activities and recovery to a recognisable form of the original biotope will not take place until this has happened. In areas where the local hydrodynamic conditions are unaffected, fine particles will be removed by wave action moderating the impact of this pressure. The rate of habitat restoration would be site-specific and would be influenced by the type of siltation and rate. Due to the naturally high hydrodynamic mixing suspended sediments and siltation from fishing gear is unlikely to surpass naturally occurring levels and so recovery is assessed as very high.	**Not Sensitive** Suspended sediment from trawling activities is likely to occur although it will not cause significant changes to the habitat or mortality to the species. Natural disturbances from wave, current and storm actions although with the settling out of sediment would result in the rapid recovery of the feature. It is therefore assessed that this habitat is not sensitive to the low levels of increased suspended sediments expected at the site.
	Characterising Species	**High** Animals associated with this biotope are generally infaunal and not photosynthetic and adapted to highly disturbed environments, and so are considered as having a high tolerance to the changes in suspended sediments expected at the site.	**Very High** Bivalves and other benthic infauna are generally able to escape from burial of more than 10cm. Bivalves are able to clear gills so would be expected to reposition in sediment and avoid gill clogging (Grant & Thorpe 1991). Cockles buried under 5cm of sediment have been able to re-establish siphon contact with surface in less than 24 hours (Chang & Levings 1978). Also give the high tolerence recovery is assessed as very high.	**Not Sensitive** Characterising species are not sensitive.
Electromagnetic changes Pulse gear only	Infralittoral fine sand or infralittoral muddy sand	**High** There are no expected impact to the habitat as a result of the electronic fields and pulses created by the gear.	**Very High** No expected impact and very high recovery.	**Not Sensitive** There are no expected impacts to the habitat as a result of the electronic fields and pulses created by the gear.
	Characterising Species	**High** Electronic pulses have been observed to	**Very High** No expected impact and very high	**Not Sensitive** Characterising species are assessed as not

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		potentially cause cod spinal damage (van Marlen *et al* 2014) and this only occurred if fish were within 20 cm of the electrode. Whereas dogfish have been observed as having not affect (de Haan *et al.* 2009 in Soetaert *et al.*, 2013). Tank experiments conclude that any effects to invertebrates were not significant (ICES, 2010, 2011, 2012). van Marlen *et al.* (2013) highlights the fact that pulse stimulation on benthic species varies between the taxa and the smaller the species, the less likely it is the get an effect of electrical stimulation. Although more evidence is required, for the characterising species considered here, tolerance is assessed as being high.	recovery.	sensitive as it is expected that they have a high tolerance to and very high recovery from electromagnetic changes.
Biological disturbance through the selective extraction of species Bottom towed gear may have direct impacts on seabed and produce significant amounts of re-suspension.	Infralittoral fine sand or infralittoral muddy sand	**High** The feature is not considered to be functionally dependent on targeted or non-targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal.	**Very High** There is minimal impact from which to recover.	**Not Sensitive** The removal of target or non-target species would have no significant effect on the physio-chemical character of the habitat. Tolerance is high, and so sensitivity has been assessed as 'Not Sensitive'.
	Characterising Species	**Medium** The species supported by this are not directly dependent on other species to provide habitat (although there may be numerous indirect interactions). A study by van Marlen *et al.*, 2014 showed discard was much reduced (57% for fish and 80% for benthic species) for pulse trawls compared to conventional beam trawls. Far fewer undersized plaice were caught as well. However there is still potential for the characterising species to be removed which may result in changes to the biological community and hence the classification of the assemblage type. In addition, a large proportion of the	**High** Many of the species present at the site are infaunal and so are not expected to be removed in significant numbers. In addition, the species present are expected to be able to resettle and recolonise following a disturbance event (ABPmer, 2013). Therefore recovery is assessed as high.	**Low** The characterising species are assessed as having a low sensitivity to biological disturbance.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		species present at the site are infaunal and occupy the sediment at a depth below the depth of penetration of the ground gear and chains and/or electrodes. In addition, the target species (plaice and sole) feed on bottom living organisms such as worms, crustaceans and shellfish (Ruiz, 2007). Therefore the removal of these target species does have the potential to alter the biological community which may in turn change the classification of the given assemblage. Therefore, tolerance is assessed as medium.		

A.5 Circalittoral fine sand or circalittoral muddy sand

The sensitivity assessment for this habitat is provided in Table A.5.

Table A.5 Sensitivity for circalittoral fine sand or circalittoral muddy sand

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
Physical damage resulting from abrasion and/or selective extraction Surface abrasion	Circalittoral fine sand or circalittoral muddy sand	**High** Surface abrasion can re-suspend sediments and reduce habitat complexity (Depestele *et al*,2015 and references therein) by smoothing out structures and displacing. However, fine sands are relatively cohesive and therefore resistant to erosion following surface disturbance and surface abrasion is unlikely to alter habitat type (ABPmer, 2013). Using the natural disturbance modelled for 250 µm grain size (as described in Appendix G of ABPmer & Ichthys Marine, 2015), the top layer of sediment is mobilised by currents 20% - 80% of the time with mobile bedforms present 10–80% of the time. Tolerance is assessed as high.	**Very High** The site is a highly dynamic area (JNCC, 2012) and the North Norfolk Sandbanks are formed by strong tidal currents and it is therefore considered that the habitat would recover very rapidly between disturbance events due to the levels of natural disturbance in the areas where this habitat occurs.	**Not Sensitive** Circalittoral sands have a high tolerance to surface abrasion and the ability to be able to recover very rapidly, therefore this habitat is not sensitive to surface abrasion.
	Characterising species	**High** Species associated with sand sediments are predominantly infaunal (polycheates and bivalves) and hence have some protection against surface disturbance. Therefore tolerance is assessed as high.	**Very High** Very high recovery due to high recruitment rates and population growth rates.	**Not Sensitive** Species are infaunal and so have a high tolerance and very high recovery. Therefore it is concluded that the characterising species are not sensitive to surface abrasion.
Shallow disturbance Ground gear, chains and electrodes <25mm disturbance	Circalittoral fine sand sand or circalittoral muddy sand	**Medium** There is the potential for changes in the topography of the habitat to occur which may cause the formation of pits and trenches (ABPmer, 2013). However material is not removed from or added to the environment as a result of beam trawling, and as such, the habitat will remain intact. Using the natural disturbance modelled for	**Very High** Using the natural disturbance modelled results for 63–250 µm grain sizes (as described in Appendix G of ABPmer & Ichthys Marine, 2015), the top layer of sediment in the area where this habitat is present is mobilised by currents 20%–80% of the time and so it is expected that any pits or furrows will be readily infilled.	**Low** Circalittoral sands are expected to have a low sensitivity to shallow disturbance as tolerance is predicted as medium as although there may be some changes in sediment topography, due to the dynamic nature of the area the habitat structure will remain and recovery will be very rapid due to the high levels of

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		250 µm grain size (as described in Appendix G of ABPmer & Ichthys Marine, 2015), the top layer of sediment is mobilised by currents or with active ripple bedforms (2.5 cm) 20%–80% of the time with mobile bedforms present 10–80% of the time. Circalittoral sands are considered to have medium tolerance to shallow disturbance as some of the habitat may be altered.	Active ripple bedforms (2.5 cm height) are expected to be present 10–80% of the time for 250 µm grain size and 0–20% of the time for 63 µm grain size. Studies by Collie *et al.*, (2000) and Constantino *et al.*, (2008) report that sandy habitats have a rapid recovery, within 100 days following a trawl event. It has also been suggested by Dignan *et al.*, (2014) that high energy environments are likely to recover at a faster rate than lower energy environments.	sediment mobility from natural disturbance.
	Characterising species	**High–Medium**	**Very High**	**Low**
		According to several studies, macrobenthic communities from high-energy environments (characterised by clean sediments) tend to be less affected by fishing as they are subject to natural sediment disturbance (e.g. Currie and Parry, 1996; Kaiser *et al*. 1996; Zajac and Whitlatch, 2003). Nevertheless, in a moderately disturbed environment, Morello *et al*. (2006) found that fishing impacts on benthic community structure were still distinguishable from those resulting from natural variation. The tolerance of the various taxa will vary depending upon their biological traits (Appendix E, ABPmer & Ichthys Marine , 2015) For example *Bathyporeia* spp. is a small mobile species capable of moving out of the path of fishing gear (Appendix E, ABPmer & Ichthys Marine, 2015). It is a burrow-dwelling amphipod and therefore is unlikely to be impacted by surface abrasion and has a high tolerance. N. *cirrosa* is able to burrow or swim away from disturbance. When in the sediment it is found between 5–15 cm depth (Appendix E, ABPmer & Ichthys Marine,	The ability of the species present at the site to recover is linked to biological traits such as whether they or not they are 'R-selected species', their recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). Because this is a high energy environment it is expected that the species present will have the ability of recovering rapidly following physical disturbance. Further, Polychaetes such as *N. cirrosa* may even benefit from disturbance. The amount of available food for predator/scavenger species may increase due to the number of injured and killed organisms (Frid *et al*., 2000). Species such as *L. conchilega* have been categorised by Gittenberger and van Loon (2011) through literature and expert review, as AMBI fisheries Group IV — a second-order opportunistic species, which are sensitive to fisheries in which the bottom is disturbed (ABPmer, 2013). However, their populations are able to recover relatively quickly and benefit from the disturbance, causing their population sizes to increase significantly in areas with	Based on the potential impact of physical damage by shallow disturbance on the characterising species, this feature has been assessed to have a medium tolerance. Recoverability will be high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		2015), therefore will not be affected by surface abrasion and has high tolerance. Therefore tolerance is assessed as high to medium	intense fisheries (Gittenberger & van Loon, 2011; ABPmer, 2013).	
Deep disturbance Trawl Shoes >25mm disturbance	Circalittoral fine sand or circalittoral muddy sand	**Medium** Deep disturbance will result in the surface and shallow disturbance effects outlined above, but to a more severe degree. Habitat tolerance is assessed as 'medium' as changes will occur but the habitat will remain intact (ABPmer, 2013). Surface compaction can collapse burrows and reduce the pore space between particles, decreasing penetrability and reducing stability and oxygen content.	**High** This is a dynamic environment and so any tracks or furrows will be readily infilled. Studies by Collie *et al.*, (2000) and Constantino *et al.*, (2008) report that sandy habitats have a rapid recovery, within 100 days following a trawl event. It has also been suggested by Dignan *et al.,* (2014) that high energy environments are likely to recover at a faster rate than lower energy environments. In a study comparing the responses of marine benthic communities within a variety of sediment types to physical disturbance, Dernie *et al.* (2003) found that clean sand communities had the most rapid recovery rate following disturbance. Given that this is a deeper habitat and so will not be as naturally disturbed as some of the shallower habitats, recovery is assessed as high (within 2 years).	**Low** Based on the potential impact of deep disturbance on the habitat , this feature has been assessed to have a medium tolerance. Recoverability will be high and as a result, sensitivity has been assessed as low.
	Characterising Species	**Low–High** The impacts of deep disturbance will be the same as surface and shallow but more severe. The tolerance of the species will be dependent upon their position within the sediment and biological traits such as their size and mobility (Appendix E, ABPmer & Ichthys Marine, 2015). And so tolerance will vary between taxa from low to high (ABPmer, 2013).	**High** As described above, the ability of the species present at the site to recover is linked to biological traits such as whether they or not they are 'R- selected species', their recolonisation rate and/or re-recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). Therefore it is assessed that recovery will be high.	**Not Sensitive–Medium** The sensitivity of the characterising species to deep disturbance ranges from not sensitive to medium sensitivity. Deep disturbance has the potential to cause directly mortality and consequently alter species composition. However, the impacts of this pressure is dependent upon the biological traits of the individual taxa.
Physical damage and disturbance from changes in suspended sediment levels	Circalittoral fine sand or circalittoral muddy sand	**High** As described in tables above, as the gear moves over the sediment, sediment will be mobilised into the water column. The	**Very High** Recovery will depend on the rate of sediment mixing or removal of the overburden, either naturally or through	**Not Sensitive** Suspended sediment from trawling activities is likely to occur although it will not cause significant changes to

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
An average equivalent sediment layer across the whole swept area is 9.7mm for a tickler beam trawl and 4.4mm for a pulse wing trawl (assuming 20% silt fraction).		quantity of sediment re-suspended by trawling depends on the sediment grain size and the degree of compaction, which is lower on coarse sand (Jennings and Kaiser, 1998). As discussed in detail in Appendix G, ABPmer & Ichthys Marine (2015) only small amounts of material is expected to be mobilised at the site as a result of beam and pulse wing trawling. As this is a high energy environment as described within Section 3.10, sediment is regularly mobilised and so it is not expected to impact the composition of the sediment type. Therefore tolernce is assessed as high.	human activities and recovery to a recognisable form of the original biotope will not take place until this has happened. In areas where the local hydrodynamic conditions are unaffected, fine particles will be removed by wave action moderating the impact of this pressure. The rate of habitat restoration would be site-specific and would be influenced by the type of siltation and rate. Due to the naturally high hydrodynamic mixing suspended sediments and siltation from fishing gear is unlikely to surpass naturally occurring levels and so recovery is assessed as very high.	the habitat or mortality to the species. Natural disturbances from wave, current and storm actions although with the settling out of sediment would result in the rapid recovery of the feature. It is therefore assessed that this habitat is not sensitive to the low levels of increased suspended sediments expected at the site.
	Characterising Species	**High**	**Very high**	**Not Sensitive**
		Animals associated with this biotope are generally infaunal and adapted to highly disturbed environments, and so are considered as having a high tolerance to the changes in suspended sediments expected at the site.	Bivalves and other benthic infauna are generally able to escape from burial of more than 10cm. Bivalves are able to clear gills so would be expected to reposition in sediment and avoid gill clogging (Grant & Thorpe 1991). Cockles buried under 5cm of sediment have been able to re-establish siphon contact with surface in less than 24 hours (Chang & Levings 1978). Also give the high tolerence recovery is assessed as very high.	Characterising species are not sensitive.
Electromagnetic changes Relevant to pulse trawls only	Circalittoral fine sand or circalittoral muddy sand	**High**	**Very High**	**Not Sensitive**
		There are no expected impact to the habitat as a result of the electronic fields and pulses created by the gear.	No expected impact and very high recovery.	There are no expected impacts to the habitat as a result of the electronic fields and pulses created by the gear.
	Characterising Species	**High**	**Very High**	**Not Sensitive**
		Electronic pulses have been observed to potentially cause cod spinal damage (van Marlen *et al* 2014) and this only occurred if fish were within 20 cm of the electrode. Whereas dogfish have been observed as having not affect (de Haan *et al.* 2009 in	No expected impact and very high recovery.	Characterising species are assessed as not sensitive as it is expected that they have a high tolerance to and very high recovery from electromagnetic changes.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		Soetaert *et al.*, 2013). Tank experiments conclude that any effects to invertebrates were not significant (ICES, 2010, 2011, 2012). van Marlen *et al.* (2013) highlights the fact that pulse stimulation on benthic species varies between the taxa and the smaller the species, the less likely it is the get an effect of electrical stimulation. Although more evidence is required, for the characterising species considered here, tolerance is assessed as being high.		
Biological disturbance through the selective extraction of species Bottom-towed gear may have direct impacts on seabed and produce significant amounts of re-suspension.	Circalittoral fine sand sand or circalittoral muddy sand	**High** The feature is not considered to be functionally dependent on targeted or non-targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal.	**Very High** There is minimal impact from which to recover.	**Not Sensitive** The removal of target or non-target species would have no significant effect on the physio-chemical character of the habitat. Tolerance is high, and so sensitivity has been assessed as 'Not Sensitive'.
	Characterising Species	**Medium** The characterising species are not directly dependent on other species to provide habitat (although there may be numerous indirect interactions). A study by van Marlen *et al.,* 2014 showed discard was much reduced (57% for fish and 80% for benthic species) for pulse trawls compared to conventional beam trawls. Far fewer undersized plaice were caught as well. However there is still potential for the characterising species to be removed which may result in changes to the biological community and hence the classification of the assemblage type. In addition, a large proportion of the species present at the site are infaunal and occupy the sediment at a depth below the depth of disturbance of the ground gear and chains and/or electrodes. In addition, the target species (plaice and	**High** Many of the species present at the site are infaunal and so are not expected to be removed in significant numbers. In addition, the species present are expected to be able to resettle and recolonise following a disturbance event (ABPmer, 2013). Therefore recovery is assessed as high.	**Low** The characterising species are assessed as having a low sensitivity to biological disturbance.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		sole) feed on bottom living organisams such as worms, crustaceans and shellfish (Ruiz, 2007). Therefore the removal of these target species does have the potential to alter the biological community which may in turn change the classification of the given assemblage. Therefore, tolerance is assessed as medium.		

A.6 Deep circalittoral sand

The sensitivity assessment for this habitat is provided in Table A.6.

Table A.6 Sensitivity for deep circalittoral sand

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
Physical damage resulting from abrasion and/or selective extraction Surface abrasion	Deep circalittoral sand	**High** Surface abrasion can re-suspend sediments and reduce habitat complexity (Depestele *et al*,2015 and references therein) by smoothing out structures and displacing. However, fine sands are relatively cohesive and therefore resistant to erosion following surface disturbance and surface abrasion is unlikely to alter habitat type (ABPmer, 2013). Using the natural disturbance modelled for 250 µm grain size (as described in Appendix G of ABPmer & Ichthys Marine, 2015), the top layer of sediment is regularly mobilised and active bedforms are present60%–70% of the time, and so tolerance is assessed as high.	**Very High** The site is a highly dynamic area (JNCC, 2012) and the North Norfolk Sandbanks are formed by strong tidal currents and it is therefore considered that the habitat would recover very rapidly between disturbance events due to the levels of natural disturbance in the areas where this habitat occurs.	**Not Sensitive** Circalittoral sands have a high tolerance to surface abrasion and the ability to be able to recover very rapidly, therefore this habitat is not sensitive to surface abrasion.
	Characterising species	**High** Species associated with sand sediments are predominantly infaunal (polycheates and bivalves) and hence have some protection against surface disturbance. Therefore tolerance is assessed as high.	**Very High** Very high recovery due to high recruitment rates and population growth rates.	**Not Sensitive** Species are infaunal and so have a high tolerance and very high recovery. Therefore it is concluded that the characterising species are not sensitive to surface abrasion.
Shallow disturbance Ground gear, chains and electrodes <25mm disturbance	Deep circalittoral sand	**Medium** There is the potential for changes in the topography of the habitat to occur which may cause the formation of pits and trenches (ABPmer, 2013). However material is not removed from or added to the environment as a result of beam trawling, and as such, the habitat will remain in tack. Using the natural disturbance modelled for	**High** This is a dynamic environment and so any tracks or furrows will be readily infilled. Studies by Collie *et al.*, (2000) and Constantino *et al.*, (2008) report that sandy habitats have a rapid recovery, within 100 days following a trawl event. It has also been suggested by Dignan *et al.*, (2014)	**Low** Circalittoral sands are expected to have a low sensitivity to shallow disturbance as tolerance is predicted as medium as although there may be some changes in sediment topography, due to the dynamic nature of the area the habitat structure will remain and recovery

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		250 µm grain size (as described in Appendix G of ABPmer & Ichthys Marine, 2015), the top layer of sediment is regularly mobilised by currents or with active ripple bedforms (2.5 cm) 60% –70% of the time. Deep circalittoral sands are considered to have medium tolerance to shallow disturbance as some of the habitat may be altered.	that high energy environments are likely to recover at a faster rate than lower energy environments.	will be rapid.
	Characterising species	**Medium** According to several studies, macrobenthic communities from high-energy environments (characterised by clean sediments) tend to be less affected by fishing as they are subject to natural sediment disturbance (e.g. Currie and Parry, 1996; Kaiser *et al*. 1996; Zajac and Whitlatch, 2003). Nevertheless, in a moderately disturbed environment, Morello *et al*. (2006) found that fishing impacts on benthic community structure were still distinguishable from those resulting from natural variation. The tolerance of the various taxa will vary depending upon their biological traits (Appendix E, ABPmer & Ichthys Marine , 2015) and the species present are described as infaunal. Therefore tolerance is assessed as medium	**Very High** The ability of the species present at the site to recover is linked to biological traits such as whether they or not they are 'R-selected species', their recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). Because this is a high energy environment it is expected that the species present will have the ability of recovering rapidly following physical disturbance.	**Low** Based on the potential impact of physical damage by shallow disturbance on the characterising species, this feature has been assessed to have a medium tolerance. Recoverability will be high due to the natural disturbance by wave, current, and storm action. As a result, sensitivity has been assessed as low.
Deep disturbance Trawl Shoes >25mm disturbance	Deep circalittoral sand	**Medium** Deep disturbance will result in the surface and shallow disturbance effects outlined above, but to a more severe degree. Habitat tolerance is assessed as 'Medium' as changes will occur but the habitat will remain intact (ABPmer, 2013). Surface compaction can collapse burrows and reduce the pore space between particles, decreasing penetrability and reducing stability and oxygen content.	**High** This is a dynamic environment and so any pits or trenches will be readily infilled. Studies by Collie *et al*., (2000) and Constantino *et al*., (2008) report that sandy habitats have a rapid recovery, within 100 days following a trawl event. It has also been suggested by Dignan *et al.,* (2014) that high energy environments are likely to recover at a faster rate than lower energy environments. In a study comparing the	**Low** Based on the potential impact of deep disturbance on the habitat, this feature has been scored to have a medium tolerance. Recoverability will be high and as a result, sensitivity has been assessed as low.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
			responses of marine benthic communities within a variety of sediment types to physical disturbance, Dernie *et al.* (2003) found that clean sand communities had the most rapid recovery rate following disturbance. Given that this is a deeper habitat and so will not be as naturally disturbed as some of the shallower habitats, recovery is assessed as high (within 2 years).	
	Characterising species	**Low–High** The impacts of deep disturbance will be the same as surface and shallow but more severe. The tolerance of the species will be dependent upon their position within the sediment and biological traits such as their size and mobility (Appendix E, ABPmer & Ichthys Marine , 2015). And so tolerance will vary between taxa from low to high (ABPmer, 2013).	**High** As described above, the ability of the species present at the site to recover is linked to biological traits such as whether they or not they are 'R- selected species', their recolonisation rate and/or re-recolonisation rate and/or re-settlement but also the recovery rate of the abiotic feature (ABPmer, 2013). Therefore it is assessed that recovery will be high.	**Not Sensitive–Medium** The sensitivity of the characterising species to deep disturbance ranges from not sensitive to medium sensitivity. Deep disturbance has the potential to cause directly mortality and consequently alter species composition. However, the impacts of this pressure is dependent upon the biological traits of the individual taxa.
Physical damage and disturbance from changes in suspended sediment levels	Deep circalittoral sand	**High** Very little data is available on these habitats however they are likely to be more stable than their shallower counterparts and characterised by a diverse range of polychaetes, amphipods, bivalves and echinoderms most of which will be able to reposition themselves within the sediment to avoid smothering.	**Very High** Smothering is not likely to cause considerable mortality to the species associated with the biotopes comprising this habitat type as most are able to reposition themselves at their preferred depth relatively quickly or are infaunal species (Lancaster *et al.*, 2014).	**Not Sensitive**
	Characterising species	**High** Animals associated with this biotope are generally infaunal so are considered as having a high tolerance to the changes in suspended sediments expected at the site.	**Very high** Bivalves and other benthic infauna are generally able to escape from burial of more than 10cm. Bivalves are able to clear gills so would be expected to reposition in sediment and avoid gill clogging (Grant & Thorpe 1991). Cockles buried under 5cm of sediment have been able to re-establish siphon contact with surface in less than 24	**Not Sensitive** Characterising species are not sensitive.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
			hours (Chang & Levings 1978). Also give the high tolerence recovery is assessed as very high.	
Electromagnetic changes	Deep circalittoral sand	**High** There are no expected impact to the habitat as a result of the electronic fields and pulses created by the gear.	**Very High** -	**Not Sensitive** There are no expected impact to the habitat as a result of the electronic fields and pulses created by the gear.
	Characterising species	**High** Electronic pulses have been observed to potentially cause cod spinal damage (van Marlen *et al* 2014) and this only occurred if fish were within 20 cm of the electrode. Whereas dogfish have been observed as having not affect (de Haan *et al.* 2009 in Soetaert *et al.*, 2013). Tank experiments conclude that any effects to invertebrates were not significant (ICES, 2010, 2011, 2012). van Marlen *et al.* (2013) highlights the fact that pulse stimulation on benthic species varies between the taxa and the smaller the species, the less likely it is the get an effect of electrical stimulation. Although more evidence is required, for the characterising species considered here, tolerance is assessed as being high.	**Very High** No expected impact and very high recovery.	**Not Sensitive** Characterising species are assessed as not sensitive as it is expected that they have a high tolerance to electromagnetic changes.
Biological disturbance through the selective extraction of species Bottom towed gear may have direct impacts on seabed and produce significant amounts of re-suspension which may trigger off considerable productivity pulses due to the rate of dissolved and particulate nutrient releases from seabed disturbance.	Circalittoral coarse sediment	**High** The feature is not considered to be functionally dependent on targeted or non-targeted organisms and therefore is not considered to be sensitive to the biological effect of their removal.	**Very High** There is minimal impact from which to recover.	**Not Sensitive** The removal of target or non-target species would have no significant effect on the physio-chemical character of the habitat. Tolerance is high, and so sensitivity has been assessed as 'Not Sensitive'.
	Characterising Species	**Medium** The characterising species are not directly dependent on other species to provide habitat (although there may be numerous indirect interactions).	**Very High** Many of the species present at the site are infaunal and so are not expected to be removed in significant numbers. In addition, the species present are expected to be able to resettle and recolonise	**Low** The characterising species are assessed as having a low sensitivity to biological disturbance given their ability to recover within 2 years.

Impact Pathway	Feature	Tolerance	Recoverability	Sensitivity
		A study by van Marlen *et al.*, 2014 showed discard was much reduced (57% for fish and 80% for benthic species) for pulse trawls compared to conventional beam trawls. Far fewer undersized plaice were caught as well. However there is still potential for the characterising species to be removed which may result in changes to the biological community and hence the classification of the assemblage type. In addition, a large proportion of the species present at the site is infaunal and occupy the sediment at a depth below the depth of disturbance of the ground gear and chains and/or electrodes. In addition, the target species (plaice and sole) feed on bottom living organisms such as worms, crustaceans and shellfish (Ruiz, 2007). Therefore the removal of these target species does have the potential to alter the biological community which may in turn change the classification of the given assemblage. Therefore, tolerance is assessed as medium.	following a disturbance event (ABPmer, 2013). Therefore recovery is assessed as high.	

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